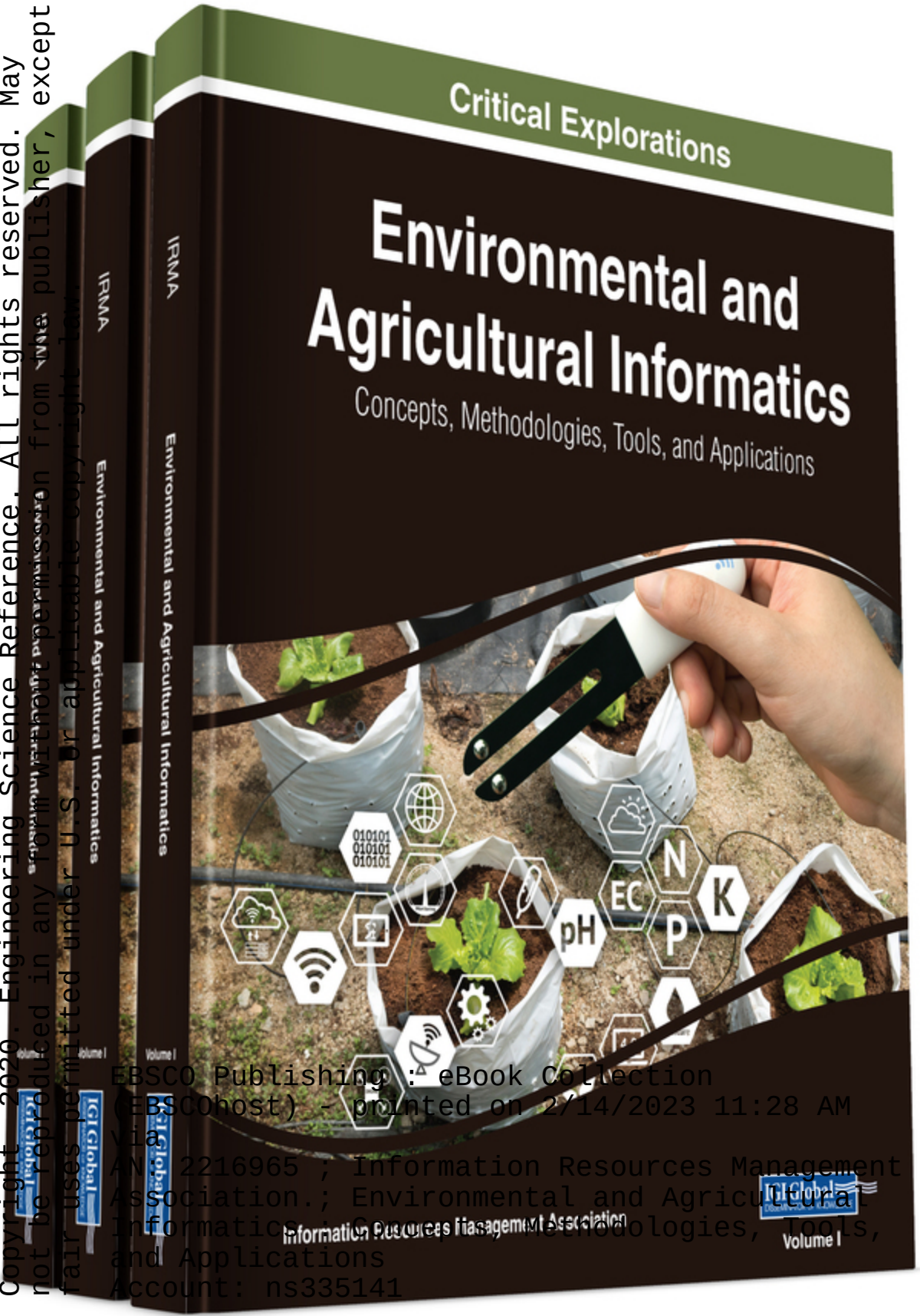

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Preface

Due to continual advancements in technological applications, contemporary society has the ability to rapidly process large amounts of information and data in a variety of fields in order to solve complex problems and issues. In the field of environmental science, informatics can be used to quickly process and access environmental data in order to plan preventive measures and solve current environmental problems for the protection of the environment. These advancements are providing assistance, tools, applications, and solutions for agriculturalists and environmentalists on a number of issues such as the sustainable use of water and land, crop growth and maintenance, climate change, water pollution, deforestation, etc.

The constantly changing landscape of environmental and agricultural informatics makes it challenging for experts and practitioners to stay informed of the field's most up-to-date research. That is why IGI Global is pleased to offer this three-volume reference collection that will empower environmentalists, agriculturalists, researchers, professionals, academics, students, and scientists with a strong understanding of critical issues surrounding environmental and agricultural informatics by providing both broad and detailed perspectives on cutting-edge theories and developments. This reference is designed to act as a single reference source on conceptual, methodological, technical, and managerial issues, as well as to provide insight into emerging trends and future opportunities within the field.

Environmental and Agricultural Informatics: Concepts, Methodologies, Tools, and Applications is organized into seven distinct sections that provide comprehensive coverage of important topics. The sections are:

1. Fundamental Concepts and Theories;
2. Development and Design Methodologies;
3. Tools and Technologies;
4. Utilization and Applications;
5. Organizational and Social Implications;
6. Managerial Impact; and
7. Critical Issues and Challenges.

The following paragraphs provide a summary of what to expect from this invaluable reference tool.

Section 1, "Fundamental Concepts and Theories," serves as a foundation for this extensive reference tool by addressing crucial theories essential to the understanding of Environmental and Agricultural Informatics. Introducing the book is "Technological Innovation and the Agricultural Sustainability: What Compatibility for the Mechanization?" by Rachida Khaled (Faculty of Economics and Management of Sousse, Department of Economics, University of Sousse, Sousse, Tunisia) and Lamine Hammas (Faculty

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of Economics and Management of Sousse, Department of Economics, University of Sousse, Sousse, Tunisia): a great foundation laying the groundwork for the basic concepts and theories that will be discussed throughout the rest of the book. Section 1 concludes and leads into the following portion of the book with a nice segue chapter, "Aggressions of the Socio-Economic System on the Natural Capital," by Constanţa Popescu (Valahia University of Târgovişte, Romania), Constantin Popescu (Valahia University of Târgovişte, Romania), and Maria Luiza Hrestic (Valahia University of Târgovişte, Romania).

Section 2, "Development and Design Methodologies," presents in-depth coverage of the conceptual design and architecture of Environmental and Agricultural Informatics. Opening this section is "Appropriate Extension Methodologies for Agricultural Development in Emerging Economies," by B. S. Famuyiwa (Cocoa Research Institute of Nigeria [CRIN], Nigeria), O. A. Olaniyi (Ladoke Akintola University of Technology, Nigeria), and S. A. Adesoji (Obafemi Awolowo University, Nigeria). Through case studies, this section lays excellent groundwork for later sections that will get into present and future applications for Environmental and Agricultural Informatics. This section concludes with an excellent work by Carey Clouse (University of Massachusetts – Amherst, USA), "Design for Autonomy: Water Resources in Ladakh."

Section 3, "Tools and Technologies," presents extensive coverage of the various tools and technologies used in the implementation of Environmental and Agricultural Informatics. The first chapter, "Web Based Automatic Soil Chemical Contents Monitoring System," by Samuel Dayo Okegbile (Obafemi Awolowo University, Ile-Ife, Nigeria), Adeniran Ishola Oluwaranti (Obafemi Awolowo University, Ile-Ife, Nigeria), and Adekunle Aderibigbe (Obafemi Awolowo University, Ile-Ife, Nigeria) lays a framework for the types of works that can be found in this section. This section concludes with "Simulation-Based Approaches for Ecological Niche Modelling: A Geospatial Reference" by Anusheema Chakraborty (TERI University, India) and P K. Joshi (Jawaharlal Nehru University, India). Where Section 3 described specific tools and technologies at the disposal of practitioners, Section 4 describes the use and applications of the tools and frameworks discussed in previous sections.

Section 4, "Utilization and Applications," describes how the broad range of Environmental and Agricultural Informatics efforts has been utilized and offers insight on and important lessons for their applications and impact. The first chapter in this section is "Information Societies to Interactive Societies: ICT Adoptions in the Agriculture Sector in Sri Lanka," written by Uvasara Dissanayeke (University of Peradeniya, Sri Lanka) and H.V.A. Wickramasuriya (University of Peradeniya, Sri Lanka). This section includes the widest range of topics because it describes case studies, research, methodologies, frameworks, architectures, theory, analysis, and guides for implementation. The breadth of topics covered in this section is also reflected in the diversity of its authors from countries all over the globe. This section concludes with "Low Carbon Energy Innovations Systems in Natural Resource Rich Developing Countries: The Case of Brazil" by André Tosi Furtado (University of Campinas, Brazil), a great transition chapter into the next section.

Section 5, "Organizational and Social Implications," includes chapters discussing the organizational and social impact of Environmental and Agricultural Informatics. This section opens with "The Collective Aestheticization of Farming as Participatory Civic Engagement" by Cala Coats (Stephen F. Austin State University, USA). This section focuses exclusively on how these technologies affect human lives, either through the way they interact with each other or through how they affect behavioral/workplace situations. This section concludes with "Impact of Overpopulation on Land Use Pattern" by Shivani Garg (Kurukshetra University, India).

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Section 6, "Managerial Impact," presents focused coverage of Environmental and Agricultural Informatics in a managerial perspective. This section begins with "Characterization and Management Concerns of Water Resources around Pallikaranai Marsh, South Chennai" by Avantika Bhaskar (Care Earth Trust, India), G. Babu Rao (Care Earth Trust, India), and Jayshree Vencatesan (Care Earth Trust, India). This section serves as a vital resource for developers who want to utilize the latest research to bolster the capabilities and functionalities of their processes. The chapters in this section offer unmistakable value to managers looking to implement new strategies that work at larger bureaucratic levels. This section concludes with "Assessing the Readiness of Farmers towards Cold Chain Management: Evidences from India" by Rohit Joshi (IIM Shillong, India) and Sudhanshu Joshi (Doon University, India).

Section 7, "Critical Issues and Challenges," presents coverage of academic and research perspectives on Environmental and Agricultural Informatics tools and applications. This section begins with "The Loss and Damage of Environmental Ethics in the Threshold of African Culture: Environmental Ethics and African Culture" by Essien D. Essien (University of Uyo, Uyo, Nigeria). Chapters in this section look into theoretical approaches and offer alternatives to crucial questions on the subject of Environmental and Agricultural Informatics. This section concludes with "Human Overpopulation: Impact on Environment" by Shivani Uniyal (Banaras Hindu University, India), Rashmi Paliwal (Kurukshetra University, India), Bhumija Kaphaliya (Kurukshetra University, India), and R. K. Sharma (Banaras Hindu University, India).

Although the primary organization of the contents in this multi-volume work is based on its seven sections, offering a progression of coverage of the important concepts, methodologies, technologies, applications, social issues, and emerging trends, the reader can also identify specific contents by utilizing the extensive indexing system listed at the end of each volume. As a comprehensive collection of research on the latest findings related to using technology to providing various services, *Environmental and Agricultural Informatics: Concepts, Methodologies, Tools, and Applications* provides researchers, administrators, and all audiences with a complete understanding of the development of applications and concepts in Environmental and Agricultural Informatics. Given the vast number of issues concerning usage, failure, success, policies, strategies, and applications of Environmental and Agricultural Informatics in countries around the world, *Environmental and Agricultural Informatics: Concepts, Methodologies, Tools, and Applications* addresses the demand for a resource that encompasses the most pertinent research in technologies being employed to globally bolster the knowledge and applications of Environmental and Agricultural Informatics.

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Section 1

Fundamental Concepts and Theories

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Chapter 1
Technological Innovation and the Agricultural Sustainability: What Compatibility for the Mechanization?

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ABSTRACT

The diffusion of the technological innovation can affect the agricultural sector in the three-sided (social, economic and environmental), a hand, it can contribute to solve problems of the agricultural sector: the effects of the climatic changes, the farming exodus and the migration and the problems of poverty and it can improve the agricultural productivity. But on the other hand, he can lead to new problems, such as depletion of energy resources caused by excessive use of energizing technologies, pollution of air and water and the destruction of soil by industrial waste. This paper aims to theoretically and empirically analyze the role of technological innovation in improving agricultural sustainability through the impact of mechanization on agricultural productivity, energy production and net income per capita for a panel of three Maghreb countries (Algeria, Morocco and Tunisia) during the period 1997-2012. By using simultaneous equations, the authors' finding that technological innovation cannot achieve the purpose of sustainable development in the agriculture sector in the Maghreb countries through the negative impact of mechanization and research and development on agricultural productivity.

1. INTRODUCTION

The world today endures some several economic, social, political and environmental problems, as the climatic change, the reduction of biodiversity, the destruction of soils, the shortcomings of production and consumption, poverty, the transferable illness development, the problems of unemployment, etc.

A new approach has emerged in development economics for solving these problems, which incorporates the concept of sustainability is «sustainable development».

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On this new basis, a sustainable development was defined by the Brundtland Report (1987) as:

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet in their generations. (Franck-Dominique, 2003; Karen Delchet, 2004; Olivier Godard, 2002)

In 1992, have Rio politicians negotiated during a summit of the earth, the development situation and environment, their issues and constraints (Franck-Dominique, 2003; Karen Delchet; Olivier Godard, 2002). In this summit was also attended by men of science and technology, recognizing that environmental issues should be a major concern in all areas of humanity.

The innovation is indispensable to the sustainable development and reciprocally the sustainable development determines the orientation of the innovation. These two principles are complementary and their convergence can constitute a big advantage for the economy of tomorrow.

While the question of whether technological innovation, particularly the mechanization improves or prevents the agricultural sustainability opens the door to the birth of several economic and political debates, there are little theoretical and empirical studies on the factors of development and economic durability of irrigation system in Maghreb countries.

The objective of this paper is to make up the void in the literature and make an in-depth analysis the agriculture sector of the Maghreb countries in order to identify their main factors.

To better understand what leads the mechanization effect on the Maghreb agriculture sustainability, we browse in this paper three types of factors, social, economic and environmental. The scope of our study covered 3 Maghreb countries during the 1997-2012 periods. We utilized an econometric methodology based on the simultaneous equations.

Our results show that the technological innovation such as mechanization, research and development cannot achieve the sustainable development purpose in the agricultural sector of the Maghreb country in particular economic efficiency.

The rest of the paper is organized as follows. Section 2 furnishes a brief literature review of the impact of technological innovation in the agricultural sustainability. Section 3 presents the trend of agriculture and mechanization in the Maghreb countries. Section 4 shows the data and the adopted econometric methodology. The empirical results are obtained and interpreted in section 5. Finally, section 6 presents some conclusions and policy implications.

2. TECHNOLOGICAL INNOVATION AND SUSTAINABLE DEVELOPMENT IN AGRICULTURE: A BRIEF LITERATURE REVIEW

Major prior studies related to the present paper include Jimmy Alani (2012), Jean - Marc Blazy, Alain carpentier and Alban Thomas (2011), Roberto Esposti (2002),Fédes van Rijn, Erwin Bulte and Adewale Adekunle (2012), Graeme J. Doole (2012),Gershon Feder and Dina L. Umali (1993),Vernon W. Ruttan (1977), Khaled et Hammas (2014). These studies focus on the effects of technological innovation on the development of agricultural sustainability in developed and developing countries.

Jimmy Alani (2012) shows that improving agricultural productivity is linked with technical progress, he argues their work by a theoretical model derived from a production function type Cobb - Douglas.

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Jean - Marc Blazy Alain Carpentier and Alban Thomas (2011) indicate that improvement in agricultural production based on the reduction of pesticide use and renovation of soil fertility in the fight against weed, provide the nitrogen to the soil without insecticides increases in numbers, each of this way has led to technological innovation. According to the authors the innovations also have different effects on the net operating income and the productivity. The implementation of some innovating method in the sectors agricultural based on conditions environmental, social and economic.

Recent research shows that agricultural development is improving by the technological innovation, but whereas the durability can affect positively or negatively by the mechanization as it explains Colin Thirtle, Robert Townsend and Joban van Zyl (1995) in his empirical analysis that is founded on the OLS modelling.

The innovation in agriculture and rural enterprise comes from whatever source (formal or informal) of new modes in the production and organization of agricultural activity.

The rural populations have a human capital integrating essential sources of knowledge and new procedures through their knowledge and modes of organization.

Good solutions found by small farmers themselves are a necessary source for enhancing agricultural productivity of developing countries.

Nigel Poole (2006) shows that the mechanism and the level of research and innovation in the formal agricultural system have increased in the eighteenth and/or nineteenth century later has the use of scientific methods in relatively advanced economies.

The R&D preferences in agriculture were encouraged during the last century by the government, which led to the birth of the formal national research systems in advanced and developing countries and the creation of organism's international research.

The green revolution is represented as a result of public research or as a classic example of a method giving land ownership to the farmer.

At this point, we can say that innovation is constituted by various researches and it can be spread through different distribution procedures by economic historical, political, institutional and climate contexts. In recent years, the increasing advances in technology led to the creation of technology platforms such as information and communication technology (ICT) and biotechnology.

3. EVALUATION OF ENVIRONMENTAL, ECONOMIC AND SOCIAL FACTORS

3.1. Energy

The farming surroundings and the agricultural sectors endure mediocrity of the infrastructure and the lack of information. These two difficulties cause the reduction of the outputs of the agricultural production and the decrease of the level of employment in this sector, what conducted to the apparition of poverty in these surroundings.

For solving these problems, it is necessary to encourage the investment in the energy since he/it is considered like means of enhancing the life quality for rural populations, while being based on the technologies, in particular of information and the communication.

The lack of infrastructure and high costs are often explained by the lack of rural energy associated with various social, economic and political difficulties.

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The energy is necessary to reinforce the non-agricultural farming economy directly and the agricultural farming economy indirectly.

The current price of oil and its derivatives can release hazardous effects that affect various areas such as air pollution, sea pollution that led to the decline the marine resources and soil pollution and thus to reduce the fertility of agricultural land and subsequently to lower yields and lower employment in this sector, Which encourages migration from rural to industrial or other services.

Energy supply associated with conventional technologies in rural areas can be more expensive. The social and environmental benefits of the development of services based on energy sources other than oil are viable.

We must invest in the energy sectors other than oil for environmental and economic reasons, such as wind and solar energy, which are technically feasible for local markets in rural areas.

3.2. Poverty Reduction

The project " objectives of the millennium for the development " (OMD) defined real strategies to avoid poverty while improving the investments in the infrastructure and the human capital in the farming surroundings, what permits to improve the agricultural sector by a qualified manpower, as well as the increase of production following the increase of the transportation means and thereafter a growth of the outputs and a reduction of poverty in the background farming, while motivating the equality between the sexes and the protection of the environment.

The project of the OMD includes the science, the technology and the innovation and permits to apply the knowledge to the development.

The difficulties faced by developing countries in innovation are not related to the creation of new knowledge, but the effective use of existing techniques.

3.3. The System of Supermarkets

The impact of the international proliferation of large series on food retail sectors was generally analysed for developing countries and also in several other regions such as Latin America, Central and Eastern Europe, sub-Saharan Africa and Asia.

In developing countries, to reason at a time of demand bound to the tendency of the local life forms and to the big international business entry, the food systems are quickly going to be complex. In Tunisia the international supermarket entry is increasing with the time the sample Carrefour Market that has developed in most regions of Tunisia.

However, the international supermarket is a novelty that ensures the sale of food products, such as fresh produce, namely fruits, vegetables, meat and fish, which promotes the growth of production in the two sectors agriculture and fisheries.

So the international supermarket is an innovation that improves several areas such as fisheries and agriculture, and for industry.

The international supermarket system offers the advantages that are the development of the employment in these stores and in their specific supply chains, an overall increase in the quality of food coming from the technology transfer and commercial uses of farmers.

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National supermarkets are represented as major suppliers and demanders of local products, in the less advanced countries. These companies run into relationship marketing and ensure the root of supply series. This new business model is distinguished by low margins and high quality, creating new opportunities and new challenges for providers, such as self-service sales, healthy environments, indicating prices, the aggressive marketing and the promotions are henceforth the strategic norm (Cadilhom et al, 2006).

The development of monopsony system and economies of scale associated with the production, the basis of the standards and the organization rule and multiplication of knowledge to make, transmission of the markets that explains the situation of the small agriculturists of the difficult zones that is outside of these markets.

3.4. The Lack of Information

Because of the lack for a communication system that includes not only the technology, but also information there for smallholders a significant information deficit (Poole et al, 2000).

Small farmers do not inform about the price, on the situation of effective demand, or the quality of favourite products, in this situation the producers cannot negotiate traders.

The information available in the rural area may not be equally distributed, and producers who are excluded from markets are the most disadvantaged. Other factors act on the commercial efficiency and can form difficulties of horizontal nature to the orientation of the markets and the fluxes of information as the sex, the family, the level of education.

4. AGRICULTURAL EVOLUATION IN THE MAGHREB COUNTRY

The Maghreb region includes richest country in oil and gas (Libya, Algeria) and countries whose resources are very limited compared to their populations (Tunisia, Morocco and especially Mauritania) throughout the region of Africa north (Houssem Eooine Chebbi, Lassao Lachaal, 2004).

To solve this problem of limited natural resources, many economic and political leaders put agriculture in question. For all the Maghreb countries, the agricultural sector remains of major importance in the economic, social and political level.

Table 1. Summarize the number of exploitation, cultivated surface, number of mechanization and spending in R&D in the three Maghreb countries in 2005

Country	Agriculture Productivity	Energy Production	Number of Mechanization	Net income per capita
Algeria	8.221	166662.44	1693.00	10270.00
Morocco	14.677	610.282	1397.00	4710.00
Tunisia	10.127	6681.4	1700.00	7360.00

Legend: the agriculture productivity is the value added (% of GDP), energy production includes forms of primary energy, or oil, natural gas, other solid fuels and renewable and waste-derived fuels and primary electricity, all converted into oil, number of mechanization measured by the number of tractors per 100 square km of arable land, net income per capita based on rate parity purchasing power (PPP).

Source: WDI, 2011

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The sector must continue to achieve two strategic objectives: the protection of the development of basic agricultural products so-called strategic (cereals, milk, potatoes and sugar) and compensation for producers in the event of agricultural disasters.

Globally, on the basis of the green revolution goal, the success of these R&D should result increased the production volume of basic agricultural products, by increasing yields and agricultural productivity and lower the level of agricultural imports expensive and rarely by the degree of respect and apply the principles of sustainable development.

So the use of new technologies such as cultural diversity or animal genetic material shows very contradictory results, with rising environmental costs (protection of forest areas and backgrounds, the use of mechanization on fragile soils with increased erosion, ...) and the social costs (loss of a genetic heritage applied to the arid conditions, deterioration of the collective actions with the individual production motivations).

In some difficult areas, these new technologies do not find their place because of the lack of infrastructure for production and transport, and low participation in services such credits to finance the costly inputs.

Also applied research, partly in experimental research institutions overlooked the local expertise of the actors and the spread of this research was done at the expense of local knowledge which ensured a balance between the medium and the community.

In the arid media, the options distribution difficulties are in intensive systems, which have been frequently reduced for social reasons, such as non-rationality of producers or low level of education in marginal and disadvantaged areas, etc.

The basic consequence is the reduction of the actions to the destructive technical applications of the nature to restrict the environmental risks, in particular the risks of drought.

However, facing the demographic increase of the Maghreb countries, and in light of the urbanization and unemployment increases rates attached to the emigration from the marginal surroundings, of the pastoral zones deterioration, the increasing desertification problem, and the weak technological transfer of research in the difficult zones that correspond to more of 85% of the territory, the agricultural research was interested again controlled in the small and medium agricultural farmers of the arid and semi-arid zones, but this new orientation made itself it in a setting of liberalization, from the years 80, named pre – adjustment period.

5. ECONOMETRIC METHODOLOGY AND DATA

The approach selected in this paper was to model the mechanization impact on the agriculture sustainability in the Maghreb countries. Our initial intention was to cover all countries in the Maghreb, but given that some countries have not yet data of agricultural productivity (for example, Libya, Mauritania), the samples are included only 3 Maghreb countries: over the period of 1997-2010.

5.1. Data

Data were extracted from two sources, the data will be used for the measurement of variables are taken from the database of the World Development Indicators (WDI 2010) and food agriculture organization (FAO 2010).

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Information related the expenses in research and development "R&D" (ERD), the expenses in information and communication technology "ICT" (EICT), the energy production (EP) and the net income per capita (NI) are collected from Worlds Development Indicators (World Bank, 2010). Other information related to agricultural productivity (AP), the mechanization, the Labor (L), the farming population (FP) is collected from food agriculture organization (FAO, 2010).

The dependent variables of interest are agriculture productivity, energy production and net income per capita.

5.2. The Variables

Our analysis founded on macroeconomic factors:

- **Agricultural Productivity (AP):** is agriculture in value added by the worker (% of GDP) (WDI, 2009). V. Ruttan (1977) indicates that the agricultural growth, improvement begins with the apparition of one sustained increase period in the total productivity via the use of new factors and new technologies; our technology is the system of irrigation (Rachida Khaled and Lamine Hammas, 2014).
- **The Expenses in Research and Development (ERD):** Clark and Youngblood (1992) showed that the variable " technology ", as the expenses of the R&D changes the supple utilitarian shape with time is included in the specification of the function of profit, this variable permits to solve the problem of tendency of time (Colin Thirtle, Robert Townsend et Joban van Zyl, 1995). The R&D is the key of development and modernization of the agricultural sector.

Even in the developed country, the agricultural systems of research meaningful are dedicated to testing and refined the innovations of the agriculturists and to test the adaptation of exotic exploitation varieties and the species of the animal (Vernon W. Ruttan, 1977).

- **The Expenses in Information and Communication Technology (EICT):** permits to improve the sector by the diffusion of innovation to the world level and the diffusion of the R&D toward the producers and the consumers.

The ICT decreases the uncertainty of the producers concerning the bought input and of the consumers concerning the consumed product (Gershon Feder and Dina L. Umali, 1993).

- **The Mechanization (M):** it is a very important technology to improve the outputs of producers. (E.J.Clay, 1982).
- **The Labor (L):** Jimmy Alani (2012) proved that the labor is considered as a technology that permits of replaced the machinery in some cases to keep the durability of the sector.
- **The Farming Population (FP):** is himself the producers, the consumers and the manpower. The farming sociologist research has contributed to the diffusion efficiency of technology (Vernon W. Ruttan, 1977).
- **The Energy Production (EP):** energy production includes forms of primary energy, or oil (crude oil, natural gas liquids, and oil from unconventional sources), natural gas, other solid fuels (coal,

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lignite, and other derived fuels) and renewable and waste-derived fuels and primary electricity, all converted into oil equivalent (WDI, 2011).

- **Net Income Per Capita (NI):** net income per capita based on rate parity purchasing power (PPP). Net income per capita in PPP is gross national income converted to international dollars using the rate parity purchasing power (PPP). An international dollar has the same purchasing power over net income per capita stating that a US dollar in the United States. The net income per capita is the sum of value added produced by all residents, most all tax revenues (less subsidies) not included in the value of production plus net receipts of income (compensation of employees and property income) from the abroad. The data are in current dollars International (WDI, 2014).

5.3. Econometric Methodology

From a methodological viewpoint, we chose to value the involvement of the innovations technological to the durability and the growth of the agricultural sector based on the standard production function of Cobb - Douglas type (1928) improves by Dowricks and Rogers (2002) respecting the properties traditional neoclassical (Teheni El Ghak, 2009).

$$Y = AK^{\alpha_k} H^{\alpha_h} L^{\beta} \text{ or } \beta = 1 - \left(\alpha_k + \alpha_h\right) \tag{1}$$

where, Y is a dependent variable which is defined by agricultural productivity, energy production and net income per capita. K, H, L and A are, respectively, the physical capital, the human capital, the labor that grows to the rate exogenous and constant " n ", the technical progress is neutral in the sense of Hicks (1932) and αk, α_h, β are the production elasticity's (Teheni el Ghak, 2009).

However to evaluate the participation of technological innovation, we decomposed the stock of physical capital in two parts: the material, physical capital is the mechanization (M) and the immaterial physical capital is the expenses in the information and communication technology ICT (EICT).

The ERD is the investment in human capital, according to the theory of human capital (Malam Mom Nafiou, 2009).

The expenses in R&D (ERD) and the expenses in the technology of information and communication, ICT (EICT) are considered like an investment in the innovation (OECD, 1999).

The stock of the labor is decomposed into two parts: the labor in the agricultural sector (L) and the farming population (FP).

The goal of this paper is to examine the relationship between technological innovation and agricultural sustainability through the impact of mechanization on agricultural productivity, energy production and net income per capita.

This relationship is measured by a simultaneous equations model (3SLS) extended as follows:

$$\begin{aligned} AP_{it} &= \alpha + \beta_1 \left(EICT\right)_{i,t} + \beta_2 \left(M\right)_{i,t} + \beta_3 \left(ERD\right)_{i,t} \\ &+ \beta_4 \left(L\right)_{i,t} + \beta_5 \left(FP\right)_{i,t} + \beta_6 \left(EP\right)_{i,t} + \beta_7 \left(NI\right)_{i,t} + \xi_{i,t} \end{aligned} \tag{2}$$

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$$EP_{it} = \alpha + \beta_1 \left(EICT\right)_{i,t} + \beta_2 \left(M\right)_{i,t} + \beta_3 \left(ERD\right)_{i,t} + \beta_4 \left(L\right)_{i,t} + \beta_5 \left(FP\right)_{i,t} + \beta_6 \left(AP\right)_{i,t} + \beta_7 \left(NI\right)_{i,t} + \xi_{i,t} \quad (3)$$

$$NI_{i,t} = \alpha + \beta_1 \left(EICT\right)_{i,t} + \beta_2 \left(M\right)_{i,t} + \beta_3 \left(ERD\right)_{i,t} + \beta_4 \left(L\right)_{i,t} + \beta_5 \left(FP\right)_{i,t} + \beta_6 \left(AP\right)_{i,t} + \beta_7 \left(EP\right)_{i,t} + \xi_{i,t} \quad (4)$$

i = 1, 2,…N, t = 1,2,…Ti

where AP, EP and NI are the dependent variables, are defined respectively as agricultural productivity, energy production and net income per capita. The Independent variables are the expenses in research and development (ERD), the expenses in information and communication technology (EICT), the mechanization (M), the labor (L), and the farming population (FP).

Equation (2), allows measure the impact of technological innovation on economic sustainability through the effect of the mechanization (M) on the agriculture productivity (AP), as well as the spending of research and development (ERD) and spending of information and communication technology (EICT) impact.

Equation (3), allows examine the impact of technological innovation on environmental sustainability through the effect of the mechanization (M) on the energy production (EP), as well as the spending of research and development (ERD) and spending of information and communication technology (EICT) impact.

Equation (4), examines the impact of technological innovation on social sustainability through the effect of the mechanization (M) on the net income per capita (NI), as well as the spending of research and development (ERD) and spending of information and communication technology (EICT) impact.

Our methodology is based on an estimate of the simultaneous equations model (3SLS), a sample of 3 Maghreb countries (Algeria, Morocco, Tunisia) and a measurement of the variables from the data for the countries will of 1997 until to 2010.

This simultaneous equations model is estimated by the generalized method of moments (GMM). Since generally, the results of GMM are robust.

6. RESULTS AND INTERPRETATION

Table 2 provides summary statistics on the variables.

Table 2 shows that the average agricultural productivity, the entire sample is 2.437398%. The inter-individual variance (between) 0.0908%, while the intra individual variance (time) is equal to 0.0172%, in our case the inter-individual dimension (3 countries) is very important that the intra-individual dimension (17 years country) (0.0908%> 0.0172%). The same for the regression (3) and (4).

Table 3 summarized the results of three least squares (3SLS) models for the sample of the 3 Maghreb countries from 1997 to 2013.

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Table 2. Descriptive statistics

Variable	Mean	Std. Dev	Min	Max
AP	2.437398	.2811494	1.899224	3.006836
ERD	-.8185559	.7113078	-2.65926	.4054651
EICT	1.316085	.5931466	.4054651	2.674149
L	1.743967	.5446175	.8329091	2.388763
FP	3.669752	.1182476	3.510638	3.863899
M	4.495038	.4879865	3.805239	5.002106
AEP	9.090681	2.234337	6.346817	12.02373
NI	8.847955	.3956486	8.02617	9.478075
N 51 **N 17** **T 3**				

Note. — N, total number of observation; n, number of observation for only one country; T, number of country.

Table 3. Estimation of the model by the method 3SLS

models	**(2)**	**(3)**	**(4)**
Variables	**AP**	**EP**	**NI**
AP	---	.0443973 (0.324)	.0053343 (0.448)
EP	2.66 (0.074)*	---	3.25 (0.000)***
NI	-.0000302 (0.293)	-.0000361 (0.676)	---
M	**-.0075109** **(0.007)*** **	**.0752307** **(0.000)*** **	**.0032048** **(0.047)** **
ERD	.2154256 (0.144)	-2.626171 (0.000)***	.1818109 (0.012)**
EICT	.0140135 (0.127)	.0401492 (0.175)	.0365969 (0.000)***
L	-.0595136 (0.002)***	.2157 (0.000)***	.0197317 (0.076)*
FP	.0148279 (0.324)	.1443269 (0.000)***	-.037439 (0.000)***
Constante	2.894438 (0.001)	-4.792734 (0.006)	9.310632 (0.000)
Observations	37	37	37
R^2	0.9243	0.9867	0.9879

Note. — Panel estimations of the 3 Maghreb countries. The dependent variable is the agriculture productivity (AP), energy production (EP) and the net income per capita (NI). Variables in parentheses are at the significance level of 1% *, 5%** and 10%***.

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The first column presents the effect of mechanization on economic sustainability through her impact on agricultural productivity. The second column indicates the effect of the mechanization on environmental sustainability through her effect in energy production. The third column shows the impact of mechanization on social sustainability through her effect on net income per capita.

According to the regression (2), we show that where agricultural productivity (AP) increases by 1 percentage points, mechanization (M) decreases by 0.0075109 percentage points, labor (L) decreases by 0.0595136 percentage points, net income per capita (NI) drops by 0.0000302 percentage points, R&D expenditure (ERD) and communication and information technology expenditure (EICT) increase respectively by 0.2154256 percentage point and 0.0140135 percentage point, farming population (FP) raises by .0148279 percentage points, and energy production (EP) increases by 2.66 percentage points.

This negative impact of mechanization on the sustainability economic explains that the mechanization cannot achieve economic efficiency in the Maghreb countries due to the intensive use of mechanization in the sector, allowing deteriorate soil fertility over time and eventually lowers productivity and performance in the agricultural sector.

In the regression (3), we mark that wen energy production rises by 1 percentage points, mechanization (M) increases by 0.0752307 percentage points, labor (L) increases by 0.2157 percentage points, net income per capita (NI) drops by 0.0000361 percentage points, R&D expenditure (ERD) drops by 2.626171 percentage points, communication and information technology expenditure (EICT) increase by 0.0401492 percentage points, farming population (FP) raises by .1443269 percentage points, and agriculture productivity (AP) increases by 0.0443973 percentage points.

According to the study of L. Kallivroussis; A. Natsis; G. Papadakis (2002), the mechanization ensures the transportation of the oleaginous plant energy to processing for the production of biodiesel. The use of mechanization in agriculture increases the energy work by reducing the working hours of each employer. So the mechanization increases energy production.

Regression (4), indicate that when net income per capita (NI) increases by 1 percentage points mechanization (M) increases by 0.0032048 percentage points, labor (L) increases by 0.0197317 percentage points, energy production (EP) rises by 3.25 percentage points, R&D expenditure (ERD) increases by 0.1818109 percentage points, communication and information technology expenditure (ECIT) increase by 0.0365969 percentage points, farming population (FP) decreases by 0.037439 percentage points, and agriculture productivity (AP) increases by 0.0053343 percentage points.

Usually technological innovation affects positively the social aspect, mechanization is produced by innovative societies and eventually allows increased wages of companies and their purchasing power that leads as the decline in poverty.

Mechanization improves the purchasing power of Employers in the industrial sector such as an equipment manufacturing society, for against the rural population suffers from very high level of poverty. As he explains C.P.Timmer (1992), the agricultural sector is like a black box, it provides power to all the other sectors against it is not growing.

In the Maghreb countries, the mechanization affects positively the sustainability's environmental and social but it affects negatively the sustainability economic.

According to the results of the simultaneous equations model (3SLS) estimation, we noticed that the workforce has an important role in the functioning of agricultural machines. The three regressions (2), (3) and (4) show that the relationship between mechanization and labor is positive.

The impact of mechanization on economic, social and environmental aspects is explained by the effect of labor on the three durabilities. The workforce in agriculture of the Maghreb countries is unqualified.

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The lack of learning by doing in the agricultural sector prevents increasing performance and productivity through step full of ecological, poor use of fertilizers, spreading pollution and over-exploitation of water resources (Feder and Umali, 1993).

The result of the estimated regression No. 3 shows that the level of research and development to a negative impact on the environmental aspect through their impact on energy production, this result can be interpreted by the novelty of the sustainable agriculture in the Maghreb countries, such as organic farming.

Biological research and development remains until today in the laboratories and has not yet applied to a field.

The information and communication technology (ICT) has a positive effect on all three aspects (economic, social and environmental), this result is explained by the introduction of new technology (mobile, internet, etc.) in rural areas and their participation in the agricultural sector through improved marketing of agricultural product line, development and definition of sustainable agriculture concept and organic products in the Maghreb countries.

The result of the estimated regression No. 4 indicates the farming population affects the affects negatively the social aspect through their impact on the net income per capita.

The population increase in rural areas increases the pollution in the zone and increases the use of water resources, leading to over-exploitation of natural resources.

Despite the positive effect of mechanization on the social and environmental aspect, mechanization used by Maghreb countries is not sustainable since it cannot achieve economic efficiency.

7. CONCLUSION AND POLICY RECOMMENDATIONS

The concept of sustainable development has spread during the 90s in scientific research both locally and planetary. All this research agrees that the achievement of sustainable development depends on the respect of four essential principles: equity between nations and generations, the equilibrium of the economic situation and the protection of the environment.

On this basis, several economists and scientists believe that the diffusion of technological innovation is a basic means to ensure sustainable development in the agricultural sector.

To verify this effectiveness, we tested the effects of technological innovation on the agricultural sector in the three Maghreb countries (Tunisia, Morocco and Algeria) for a period from 1997 to 2010 by a model of simultaneous equations, as well as their ability or non to achieving the objectives of sustainable development in agriculture sector.

The estimation results show that mechanization used by Maghrebin farmers is unsustainable. For this it's unable to achieve the sustainable development objectives in the agricultural sector of Maghreb countries. The mechanized agricultural land use may lead to reduced fertility and increased pollution.

A recent study done by CEMA (2014) indicates that there are 12 types of agricultural mechanization in the world. The weak type is used by developing countries, particularly Africa. It can be concluded that the poor quality of mechanization used by Maghreb countries to impact the agricultural sector sustainability.

Our findings have important policy recommendations for Maghreb countries.

First, the government support for funding and Development: the Maghreb Farmers need for state subsidies to buy sustainable agricultural machines with good quality. They also need the development of their rural areas by building infrastructure to attract investors to invest in the agriculture sector.

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Secondly, improve training in the rural middle, especially how to operate farm machinery: the workforce in the agricultural sector of the Maghreb countries is not qualified because of their limited education level. The majority of labor worked in agriculture is the farming population.

Third, the development of environmental protection strategy and implementation in the rural middle, for example, the payment of fees for people that generate negative externalities in the rural areas.

REFERENCES

Abderraouf, L. (2007). L'agriculture biologique en Tunisie: un nouveau créneau en développement. Les notes d'alerte du CIHEAM, N°35-2.

Ademar. R.R. (1989). Agriculture et progrès technique: une étude sur la dynamique des innovations. Cahier du brésil contemporain, N 4.

Alani, J. (2012). Effects of Technological Progress and Productivity on Economic Growth In Uganda. *Revue Procedia Economics and Finance*, 1, 14 – 23.

Alexandre, G. (2008). La sélection des produits agricoles sensibles: Le cas européen. *Revue d'Etudes en Agriculture et Environnement*, *87*(2), 49–76.

Alphandéry, P., & Billaud, J.-P. (1996). L'agriculture a l'article de l'environnement: introduction. *Études rurales, cultiver la nature*, 142, 9-19.

Blazy, J.-M., Carpentier, A., & Thomas, A. (2011). The willingness to adopt agro-ecological innovations: Application of choice modelling to Caribbean banana planters. *Revue Ecological Economics*, *72*, 140–150. doi:10.1016/j.ecolecon.2011.09.021

Bodiguel, M. (1970). la diffusion des innovations agricoles: Psycho-sociologie de l'innovation ou sociologie du changement? *Revue Francaise de Sociologie*, *11*(4), 566–571. doi:10.2307/3320546

Boughanmi, H. (1995). Les principaux volets des politiques agricoles en Tunisie: évolution, analyse et performances agricoles. CIHEAM-options méditerranéennes, ser.B/n 14, les agricultures maghrébines à l'aube de l'an 2000.

Cadilhon, J.-J., Fearne, A. P., Giac Tam, P. T., Moustier, P., & Poole, N. D. (2006). Quality incentives and dependence in vegetable supply chains to Ho Chi Minh City. *Acta Horticulturae*, (699,): 111–117. doi:10.17660/ActaHortic.2006.699.11

Capitaine, M., David, C., & Freycenon, R. (2009). Evaluation et amélioration de la durabilité de l'agriculture biologique: éléments R. de débats. *Innovations agronomiques*, 4, 209-215.

Carrel, J. (1953). Le commerce des produits agricoles et les marges commerciales. revue économique, vol 4. No 5, septembre, pp 673-694.

CEMA (2014). Promouvoir le développement rural et agricole en Afrique grâce à la mécanisation agricole (MA) avancée. Comité Européen des groupements de constructeurs du machinisme agrico.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Chebbi, H.E., & Lachaal, L. (2004). L'agriculture et la Sécurité Alimentaire: Une étude comparative des Pays du Maghreb. NEW MEDIT N. 3.

Chen, J. (2005). Biodiversity and biotechnology: a misunderstood relation. MICH.ST.L.Rev.51.

Clavel, D., Barro, A., Belay, T., Lahmar, R., & Maraux, F. (2008). Changements techniques et dynamique d'innovation agricole en Afrique sahelienne: le cas du Zaï mécanisé au Burkina Faso et de l'introduction cactée en Ethiopie. Vertigo la revue électronique en sciences de l'environnement, 8(3).

Clay, E.J. (1982). Technical innovation and public polic: agricultural development in the Kosi Region, BIHAR, INDIA. Agricultural administration, n° 9 pp 189-210.

CNUCED. (2003, May). Le contexte général de l'agriculture biologique et le potentiel de marché pour les exportations.

Commission Européenne. (2007). Evolution environnementale stratégique pour le programme de bassin maritime méditerranée. LOT n°6, environnement.

Conseil de la science et de la technologie au Québec. (2001). Innovation et développement durable: l'économie de demain.

Delchet, K. (2004). Qu'est-ce que le développement durable?

Dimara, E., & Skura, D, (2003). Adoption of agricultural innovations as a two-stage partial observability process. *Revue Agricultural Economics*, 28, 187–196.

Esposti, R. (2002). Public agricultural R&D design and technological spill-ins a dynamic model. *Revue Research Policy*, 31, 693–717.

Faucheux, S., Hue C., & Petit, O. (2001). NTIC et environnement: enjeux, risque et opportunités. *Cahiers du C3ED*, 1.

Feder, G., & Umali, D.L. (1993). The Adoption of Agricultural Innovations. *Technological forecasting and social change*, 43, 215-239.

Franck-Dominique. (2003). Jalons pour une histoire de la nation de développement durable. Monde en développement, 31(121).

Doole, G.J. (2012). Evaluation of an agricultural innovation in the presence of severe parametric uncertainty: An application of robust counterpart optimization. *Revue Computers and Electronics in Agriculture*, 84, 16–25.

Gall, E., Millot, G., & Neubauer C., (2009). Faiblesse de l'effort français pour la recherché dans le domaine de l'agriculture biologique: approche scientométrique. *Innovations agronomiques*, 4, 363-375.

Godard, O. (2002). Le développement durable et les entreprises. *Revue des Deux Mondes (Paris, France)*, Octobre-Novembre, 101–128.

ICROFS. (2010). Comment l'agriculture biologique contribue au développement économique en Afrique. n°4.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Jacque, P. (n. d.). Valeur et développement durable "chapitre1 et chapitre2:" "le développement durable: une illusion mortice" et "l'enjeu écologique du développement durable".

Kallivroussis, L., Natsis, A., & Papadakis, G. (2002). The Energy Balance of Sunflower Production for Biodiesel in Greece. *Biosystems Engineering revue*, 81(3), 347–354.

Ayang, L.A. (n. d.). Indicateurs nationaux du développement durable les quels retenir?

Labatut. J.-M. (1995). La place et le rôle des communautés paysannes dans la recherche pour lutter contre le processus de désertification dans le Sahel. *Revue canadienne des études Africaines*, 29(1), 26-50.

Lamine, C., Meynard, J-M., Perrot, N., & Bellon, S. (2009). Analyse des formes de transition vers des agriculteurs plus écologiques: les cas de l'agriculture biologique et de la protection intégrée. *Innovations agronomiques*, 4, 483-493.

Latouche, S. (2003). L'imposture du développement durable ou les habits neufs du développement. *Mondes en Developpement*, *31*(121).

Leroux, B. (2009). Stratégies, innovations et propriétés spécifiques des agriculteurs biologiques: éléments d'analyse sociologique du champ professionnel agrobiologique. *Innovations agronomiques*, 4, 389-399.

Louhichi, K. (2010). FSSIM, a bio-economic farm model for simulating the response of EU farming systems to agricultural and environmental policies. *Revue Agricultural Systems*, 103, 585–597.

Mélanie Requier-Desjardins. (2010). Impact des changements climatiques sur l'agriculture au Maroc et en Tunisie et priorités d'adaptation. Les notes d'analyse du CIHEAM n°56-mars.

Monday, B., Terrieux, A., Gafsi, M., & Hemptienne, J.L. (2009). Enjeux et perspectives de développement de l'agriculture biologique en Midi-Pyrénées. *Innovations agronomiques*, 4, 377-388.

Murua, J.R., & Laajimi, A. (1995). Transition de l'agriculture conventionnelle vers l'agriculture durable: quelques réflexions. *Cahiers Options Méditerranéennes*, 9, 75-86.

Nations Unies. (2010). Commission économique pour l'Afrique et bureau pour l'Afrique du nord. Développement durable et changement climatique: comment se positionne l'Afrique de nord ?. CEA-AN/PUB/10/1.

OCDE. (1999). Développement durable les grands questions?

Philippe County. (1991). L'agriculture Africaine réserve, réflexion sur l'innovation et l'intensification agricoles en Afrique tropicale. Cahier d'études africaines, 31(121/122), 65-81.

Poole, N. (2006). L'innovation: enjeux, contraintes et opportunités pour les ruraux pauvres. Document de synthèse, Janvier.

Ruttan, V. W. (1974). Induced innovation and agricultural development. *RE:view*, *64*(May), I-14.

Ruttan, V. W. (1989). Institutional-Innovation and Agricultural Development. *Review World Development*, *17*(9), 1375–1387. doi:10.1016/0305-750X(89)90079-X

Simmonds, N.W. (1988). Observations on Induced Diffusion of Innovations as a Component of Tropical Agricultural Extension Systems. Revue Agric. Admin. & Extension n°28 pp 207-216.

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Stassart, P.M., & Jamar, D. (2009). Agriculture biologique et verrouillage des systèmes de connaissances conventionalisation des filières agroalimentaire bio. *Innovations agronomiques*, 4, 313-328.

Thirtle, C., Townsend, R., & van Zyl, J. (1998). Testing the Induced Innovation Hypothesis in South African Agriculture (An Error Correction Approach). *Agricultural Economics*, (19): 145–157. doi:10.1016/S0169-5150(98)00030-9

Timmer, C. P. (1992). Agricultural and economic development revisited. *Agricultural Systems*, *40*(1-3), 21–58. doi:10.1016/0308-521X(92)90015-G

Valenduc, G., & Warrant, F. (2001). L'innovation technologique au service de développement durable. Working paper n1 aspecFt conceptuelles (février 2001).

Van Mansvelt; J.D. (1992). *Vers une agriculture renouvelable et durable; agriculture biologique: d'une avant-garde marginale au fer de lance d'une agriculture d'avenir. Revue Tiers monde, T.XXX III, N°130*. Avril-Juin.

van Rijn, F., Bulte, E., & Adekunle A. (2012). Social capital and agricultural innovation in Sub-Saharan Africa. Revue Agricultural Systems, n°108 pp 112–122.

Zoundi, S. J., & Hitimana, L. (n. d.). Défis de l'accès des exploitations familiales aux innovations agricoles en Afrique de l'ouest: Implications institutionnelles et politiques. *OCDE, Paris.*

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Chapter 2
Practice of Green Marketıng Activities in the Organic Agricultural Sector in Turkey

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ABSTRACT

Requests and needs are not static in a growing and changing world. On the contrary, they can develop and change with the effect of both environmental and internal factors. Green marketing is the request of social civilization. One of the effects of this growing interest in environmental markets in Turkey and the rest of the world can be seen in the move towards organic agriculture. The main purposes of this study are to define organic agriculture as described by environmental marketers and as practised in the agricultural sector, and to explore the current condition of organic agriculture in Turkey and the rest of the world. Subsequently, organic agriculture and the main problems in its related sectors will be discussed and suggestions for solutions will be given. Suggestions will be given that include political, as well as research and development and training programs that are related to improving organic agriculture and increasing organic exports.

INTRODUCTION

Sustainable agriculture involves the production of food products with sufficient and quality amounts and with appropriate costs. Besides, economic vitality of world agriculture involves protection of environment and natural agriculture resources and systems and practice that will develop welfare of population of the World. The most important fact which should be examined about sustainability in Turkey is agricultural activities and the subject of organic agriculture. Because, agriculture is the starting point which we define as prime production of food chain. Therefore, organic agricultural activities in Turkey will be tried to be examined in the study and problems faced will be put forward and solution ways will be discussed.

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GREEN MARKETING

Although environmental issues affect human activities and whole human health, the number of science fields dealing with environmental issues are pretty few. The more the interest of society towards natural environment increases, the more businesses should review their internal policies in order for them to be able to fulfill the requests of society. Green Marketing takes places in the literature with different names such as ecological marketing, environmental marketing, sustainable marketing and conservationist marketing and etc. All of these concepts take reviewing marketing programs to be applied in meeting requests and needs of consumer with conservationist approach as a basis (Shehu, 2010).

Marketers haandcompiled process of change of green marketing definitions in time. According to this, development process of green marketing in time can be stated as below;

At firstly, Henion and Wilson (1976) emphasized the necessity of that all marketing activities in environmentalist marketing should become remedy for the causes of environmental problems and should bring awareness. Recently, İslamoğlu (2013) defined green marketing as "businesses' determining their marketing strategies, programs in a way that will protect and develop natural environment and applying them."

It is stated by financial communities that green marketing involved in marketing literature in a seminar, the subject of which was ecological marketing, American Marketing Union organized in the USA in 1975 for the first time (Erbaşlar, 2007; Ay & Ecevit, 2005).

As Ottman (1993) informed, green marketing is a work strategy which examines positive and negative sides of pollution, energy consumption and consumption of exhaustible resources, which aims at long-term profitability within the perception of responsibility in meeting the needs of society and consumers (Alagöz, 2008). It may be stated that green marketing has arisen from societal marketing with its one aspect. Societal Marketing is a marketing approach which aims at not only satisfying only its customers but also considering the expectations of society (Pezikoğlu, 2012).

Green Marketing is an approach which has been advancing by becoming more and more powerful since 1980s as a new marketing strategy which has double-sided (producer-consumer) interaction and compulsivity. Besides, green marketing means a process which renews itself continuously. It is observed that green marketing has become different conceptually in time. According to this, "ecological marketing, which involves all marketing activities which causes environmental problems and which will become solution to these environmental problems, and which showed up with phrases of recycling, ozone-friend and etc." comprises the first stage. The second stage is "green-environmentalist marketing". The third stage is stated as "sustainable-green marketing". Undoubtedly, development of environmental marketing has had some effects on marketing in the last 10 years. It is known that giant companies such as IBM, McDonalds and BT and etc. force their suppliers to show higher eco-performance by using their purchasing power in their hands. And it is seen that they control these works with green supervising. (Pezikoğlu, 2008).

SUSTAINABLE AGRICULTURE AND ORGANIC AGRICULTURE: TRADES AND SUBSIDIES

Sustainable agriculture is related to agricultural dimension of sustainable development. In sustainable agriculture, it is essential that in addition to that natural resources should be protected in the long run,

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agricultural structure where agricultural technologies which do not harm environment should be formed. Synthetic production inputs are used without supervision in a number of countries in the world. And at the same time, intense (conventional or intensive) agricultural production are being carried out without thinking negative results that cultivation techniques and technologies form. Nowadays, these practices has started to get attention as much as waste industry or urban pollutions with their characteristic of creating danger of life which may reach human via their effects on deformation of natural balance and also all creatures. Because of this, in sustainable agriculture, techniques that have not lost their naturality yet have had necessity. Here, using inputs which are not natural such as pesticides, synthetic fertilizers and etc. should be avoided and organic agricultural techniques meeting with health and environmental standards play a key role. Organic agriculture which bear importance in terms of reflection of sustainable agriculture to practice has started to constitute a necessity together with the development of environment awareness especially in recent years. In addition to this, products chosen in order to know and protect some agricultural products in especially European Union (EU) countries are registered in sustainable agriculture perception (Turhan, 2005).

Sustainable agriculture are being tried to be carried out with different systems in a number of countries round the World. Products produced by using this method and system are among the green products. HACCP (Hazard Analysis and Critical Control Point), ISO (International Organization for Standardization) series, organic and good agricultural practices confront us as green marketing products. (Albayrak et al., 2010).

Organic Agriculture is one of the systems of sustainable agriculture. However, Organic Agriculture has specific principles and practices in the process from the production of products on the field to their marketing (Demiryürek, 2011).

Sustainable aspects of organic agriculture within sustainable agriculture concept can be summarized as below:

- Avoiding earth and water pollution, even if it is low, as a result of choice and application of natural chemicals applied compatible with ecological environment and designing an agricultural production system which may be within ecological environment,
- Having formed a new system in terms of economic sectors, actors within conventional system being able to be within this commercial system.
- Producer's Adopting production methods protecting environment in rural areas,
- Distributing risk by having activity which has any other market network and price within agricultural activities carried out on the basis of businesses,
- Because work power need is higher, preventing unemployment and, being positive for businesses whose work power is intense,
- Being in the market as a new product which is just in the beginning of product life cycle, having become a trademark, and being able to form organic label at the national level.

As against the aspects mentioned above, criteria which should be taken into consideration in order to examine organic agriculture with regard to sustainability of agriculture can be classified as:

- Food safety and guarantee,
- Sufficiency and continuity in business income,

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- Continuity of employment in rural areas,
- Rural welfare (Pezikoğlu & Yavuz, 2006).

When the literature is examined, there are a number of definitions about the concept of organic agriculture. However, because there is no common definition which is agreed generally, it brings together some discussions and differences of opinion. Here will be given a definition whose framework has been drawn up technically by USA Agriculture Department (USDA). According to this "organic agriculture is a production system which forbids use of fertilizers with synthetic content, pesticides, growth regulators or which avoids them to a large extent. Organic agriculture systems depend on processes of product alternation, plant residues, animal fertilizer, legume, green fertilizing, organic farm waste and control of biological pests in so far as possible in order to cultivate the soil, protect the productivity, to provide plant foodstuff, to control pests, weeds and diseases (Anonymous, 1980).

Lampkin (1990) emphasized sustainability advantages of organic agriculture and defined organic agriculture as an agricultural approach aiming at the purpose of forming an integrated agricultural system which is environmentally, socially and economically sustainable. He emphasized that dependence on out-of-farm inputs should be reduced whether they have chemical or organic roots.

As a result of long-term studies, the definition of organic agriculture was approved by International Organic Agricultural Movement Federation (IFOAM) in Italy in 2008. According to this; "Organic Agriculture is a production system which sustains soil, ecosystem and human health. The system depends on ecological processes, biological diversity and cycles which have been adapted local conditions. Organic agriculture brings traditions, innovations and science together in order to be beneficial to the environment in which it is lived, to generalize fair relation and a better life quality for all related parties" (Anonymous, 2009).

In the efforts of increasing especially agricultural lands and water resources in the world in recent years, more and more difficulties are being met. Environmental effects such as oil erosion and air pollution have slowed down the increase of agricultural lands in the world, even they have brought it just to the point of stop. Not being able to cultivate the lands which have suffered from erosion seriously, and the lands' being used in out-of-agriculture areas such as buildings and factories cause millions of hectares of lands to be lost every year. While some countries such as Brazil, Israel and etc. are forming new agricultural lands by rehabilitating deprived lands in terms of productivity, other countries such as Turkey, China etc. convert 1. class agricultural lands into other usage areas. As a result of all of these, the amount of agricultural lands per person reduces in both Turkey and the World (Rehber and Çetin, 1999). On one side, the world population is increasing and on the other side decrease in cultivated lands is seen as an important problem. Developed and developing countries began to try to take precautions against all of these threats and started studies related to this subject in 1950s (Turhan, 2005).

Studies, which continued separately until 1970s, gathered movements of organic agriculture all round the world under a common roof in 1972. With the foundation of IFOAM which aims at directing development of the movement healthily, protecting required standards and methods, conveying all developments to its members and farmers, this gathering gained a different dimension. Really, practices of production standards which have been combined and/or have become adapted, aiming at production of organic foodstuff all round the world, are quite important for growing organic agricultural land and organic product markets to develop more. Harmonizing rules and every country's organizing its own regulations commonly is necessary in order to remove the difficulties of trade of organic products (İpek & Çil, 2010).

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It is known that organic agriculture started for the first time in EU and USA and then spread to other countries. There are total 37.2 million hectares of organic agriculture land (including transition process areas) in the world. In today's world, 1,2% of agricultural land cultivated in the world is organic agricultural land. (Eryılmaz et al.,2015; Emir & Demiryürek, 2015; Willer & Klicher, 2011). Nowadays, organic agriculture is becoming a sector whose market volume and consumption demand are increasing more and more all round the world. It gets attention that developed countries start to be in the position of consumer and developing countries start to be in the position of producer.

One of the most important driving power at the back of organic agriculture is that organic products are more reliable than conventionals with regard to chemical use and residue problem and that the number of consumers believing this is increasing. It is a fact that organic agriculture reduces toxic chemicals, prevents the use of Genetically Modified Organisms (GMO) definitely, reduces food additives and colorant use, on the other hand, increases beneficial minerals and foodstuff, beneficial oil acids and antioxidants. In addition to this, organic products it is mentioned that organic products have the potential to reduce the risk of formation of cancer, coronary heart diseases, allergy and hypermobility problem in children. A number of studies showing comparative benefits of organic food and forage in terms of health have been conducted. There are claims that organic products are more superior than products produced with other alternatives in terms of safety nutrition content and value. Especially, expectation that vegetables and fruit produced via organic way will be more beneficial than conventionals in terms of health is common (Rehber & Pezikoğlu, 2013). While up to 500 additives are permitted in conventional food production, the number of additives permitted in organic production is only about 30 (Heaton, 2002).

Countries making organic agricultural production preferred starting from usually conventional products of their countries in the transition towards production all round the world. For example, the first products produced organically are tea in India, milk and dairies in Denmark, meat and meat products in Argentina, banana in central America and Africa countries, date palm, olive oil in Tunisia, dried and fruit with hard shell (İpek & Çil, 2010).

While a fast production decrease is the point in question at first in the transition towards organic agriculture when compared to conventional agriculture, production level approaches to the previous level with precautions taken afterwards. While giving up using synthetic inputs causes productivity decrease, it provides important cost savings. In an evaluation made, while gross yield with the rate of 6-17% is the point in question in transition towards organic agriculture in plant production, because of decrease in costs, net income loss is said to be about 13% at most. Even if organic agriculture seems to be financially less advantageous than conventional agriculture, especially in the long run, it is actually more superior with economic contributions in the way of protecting environment and natural balance. Consumer income in the long run is very important in sustainable agriculture and so in organic agriculture (Turhan, 2005).

In World Trade Organization (WTO) organizations, agriculture has been involved within globalization. In WTO agreement, opinion of market mechanisms' directing agricultural production and change by purging agricultural policies of state intervention and social dimension has been agreed. However, because of welfare differences between rural communities, some privileges have been granted in certain subjects in agriculture. According to this, internal supports are examined in 3 parts, Red Box, Blue Box and Green Box. Green Box includes supports from which any discount is not requested in internal supports. Organic agriculture is assessed within this box. By the same token, direct income support payments are within this scope and direct income support payments made to organic agriculture does not get limited by WTO. FAO grants supports to organic agriculture and similar environment-focused

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agricultural systems. Principles and standards of organic agriculture was defined by Codex Allimentarius (Pezikoğlu & Yavuz, 2006).

Before mentioning supports given to organic agriculture in Turkey, it is beneficial to mention their examples in the world briefly;

Organic agriculture have been conducted under the control of the state in the USA. Organic Agricultural Producers are supported with advance payments or payment conveniences for especially certification.

In Latin America, organic action generally has developed with its own effort. There is no state which provide support or economic help directly. As an exception, the state has published interministy organic plan in order to encourage organic production, research, marketing and trade in Brazil. In Bolivia, an action plan has been created in order to support development of organic production and to establish national control system.

EU Countries, which own more than 50% of organic food market, is also in the position of the biggest foreign purchaser of the world. Organic agriculture has located in the center of agricultural policy of the Union with Common Agricultural Policy (CAP), which took effect on 1 January 2005. With reforms made in common agricultural policy, agricultural subsidy policy has changed completely. According to this, protection of environment, food safety, animal and plant health and sustainable use of agricultural land are predicted with new regulations. In addition, both regulations related to agriculture-environment relations and various regulations dealt with within the scope of environment policies, and national programs which each country member of EU has developed according to their own conditions contributes for organic agriculture to be directed. Farmers in all EU countries gets support within the scope of agricultural environment programs. State supports aimed at organic agriculture in different EU countries are as follows;

The United Kingdom (UK) has given the biggest environmental priority to sensitive regions. Depending on the structure of land, farmers are granted previous period supports paid in the last 5 years in this country. In Germany, development of organic agriculture was supported by forbidding chemicals from 1989 to 1992. There are a number of different applications about the support granted to organic agriculture resulting from federal structure. Different programs are applied in each one of states in order to support farmers dealing with organic agriculture and participation conditions to these programs show differences. Annual subsidies are granted to farmers dealing with organic agriculture in vegetable production per hectare in Belgium and finance of two research centers which have been established for organic agriculture is provided. In Denmark, the government supports organic agriculture projects and grants subsidies per hectare. Although Danish Farmers are involuntary about transition towards organic agriculture, transition towards organic agriculture has been considerably enabled as a result of government policies and market pressures. In Italy, supports granted to organic agriculture are used like direct income support in some regions. Tax applications to pesticides are started in order to create financial resources in order to be used in development of organic market. In addition, campaigns of awareness-raising of the population are being carried out. In Netherlands, various precautions have been taken in order to increase production and consumption of organic agriculture according to policy called "Organic Market in order to Win". The purpose of legal regulations aimed at farmers making organic production in Netherlands is to increase sustainable investments in agriculture (Anonymous, 2012).

Because of fewness of studies in which organic agricultural trade and state supports are told together in developing states before in the literature, current condition in Turkey, insufficiencies, support elements which are and should be provided to organic agriculture will be examined in the study afterwards.

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BACKGROUND

In a study that Eryılmaz et al. (2015) conducted, according to results of the research made in certain provinces of Turkey, among the reasons that consumption of organic agriculture and food products is low are highness of prices and knowledge insufficiency. Increasing demand for organic agriculture and food products is important with regard to sustainability of production. Therefore, organic producers who want to continue their existence in the sector and who want to follow the development in the world should turn towards the perception of consumer-focused marketing.

According to Armağan and Özdoğan (2015), in Aydın province consumers prefer organic food products which they qualify as healthy and delicious more as their income level and education level increases. 30,4% of consumers stated that they could pay more to organic chicken and 30,4% of those to organic eggs.

According to results of researches that Akgüngör and et al. (2010) conducted on the people living in urban areas of İstanbul and İzmir provinces, the reasons for consumers to prefer organic products are that their nutrition values are higher and their health risks are lower. Consumers do not perceive organic food products more expensive than conventional equals and they are voluntary to pay up to 36% more to organic labeled and certificated products.

According to Akın et al. (2010), in Niğde province, families under the age of 40, whose income levels are over 1000, with one or two children and especially women consumers within this group are more sensitive about organic food subject than the groups having other socio-demographic characteristics.

According to a research that Dağıstan and et al. (2010) made on consumers living in the center of Hatay Province, 57% of consumers consumed at least one organic agriculture and food product. Knowledge deficit and price highness (70%) are among the leading reasons for consumers' not consuming organic products.

Sarıkaya (2007) determined in his research that the organic product groups which consumers, living in Ankara and İstanbul where organic agriculture and food product market intensifies, buy most are vegetables, fruit and drinks because they are easily found and their product ranges are wide.

Aydın (2011) found out that 7,81% of consumers living in urban areas of Samsun province regularly consume organic products and that knowledge deficit, with 43,22%, is in the first place.

According to Gündüz and Bayramoğlu (2011), 81% of families living in Samsun province agree to pay more for organic chicken. It was determined that monthly family income, education level of family head, monthly chicken consumption, organic food consumption and opinion of consumers related to risks conventional chicken bear in terms of health have effect on payment desire.

Ergin and Özsaçmacı (2011) found out in their study where he researched main reasons for consumers' buying organic product in İstanbul and Ankara provinces that thoughts that organic foods are more healthy, tasty, fresh and environment-friendly are dominant when compared to their conventional alternatives according to findings obtained.

As Erılmaz et al. (2015) stated in their compilation study they conducted, It was determined that markets of organic agriculture and food products intensifies in different parts of Turkey especially in big provinces such as İstanbul, Ankara and İzmir. It was seen that consumers' habit of purchasing organic agriculture and food products is not common in Turkey in general. Among the main reasons for this condition are that consumers do not have sufficient knowledge about organic production and they regard prices as high.

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In a study Hassan et al. (2009) conducted, education was found to be the first of effective factors in the formation of consumer attitude and behavior in EU countries against organic food and agricultural products. Because, it is seen that organic agriculture and food products are preferred more by those whose education levels are higher.

In a study Urena et al. (2008) conducted, it was found out that another effective factor in the consumption of organic agriculture and food products is gender. According to findings, although tendencies of women consumers towards buying organic products are higher than men, their wills to pay to these products are lower.

In a research Kızılaslan and Olgun (2012) made, they found out that organic agriculture land and the number of producers are increasing more and more and on the other hand, Turkey cannot use the potential it has about organic agriculture sufficiently.

Gülse Bal et al. (2006) determined in a study conducted in Tokat province that 90% of consumers may pay more to reliable food.

In an organic product demand research conducted by Koç et al. (2001) in the center of Ankara, the rate of voluntary consumers to pay 50% and %100 price difference without reducing their consumption was determined to be 24,2 for tomatoes and 16% for cucumbers (Koç et al., 2001).

In a study Karahan Uysal et al. (2010) conducted, although the most important fact defining organic product is "logo", it is thought that Turkish consumers do not have sufficient information about it. In a study conducted on organic product consumers in İzmir and Ankara, it was determined that knowledge levels of consumers about organic product logos and standards are low and on the other hand, trust in logos is above average.

In a research made by Pezikoğlu (2004), price difference Turkish consumers are ready to pay for organic product was found to be about 2%.

In a research made by Demiryürek (2004), economic factors (especially premium price and market guarantee) were found out to be the most effective motivation element in transition of producers towards organic production in Turkey.

In another research made by Demiryürek (2011), a number of suggestions were made aimed at policies, research and development and training programs related to developing organic agriculture in Turkey and increasing our organic product export.

In a research Bahrs(2004) made, he stated that subsidies should be also supported with tax incentives.

According to findings they obtained in a research Azak and Miran (2015) made in İzmir province, Turkey, they stated that if supports that will increase the number of organic producers are made, the number of producers and consumers will increase, this will increase supply and may be able to balance product prices. State and municipalities should give supports that will reduce the costs of especially sellers, for example, paying transportation costs may prevent product prices from increasing. By increasing market places, opportunity of marketing their products easily should be given to producers, and it should be targeted to reach more consumers.

In a study Lotter (2003) conducted, the aspect of organic agriculture's being a system which provide important benefits to public about reducing environmental costs was emphasized. In the study was also stated the necessity of transferring high costs in transition towards organic agriculture from farmer and organic product customer to public.

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ORGANIC AGRICULTURE TRADES AND SUBSIDIES IN TURKEY

Issues, Controversies, Problems

One of agricultural effects of sustainable and green marketing is seen in the shape of turning towards organic agriculture in Turkey and in the world. Organic agriculture practices is becoming widespread not only in developed countries but also in developing countries. This condition has become clear with increasing importance the consumers especially in developed countries give to their health and protecting environment. In parallel with this, organic food market is developing especially in Europe, America and Oceania. Demand for organic products which are not produced in developed countries has caused international trade to develop. So, developing countries whose ecology is suitable for organic agriculture have become organic product producers and exporters in order to be able to meet demands coming from developed countries. With this aspect, organic agriculture is a very valuable element whose importance in Turkish trade is increasing fast (Rehber & Turhan, 2001; Demiryürek, 2011; İpek & Çil, 2010)

Organic agriculture in Turkey started in the direction of demand of European importers and with export of sultanas and dried figs in Aegean Region for the first time in mid-80s and spread all round Turkey from here. Although farmers led the development of organic agriculture in the countries where organic agriculture started, European private organic agriculture companies played an active role in promotion of organic agriculture and adopting it to farmers in Turkey. That is, whereas Europe and in the USA realized bottom-up starting from producer (supply-based), top-bottom structuring of organic agriculture from companies dealing with organic agriculture towards producer (demand-based) is the point in Turkey (Kizilaslan & Olgun, 2012; Demiryürek, 2004; 2011).

Organic products started to gain importance commercially all round the world in 1990s. It became necessity for a national legislation on organic product which came to the fore in those years in Turkey which organizes all stages of organic agricultural activities from production to marketing to be created. In this direction, "Legislation on Production of Herbal and Animal Products" was enacted in 1994. With this legislation, organic agricultural activities were started to be carried out in Turkey for the first time under the supervision of Food, Agriculture and Livestock Ministry (FALM) and within rules determined. Later years, the legislation mentioned was modified in order to comply with changes in EU legislation together with developments lived in the sector and "Legislation on Principles and Practice of Organic Agriculture" was published in 2002.

By considering increasing importance of Organic Agriculture, "Organic Agriculture Law" No:5262 involving provisions of production, consumption and supervision of organic products was published in order to form a ground to penal sanctions and duties and responsibilities of the parties and to strengthen legal regulations made with the legislation in this field. "Legislation on Principles and Practice of Organic Agriculture" which was prepared by depending on this law took effect in 2005. In the direction of demands and needs coming from the sector, changes were made 3 times. At last, Council Regulation No:834/2007 and Council Directive No: 889/2008 were put into practice instead of Council regulation No: 2092/91, and national legislation was brought into conformity with European Union Legislation and was published in 2010. Besides, organic Agriculture Units were formed within 81 Province directorates of the Ministry in order to carry out activities related to organic agriculture. Duties and authorities of those to work in this unit were determined with Communique No: 2005/1. The Communique mentioned was revised as communiques, No: 2009/1 and 2011/4 (Anonymous, 2012).

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There are 42 accredited institutions for certification procedures of organic agricultural producers in Turkey as of 2016. The number of producer businesses having legal entity authorized by these institutions is 1106 (Anonymous, 2016b).

As specified in Table 1, organic agriculture has shown important developments year by year in every sense from the number of products to the number of producers, from total production land to total production amount.

As specified in Table 2, Turkey exported organic fig and fig products the most in 2014 (21.626.691 $). Afterwards nut and nut products (17.046.378 $) and sultanas (13.557.823 $) come.

As seen in Table 3, Turkey exported the most to Germany (19.248.646 $), the USA (19.053.760 $) and France (8.507.402 $) respectively. It is seen that the countries mentioned are developed countries as stated in previous sections.

As specified in Table 4, the first three of organic product import of Turkey the most in the basis of amount are baby food and drink, sultanas and composte (Plum, fig, apricot, peach, cherry)

In addition to general agricultural supports to producers performing organic agriculture, supports of 70 TL/da for vegetable-fruit, 10 TL/da for field crops will be granted in Turkey in 2015 with the decision of Board of Ministers No: 2015/7495 published in Official Gazette on 8 April 2015 and No: 29320. Support payments to be made to producers who practice ranching, to beekepers and to those who produce water products based on kinds are shown in Table 5.

Official documents from which supports related to organic agriculture in Turkey are taken as a reference are as follows;

- Communique on making payment of herbal production support (Communique No: 2015/21).
- Communique on making payment of support to organic ranching and organic water product cultivation (Communique No: 2015/31).

Table 1. Organic agricultural production data in Turkey in terms of years (including transition period)

Years	The number of products	The number of farmers	Land cultivated (ha)	Natural gathering land (ha)	Total Production land (ha)	Production Amount (ton)
2002	150	12.428	57.365	32.462	89.827	310.125
2003	179	14.798	73.368	40.253	113.621	323.981
2004	174	12.751	108.598	100.975	209.573	377.616
2005	205	14.401	93.134	110.677	203.811	421.934
2006	203	14.256	100.275	92.514	192.789	458.095
2007	201	16.276	124.263	50.020	174.283	568.128
2008	247	14.926	109.387	57.496	166.883	530.224
2009	212	35.565	325.831	175.810	501.641	983.715
2010	216	42.097	383.782	126.251	510.033	1.343.737
2011	225	42.460	442.581	172.037	614.618	1.659.543
2012	204	54.635	523.627	179.282	702.909	1.750.127
2013	213	60.797	461.395	307.619	769.014	1.620.387
2014	208	71.472	491.977	350.239	842.216	1.642.235

Source: Anonymous, 2015a

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Table 2. Organic products which were exported the most in Turkey in 2014

Product	Amount(Kg)	Sum ($)	% Kg	% $
Fig and fig products	4.523.936	21.626.691	29,09	27,5
Nut and Nut products	1.642.488	17.046.378	10,56	21,6
Sultanas	4.118.835	13.557.823	26,48	17,2
Apricot and apricot products	1.975.009	11.102.466	12,70	14,1
Fruit and Fruit products	1.292.370	8.595.480	8,31	10,9
Cotton and textile products	132.447	1.814.432	0,85	2,3
Pistachio	21.807	854.089	0,14	1,1
Lentil and kinds	365.123	709.020	2,35	0,9
Caper	76.125	604.698	0,49	0,8
Wheat and Wheat Products	845.340	364.871	5,44	0,5
Vegetables and vegetable products	56.256	347.835	0,36	0,4
Walnut	22.258	343.069	0,14	0,4
Total	**15.071.994**	**76.966.852**	**96,9**	**97,7**
General Sum (including others)	**15.552.638**	**78.779.537**	**100**	**100**

Source: Anonymous,2015b

Table 3. Countries to which organic product export was made the most in 2004 by Turkey

Country	Amount (Kg)	Sum ($)	% Value
Germany	3.335.466	19.248.646	24,4
United States	3.782.712	19.053.760	24,2
France	1.488.675	8.507.402	10,8
Netherlands	1.254.091	7.075.308	9,0
Switzerland	1.190.599	6.217.360	7,9
The UK	998.137	4.446.227	5,6
Sweden	808.811	4.360.203	5,5
Italy	389.770	2.775.607	3,5
Japan	296.571	1.910.147	2,4
Denmark	250.452	1.201.498	1,5
Australia	211.130	1.038.758	1,3
Belgium	136.720	471.784	0,6
total	**14.143.134**	**76.306.700**	**96,9**
General sum (including others)	**15.552.638**	**78.779.537**	**100**

Source: Anonymous, 2015b

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Table 4. Organic food import in 2014

Product Name	Amount (Kg)	Country from which it is imported
Baby food and drink	1.532.148	Germany, Austria, Czech Republic, Poland
Sultanas	268.000	America, Netherlands, The UK
Composte (Plum, fig, apricot, peach, cherry)	178.592	Germany
Fruit kinds (Pear, strawberry, plum, Mandarin, Grapefruit)	122.502	Germany, Denmark, France, Netherlands
Dried fruit (Berry, Fig, Plum,date palm)	53.118	Afghanistan, Germany, Moldova, Poland, Tunisia)
Vegetables	24.120	Afghanistan, Germany
Medical smelly herbs(Daphne, thyme, locust Gum, Stevia)	23.612	America, Netherlands, The UK, Italy
Nigella and Nigella products	12.850	Germany, India
Ageve Syrup	8.500	The UK, Mexico
Nut	7.000	Germany
Coconut milk and oil	6.083	Sri lanka
Bread Mixture	4.300	Germany
Coffee and Coffee kinds	4.050	America, Belgium, Netherlands
Spreadable chocolate	2.548	Belgium
Kidney bean	2.322	France
Sunflower oil	1.824	Germany, Italy
Fruit tea and tea kinds	1.739	Netherlands
Fruit jam kinds	1.076	Belgium
Organic cookie with ginger	122	Afghanistan
Beemilk honey	116	Afghanistan
Sumach	20	Denmark

Source: Anonymous, 2015b

Table 5. Organic agriculture supports

Product	Price
Fruit, Vegetable	70 TL/decare
Farm crops	10 TL/decare
Mature cattle, water buffalo	150 TL/a head
Calf	50 TL/a head
Mature sheep, goat	10 TL/a head
Hive with bees	5 TL/a hive
Trout	0,35 TL/kg
Seabream, sea bass	0,45 TL/kg

Source: Anonymous, 2016a

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- Investment management credit with low interest Decision of Board of Minsters (2014/7201 published in official gazette dated 21.01.2015 and No: 29244).
- Decision of Board of Minsters No:2015/8299 published in official gazette dated 16.12.2015 and no: 29564 on Having Investment and Management Credit with low interest for agricultural production used by TR Ziraat Bankası A.Ş. and Agricultural Credit Cooperatives.

Briefly, under the light of documents above, supports granted to organic agriculture in Turkey can be summarized in four main items.

- Land based support payment.
- Product based supports in Organic ranching.
- Having Investment and Management Credit with low interest for agricultural production used by TR Ziraat Bankası A.Ş. and Agricultural Credit Cooperatives (In 2016, the opportunity of credit use with 5.000.000 TL credit top limit with 50% discount from the rate of current interest rate has been provided).
- Support payments which are made to farmers who sign grant agreement and who participate in Protection of Agricultural Land with Environmental Purpose by FALM in order to protect soil and water quality in agricultural land, for the sustainability of renewable natural resources and taking required cultural precautions aimed at reducing negative effects of intensive agricultural activities are being made. Within this scope, 135 TL/da payment is being made to 3.category environment-friendly agricultural techniques and cultural practices (Anonymous, 2012).

In addition to these supports:

- Vegetable market tax are being taken within the scope of "The law on Regulating trade of vegetables and Fruit from raw, semi-products or products and other goods which have sufficient supply and demand depth having organic agriculture certificates".
- Within the scope of Communique on Supporting Environmental Costs, costs of certificate and analysis of organic products aimed at export. Expenditures of Certification and lab analysis (per certificate and/or analysis) are supported with the rate of 50% and up to 25.000 USD.
- Treasure lands are leased for 49 years to investments who undertake to make organic agriculture investment with the amount in TL equals to 10 million USD at least and employ 10 people at least for 10 years within the scope of the project. Entrepreneurs making organic product export benefit from export refund payments within the limits predicted.
- In addition, 600 TL support payment are being made to producers utilizing agricultural publishing and consultancy services. In order to agricultural entrepreneurs to be able to benefit from this support, they should be registered to farmer's registry and/or greenhouse, water products, beekeeping, sheep-goad registry system (Anonymous, 2012).

SOLUTIONS AND RECOMMENDATIONS

In order to create a difference in the market and enlarging marketing opportunities of countries in terms of global competition, first of all strategies about green marketing, developing conventional and organic

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product potential, e-trade's, which has various advantages, becoming widespread and supports', given aimed at e-trade and marketing, becoming widespread in the dimension of farmers are needed. Using values and products especially specific to Turkey is important on the point of view of Turkey.

When organic product production and export data of Turkey are examined, it is seen that it has not used the potential it has sufficiently and efficiently. But Turkey, whose climate and soil conditions are already suitable for agriculture, is an appropriate country for organic agriculture system because it has lots of biological and genetic diversity. In this case, organic production level should be increased much more and in addition to this it should be encouraged more.

In order for environment-friendly organic agriculture to settle as a sustainable and preferred agricultural system, producers should be motivated, encouraged to this system, and in addition they should be enabled to get more profit than conventional agriculture. Otherwise, producers will not adopt and continue this system especially, when it is considered that income is low in organic agriculture, producers need to be supported especially in transition period.

In addition, supports granted to organic agriculture by the state should be increased and conversion of producers to organic agriculture should be encouraged. Research, training and publishings related to organic agriculture should be generalized by the state, private sector and NGOs. As a result of this, it is thought that both the incomes of producers increase and important amount of contribution will be provided to the economy of the country.

In developed and especially developing countries, some problems in both technical and economic sense are faced in transition towards organic agriculture. One of the most important of these is deficiency of technical knowledge and personnel related to the subject. Organic product raising techniques are a system which needs special knowledge and technology at each stage from production of product, even from preparing soil to collecting, processing, and packaging and distribution stages and which bring a number of rules together with it. Provided that Farmers and industrialist advance their technical knowledge and skills continuously, organic agriculture will be able to develop. Because of this, if expert personnel is added to support items to be granted by the state, it should be enlarged in a way that it will include salary and insurance Premium.

There are some differences in two items within production cost in organic agriculture when compared to other systems. One of these is the cost of certification and the other is the need of increasing work power. This additional work power need may be thought to be employment booster from the point of businesses whose family work power is high. But, it causes foreign work power need to increase in other businesses and to cause work power cost to increase. On the other hand, certification cost causes negativeness for both types of businesses. This condition does not leave any other choice other than contracted production for small businesses. In order to remove problems showing up at the marketing stage of organic products produced, contracted cultivation concept comes to the forefront here. Thanks to this, both producers market their products they have produced easily and industrialists gain the guarantee of obtaining raw material required with the quality and amount they request.

Target for the next a couple of years should be determined and market share and growth rates should be followed according to this. Contact offices that will give consumers information about it should be formed. Questions and problems of producers should be removed via these offices, required applications for incentives should be able to be made. Because it is known that Province directorates of Food, Agriculture and Livestock ministry are dealing with intensive bureaucracy and personnel problems, it is obligatory for a separate organization structure for organic agriculture to be established. In addition

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to this, agricultural engineers who will carry out consultancy for organic agriculture should be trained and assessed separately.

It is targeted for the energy used in transportation by consuming products produced in organic agriculture domestically. Nevertheless, products are sent to different parts of the world and it is observed that it has a similar structuring to conventional product trade. Therefore, classic supports as well as logistic supports should be provided.

Certification and branding in organic products' opening to world market are among indispensable works. Producers should be supported and their costs should be covered for these.

Although some deficiencies are generally in policies of developing countries related to organic agriculture, the advantages that they have should be remembered. In organic agriculture, there is no need for big investments for irrigation, energy and outside inputs. But investment is needed in order to make production by giving importance to especially trainings and researches. Additional supports for these should be provided to universities and research institutes. R&D activities conducted by public and private sector institutions related to organic agriculture is limited although they have increased with the efforts of some university research institutions in recent years. R&D works in organic agriculture should be supported continuously. One of the most important steps to be taken is that more agricultural (especially as aimed at organic agriculture) R&D activities should be encouraged in Technoparks which continue their activities under the coordination of universities and which are established in some parts of Turkey.

Technics and technologies used in organic agriculture are acceptable indicators in terms of green marketing with current condition. So, it is not necessary for new environmental systems with more cost as in conventional production systems to be formed. However, following new technologies produced on this subject may be useful for differentiation of organic producers and for being favored in the market more. It is significantly important to consider differences the business is within in the use of new technologies in organic agriculture. The new technology produced should be examined thoroughly with regard to location of the business, species produced, kind and business capital and should be adopted according to this. Especially as new packaging technologies, compostable packages, reduced production materials or those that may be used with different purposes, technological systems which increase the efficiency in water and energy use during production process and recycling involve techniques and technologies that may form differences depending on business and that may be used in organic agriculture within green marketing perception. In order them to be able to follow the technologies which improves fast in these matters, limits of supports of current technological renewing and capacity increasing applied to SMEs should be enlarged in a way that will be valid for organic agriculture producers.

Although export of organic agriculture products in Turkey is increasing more and more, the share of the country in organic agriculture and food products market is too low. Especially, supply of organic agriculture and food products in North American and European countries cannot meet demand increase in these markets. Therefore, these markets present a good opportunity for developing countries whose ecology and infrastructure is suitable for organic agricultural production and export like Turkey. Unfortunately, organic products which are exported as raw material without being processed such as dried fruit, nut, peanut and field corps and etc. mean loss in potential export revenues. In this sense, consultancy and technical support should be provided to producers in order for them to produce processed production not raw material. So added values will have stayed within the country.

Because of limited works of non-governmental organizations (NGO) with local quality, organic agriculture and food market in Turkey is far from reaching the level intentioned and targeted. Besides, deficiency of cooperation between public, private sector and NGO's and that there is no knowledge

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sharing network confront us as another critical question. The numbers of producer cooperatives and organizations formed by producers' making organic production coming together is limited. Because they cannot get sufficient incentives from governments, they cannot defend their rights against private sector sufficiently and they cannot play an effective role in organic agriculture and food product market.

FALM should apply suitable incentive instruments and polices via especially organic producer unions, NGOs or private companies or directly to producers in order to ease transition process of producers towards organic production via financial incentives such as credit with low interest, premium price, cheap organic input and marketing guarantee. Similarly, FALM should support organic producer organizations via research, training and publishing activities.

Organic agriculture should be encouraged via public and private institutions with pilot projects in places whose ecology is suitable for organic agriculture in order for organic agriculture to be adopted and become widespread. In addition to organic herbal production at which we are good, special importance should be given to organic animal production which is too limited in order to increase export potential of Turkey in the world's market of organic agriculture and food where a great completion are lived and required encouragement precautions should be taken in order for it to improve.

In addition to organic marketing companies working as aimed at export, especially local organic producer unions should be supported financially by the government. In order for organic production and domestic market of organic food to improve, process of organic production, control, certification and marketing which are complex should be eased via required legal regulations.

In recent years, Conformity of the legislation of our country to the works done in order to simplify organic agriculture legislation in EU should be enabled. Works aimed at increasing consumer awareness about organic agriculture and food products via works of raising awareness of consumers should be increased. Turkish organic agriculture sector should be coordinated with the help of a high council to be formed and cooperation should be increased between related institutions.

Data aimed at organic production and export should be gathered single-handedly, a reliable database should be formed and results should be published officially. Works of product branding and labeling which are wrong like "Natural", "village product", "without fertilizer", "without pesticides" organic agriculture and food product or which are used to mislead consumers and which causes concept confusion should be terminated legally. In order to increase consumer trust in organic products, project management, and control and certification process of organic products should be brought into conformity with international Organic Agriculture and food legislation and standards.

Organic agricultural production works should be integrated with ecologic agricultural tourism services within the country and local practices should open to international ecotourism field. In addition to this, trade of organic products other than organic agriculture and food products (such as organic cosmetics, textile, wood, tree and local handcraft products etc.), production processes which do not pollute environment and which are compatible with ecology should be encouraged.

FUTURE RESEARCH DIRECTIONS

The most important subject emphasized usually in the studies where Organic agriculture in Turkey is examined is that Eastern and Southeastern parts of Turkey are very suitable for organic agriculture. But, Eastern and Southeastern parts of Turkey are also the most problematic geography of Turkey socio-economically. Because of terrorism lived for years, these regions are in the last places of regional

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development ranking. In addition, the provinces in this region are in the last places of economic and social criteria such as education, employment and growth. It is a reality which is known and accepted by everyone that supports, subsidies and donations granted in these regions are not used efficiently and effectively at desired level.

Because of terrorist activities, which have increased recently, the number of investors coming are very limited even if the region is the place where investments are encouraged the most. As in all kinds of investments, the most important factor for people who want to make investment in organic agriculture is the feeling of security. Therefore, in addition to supports and incentives granted, formation of atmosphere of security and stability in especially Eastern-Southeastern region should be primary goal.

One of the most important ways of being able to give the required feeling of security to investors and getting rid of deadlock stated above is to bring Government Business Enterprises (GBE) which were carried out as an effective policy in a period to the agenda again with the occasion of organic agriculture investments.

The state can collect private enterprises and entrepreneurs in the GBEs within by controlling supervision mechanism and administrative mechanisms. In the structure of GBEs are partnership structures which are established between private sector and the public in general. So, investors who feel the support of public on their back can make investments more comfortably and securely. This model was applied in Kibbutz farms in Israel and gave positive results. Similar structures may be formed in Turkey. Local people can carry out organic agricultural activities jointly on their own land or on treasure land by working in coordination with the state. With this occasion, wrong use of supports and subsidies granted may be avoided. This system will be an important argument in the solution of unemployment which is one of the biggest problems in especially Eastern and Southeastern Region of Turkey. In the periods ahead, researchers may concentrate on this subject. And benefit of probable organic agriculture GBEs that will be formed may be discussed.

CONCLUSION

In recent years, the greatest agricultural successes are to be found in being able to realize production increases by reducing negative environmental conditions. This is only made possible by using sustainable and environmentally friendly methods in agricultural production. Green Marketing practices bring an agenda of activities aimed at increasing the use of organic methods in the agricultural sector.

Communities around the world are becoming increasingly aware of the environment and its effect on human health. As this awareness increases, the demand for organic products will also increase. As the production of organic produce rapidly increases around the world, this will cause competition between developing countries in the international market. Turkey is in a position to be one of the most important countries with a say in the global market for organic produce, if it can activate its potential in this field with timely interventions.

When Organic Agriculture becomes economically viable, it can generate new employment opportunities and can reveal the new organic products of input giants. It also protects the environment, meets the quality demands of consumers, generates alternatives with regard to rural welfare, and provides increased added value with new products. In terms of sustainability, although organic agriculture has its weaknesses and strengths, its greatest strength can be summarized as the continuity of soil and water resources, thus

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protecting and maintaining the continuity of agricultural production. In terms of protecting soil resources, it is important to prevent agricultural land from being used for purposes other than agriculture.

Rich biological diversity, relatively clean ecological areas, plant species that are resistant to diseases and pests, and low levels of chemical input are among the main advantages that would come with the development of organic agriculture in Turkey and other developing countries. Therefore, Turkey has great potential to develop and produce a number of products (though not some tropical fruit) because of its ecology, geographical and topographical structure, and various climate characteristics. In addition, the agricultural production system in Turkey is spread over a very large area. Compared to industrialized countries, Turkey's use of chemical input per unit area of agriculture is very low. As a result, there is no intensive pollution in its agricultural land, especially in the Eastern part of Turkey, where the transition towards organic agriculture would be easier than in industrialized regions. Therefore, Turkey can avoid the environmental problems associated with intensive chemical input in agriculture, which is a problem in a number of developed countries. On the other hand, rural employment can be helped by increasing the organic production of labor-intensive products with high added value.

As a result, the development of organic agriculture in Turkey should be accelerated, together with:

- The financial support of governments for types and figures increasing.
- Producer and consumer training.
- Universities and research institutions' increasing their R&D activities.
- The continuous informing the public with visual and written media tools.
- The publishing of agricultural and research studies Cooperation with the private sector and NGOs.

REFERENCES

Akgüngör, S., Miran, B., & Akbay, C. (2010). Consumer Willingness To Pay For Organic Products In Urban Turkey. *Journal of International Food & Agribusiness Marketing*, *22*(3-4), 299–313. doi:10.1080/08974431003641455

Akın, M., Çiçek, R., İnal, M. E., & Toksarı, M. (2010). Niğde İlindeki tüketicilerin sosyo-demografik özellikleri ile organik gıdalara ilişkin tutum ve bireysel değerleri arasındaki farklılığın incelenmesine yönelik bir araştırma. *Dokuz Eylül Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, *12*(1), 29–56.

Albayrak, M., Taşdan, K., Güneş, E., Saner, G., Atış, E., Çukur, F., & Pezikoğlu, F. (2010, January). *Küresel Rekabet Açısından Türkiye'de Tarım Ve Gıda Ürünlerinin Pazarlama Sistemlerine Bakış: Mevcut Yapı, Sorunlar Fırsatlar, Hedefler*. Paper presented at the meeting of the Türkiye Ziraat Mühendisliği VII. Teknik Kongresi, Ankara.

Anonymous. (1980). *USDA, Report and Recommendations on Organic Farming*. Washington, DC: USDA.

Anonymous. (2009). *IFOAM, Definition of Organic Agriculture*. IFOAM General Assembly.

Anonymous. (2012). *Türkiye Organik Tarım Stratejik Planı (2012-2016)*. Retrieved April 5, 2016, from http://www.tarim.gov.tr/Konular/Bitkisel-Uretim/Organik-Tarim/Genel-Bilgiler

Anonymous. (2013). *Organik Tarım Ulusal Eylem Planı (2013-2016)*. Retrieved April 6, 2016, from http://www.tarim.gov.tr/BUGEM/Duyuru/9/organik-tarim-ulusal-eylem-plani--2013---2016--yayinlanmisti

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Anonymous. (2015a). *GTHB Bitkisel Üretim Genel Müdürlüğü Faaliyetleri Raporu*. Retrieved April 11, 2016, from http://www.tarim.gov.tr/BUGEM/Menu/9/Veriler

Anonymous. (2015b). *GTHB Organik Tarım İstatistikleri*. Retrieved April 11, 2016, from http://www.tarim.gov.tr/Konular/Bitkisel-Uretim/Organik-Tarim/Istatistikler

Anonymous. (2016a). *GTHB Organik Tarım Destekleri.* Retrieved April 13, 2016, from http://www.tarim.gov.tr/Konular/Tarimsal-Destekler/Alan-Bazli-Destekler/Organik-Tarim-Destegi

Anonymous. (2016b). *GTHB tarafından yetkilendirilen kuruluşların listesi*. Retrieved April 13, 2016, from http://www.tarim.gov.tr/Konular/Bitkisel-Uretim/Organik-Tarim/Yetkili-Kuruluslar-KSK

Armağan, G., & Özdoğan, M. (2005). Ekolojik yumurta ve tavuk etinin tüketim eğilimleri ve tüketici özelliklerinin belirlenmesi. *Hayvansal Üretim*, *46*(2), 14–21.

Ay, C., & Ecevit, Z. (2005). Çevre Bilinçli Tüketiciler. *Akdeniz İ.İ.B.F. Dergisi*, (10), 238-263.

Aydın, G. (2011). *Tüketicilerin Gıda Güvenliği Bilinç Düzeylerine Etki Eden Faktörlerin Analizi: Samsun İli Kentsel Alan Örneği* (Unpublished master's thesis). Ondokuz Mayıs University, Samsun, Türkiye.

Azak, Ş., & Miran, B. (2015). *Türk Tüketicilerin Organik Pazara ve Organik Ürünlere Yönelik Davranışlarının Analizi: İzmir Örneği*. Retrieved April 20, 2016, from http://www.eto.org.tr/?cat=28

Bahrs, E. (2004). Proposal for a more efficient subsidy system for organic farming: Potential use of the tax system within the European Union. *Renewable Agriculture and Food Systems*, *20*(3), 148–154. doi:10.1079/RAF200484

Chartand, T. L. (2005). The Role of Conscious Awareness in Consumer Behaviour. *Journal of Consumer Psychology*, *3*(15), 203–210. doi:10.120715327663jcp1503_4

Dağıstan, E., Demirtaş, B., Yılmaz, Y., & Tapkı, N. (2010, September). *Organik Ürün Tüketim Eğilimi*. Paper presented at the meeting of the Türkiye IX. Tarım Ekonomisi Kongresi Şanlıurfa, Turkey.

Demiryürek, K. (2004). Dünya ve Türkiye'de Organik Tarım. *Harran Üniversitesi Ziraat Fakültesi Dergisi*, *8*(3/4), 63–71.

Demiryürek, K. (2011). Organik Tarım Kavramı ve Organik Tarımın Dünya ve Türkiye'deki Durumu. *Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Dergisi*, *28*(1), 27–36.

Emir, M., & Demiryürek, K. (2015). Avrupa Birliği Ve Türkiye'deki Organik Tarım Mevzuatındaki Gelişmeler Ve Son Yönetmeliklerin Analizi. *Adnan Menderes Üniversitesi Ziraat Fakültesi Dergisi*, *11*(2), 21–28.

Erbaşlar, G. (2007). Yeşil Pazarlama. *Paradoks, Ekonomi*. *Sosyoloji ve Politika Dergisi*, *1*(1), 2–12.

Ergin, E. A., & Özsaçmacı, B. (2011). Turkish Consumers' Perceptions and Consumption of Organic Foods. *African Journal of Business Management*, *5*(3), 910–914.

Eryılmaz, G., Demiryürek, K., & Emir, M. (2015). Avrupa Birliği ve Türkiye'de Organik Tarım ve Gıda Ürünlerine Karşı Tüketici Davranışları. *Anadolu Tarım Bilimleri Dergisi*, *30*, 199–206.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Gil, M. J., & Dimitrious, M. V. (2013). Emission Taxes And The Adoption Of Cleaner Technologies: The Case Of Environmental Concern and Ecologically Conscious Consumer Behaviour. *Journal of Business Research*, (35): 486–504.

Gülmez, M. (2012), *Türk, Amerikan, İngiliz Ve Fransız Şirketlerinin Web Siteleri Aracılığı İle Gerçekleştirdikleri Kurumsal Sosyal Sorumluluk İletişimi Üzerine Bir Araştırma* (Unpublished doctoral dissertation). Çukurova University, Adana, Turkey.

Gülse Bal, H. S., Göktolga, Z. G., & Karkacıer, O. (2006). Gıda Güvenliği Konusunda Tüketici Bilincinin İncelenmesi Tokat Örneği. *Tarım Ekonomisi Dergisi*, *12*(1), 9–18.

Gündüz, O., & Bayramoğlu, Z. (2011). Consumers Willingness to Pay for Organic Chicken Meat in Samsun Province of Turkey. *Journal of Animal and Veterinary Advances*, *10*(3), 334–340. doi:10.3923/javaa.2011.334.340

Hassan, D., Monier-Dilhan, S., Nichèle, V., & Simioni, M. (2009, August). *Organic Food Consumption Patterns in France*. Paper presented at the meeting of the Pre-Conference Workshop, Diet and Obesity: Role of Prices and Policies, France.

Heaton, S. (2002). *Assessing Organic Food Quality: Is Better for You.* Paper presented at the meeting of Proceedings of the COR Conference, Aberystwyth. Retrieved April 13, 2016, from http://orgprints.org/8361

Henion, K. E., & Wilson, W. R. (1976). The Ecologically Concerned Consumer and Locus of Control. In K. E. Henion & T. C. Kinnear (Eds.), *Ecological Marketing*. Chicago, IL: American Marketing Association.

İpek, S., & Çil Yaşar, G. (2010). Uluslararası Ticari Boyutlarıyla Organik Tarım ve Devlet Destekleri. *Girişimcilik ve Kalkınma Dergisi*, *5*(1), 135–162.

İslamoğlu, A. H. (2013). *Pazarlama Yönetimi (Stratejik Yaklaşım)*. İstanbul, Turkey: Beta Basım Yayım (6. Baskı).

Karahan Uysal, Ö., Miran, B., Abay, C., Boyacı, M., Janssen, M., & Hamm, U. (2010-September). *Türkiye'de Tüketicilerin Organik Logolara Yaklaşımları*. Paper presented at the meeting of Türkiye 9. Tarım Ekonomisi Kongresi, Şanlıurfa, Turkey.

Kızılaslan, H., & Olgun, A. (2012). Türkiye'de Organik Tarım ve Organik Tarıma Verilen Desteklemeler. *GOÜ Ziraat Fakültesi Dergisi*, *29*(1), 1–12.

Koç, A., Akyıl, N., Ertürk, Y. E., & Kandemir, M. U. (2001, November). *Türkiye'de Organik Ürün Talebi: Tüketicinin Kalite İçin Ödemeye Gönüllü Olduğu Fiyat Farkı*. Paper presented at the meeting of Türkiye II. Ekolojik Tarım Sempozyumu, Antalya, Turkey.

Lampkin, N. (1990). *Organic Farming*. Ipswich: Farming Press.

Lotter, W. D. (2003). Organic Agriculture. *Journal of Sustainable Agriculture*, *21*(4), 59–128. doi:10.1300/J064v21n04_06

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Perreault, J. W., Cannon, J. P., Mc Carthy, E. J., & Önce, E. (2013). *Pazarlamanın Temelleri. Değişen Pazar Çevresinde Fırsatları Değerlendirme*. Ankara, Turkey: Nobel Yayınları.

Pezikoğlu, F. (2004). *Organik (Ekolojik, Biyolojik) Tarımda Arz, Talep ve Pazarlama*, Atatürk Bahçe Kültürleri Merkezi Araştırma Enstitüsü, (Unpublished Report), Yalova.Turkey.

Pezikoğlu, F. (2008, November). *Bahçe Bitkilerinde Yeşil Pazarlama Stratejileri*. Paper presented at the meeting Bahçe Üürünleri 4. Muhafaza ve Pazarlama Sempozyumu, Antalya, Turkey.

Pezikoğlu, F. (2012, September). *Yeşil Etiketleme*. Paper presented at the meeting 5.Muhafaza ve Pazarlama Sempozyumu, İzmir, Turkey.

Pezikoğlu, F., & Yavuz, O. (2006, November). *Organik Tarımın Sürdürülebilir Tarım Kavramı İçindeki Yeri ve Küreselleşme Boyutu*. Paper presented at the meeting of Türkiye 3. Organik Tarım Sempozyumu, Yalova, Turkey.

Rehber, E., & Pezikoğlu, F. (2013, September). *Gıda Güvenliği ve Organik Tarım*. Paper presented at the meeting of Türkiye 5.Organik Tarım Sempozyumu, Samsun, Turkey.

Rehber, E., & Turhan, Ş. (2001). *Prospects And Challenges For Developing Countries In Trade And Production Of Organic Food And Fibers: The Case Of Turkey*. Paper presented at the meeting of 72nd Eaae Seminar Organic Food And Marketing Trends, Chania, Greece.

Sarıkaya, N. (2007). Organik Ürün Tüketimini Etkileyen Faktörler ve Tutumlar Üzerine Bir Saha Çalışması. *Kocaeli Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, *2*(14), 110–125.

Shehu, V. (2010). *Uluslararası İşletmelerde Yeşil Pazarlama Uygulamaları ve Halkla İlişkilerin Rolü* (Unpublished master thesis). Ege University, İzmir, Turkey.

Turhan, Ş. (2005). Tarımda Sürdürülebilirlik ve Organik Tarım. *Tarım Ekonomisi Dergisi*, *11*(1), 13–24.

Urena, F., Bernabeu, R., & Olmeda, M. (2008). Women, Men and Organic Food: Differences in Their Attitudes and Willingness to Pay. A Spanish Case Study. *International Journal of Consumer Studies*, *32*(1), 18–26.

Willer, H., & Klicher, L. (Eds.). (2011). *The World of Organic Agriculture. Statistics and Emerging Trends 2011. FiBL-IFOAM Report. IFOAM, Bonn and FiBL*. Frick.

Yılmaz Sert, N. (2012). *Kurumsal Sosyal Sorumluluk ve Aktivizm İlişkisinin Araştırılması: Türkiye'de Özel Sektör, KSS ve Aktivizm İlintisi* (Unpublished doctoral dissertation). İstanbul University, İstanbul, Turkey.

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Chapter 3
Rights of Nature to Protect Human Rights in Times of Environmental Crisis

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ABSTRACT

The well-being of humans and nature are inextricably linked. Nature is particularly mistreated in light of its characterization as merely "property" to be bought, sold, and ultimately degraded for profit. Reinforcing this misperception is the fact that modern environmental laws themselves implicitly accept this claim of "nature as property." They legalize nature's destruction by dictating how much of the environment can be exploited and degraded, rather than as an integral ecological partner with its own rights to exist and thrive. Instead, we need laws grounded in the inherent rights of natural world to exist, thrive, and evolve. The article focuses on the transition from the 'right to the environment' to a biocentric approach constructed around 'rights of nature.' This transition is evident in various new legal instruments, which serve as models for legal systems that can steer us towards more robust and effective environmental laws.

I. INTRODUCTION: FACING NEW CHALLENGES ON ENVIRONMENTAL PROTECTION[1]

The possibility to recognize and protect the Rights of the Nature is, with no doubt, a brand new approach in the field of environmental law. Traditionally, legal systems have considered nature as a "property", as an object over which human rights have been recognized and protected. Moreover, the promotion of laws and contracts to guarantee the property rights of individuals, corporations and any other legal entities as subjects of rightshave been common. The consequence, therefore, is that environmental laws and regulations, despite their preventive approach, have been developed over the last years in a way that recognize and legalize environmental harm. The amount of pollution and degradation allowed in the environment has been regulated within the legal framework and in some cases foresee the potential for environmental degradation.

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Therefore, the human rights approach would offer a chance to protect the environment, conceiving it as a necessary dimension to enhance the most fundamental human rights. Certainly, the recognition ofindividual rightsin relation tothe environmenthas had a significantinfluence at supranational level. However, in general, the level of recognition of a human right to an adequate environment has not been without controversy: first of all, the protection of the environment through the configuration of a human right to an adequate environment rather than imposing obligations to protect the environment has no positive impact on the conservation of natural resources; secondly, the recognition of the protection of the environment is not really an individual right, but a programmatic norm lacking forcibility and, therefore, not required to the State (Bedoya, 2006).

Differently, a new approach is emerging, the recognition of the rights of nature, which imply a holistic approach to all ways of life, including all ecosystems. In recent years, a series of normativeprecedents have surfaced, which recognize nature has certain rightsas a legal subject and holder of rights. These precedentscontribute, together with greater sensitivity to the environment, to areorientation ofhow to protect the environment, considering the Earth as the center where life takes place. Therefore, the rights of nature are recognized as a holistic concept comprising all kinds of life and their ecosystems.

Through this perspective, called "biocentrism", Nature is not an object of protection anymore, but a real subject of rights, with fundamental rights as any other subject has, for example the right to exist, to survive and to maintain and regenerate vital cycles. The implication of this recognition is that human beings have the legal authority and responsibility to enforce these rights on behalf of nature. This concept is based on humans as part of life on earth having to live within its ecological limits, rather than being the center of environmental protection as the "anthropocentric" approach proposes.

Recognizing the rights of nature, Ecuador, Bolivia and a growing number of communities in the United States are basing their environmental protection policies on the premise that nature has inalienable rights, as have human beings. This premise is a radical but natural move away from the assumption that nature is a property under the rule of human law. Certainly, this view is a departure from Western culture and the development model which promotes the destruction of environment and life: climate change, disappearance of natural areas, indiscriminate surface felling of trees, desertification of new territories, dumping of toxic substances from industries into rivers, seas or lakes, oil slicks caused by ships and endless actions of a system that appears to legitimize environmental damage. This article, tracks the change in approach from anthropocentric to biocentric, which allows for an evolution in the legal protection of the environment: from human rights to the rights of nature. This new vision of environmental protection and how it is introduced into the different regulatory systems and its implementation is analyzed, including the recent trend in attributing a greater role to human responsibility in environmental protection. The article also discusses these new regulatory precedents, which undoubtedly mark an evolution in environmental law, both nationally and internationally. This new way ofprotecting the environment, due to the awareness of events, has led to the adoption of legislative measures on environmental law aimed at achieving an environmental policy more consistent with the conservation of natural resources, and establishing offenses andsanctions pointing more to the responsibility of those human beings who damaged nature. Nature meets its obligation to support life while humans increasingly take advantage of natural resources, causing irreversible environmental damage. This article explores how this recognition involves a number of issues to be resolved, as to who is able to claim these rights (on behalf of Nature) and how to make the legal system defend them.

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II. THE ENVIRONMENTAL PROTECTION THROUGH HUMAN RIGHTS APPROACH

The traditional perspective to protect the environment has been "anthropogenic" based on the idea that a healthy environment is inherent for the dignity of every person. This concept necessarily takes for granted other human rights, including the right to life and human development. The indivisibility and interdependence exerted by the right to environment on the other human rights is evident: it strengthens and extends the meaning of already secured rights or rights, which, like the right to environment, are in the process of being set up. For example, the right to environment reinforces the content of the right to life, that is, a right to a dignified life in environmentally suitable conditions to promote healthy human development.

The fact that there is interdependence between environmental rights and other fundamental rights has actually divided the doctrine, in the sense that few understand that the right to environment reinforces the content of other rights and what should be done is to integrate environmental aspects into the definition of other human rights.In this respect, there is a need to recognize a right to an indivisible and substantive environment, being the reflection of social demand to live in a decent and ecologically suitable environment, where the person can develop in harmony with nature (Déjeant-Pons, 1994).

The existence of a growing social concern about the state of the environment and scientific alarm alerting us to the serious consequences of economic growth without limits requires the need for environmental protection through the adoption of international legal measures as well as regional and national ones.

The Universal Declaration of Human Rights of 1948 (UN, 1948), although being a document that does not explicitly relate to environment, is the first legal basis on which they could settle the right to an adequate environment. Article 25 states that "everyone has the right to a standard of living adequate for himself and his family, health and well-being ...". Subsequently, the International Covenant on Civil and Political Rights (UN, 1966a) and the International Covenant on Economic, Social and Cultural Rights (UN, 1966b), both of 1966, indirectly refer to the right to a healthy environment, relative to the right to life, as Article 6 of the International Covenant on Civil and Political Rights states by the express provisions the need to improve the environment as one of the requirements for the proper development of the individual. For example, Article 11 of the International Covenant on Economic, Social and Cultural Rights, when it recognizes the right of all people to an adequate standard of living and to the continuous improvement of living conditions; or Article 6 of the International Covenant on Civil and Political Rights, when a reference to the universal right to life is made.

In this regard, the Human Rights Committee has stated:

The term 'the right to life is inherent in the human person' cannot be understood in a restrictive manner (...) the protection of this right requires the adoption of positive measures by States. In this respect, the Committee considers it appropriate that States take all possible measures to reduce infant mortality and increase life expectancy, especially adopting measures to eliminate malnutrition and epidemics. (UN Human Rights Committee, 1982)

Therefore, the right environment is not a result of social development but *a prius* for human existence. Logically, suitable environment precedes the law itself: without a suitable environment, there are no humans, no society, no law…(Gormley, 1990, p. 97).

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The first written suggestion that there should be a human right to a healthy environment came from Rachel Carsonin her book *Silent Spring*, published in 1962:

If the Bill of Rights contains no guarantees that a citizen shall be secure against lethal poisons distributed either by private individuals or by public officials, it is surely only because our forefathers, despite their considerable wisdom and foresight, could conceive of no such problem. (Carson, 1962, pp. 12-3)

But the first formal recognition of the right to environment occurs in the United Nations Declaration on the Human Environment, Stockholm, 1972 (U.N. GAOR, 1972), which states in Principle I that the person has the fundamental right to freedom, equality and the enjoyment of "satisfactory living conditions in an environment whose quality allows him to live with dignity and welfare", and has a solemn obligation, in return for this right, "... to protect and improve the environment for present and future generations.". This principle states that in addition to the rights for first and second generations, man has a "fundamental right" to enjoy adequate living conditions in an environment the quality of which allowsdignity oflifeand well-being, that is to say, a life, which will enhance the rights of future generations. This idea is expressed in the Preamble to the Declaration, paragraphs 1 and 2, stating that "the two aspects of human, natural and built environment are essential to human well-being and to the enjoyment of fundamental human rights, including the right to life", adding later that "the protection and improvement of human environment is a major issue which affects the well-being of peoples and economic development throughout the world, (...), and the duty of all governments". Despite this express recognition in an international document, the Declaration does not provide the necessary control mechanisms to make them effective and also is a non-legally binding document. From the substantive content of human rightspoint of view, after the 1972 Stockholm Declaration there has been a major trend in national legal orders towards recognising the environment –often at a constitutional level–as a specific right with different characteristics, depending on the political context and legal traditions of each country.

In similar terms, Article 1 of the Charter of Environmental Rights and Obligations of Individual, Groups and Organizations, adopted in Geneva in 1991, provides that: "All the Human Beings Have the basic right to an environment adequate for their health and well-being and the responsibility to protect the environment for the benefit of present and future generations". Subsequently, the World Commission on Environment and Development UN proposed as a legal principle: "All human beings have the fundamental right to an environment adequate for their health and welfare" (UNEP, 1987). Similarly, in 1990, in its Resolution 45/94, the General Assembly adopted a milder version of this formulation: "Everyone has the right to live in an environment adequate for their health and welfare."(UN, 1990). The Rio Declaration on Environment and Development of 1992 (UN, 1992) consolidated this trend by pointing out in the first Principle that all human beings are at the centre of concerns for sustainable development and are entitled to a healthy and productive life in harmony with nature. However, this Principle of the Rio Declaration loses firmness in relation to the provisions of the Stockholm Declaration, and as with the Stockholm Declaration, no accurate means exist to enforce the principles of the Declaration. Despite these shortcomings, both the Stockholm Declaration and the Rio assume an important role in the recognition of environmental problems and are a step in the development of international environmental law. In later lectures on Sustainable Development in Johannesburg in 2002 and Rio de Janeiro in 2012, it was possible to proclaim the right to a healthy environment.

Parallel to these developments in the recognition of the human right to environment, in the field of the Economic and Social Council (ECOSOC) of the United Nations, the Sub-Commission on Prevention of

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Discrimination and Protection of Minorities, under the Commission on Human Rights, has carried out important work. This has covered the harmful effects of the illicit movement and dumping of dangerous and toxic waste and products on the enjoyment of human rights, as well as the issue of human rights and the environment, through the work of the special Rapporteur Mme. Fatma Zohra Ksentini. This special Rapporteur carried out work in relation to the issues of dangerous products and waste dating back to 1989. As a result, the Subcommittee (coming out of the Sub-Commission on Prevention of Discrimination and Protection of Minorities)[2] concludes that the information available to them on human rights and environment, including "Environmental Perspective to the Year 2000 and after", justified the need for a study of the environment and its relationship with human rights (UN, 1989). Following the studies conducted in 1994 Mme. Ksentini presented a final report in which a concept of human rights and the environment is much closer to Principle I of the Stockholm Declaration of 1972 than the Principle I of the 1992 Rio Declaration.[3] The main conclusion of this report is that there has been a change in environmental law to provide the right to a healthy and decent environment. This right is part of the existing international law and has the capacity for immediate implementation through bodies dedicated to the protection of human rights. According to this report, the substantive elements of environmental rights include the right to development, life, and health and have procedural aspects such as public participation and access to effective national solutions. Attached to this report, there is the draft of the Declaration of Principles on Human Rights and the Environment, an overview of consultations with NGOs between 1990 and 1994, and a summary of national legislation and practices compiled by the Special Rapporteur based on the responses received from 67 governments.

Despite the important content of this document, there has been no attempt to complete this project, neither by the General Assembly nor by the Human Rights Commission nor the Economic and Social Council. Only the United Nations General Assembly in its Resolution 45/1994, adopted on December 14 1990, states that everyone has the right to live in an environment adequate to ensure their health and well-being. Similar expressions are found in various multilateral treaties dedicated to environmental protection, such as the Convention on Biological Diversity, 1992; the 1992 United Nations Framework Convention on Climate Change; the United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification, particularly in Africa, 1994; and Convention 169 of the International Labour Organization on Indigenous and Tribal Peoples in Independent Countries 1989. It is also necessary to add that the Institute of International Law, in its 68th session in Strasbourg in 1997, stated in Article 2 of its Resolution n. 1 of September 41997 "... every human being has the right to live in a healthy environment" (IDI, 1998).

Moreover, the 7th Goal of the Millennium Development Goals was about ensuring environmental sustainability, including the incorporation of the principles of sustainable development into countries' policies and programmes to reverse the loss of environmental resources (UN, 2000). Later, in 2007, the UN General Assembly adopted the UN Declaration on the Rights of Indigenous Peoples, which in article 29 proclaims "Indigenous peoples have the right to the conservation and protection of the environment..." (UN, 2007).

In March 2012, based on several other resolutions related to human rights and the environment and human rights and climate change, the Human Rights Council during its 19th session, established by Resolution 19/10, the mandate of the human rights and the environment (HRC, 2012a), which aims, among other things, to study human rights obligations related to the enjoyment of a safe, clean, healthy and sustainableenvironment, promoting best practices regarding the use of human rights in the formulation of environmental policies.[4] In the first report of December 22 2012 on the issue of human rights

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obligations related to the enjoyment of a safe, clean, healthy and sustainableenvironment, states and others concerned are urged to remember that the lack of a full understanding of the contents of all the human rights obligations related to the environment should not be interpreted as that such obligations do not exist (HRC, 2012b).

In June 2012, at the UN Conference on Sustainable Development, States renewed their commitment to "the promotion of economically, socially and environmentally sustainable future for our planet and for present and future generations" (UN, 2012), without asserting the real right for humans to a healthy and safety environment. In general, linking human rights with the environment creates a rights-based approach to environmental protection that places the people harmed by environmental degradation at its center, but leaves the environment undermined to people needs.

III. HUMAN RIGHTS PROTECTION WITHOUT PROTECTING NATURE?

The formal recognition of a universal right to an adequate environment faces a number of obstacles, which have led to a sector denying its existence. In part because this right departs from the utilitarian and anthropocentric perspective, which has allowed the existing formal recognition of such right, but it has not been enough to protect nature, biodiversity and even the human health.

The major obstacles have been the traditional notion of state sovereignty, the lack of legally binding instruments and the unenforceability of this right due to the legal uncertainty of the protected object and the legitimacy of the holders. This leads to an absence of effective means for its defense and implementation of its protection. However, this has not prevented the protection of the environment, as part of the contents of a new human right by various international instruments. While it is true that currently there is no legally binding international instrument declaring a human right to the environment for the implementation of other fundamental rights.

The recognition of this right, however, can be sensed in the existing international consensus to protect the environment for the benefit of humans. However, a suitable and quality environment does not presuppose respect and guarantee of human rights.

The idea is well-established in international law that States should take measures to ensure respect for and protection of the environment as essential to the fulfillment of human rights (Lewis, 2012, p. 36). Considering that a suitable environment is a necessary component of human rights is also a priority for the competent bodies of the United Nations on the matter. As of 2012, 177 of the world's 193 UN member nations recognize this right through their constitution, environmental legislation, court decisions, or ratification of an international agreement, among these, some subnational governments recognize the right to a healthy environment, including six American states, five Canadian provinces or territories, and a growing number of cities. One of the biggest obstacles to the recognition of this right lies in state sovereignty; that is, the set of powers, which a state exercises exclusively on their territory recognized by the international order. Currently the only existing limit on the sovereign exercise of the functions of environmental management and imposed by international law is to manage the environment in a way that other States are not disadvantaged by the misuse of the natural resources. This question is contained in Principle 21 of the Stockholm Declaration, which states:

In accordance with the UN Charter and the principles of international law, States have the sovereign right to exploit their own resources pursuant to their own environmental policy and the obligation to

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ensure that the activities carried out within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond national jurisdiction. (UN, 1972)

Also, the Rio Declaration in Principle 2 (UN, 1992) reproduces the provisions of Principle 21 of the Stockholm Declaration.

Another obstacle to the recognition and realization of the right to the environment, which is already been referred to above, is the absence of a legally binding international instrument that explicitly recognizes this right. Some authors such as Makarewicz understand that documents like the Declaration of Stockholm or Rio constitute a generally accepted interpretation of the notion of human rights contained in the United Nations Charter (Makarewicz, 1986, p. 81). Handl and others (1995, p. 287) state that even if in some state practices this right does not separately exist, those states understand the right to environment is implied in inalienable rights, which cannot be knocked down, but in practice, this is not the case related to the right to environment. Nevertheless, within the limitations of economic and social rulings, the right to environment gets stronger.

Despite the "soft law" character of the international instruments, which recognize the right to environment, this right is inalienable qualifying; while the environmental degradation threatens the survival of humankind. Moreover, the flexible nature of existing instruments in this area can provide the further development of legally binding instruments, because "…when new values emerge, they need first to be so formulated as to pave the way for future developments in the form of binding instruments." (Kiss, Cançado Trindade, 1995, p. 287). In fact, the various aforementioned international instruments reflect the willingness to recognize the human right to the environment both for environmental protection and to ensure human survival. In this sense, perhaps the only way to articulate a human right to the environment is through the recognition of the existence of an international tradition generated by a constant and repeated international legal practice, along with the willingness to conceive this human right to a healthy environment (Lee, 2000, pp. 308-09). Lee states that consecutive unreserved reinforcement of this right in different non-binding documents constitutes an evidence of a comprehensive and consistent practice of States in the international arena. This practice can contribute to the final creation of a right to a proper and healthy environment as a principle of customary international law.

Another present difficulty in the recognition of the right to the environment is the inability to exercise the right to environment properly before the court because of the indecisive nature of the legal concept of "environment" and the lack of procedural mechanisms to invoke its protection.

These obstacles prevent full recognition of a right, which is still in formation, but its implementation can be promoted by establishing mechanisms such as information, participation, resources and education to influence the political will of the states and enable a human right to the environment to be legally binding. Legal systems seem to ignore the current social impulse, which recognizes the right to environment only acknowledging the legal status of other human rights. This clearly reflects which difficulties international human rights theory poses for the introduction of ecological limitations into international human rights law. In some sense, because the anthropocentric perspective, which is also the case for traditional western view of development and progress, centers on humans and it implies that humans are separate from Nature; in short, Nature is just a basket of resources that humans must take advantage of to feed economic growth (Gudynas, 2011, p. 262).

Based on the idea that the anthropocentric, a human right to environment is required to protect the most vulnerable people to the impacts of environmental degradation, but this view should to be combined with a complementary approach to protect the environment with the protection of human rights.

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IV. TOWARDS THE PROTECTION OF NATURE

In current legal systems, our living Earth is perceived as an object without rights. Yet fictitious entities, such as corporations, are granted rights similar to those of humans without reciprocal and enforceable responsibilities and accountability. Since the existing environmental and human right laws are not enough to protect nature, biodiversity and human health, the destruction of our Earth continues, and without redress. Therefore, another approach to environmental protection is required. The so-called "biocentric approach", developed mainly by mega-diverse countries and developing with indigenous populations, offers a different world view raising the "anthropogenic" to recognize and protect nature as having rights and as a legal entity. This possibility is certainly a novel perspective on environmental law, as it departs from the above-mentioned perspective. As already discussed, traditionally legal systems have regarded nature as "property", an object on which to develop and protect rights. The most common has been the promotion of laws and contracts to protect the property rights of individuals, corporations and other legal entities, such as legal subjects. The consequence is that the laws and regulations on environmental protection, which have mushroomed in recent times, despite emphasizing the preventive orientation, actually legalize environmental damage by regulating how much pollution or destruction of nature may occur in the context of the law. Even the recognition of the human right to the environment or the environmental dimension of the human rights has not been sufficient to ensure the protection of the environment and the welfare of the people. This approach is not free of criticism, in the opinion of Bosselmann (2001, p. 108):

[…] in the long term the existence of an environmental human right could be seen as self-contradictory. A better option is the development of all human rights in a manner, which demonstrates that humanity is an integral part of the biosphere, that nature has an intrinsic value, and that humanity has obligations toward nature. In short, ecological limitations, together with corollary obligations should be part of the rights discourse.

The recognition of the rights of nature is an integral holistic view of all lifestyles comprising all ecosystems. Through this perspective, nature is no longer protected, but a subject of protection rights granted to nature in all forms of life, has the right to exist, persist, maintain and regenerate its vital cycles. The counterpart to this recognition means that humans have the legal authority and responsibility to enforce these rights on behalf of nature. This conception is based on humans as part of life on earth and living within ecological limits and therefore as Caldwell has observed: "Humanity has no extraordinary moral claim or rights over the natural world." (1972, pp. 236).

The "biocentric" view arises from the severity of the environmental status and the threat on natural ecosystems. The conception "biocentrism" is based on the idea that humans are part of nature and that nature conservation is, above all, a duty of human beings: both must coexist for the perfect organic balance of the planet (Lanza & Berman, 2009). According to this argument, any form of life is important to the balance of nature (Emmenegger & Tschentscher, 1994, pp. 545-92).

The idea that nature possesses inalienable rights akin to human rights has gone from a strictly theoretical concept to the basis for policy changes in several countries. To recognize the rights of nature Ecuador in its constitution, Bolivia in its legislation, and a growing number of communities in the United States, are basing their environmental protection systems on the premise that nature has inalienable rights, as do humans. This premise is radical but natural, emerging as a reaction to "anthropogenic" forces that

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subordinate the environmental protection to the interests and / or human needs, reducing nature to a mere property, under the rule of law (Galeano, 2008).

1. Changing the Approaches to Protect the Nature

Following this other perspective of environmental protection, one of the first cases in which the rights of nature appear was the historic case of environmental law on the redwoods of California (*Sierra Club v. Morton*) in 1972, where the excessive corporate profit motives aimed to turn the habitat of huge old trees into an amusement park. It created a legal battle in which judges and academics questioned whether the trees should be entitled to a judicial proceeding (Pelizzon, 2011, pp. 6-12). In his dissenting opinion, Judge William O. Douglas argued that "inanimate objects" should legitimately to sue before the courts:

The critical question of "standing" would be simplified and also put neatly in focus if we fashioned a federal rule that allowed environmental issues to be litigated before federal agencies or federal courts in the name of the inanimate object about to be despoiled, defaced, or invaded by roads and bulldozers and where injury is the subject of public outrage. Contemporary public concern for protecting nature's ecological equilibrium should lead to the conferral of standing upon environmental objects to sue for their own preservation. This suit would therefore be more properly labeled as Mineral King v. Morton. (Sierra Club v. Morton, pp. 742-43)

Douglas continued:

Inanimate objects are sometimes parties in litigation. A ship has a legal personality, a fiction found useful for maritime purposes. The corporation sole—a creature of ecclesiastical law—is an acceptable adversary and large fortunes ride on its cases.... So it should be as respects valleys, alpine meadows, rivers, lakes, estuaries, beaches, ridges, groves of trees, swampland, or even air that feels the destructive pressures of modern technology and modern life. The river, for example, is the living symbol of all the life it sustains or nourishes—fish, aquatic insects, water ouzels, otter, fisher, deer, elk, bear, and all other animals, including man, who are dependent on it or who enjoy it for its sight, its sound, or its life. The river as plaintiff speaks for the ecological unit of life that is part of it. (Sierra Club v. Morton, p. 743)

As Berry (2014) explains, every being in the Earth Community has three rights: the right to be, the right to habitat, and the right to fulfil its role in the ever-renewing processes of the Earth community. This same reflection, led several authors from around the world to address this issue (Frazier Nash, 1989; Hanna et al., 1996; Boyle, 2006; Harding, 2007; Cameron, 2007). To mention a few: Stone (1972; 2010) in the United States, Godofredo Stutzin (1984, 2002) in Chile, or Cormac Cullinan (2002, 2008 and 2011) in South Africa.

A few years later, in 1982, over one hundred member states of the General Assembly of the United Nations adopted the World Charter for Nature, which states that "Humanity is a part of nature and life depends on the uninterrupted functioning of natural systems which ensure the supply of energy and nutrients" and provides a set of principles to be considered by man in their procedures with respect to the environment (UN, 1982). In this sense, the article establishes the duty of every person to act in accordance with the provisions of the Charter and to ensure the objectives set out in the Charter. This document recognizes the intrinsic value of nature and human beings aspart of nature, and it calls for humans to be

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guided by a moral code of conduct that does not compromise the integrity of those other ecosystems or species with which they coexist. It also regulates that human activity must be developed according to the earth limits and processes, and according with the common equity and the precautionary principle. The Charter states, "Humanity is part of nature and life depends on the uninterrupted functioning natural systems that are sources of energy and nutrients. Every form of life is unique, warranting respect regardless of its worth to human beings and other living things for recognition; man must be guided by a moral code of action". Ashby (1978, pp. 82-5) asserts that no one can predict the full consequences of tinkering with any part of an ecosystem. Even the non-living environment has properties without which life as we know it would be inconceivable. Consequently, the author continues, "the rights of nature" must be protected by law.

Regarding the nature of Rights, Thomas Berry (Bell, 2003) explains that:

1. All rights are role-specific or species-specific, and limited. Rivers have river rights. Birds have bird rights. Insects have insect rights. Humans have human rights. Difference in rights is qualitative, not quantitative. The rights of an insect would be of no value to a tree or a fish. 2. Human rights do not cancel out the rights of other modes of being to exist in their natural state. Human property rights are not absolute.

According to Stone (1972, p. 489), one of the strengths of regarding natural objects as bearers of rights, Stone contends, is that it would reflect a fundamental shift away from the current view that nature exists for men.

In 2000, a group of non-governmental organizations and movements adopted the Earth Charter, which "seeks to inspire in all peoples a sense of global interdependence and shared responsibility for the welfare of the human family, the greater community of life and future generations" (Earth Charter, 2000). Four pillars of sustainability are:

1. Respect and care for the community of life;
2. Ecological integrity,
3. Social and economic justice, and
4. Democracy, Nonviolence and Peace, and sixteen other principles.

The Charter also recognizes the role of traditional, cultural and spiritual knowledge of indigenous peoples, non-discrimination and self-determination. Although this document is not legally binding, its principles are considered of universal relevance.

In 2009, Polly Higgins, a lawyer and activist in the UK, started a campaign calling on the United Nations to adapt a law recognizing the mass destruction of ecosystems a crime against international peace, that is, as an 'ecocide'.[5] Ecocide is defined as "The extensive destruction, damage to or loss of ecosystem(s) of a given territory, whether by human agency or by other causes, to such an extent that peaceful enjoyment by the inhabitants of that territory has been severely diminished" (Higgins et al., 2013, pp. 251-66). Founded on the duty to care for the planet, this crime against peace would be strict liability and *erga omnes*: which means compulsory for all, even those States who are not subscribed to the International Criminal Court (ICC). Mining, extraction of fossil fuels and deforestation could be classified as ecocide according to the "Eradicating ecocide campaign", which is a law against ecocide to be fully implemented in 2020.

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Thus, over 10 countries have already recognized a form of ecocide in their national laws, including Georgia, Kyrgyzstan, Russia and Vietnam. In 2011, The Hamilton Group and held a mock trial in the Supreme Court of the United Kingdom to test the proposed crime of ecocide.[6] A process of restorative justice[7] was followed in 2012 from a fictitious company and victims including Earth (the voice of the Gaia Foundation), indigenous peoples and future generations. Since January 2014, in Europe, more than 112,000 people signed a petition through the European Citizen's Initiative for a European Directive on ecocide.[8]

In 2014, a coalition including End Ecocide in Europe, the European Network of Environmental Prosecutors, Globe EU and Green Cross International, launched a campaign in the European Parliament calling for the establishment of a Criminal Court on the Environment and Health, both at the European and International level with legal penalties for environmental damage. Once a crime of ecocide is recognized, the Criminal Court may allow an application through the Charter of Brussels, which would create a separate court. The Charter of Brussels has been opened to signatures since September 2014.[9]

In addition to this initiative of "ecocide" on April 22, 2010, World Day of Mother Earth, participants at the World People's Conference on Climate Change and the rights of nature developed and adopted the Universal Declaration of Rights of Mother Earth (People's Conference on Climate Change and the Rights of Mother Earth, 2010). This Declaration acknowledges Mother Earth as a living being with rights, including the rights to life, to existence and continues its vital cycles and processes free from any human interference. Even in 2012 the UN Conference Rio + 20 the need to live in harmony with nature has been recognized and in paragraph 39 of the Resolution of the General Assembly of the United Nations, "The Future We Want" refers to some countries recognize the "Rights of Nature" (UN GAOR, 2012), when asserts that:

39. We recognize that planet Earth and its ecosystems are our home and that "Mother Earth" is a common expression in a number of countries and regions, and we note that some countries recognize the rights of nature in the context of the promotion of sustainable development. We are convinced that in order to achieve a just balance among the economic, social and environmental needs of present and future generations, it is necessary to promote harmony with nature.

Peter Roderick, a lawyer also from the UK, proposed in 2011 a "Draft Declaration on Planetary boundaries"[10], in order to recognize and respect the Earth system processes that sustain life and promote responsibility to safeguard these processes of serious or irreversible harm. The Declaration is based on research conducted by Rockström (2009) and published in Nature in 2009 holding that there are 9 Earth-critical processes and associated thresholds that we must live within in order to avoid irreversible damage to our planet Earth and. According to this research, three of these boundaries have been breached: climate change; biodiversity and the nitrogen cycle. In this vein, in 2013, the Planetary Boundaries Initiative, a legal think tank, presented a petition for the adoption of an agreement on the protection of land system before the Open Ended Working Group of the United Nations on Sustainable Development Goals (ODS), as the main global priority to the goals of sustainable development after 2015.[11]

These are just some examples of international trends, mostly from academia and social movements, claiming environmental protection through the recognition of the legal personality of nature. This "biocentric" approach, as discussed below, has been reflected in some significant changes, legally speaking, and they deserve some attention. All demonstrate that in practice, recognising Rights of Nature is not difficult.

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2. Recognising the Rights of Nature

Among the protective laws of nature, at the oldest constitutional level is the Weimar Constitution of 1919. It has the reputation, together with the 1917 Constitution of Querétaro, of being one of the pioneers in incorporating social rights in the constitution. However, the Weimar Constitution is the first to protect nature. It provides in Article 150 that "Nature enjoys the protection and aid of the State". Despite this precedent, constitutions of the time did not include issues of nature protection and the human right to nature, including even the Universal Declaration of Human rights in 1948.

This is due to a lack of awareness about environmental damage. The first constitutions in the Americas are totally unaware of the existence of living beings other than human beings. The emphasis was on recognizing property rights related to land, water and nature.

During the 1980's and 1990's there is a wave of reforms in environmental legal frameworks in almost all South American countries, recognizing so-called third generation rights, incorporating related environmental issues, from the perspective of human rights.

Few charters on environmental protection contain the perspective on rights of and duties to nature (Boyd, 2012). The Constitutions of Colombia (1991) and Bolivia (in the 2002 reforms) provided that "all persons have the right to enjoy an ecologically balanced healthy environment" and the rights mentioned future generations. Environmental Law No. 1333, April 27 1992 (Bolivia, 1992) was a regulatory precedent recognizing the right to a healthy environment for people and living things in Bolivian legislation. In the Constitution of Peru, there is no right in itself, but an obligation of regulation. In Ecuador's Constitution, coded in 1984 "the right to live in a pollution-free environment and the states' obligation to promote the conservation of nature" is introduced. In 1998, the precautionary principal and the right for an individual to take an action to protect the environment is recognized. In 2007, Venezuela's Constitution recognizes the right and duty of each generation to protect and maintain the environment for its benefit and the future world. Everyone has to enjoy individually and collectively a live and a secure, healthy and ecologically balanced environment.

Significantly, after 89 years of Weimar, both the new Constitutions of the Plurinational State of Bolivia adopted in 2009, alongside the Ecuadorian Constitution from September 2008 included content in their respective sections, recognizing the rights of indigenous peoples and rights of all citizens to a healthy and balanced environment (Acosta & Martínez, 2009). In the Previous Constitution of Bolivia the right to a healthy environment was recognized so that individuals and communities of present and future generations, and other living beings could develop normally and securely. In particular, in Articles 33 and 34, the Magna Carta expresses the real rights of the population, and of the future generations of that country, to enjoy a healthy environment, protected and balanced, granting any person, either individually or on behalf of the communities, the power to take legal action in defence of the right to environment.

Both the Ecuadorian (2008) and Bolivian (2009) Constitutions mention nature, but while the Ecuadorian respects it as a living being with which on has to live in order to manage "living well", the Bolivian Constitution considers nature as a helpless and a vulnerable object requiring state protection (Cofre Lagos, 2006). However, in this case, nature always appears in the context of ancestral knowledge, acquired through an intense co-existence with nature itself. The text also diverges radically on another point. Bolivia's Constitution sees the industrialization of nature as a goal; whereas in the Ecuadorian case nature is presented as a subject of rights for the first time. The Bolivian text ends up creating a link between nature and modernity through progress, while the Ecuadorian Constitution breaks away from this perspective with a biocentric turn. It states that there must be a dynamic relationship between

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society, the state, and the market, but balanced and in harmony with nature; granting nature inalienable rights and thus making it a subject of law (Zaffaroni, 2010; De Prada García, 2014).[12]

The Plurinational State Constitution of Bolivia, in Article 381, declares that the State shall protect all genetic resources and micro-organisms found in the ecosystem of the territory, as well as the knowledge associated with their use and exploitation.

Article 382 says the State has power and duty for defence, recovery, protection and reparation of biological material coming from natural resources, ancestral knowledge, and other ways originating within the territory.

Article 387 states that the law will regulate the protection and use of forest species of socio-economic, cultural and ecological relevance, giving special importance to the protection of coca, establishing that the State protects the nature and ancestral coca as a cultural heritage, a renewable natural resource of biodiversity, and as a factor of social unity (Article 384).

In the two constitutions, particularly in the Bolivian case, indigenous people have incorporated their demands to build plurinational states to represent them and their cultural values, expressed in the "Vivir Bien" ("living well" or "Suma Qamaña" in Aymara). In the Bolivian legislation this meant Nature qualified as a "Subject of Rights" – a truly normative leap.

In the Ecuador's Case "Buen Vivir" ("Living Well" or in Quechua "Sumak Kawsay"). In Chapter 7, Article 71 provides that Nature, or "Pachamama", where live occurs and is reproduced, has the right to integral respect for its existence, maintenance and regeneration of its live cycles, structure, functions and evolutionary process.

The indigenous worldview is reflected in the Bolivian Constitution in its preamble

In ancient times mountains arose, rivers spread out from one place to another, lakes were formed. Our Amazonia, our swamps, our highlands and our plains and valleys were covered with greenery and flowers. We populated this sacred Mother Earth with different faces, and since that time we have understood the plurality that exists in all things and in our diversity as human beings and cultures. Thus, our peoples were formed, and we never knew racism until we were subjected to it during the terrible times of colonialism.

Everything had its place, and humans and nature co-existed in harmony. The preamble reflects a dialogue from the past, in the present, saying that since time immemorial plurality and diversity are respected. It refers to the natural environment and land, as well as Mother Earth, in which original context various indigenous peoples emerged. Harmony was broken by colonization, introducing racism and altering the order in which indigenous people lived (Caudillo Félix, 2010).

It was not until 2010 that Bolivia adopted the first legislative package in the world in which the ancient indigenous conception of nature as a living being entered, giving nature equal rights to humans. Specifically the laws are: Law No. 071 of the rights of Mother Earth (2010) and Framework Act No. 300 of Mother Earth and Integral Development of Good Living (2012). Even though these laws are mostly abstract, their existence helps elevate a debate about the relationship between people and nature. In particular, the Law on the Rights of Mother Earth endorses some guiding principles, including the "common good", not multiculturalism and commodification of nature, and requires the state and citizens to respect the rights of the Earth. Under the Act, companies and individuals may be responsible for causing environmental damage and responsible for its repair. The Act also provides for an Ombudsman for Mother Earth to protect their interests.

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As fruit of these constitutional developments, on April 22 2009, the General Assembly of the United Nations, at its 63rd meeting, unanimously adopted the draft submitted by Evo Morales, the Bolivian President, stating that every April 22 is celebrated as International Day of Mother Earth (instead of the Day of Earth) (UN, 2009). Concluding the look at Ecuador and Bolivia's Constitutions, indigenous movements there have managed to incorporate their worldview, values and requirements within their constitutions (Wray, 2008).

However, it is considered that the only way to make the principles contained in the Magna Cartas effective is through daily struggles and processes of autonomy and self-management of their people. Previous political experiences have taught them the limitations of the system and the need to continue fighting for their collective rights, the establishment of a plurinational state, and an intercultural society that recognizes and respects indigenous peoples (Vargas, 2011, pp. 70-86).

In this regard, it is important to mention that in the United States of America, more than 24 towns and cities have implemented ordinances for the Rights of Nature (Kurth *et al.* 2012). One of the first legal instruments titled "Sewage Sludge Ordinance" was adopted in 2006 in Tamaqua Borough, Pennsylvania, which meant that corporations could not spread sewage sludge as fertilizer on farmland, even where the owner of the land consented. This Ordinance recognizes the rights of natural communities and ecosystems to exist and flourish, and recognized ecosystems as legal persons (s 7.6). Corporations may not interfere with the right of ecosystems to exist and flourish and Tamaqua residents can pursue actions on behalf of ecosystems. With this move, Tamaqua became the first US municipality to recognize the rights of nature and to enable residents to take action to vindicate those rights.

Another relevant example is Pittsburgh city ruling (2010, § 618.03), which prohibits companies drilling for natural gas in the city. This ordinance elevates the rights of individuals, the community and nature over corporate "rights" and thus becomes the first city in the USA to recognize the rights of nature as legally binding. By recognizing the rights of nature, ecosystems and communities against businesses and other levels of government, which can authorize such drilling, and by authorizing Pittsburgh residents to exercise those rights on behalf of threatened ecosystems, these ecosystems are effectively protected. Santa Monica (2013) also passed a ruling that elevates its right to enforce its Sustainable City Plan, including rights to clean air, water and soil, and the rights of nature above corporate entities' privileges and powers.

Since 2010, at least 18 Community Bills of Rights to ban natural gas drilling and hydraulic fracturing have been passed in municipalities in California, New York, New Hampshire, Maine, Maryland, Ohio, Pennsylvania and Virginia, and defeated in New Mexico.[13] Specifically, the Town Mountain Lake Park Ordinance on Natural Gas Extraction (2011); West Homestead, Pennsylvania Community Rights Gas Extraction Prohibition (2011); Town of Wales, New York Community Protection of Natural Resources (2011);[14] Baldwin, Pennsylvania Community Protection from Natural Gas Extraction Ordinance (2011); Wilkinsburg, Pennsylvania Community Protection from Natural Gas Drilling Ordinance (2011);[15] Forest Hills Borough's Community Rights and Protection from Natural Gas Exploitation Ordinance (2011); State College Borough's Community Bill of Rights Home Rule Charter Amendment (2011); Las Vegas, New Mexico's Community Water Rights and Local Self-Governance Ordinance (2013), amongst many others. These are the first communities in the U.S. to ban fracking, recognizing the rights of nature, and subordinating corporations to the people by popular vote.

Although these initiatives recognize rights of nature at the local level, it poses the question whether this recognition of nature's rights is ecologically valid (Rodrigues, 2014, pp. 170-84). Although the initiatives quoted above are local, policy development in the United States shows that attributing rights to nature is no exclusive to indigenous societies with a particular worldview. Western societies also promote

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change in this direction, in response to new challenges that nature faces defenseless against the intense activity of large industrial corporations (Vermont Rights of Nature, 2012).

3. Protecting the Rights of Nature

Especially the indigenous, social movements have been the promoters of this new "biocentric" perspective, based on worldview, values and demands for the legal recognition of the rights of nature. However, it is necessary to analyze the effectiveness of these rights beyond formal legal recognition. In this sense, the practice has encompassed not only the protection of nature itself, but also the protection of the intangible and the spiritual, ensuring their preservation, and the protection of sacred sites and ancestral knowledge.

In certain cases, the formal recognition of the rights of Nature has implied the creation of institutional bodies and processes, such as Guardians for the Earth in Bolivia, and Ombudsman for Future Generations. In addition, many countries recognise locus standi/standing for the public to issue legal proceedings in the public interest (e.g. UNECE Aarhus Convention) - which could be expansively interpreted as including Nature, and even directly on behalf of Nature (e.g. Ecuadorian Constitution and local ordinances in the U.S.). These institutional tools can amplify the protection of the environment.

Regardless of the extent of rights granted to nature, it must rely on human representation to assert and defend these rights in a court of law (Donald Cameron, 2007). The first case of judicial enforcement of the rights of nature occurred in the year 2011 Action Protection, resolved on appeal by the Criminal Division of the Provincial Court of Loja (Wheeler versus Director de la Procuraduria General del Estado en Loja, 2011), presented by Richard Frederick Wheeler and Eleans Geer Huddle against the Provincial Government of Loja "for nature particularly in favor of the Vilcabamba river" over the works of the Vilcabamba-Quinara road expansion. The government project to build a highway without the required environmental impact studies, negatively affected the flow of the river causing floods and disrupted wildlife and the livelihoods of local communities. The court decision was issued on March 30, 2011 by the Provincial Court of Loja, which granted an injunction against the Provincial Government of Loja to stop violating the constitutional rights of the Vilcabama River to exist and to maintain its vital cycles, structure, functions and evolutionary processes (Daly, 2012, pp. 63-6). This is the first case of successful Nature Rights under Article 71 of the Ecuadorian Constitution (Wheeler versus Director de la Procuraduria General del Estado en Loja, 2011). The Chamber granted the motion, agreeing that "the action of protection is the only suitable and effective remedy to stop immediately and focused environmental damage" and applying the precautionary principle, the judges say "[...] "until such time it is objectively proven that no probable or certain danger exists over works carried out in a particular area producing contamination or environmental damage, it is the constitutional duty of judges to immediately pay attention to safeguarding and enforcing the legal protection of the rights of Nature, avoiding contamination by whatever means, or ensuring remedy. Note that with relation to the environment we shall consider not only certain damage, but also indications of possibility" [...]"(Wheeler versus Director de la Procuraduria General Del Estado en Loja, 2011, §5). Therefore, the Court confirmed the principle of precaution that until the government can show that the widening of the road would not affect nature; the presumption is to protect the rights of nature. The Court also endorsed the intergenerational principle, recognizing the importance of nature to protect the interests of present and future generations and ordered the government to submit environmental impact studies, develop a plan of rehabilitation and remediation, and publicly apologize for the start of construction of a road without the necessary environmental license (Smith, 2009; De Prada, 2014).

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The Chamber recalls that the Constitution "... unprecedented in the history of mankind, recognizing nature as a subject of rights [...]"; assumed as an obvious and indisputable fact the "importance of Nature", to the point that they consider "any argument about it is succinct and redundant", incorporating the decision that the idea that damage to it is "generational damage ", defined as" those which by their magnitude impact not only on the current generation but their effects will impact on future generations [...]" (Wheeler versus Director de la Procuraduria General del Estado en Loja, 2011, §7 and 8). In addition it modifies the burden of proof freeing the plaintiffs from proving damage, stating that it is the "[...] the plaintiffs did not have to prove potential damage. The Loja Provincial Government would have to provide evidence that the activity of opening a road neither affected nor would affect the environment in the future. It would be inadmissible to reject an action protecting Nature for the lack of prof presented, as in case of possible or assumed already caused environmental damage through pollution, the nonexistence of this damage should be proved not just by whoever is in a better position to do so but by the one who argues, ironically, that such damage does not exist"[...] " (Wheeler versus Director de la Procuraduria General del Estado en Loja, 2011, §10).

Despite the excitement surrounding this finding, which advocates recognition of nature as a subject of rights, the Board does not deny the possibility of the work, but states it should respect the "rights of nature" without specifying how they are violated. It merely repeats the Constitution "is violating the law of nature has to be fully respected its existence and the maintenance and regeneration of its vital cycles, structures, functions and evolutionary processes". In fact, all the reasoning is redirected towards the human right to a healthy environment. The action on behalf of the defense is of particular interest "[...] As regards the allegation that the people need [...] roads, indicates that: in case of conflict between two protected interests (sic) Constitution, the solution must be found in accordance with the legal elements which constitute the case and in light of the constitutional principles and values. This work is an essential function of interpretation by the constitutional court. But in this case there is nothing to ponder because there is no collision of constitutional rights or compromise of one of them, in that if the Vilcabamba-Quinara road is not enlarged, it complies with the constitutional rights of Nature. In any case, the interest of these populations in the road is lessened compared with the interest in a healthy environment that includes a larger number of people" (Wheeler versus Director de la Procuraduria General del Estado en Loja, 2011, §12). Accordingly, the judgment states that the Provincial Council is responsible for damages, ordering that environmental recommendations are welcome and "public apology for starting the construction of a road without the environmental licensing."

Also in Ecuador, on November 26, 2010, an international alliance of environmental activists[16] filed a lawsuit against British Petroleum (BP) in the Ecuadorian Constitutional Court, in defense of the rights of nature, which are recognized in the Ecuadorian Constitution 2008. In this sense, the Ecuadorian Constitution recognizes the right of nature to be restored and allows a citizen or group to present a case before the Constitutional Court of Ecuador for a violation occurring in a different country,which affects Earth as a whole. Instead of seeking financial compensation, the coalition calls on BP to disclose the data and information on the ecological destruction caused by the oil spill, and to restrain BP from mining oil underground as in the spill in the Gulf of Mexico disaster (Gaia Learning Centre, 2011).

Following this recognition of nature as a subject of rights, the Chief Justice in Belize ruled in 2010 that a reef is not owned, but is a living being that is part of the national heritage of Belize and cannot be sacrificed to the commercial interests (Supreme Court of Belize, A.D. 2009; Court of Appeal of Belize, A.D. 2011). The case is from January 13, 2009, when a cargo ship collided with Mesoamerican Reef, near Caye Glory in Belize, damaging 6,000 square meters of pristine reef. The Mesoamerican reef more

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than 225 million years old, is the largest coral reef in the Atlantic Ocean and is home to over 60 species of coral reef fish and 500 other species. The Court considered the shipping company responsible and required it to pay $ 11 million Belize dollars ($ 5.5 million US Dollars), plus interest at 3% per year for environmental and ecological loss and the cost of restoration.

In this line, it is also interesting that from 1997, OxlajujAjpop, an organization of indigenous Mayan spiritual leaders, has been advocating for and developing a proposal for a Sacred Sites Act in consultation with indigenous communities. This bill is to ensure the recognition of sacred sites and territories and governance, access, use and conservation of communities. It has not yet been accepted by all members of Congress and government, but negotiations continue. OxlajujAjpop is also calling for a new Constitution and the legal reform that respects Mother Earth, ecosystems and indigenous territories, and a 'socially and legally' pluralistic state (National Conference of Ministers spirituality Maya of Guatemala, 2008).

Another interesting case is related to a group of international activists, who requested the opening of a trial in the Constitutional Court of Ecuador in 2010 referring to the right of nature and the right of sea further than the territory of Ecuador, to claim justice in the case of the Deepwater Horizon disaster, which is the famous British Petroleum oil spill in the Gulf of Mexico, in the name of the right of the sea.The claim challenged the usual jurisdiction territorial competence and mobilized new rights and visions which exist only in a few countries like Ecuador and Bolivia. This case illustrates how the traditional systems to demand compensation can be changed, in that the request can require a series of actions by the company BP, and not necessarily a direct financial compensation. For example, BP shall maintain the same quantity of oil underground as before the extraction, or use specific technical cleaning mechanisms, implying an economical sacrifice or a change in behaviour by the company, as a disincentive for repeating their actions, instead of simply a financial award. Such an example teaches an important although basic lesson: losses caused by environmental injustice go further than the money value. As far as possible justice should evolve, towards a diversity of values that can be incorporated into the sentencing systems in the court.

In 2012, the "Custodians of Sacred Natural Sites" Kenya, South Africa, Ethiopia and Uganda adopted a Common Declaration of African customary law for the Protection of Sacred Natural Sites in Nanyuki, Kenya (Custodian Meeting Nanyuki, 2012). The Declaration recognizes that sacred natural sites and territories are places of ecological, spiritual and cultural significance, where laws and ecosystem boundaries exist and must be respected. The Declaration provides important guidance on sacred natural sites which should be respected and prohibited for any activity, except necessary spiritual practices, and that the traditional systems of government, which communities hold should be recognized. Similarly, in New Zealand, following more than a century of petitions and legal action by local iwi (Maori tribal group), the Whanganui river in New Zealand was granted the legal status of a person under the name Te Awa Tupua. This legal victory means that the river now enjoys the same rights and responsibilities before the law as people and corporations and both the government and the Maori have been designated guardians to ensure that the river's rights are protected (Tutohu Whakatupua, 2012). This precedent-setting legal case is the first time the rights of a river have been guaranteed in this way, opening up exciting possibilities for protecting, and changing how we understand our relationship with, the natural world.

Apart from these cases, it is worthwhile mentioning that the first Permanent Court of Ethics was established on January 17 2014, for the Rights of Nature and Mother Earth, thanks to the Global Alliance for the Rights of Nature. Its inaugural meeting, attended by over 400 people, was held in Quito, Ecuador, the country which acknowledged these rights for the first time in its constitution. The Tribunal was chaired by Vandana Shiva. This first preliminary hearing was to determine eligibility for the award

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of rights of numerous acts of nature, including those affected by mining and commercial agriculture. The role of this Court is to promote the establishment of a future permanent court to contribute to the development of legislation that recognizes the rights of nature (Viale, Machado, & Acosta, 2014). The Court is held in different parts of the world, for example, in the negotiations on climate change (COP 20) in Lima in December 2014 (Larrea, 2013; Acosta, 2013).[17]

The initiative arose and was the expression of the coordinated action of a wide range of social movements and organizations from around the world, all moved by the desire to denounce the attacks, which Nature had suffered, and the suffering that comes from the past, systematically and with increasing intensity, in the name of "progress." This Court, a pioneer in the search for ways to build global justice against crimes against life, was established as a permanent platform to hear and judge cases of violation of the rights of Mother Earth that took place around the world.

In this first session of the Permanent Court of Ethical Rights of Nature included representatives from Australia, Switzerland, South Africa, USA, Spain, Canada, India, Romania, Bolivia, Argentina and England, Colombia, Germany, France, as well as Ecuador were included. After a full day session with presentations and discussions, the court took the unanimous decision to admit nine cases considered emblematic of the violation of the laws of Nature. Six spot cases were presented: pollution Chevron-Texaco (Ecuador); the threat to the Great Barrier reef due to coal mining (Australia); copper sky mining in the Cordillera del Condor reservoir case Mirador (Ecuador); cases of hydraulic fracturing (USA) and two cases on a global scale representing systemic violations of the rights of Mother Earth, involving genetically modified or transgenic organisms and climate change; and lastly the proposed oil drilling in Yasuní-ITT (Ecuador). During the Yasuní –ITT case, because of the immediate threads, and the convincing evidence the Tribunal agreed to establish a special Courtroom for this item, to consider the harassment of defenders of nature, including the people gathering signatures for a community consultation with which to put the brakes on the exploitation of crude in the Yasuní-ITT. It was also to consider the suspension of extraction activity in Block 31 and 43 (ITT), and carry out a general audit of all activities in the Yasuní National Park.

It was consistent that the Court of the Rights of Nature originates in Ecuador, the first country to recognize these rights in its constitution. It is ironic, however, that Ecuador has abandoned its leadership and its commitment to respect the rights of nature set out in its Constitution, which was overwhelmingly approved by the Ecuadorian people at the polls (Figueroa, 2011). The Government of Ecuador is currently promoting the expansion of oil production and large-scale mining threatening three million hectares of the Amazon forest remnants, while carrying out a systematic campaign against those individuals and organizations that defend the rights of Mother Earth protected by the Ecuadorian Constitution. The criminalization of popular resistance is undoubtedly the government tool to further expanding extraction: minerals, petroleum, biofuels, etc.

These cases illustrate to a greater or lesser extent, certain changes in the way of protecting the environment, moving away from the traditional anthropogenic perspective. Graduallysocialchanges areinfluencingthe evolution of the lawfor the benefit ofnature. Thesechanges respondto the attempt tostophumanizingnature and make the human beingresponsiblefor protectingthe environment. In some sense, history shows again that culture changes law and law in turn, broadly can change culture.

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V. CONCLUSION

Environmental awareness generated by progressive degradation of the environment, from different areas has led to the call for a formal recognition of the importance of environmental protection for human well-being. However, the anthropocentric approach developed to protect human rights has shown that it is not enough to protect the environment. The traditional anthropocentricparadigm furthers dangerous ideas around the commodification and financialization of nature. So the new road for the biocentric perspective away from the Western model of development to a more holistic approach based on indigenous concepts such as "Living Well" or "Good living" and allowing for the development of the "right to a healthy environment" and "the rights of nature." The conception of an environmental dimension as an integral part of the realization of human rights has contributed to increased lack of care about environmental protection for the benefit of human welfare. The consequence has been the subordination of the well-being of ecosystems to satisfy human interests, not always respectful of natural cycles. Thus, the protection of nature through a human rights perspective has generated the dispersal of laws according to the subjective and fragmented interests of human groups.

The new focus on environmental protection, which has been discussed in this article, establishes a new relationship between humans and nature and harmony between the two, which should be preserved as a guarantee of nature's regeneration. It promotes the legal recognition of nature favouring the unification of laws throughout the different legislations by providing rules protecting the natural world with a common denominator, based on the needs of the biosphere. According to that, states must be required to prioritize the welfare of citizens and the natural world, developing public policies that promote sustainability and control of industries. The national economy should operate within the limits of nature. This certainly will not be an easy task. What may seem utopian is slowly becoming a reality in many countries. The key is to change policies and laws related to the environment, which simply encode pollution and destruction. The changes only will be succeeded, if such policies and laws recognize human rights as well as human responsibilities for a healthy and resilient Earth.

Despite the possible contradictions on a practical level, the emerging new regulations based on the biocentric approach at least raise the man's need to change the way it treats nature, but this new concept has not been widely translated into the world of laws and policies, or society in general. According to this concept, natural rights are not opposite to human rights: human rights are a subset of natural rights, because humans are a part of the nature.

The final idea is not the imposition of the biocentric view on the anthropocentric legal protection of the environment, but to change the way we conceive this protection: it is important to protect nature, but not under the blanket of protecting human interests. Social movements and even academic efforts should be made to invest in favour of the rights of nature and at least a new opportunity to preserve the environment and, of course, our welfare. Critically, therights of Nature framework provides a path through which people can re-learn respect for Mother Earth and for human rights.

REFERENCES

Acosta, A. (2013). Alberto Acosta judge's ruling on Yasuni ITT case. Rights of Nature Tribunal. *Global Alliance for the Rights of Nature*. Retrieved 23 June 2015 from http://therightsofnature.org/alberto-acosta-Yasuni-itt-case/

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Acosta, A., & Martínez, E. (Eds.). (2009). Derechos de la Naturaleza - El futuro es ahora. AbyaYala, 261-263.

Admiralty the Attorney General of Belize vs. Ms Westerhaven Schiffahrts GMBH & CO KG and Reider Shipping BV. Supreme Court of Belize, A.D. 2009 Claim No. 45 OF 2009.

Ashby, E. (1978). *Reconciling Man with the Environment*. Stanford, CA: Stanford University Press.

Bell, M. (2003). Thomas Berry and an Earth Jurisprudence: An Exploratory Essay. *The 19 Trumpeter*, (1), 69.

Berry, T. (2014). Selected Writings on the Earth Community. Modern Spiritual Masters, by Mary Evelyn Tucker. *Orbis*, 132.

Boff, L. (2008). *El siglo de los derechos de la Madre Tierra*. Retrieved 23 December 2015 from http://www.servicioskoinonia.org/boff/articulo.php?num=327

Borough Baldwin Ordinance (2011) no. 838: Ordinance of the Borough of Baldwin, Allegheny County, Commonwealth of Pennsylvania, banning the commercial extraction natural within the confines of the Borough.

Borough Council of Wilkinsburg, Allegheny County, Pennsylvania (2011), ordinance number 28-70 on the prohibition on natural gas extraction.

Borough of Forest Hills Ordinance (2011) no. 1017: an Ordinance of the Borough of Forest Hills, Allegheny County, Pennsylvania, banning the extraction of and/or exploration for natural gas within the borough of Forest Hills. Retrieved 2 August 2015 from http://www.harmonywithnatureun.org/content/documents/196Ordinance-Forest%20Hills--.pdf

Bosselmann, K. (2001). Human Rights and the Environment: Redefining Fundamental Principles?. *Governance for the Environment: Global Problems, Ethics and Democracy*. Academic Press.

Boyd, D. R. (2012). The Environmental Rights Revolution: A Global Study of Constitutions, Human Rights, and the Environment. Vancouver: UBC Press.

Boyle, S. (2006). On thin ice. *The Guardian Newspaper*. Retrieved 23 December 2015 from http://www.theguardian.com/environment/2006/nov/08/ethicalliving.society

Caldwell, L. K. (1972). *In Defense of Earth: International Protection of the Biosphere*. Bloomington, IN: Indiana University Press.

Carson, R. (1962). *Silent Spring*. Boston: Houghton Mifflin.

Caudillo Félix, A. G. (2010). Pueblos indígenas y naturaleza: la alternativa del buen vivir. *Revista electrónica del Departamento de Estudios Ibéricos y Latinoamericanos de la Universidad de Guadalajara*, *2*(1), 5-10.

City of Pittsburgh. (2010). *Marcellus shale natural gas drilling. § 618.01 Natural Gas extraction corporations operating within the City of Pittsburgh* (Ord. No. 37-2010). Retrieved 2 August from http://www.earthlawcenter.org/s/Marcellus-Shale-Ord-Pittsburgh.pdf

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

City of Santa Monica. (2013). *Ordinance of the City Council of the city of Santa Monica Establishing sustainability report*. Retrieved 2 August 2015 from http://www.smgov.net/departments/council/ agendas / 2013/20130312 / s2013031207-C-1.htm

Cofre Lagos, J. O. (2006). Sobre la fundamentación radical de la naturaleza (humana) y de los derechos humanos. *Revista de Derecho Valdivia*, *19*(1), 9–32.

Cullinan, C. (2002). *Wild Law*: *A Manifesto for Earth Justice*. SiberInk.

Cullinan, C. (2008). *If Nature Had Rights, What Would We Have to Give Up?* Orion. Retrieved 23 June 2015 from http://www.orionmagazine.org/index.php/articles/article/500

Cullinan, C. (2011a). A History of Wild Law. In P. Burdon (Ed.), Exploring Wild Law: The Philosophy of Earth Jurisprudence (pp. 12–23). Academic Press.

Cullinan, C. (2011b). Wild Law: A Manifesto for Earth Justice (2nd ed.). Totnes: Green Books.

Daly, E. (2012). Ecuadorian Exemplar: The First Ever Vindications of Constitutional Rights. *Review of European, Comparative & International*. *Environmental Law (Northwestern School of Law)*, 63–66.

De Prada García, A. (2014). Human Rights and Rights of Nature: The Individual and Pachamama. *Rechtstheorie*, *45*(3), 355–365. doi:10.3790/rth.45.3.355

Declaration of the United Nations Conference on the Human Environment. (1972). UN. Doc. A/Conf.48/14/ Rev. 1, reprinted in 11 ILM 1416. Retrieved from: http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=78&ArticleID=1163

Declaration on Environment and Development. (1972). Report of the UN Conference on Environment and Development. New York: UN. Doc. A/CONF.151/26/Rev.1, 1972.

Déjeant-Pons, M. (1994). Le Droit de l'Homme á l'Environnement, DroitFondamentalauNiveauEuropèennedans le Cadre du Conseilde l'Europe, et la ConventionEuropèenne de Sauvegarde des Droits de l'Homme et des LibertésFondamentales. *Revue Juridique de l'Environnement*, (4), 373-419.

Donald Cameron, S. (2007). *When does a tree have rights?* Halifax, Nova Scotia: The Chronicle Herald.

Emmenegger, S., & Tschentscher, A. (1994). Taking Nature's Rights Seriously: The Long Way to Biocentrism in Environmental Law. *The Georgetown Environmental Law Review*, 545–592.

Figueroa, I. (2011). La subjetivización de la naturaleza (y sus trampas jurídicas, éticas y epistémicas). *Revista Catalana de Dret Ambiental*, *2*(1), 1–19.

Frazier Nash, R. (1989). *The Rights of Nature: A History of Environmental Ethics*. Academic Press.

Gaia Learning Centre (2011). *Justice for the Earth community: defending the rights of nature and holding corporations to account*. Author.

Galeano, E. (2008). *La Naturaleza no es muda*. Retrieved 23 June 2015 from: http://www.accionecologica.org/index.php?option=com_content&task=view&id=854&Itemid=1

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Gormley, W. P. (1990). The Legal Obligation of the International Community to Guarantee a Pure and Decent Environment: The Expansion of Human Rights Norms.3. *Georgetown International Environmental Law Review*, 85–116.

Governing Council, Report of the World Commission on Environment and Development. (1987). *Our Common Future*. UN Doc. UNEP/GC.14/ 13, ES-7.

Gudynas, E. (2010). La senda biocéntrica: valores intrínsecos, derechos de la naturaleza y justicia ecológica. *Tabula Rasa*, (13), 45-71.

Gudynas, E. (2011). Los derechos de la Naturaleza en serio. In A. Acosta & E. Martínez (Eds.), La Naturaleza con derechos. De la filosofía a la práctica (pp. 239–286). Academic Press.

Gutierrez Bedoya, C. I. (2006). *El derecho al medio ambiente adecuado como derecho humano.* Centro Editorial Universidad Del Rosario.

Handl, G. (1995). Human Rights and Protection of the Environment: A Mildly "Revisionist" View. In Derechos Humanos, Desarrollo sustentable y medio ambiente. San José de Costa Rica.

Hanna, S., et al. (1996). *Rights to Nature: Ecological, Economic, Cultural, and Political Principles of Institutions for the Environment*. Academic Press.

Harding, S. (2007). Earthly rights. *The Guardian Newspaper*.

Higgins, P., Short, D., & South, N. (2013). Protecting the Planet: A Proposal for a Law of Ecocide. 59. *Crime, Law, and Social Change*, *59*(3), 251–266. doi:10.100710611-013-9413-6

Human Rights Council. (2012a). *Human rights and the environament.* Res. 19/10, A/HRC/19/L.8/Rev.1. Adopted on 22 March 2012.

Human Rights Council. (2012b). *Report of the Independent Expert on the issue of human rights obligations related to the enjoyment of a safe environment, clean, healthy and sustainable*. Retrieved 1 August 2015 from http://daccess-dds-ny.un.org/doc/UNDOC/GEN/G12/189/75/PDF/G1218975.pdf?OpenElement

IDI. (1998). Annuaire de l'Institut de Droit International. *Strasbourg Session, 67*(2), 479.

International Covenant on Civil and Political Rights, GA. Res. 2200A (XXI), 21 U.N. GAOR Supp. (No. 16) at 52, UN. Doc. A/6316 (1966), 999 U.N.T.S. 171, entered into force on Mar. 23, 1976.

International Covenant on Economic, Social and Cultural Rights, G.A. res. 2200A (XXI), 21 U.N. GAOR Supp. (No. 16) at 49, UN. Doc. A/6316 (1966), 993 U.N.T.S. 3, entered into force on Jan. 3, 1976.

Kiss, A., & Cançado Trindade, A. (1995). Two Major Challenges of Our Time: Human rights and the Environment. *Derechos Humanos, Desarrollo sustentable y medio ambiente*. San José de Costa Rica.

Kurth, T. E. (2012). *American Law and Jurisprudence on Fracing,* 10-153.

Lanza, R., & Berman, B. (2009). Biocentrism: How Life and Consciousness are the Keys to Understanding the True Nature of the Universe. Academic Press.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Larrea, C. (2013). *La Explotación Petrolera en el Parque Nacional Yasuní y los Derechos de la Naturaleza.* Retrieved from 23 June 2015 from: http://therightsofnature.org/wp-content/uploads/ITTDerechosNaturaleza.pdf

Lee, J. (2000). The Underlying Legal Theory to Support a Well-Defined Human Right to a Healthy Environment as a Principle of Customary International Law. *Columbia Journal of Environmental Law*, *25*(2), 283.

Lewis, B. (2012). Environmental Rights or a Right to the Environment? Exploring the nexus between Human Rights and Environmental Protection. *The Macquarie Journal of International and Comparative Environmental Law,* (1), 36.

Ley de derechos de la Madre Tierra. Ley Nº 071, Gaceta Oficial. December 21, 2010

Ley del Medio Ambiente. Ley 1333, Gaceta Oficial. April 27 1992.

Ley marco de la Madre Tierra y Desarrollo Integral para Vivir Bien. Gaceta Oficial October 15, 2012.

Makarewicz, A. (1986). La protection internationale du droit à l'environnement. Environnement et droits de l'Homme. UNESCO.

Melo, M. (2009). *De Montecristi a Cochabamba. Los derechos de la Madre Tierra en debate*. Retrieved 23 June 2015 from http://therightsofnature.org/wp-content/uploads/pdfs/Espanol/Melo_Montecristi%20a%20Cochabamba_2009.pdf

Mountain Lake Park (2011), Md., Ord. No. 2011-01 (Mar. 3, 2011).

Ms Westerhaven Schiffahrts GMBH & CO KG Redier Shipping BV vs. The Attorney General of Belize. Court of Appeal of Belize, A.D. 2011 Civil Appeal No. 19, 2010.

National Conference of Ministers spirituality Maya of Guatemala -OxlajujAjpop. (2008). *Organization for the recovery, conservation, dignity and administration of the holy places Mayas (NIM Q'ATB'ALtzij KECH AJQ'IJAB'OXLAJUJ Ajpop) of January 18, 2008*. Retrieved 23 June 2015 from http://sacred-naturalsites.org/es/items/nim-qatbal-tzij-kech-ajqijab-oxlajuj-ajpop/?COLLCC=1422104073

Pelizzon, A. (2011). Keeping the Fire: Impressions of Earth Jurisprudence, 14. *Southern Cross University Law Review*, 6–12.

Rockström, J., Steffen, W., Noone, K., Persson, A., Chapin F. S., Lambin, E., … Foley, J. A. (2009). A safe operating space for humanity. *Nature, 461*, 472-475. Retrieved 23 June 2015 from http://www.nature.com/news/specials/planetaryboundaries/index.html

Rodrigues, S. (2014). Localising 'the rights of nature': a critical discourse analysis, Green Letters: Studie*s. Ecocriticism*, *18*(2), 170–184.

Sierra Club v. Morton. United States Supreme Court. 405 U.S. 727, 741-43 (1972).

Smith, G. (2009). In Ecuador, Trees Now Have Rights. Earth Island Journal, 15-15.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

State College Borough Bill of Rights. (2011). *Community Bill of Rights and Natural Gas Drilling Ban Section 41.2-205*. Retrieved 30 August 2015 from http://www.statecollegepa.us/DocumentCenter/Home/View/3028

State of New Mexico, County of Mora, Ordinance 2013-01. (n.d.). Retrieved 30 August 2015 from https://es.scribd.com/doc/139339332/Mora-County-Oil-and-Gas-Ordinance

Statement of Common African Customary Laws for the Protection of Sacred Sites. (2012). Custodian Meeting Nanyuki, Kenya. Retrieved 23 June 2015 from http://sacrednaturalsites.org/es/items/statement-of-the-common-african-customary-laws-for-the-protection-of-sacred-sites/?COLLCC=1400401888

Stone, C. (1972). Should Trees Have Standing? Toward Legal Rights for Natural Objects, 45. *Southern California Law Review*, 450.

Stone, C. (2010). *Should Trees Have Standing?* Law, Morality, and the Environment.

Stutzin, G. (1984). Un imperativo ecológico: reconocer los derechos de la Naturaleza. *Ambiente y Desarrollo*, 97-114.

Stutzin, G. (2002). Nature's Rights: Justice Requires that Nature Be Recognised As a Legal Entity. *Resurgence Magazine*, (210). Retrieved 5 October 2015 from http://www.resurgence.org.uk

UN Sub-Commission on Prevention of Discrimination and Protection of Minorities Decision 1989/108, UN. Doc. E/CN.4/Sub.2/1989/58, at 71, 1989.

The Earth Charter. (2000). Retrieved 23 June 2014 from: http://www.earthcharterinaction.org/invent/images/uploads/echarter_spanish.pdf

Town of Wales, New York (2011) Intro. No. 2-2011, Local Law no. 2011: a Local Law, amended the Local Law 1 - 1993.

Tutohu Whakatupua (2012) (Agreement between Whanganui Iwiand the Crown, 30 August 2012) at 2.4.

UN General Assembly. (2009). *Declaring the International Mother Earth Day*. Retrieved from http://www.un.org/en/ga/search/view_doc.asp?symbol=A/RES/63/278&Lang=S

UN General Assembly. (2012). *The future we want*. Retrieved from http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/66/288&Lang=E

UN General Assembly. (2007). *United Nations Declaration on the Rights of Indigenous Peoples*. Retrieved from http://www.un.org/esa/socdev/unpfii/documents/DRIPS_en.pdf

UN General Assembly. (2000). *Millennium Declaration*. Retrieved from http://www.un.org/spanish/milenio/ares552.pdf

UN General Assembly. (1990). *Need to Ensure a Healthy Environment for the Well-Being of Individuals*. Retrieved from http://www.un.org/documents/ga/res/45/a45r094.htm

UN General Assembly. (1982). *World Charter for Nature*. Retrieved from: http://www.refworld.org/docid/3b00f22a10.html

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

UN Human Rights Committee (HRC). (1982). *CCPR General Comment No. 6: Article 6 (Right to Life)*. Retrieved 2 March 2016 from http://www.refworld.org/docid/45388400a.html

Universal Declaration of Human Rights. (1948). G.A. res. 217A (III), U.N. Doc A/810 at 71. Retrieved 5 October 2015 from http://www.ohchr.org/EN/UDHR/Documents/UDHR_Translations/eng.pdf

Vargas Lima, A. E. (2011). *El Derecho al Medio Ambiente en la Constitución Política del Estado Plurinacional de Bolivia*. Academic Press.

Vermont Rights of Nature. (2012). *Vermont Rights of Nature*. Retrieved 14 September 2015 from https://www.facebook.com/VermontRightsOfNature

Viale, E., Machado, H., & Acosta, A. (2014). *La Madre Tierra tiene Derechos: primero tribunal para defenderlos*. Retrieved 23 June 2015 from http://www.rebelion.org/docs/180605.pdf

West Homestead Borough. (2011). *Allegheny County*. Ordinance.

Wheeler versus Director de la Procuraduria General Del Estado en Loja, Juicio. Sentencia Causa, 30 de marzo del 2011, Acción de Protección No. 11121-2011-00010, Sala Penal de la Corte Provincial de Loja. Retrieved 23 June 2015 from http://therightsofnature.org/first-ron-case-ecuador

World People's Conference on Climate Change and the Rights of Mother Earth. (2010). *Universal Declaration of Rights of Mother Earth*. Retrieved 23 June 2015 from http://therightsofnature.org/universal-declaration/

Wray, A. (2008). *Los derechos de la naturaleza*. Retrieved 23 June 2015 from http://cywlegal.com/inter.asp?s=3&ss=13&n=107

Zaffaroni, E. R. (2010). *La naturaleza como persona: Pachamama y Gaia. In Bolivia: Nueva Constitución Política del Estado. Conceptos elementales para su desarrollo normativo* (pp. 109–132). La Paz: Vicepresidencia del Estado Plurinacional de Bolivia.

KEY TERMS AND DEFINITIONS

Anthropocentric Approach: Viewpoint arguing that human beings are the central or most significant entities in the world.

Biocentrism: The view or belief that the rights and needs of humans are not more important than those of other living things are.

Ecocide: The extensive destruction, damage to or loss of ecosystem(s) of a given territory, whether by human agency or by other causes, to such an extent that peaceful enjoyment by the inhabitants of that territory has been severely diminished.

Environmental Law: The field of law that covers the protection of environment from a legal aspect; Human right to environment: is the enjoyment of everybody, without discrimination, to a safe, healthy and ecologically balanced environment.

Environmental Protection: Policies and procedures aimed at conserving the natural resources, preserving the current state of natural environment and, where possible, reversing its degradation.

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Good Living (Buen Vivir): The Ecuadorian concept of *sumak kawsay*, meaning a full life in kichwa. It has emerged as a response to the traditional strategies for development and their negative environmental, social, or economic effects. It is an alternative concept of development that focuses on the attainment of the "good life" in a broad sense, only attainable within a community; a community that includes Nature.

Living Well (Vivir Bien): The Bolivian concept emanating from Latin America's indigenous peoples. The term translates as *sumaq kawsay* and *suma qamaña* in Quechua and Aymara, the two main indigenous languages of the Andes and it implies the creation of a new global relationship with nature and among human beings, expanding the rights to Mother Earth, setting ethical values and responsibilities of peoples with Mother Earth, the fulfillment of obligations of States, communities, and individuals with Mother Earth; and the protection of the environmental functions of Mother Earth as community-goods.

Mother Earth: A dynamic living system comprising an indivisible community of all living systems and living organisms, interrelated, interdependent and complementary, which share a common destiny.

Nature Rights: The recognition that our ecosystems – including trees, oceans, animals, mountains – have rights just as human beings have rights (nature in all its life forms has the right to exist, persist, maintain and regenerate its vital cycles).

Nature: All the animals, plants, rocks, etc. in the world and all the features, forces, and processes that happen or existindependently of people, such as the weather, the sea, mountains, the production of young animals or plants, and growth.

Rights of the Mother Earth: Mother Earth and all beings of which she is composed have the following inherent rights: the right to life and to exist; the right to be respected; the right to regenerate its bio-capacity and to continue its vital cycles and processes free from human disruptions; the right to maintain its identity and integrity as a distinct, self-regulating and interrelated being; the right to water as a source of life; the right to clean air; the right to integral health; the right to be free from contamination, pollution and toxic or radioactive waste; the right to not have its genetic structure modified or disrupted in a manner that threatens it integrity or vital and healthy functioning; the right to full and prompt restoration the violation of the rights caused by human activities; the right to a place and to play its role in Mother Earth for her harmonious functioning; the right to wellbeing and to live free from torture or cruel treatment by human beings.

ENDNOTES

[1] This chapter has been prepared under the DER2013-44009-P Project entitled"Del desarrollo sostenible a la justicia ambiental: hacia una matriz conceptual para lagobernanza global" (2014-2016), whose main researcher is Dr. Antoni Pigrau Solé.

[2] The Subcommission on the Promotion and Protection of Human Rights was established by a decision of the Commission on Human Rights of 10 Feb. 1947. Its former name was: Subcommission on Prevention of Discriminationand Protection of Minorities (renamedby ECOSOC decision 1999/256 of 27 July 1999).

[3] The Subcommittee commissioned Mme. Ksentini to develop a methodology for such a study. Two years later, Mme. Ksentini presented a preliminary report (E / CN.4 / Sub.2 / 1991/8, August 2, 1991). In this report, the provisions of several international and national human rights instruments relating to the environment, their relationship with other rights such as the rights of indigenous peoples and the right to development, the human rights violations and environmental degradation

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are discussed and so are the environment, ecological rights and the implementation of environmental protection procedures. At the request of the Subcommittee, Mme. Ksentini presented two more reports, one in 1992 (E / CN.4 / Sub. 2/1992/7 on July 2, 1992 and Add.1) and another in 1993 (E / CN.4 / Sub.2 / 1993 / 7, July 26, 1993).

[4] Mr. John Knox was appointed in August 2012 for a period of three years, as the first Independent Expert on the issue of human rights obligations related to the enjoyment of a safe, clean, healthy and sustainableenvironment. His main tasks in accordance with Resolution 19/10, which established the mandate of the independent expert, inter alia, are the following: to study the human rights obligations related to the enjoyment of a safe, clean, healthy and sustainable environment, in consultation with relevant stakeholders; identify and promote best practices, and exchange opinions, in the performance of its obligations and commitments to support human rights, support and strengthen environmental policy, especially in the field of environmental protection; develop a compendium of best practices; make, within its mandate, recommendations that could contribute to achieving the Millennium Development Goals, in particular the Millennium Development Goal; and consider the results of the UN Conference on Sustainable Development (Rio +20), and provide a perspective of human rights monitoring processes.

[5] Retrieved from http://eradicatingecocide.com/ (accessed June 23, 2015).

[6] See also online: https://www.youtube.com/playlist?list=PLFB4F5595F6740619&feature=viewall (accessed June 23, 2015).

[7] Retrieved from http://www.gaiafoundation.org/blog/the-sentencing-justice-for-the-earth-community (accessed June 23, 2015).

[8] Retrieved from http://www.endecocide.eu/end-ecocide-continues-collect-signatures/?lang=en (accessed June 23, 2015).

[9] For more information: http://iecc-I tpie.org/en (accessed June 23, 2015).

[10] Retrieved from http://planetaryboundariesinitiative.org/about-2/declarations/draftonpb (accessed June 23, 2014). A summary of seven short expert commentaries on the planetary boundary concept that were published at 3 *Nature reports, Climate Change*, October 2009, 112-119. Retrieved from http://www.anu.edu.au/climatechange/wp-content/uploads/2009/09/climate-commentary-october-2009.pdf.

[11] For more information: http://planetaryboundariesinitiative.org/2013/12/03/recommendations-evidence-from-the-planetary-boundaries-initiative-on-sdgs/ (accessed June 23, 2014). In 2012 Kate Raworth proposed combiner understanding planetary boundaries to social boundaries, being essentially interdependent. In its report *A Safe and Just Space for Humanity: 'Can we live Within the donut'* integrates the study of Rockström and other '9 Processeses Earth-system' with "11 dimensions of human deprivation".

[12] The Ecuadorian constitutional text has three Articles where the following rights for nature are established: the Article 71 on the Nature, or *Pachamama*, where life is reproduced and occurs, has the right to integral respect for its existence and for the maintenance and regeneration of its life cycles, structure, functions and evolutionary processes. Article 72 refers that the Nature has the right to be restored. This restoration shall be apart from the obligation of the State and natural people or legal entities to compensate individuals and communities that depend on affected natural systems. In those cases of severe or permanent environmental impact, including those caused by the exploitation of non-renewable natural resources, the State shall establish the most effective mechanisms to achieve the restoration and shall adopt adequate measures to eliminate or mitigate

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harmful environmental consequences. Article 73 states that the State shall apply preventive and restrictive measures on activities that might lead to the extinction of species, the destruction of ecosystems or the permanent alteration of natural cycles. The introduction of organisms and organic and inorganic material that might definitively alter the nation's genetic assets is forbidden.

[13] All these Ordinances were drafted in consultation with the Community Environmental Legal Defense Fund (CELDF). See http://celdf.org/resources-ordinances (accessed August 2, 2014).

[14] This amended another old Local Law 1 - 1993 known as "adoption of code", adopted by the Town Board of the Town of Wales on May 11, 1993, by adding a new chapter 162 known as the "protection of natural resources".

[15] Borough Council of Wilkinsburg, Allegheny County, Pennsylvania adopted ordinance number 28-70 that enacts an enforceable Local Bill of Rights, along with a prohibition on natural gas extraction to protect those rights.

[16] The group included Nnimmo Bassey from Nigeria and Vandana Shiva of India (both winners of the Right Livelihood Award), and other activists from Mexico, Peru and Ecuador, including the Chairman of the Constitutional Review Panel of Ecuador.

[17] Check the following information online. Retrieved from https://www.youtube.com/watch?v=LrD7CdQMA6g and http://derechosdelanaturaleza.org/(accessedJune23,2015).

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Chapter 4
The Impact of Kisan Call Centers on the Farming Sector

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ABSTRACT

The Indian Agriculture has been an area with varied challenges. This sector is responsible for the growth rate and generating a per capita income. This sector generates a whopping 28% of the total GDP of India and over 15% of the total exports. The usage of Internet and phone technology can fill these gaps to a large extent. A continuous two way interaction among the farmers and agricultural scientists will ensure agricultural extension. A landmark step was taken on January 21, 2004 when the Department of Agriculture & Cooperation, launched Kisan Call Centers (KCC) with the help of the extensive telecom industry to deliver extension services to the farming community. The main purpose of these call centers is to answer the queries raised by the farmers in their local language, on continuous basis. At present the Kisan Call Centers are running from 14 locations all over India. In this chapter, we are trying to analyze how this strategy to help the farming community was introduced and how it is being implemented.

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INTRODUCTION

The role of agriculture in India's socio-economic development is inherent since ancient times. Even today agriculture forms a significant part of the GDP and overall growth and sustainability of India. This sector provides employment to 51% of the total workforce, being the largest economic sector amongst others such as mining, tourism, retail, textile, industry and services. That being mentioned, the challenges before the agricultural practices in India are immense. It will not only benefit the overall economic progress of the country, but is also essential for the workforce of the nation, two thirds of which, directly or indirectly depends on the same. It contributes to around 27% of the GDP of India and somewhere around 13-16% of the exports. Still, the yields are not only lesser than expected, they are highly unstable and the gaps in technology transfer are much more intense as compared to those in areas that are irrigated.

Kisan call center is a Government of India initiative under the department of Agriculture and Cooperation. This initiative is primarily aimed towards assisting the farmer community for any issues or queries that they may have and also in training them to face the immense inevitable challenges. These knowledge centers are active throughout India providing services to farmers in terms of assistance and guidance in solving their problems in their regional local languages. Providing a structure to this entire operation of query handling involves effective use of technology, networking, a strong knowledge base, technically educated and informed staff. These call centers make use of an extensive telecommunication network, having a strong back end Management Information System to address the queries of farmers across the country, regarding agriculture practices and latest farming techniques. The scheme's objective is to serve the farming community spread over 5 lakh villages across the nation.

The need of the hour is to pay greater and more focused attention to information by extensively using the appropriate tools and technologies that help farmers cope up with the diverse challenges and learn new opportunities on a continuous basis. To capitalize on future export opportunities of agriculture products, the country needs to match global standards in terms of quality, stability and hygiene. Hence, the farmer should be aware and informed of the latest efficient agricultural practices.

The Kisan Call Center aims to fulfill the following:

- Fast and effective spreading of information
- Minimizing the gap between Farmer and Research Labs, agriculture universities, market, corporates
- On demand specific individual knowledge transfer and adequate facilitation
- Efficient use of the huge and complex telecom infrastructure

While the state of Kentucky, US is following GAP (Good Agricultural Practices) to ensure safety from post production deceases in the crops, and the GAP in Rome (Italy) are focused on setting up protocols and appropriate processes, the services provided by KCC are rather educational and informative in nature. They aim to educate the farmer with innovative and new technologies and techniques that should be implemented in order to yield better results.

Recently, to facilitate the queries of the farming community in an easier way, the Department of Agriculture and Cooperation has come up with an idea of Kisan SMS (Short Messaging Service) Portal. The users have to register and enroll themselves via a mobile number. Once registered, the user will receive regular updates about weather and agricultural alerts, absolutely free of cost. In this case, a farmer will be getting an SMS messages providing expert information and delivering services on his mobile from

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agriculture scientists at various levels. The services cover diverse areas such as crop production and protection, animal husbandry, fisheries as well as dairying.

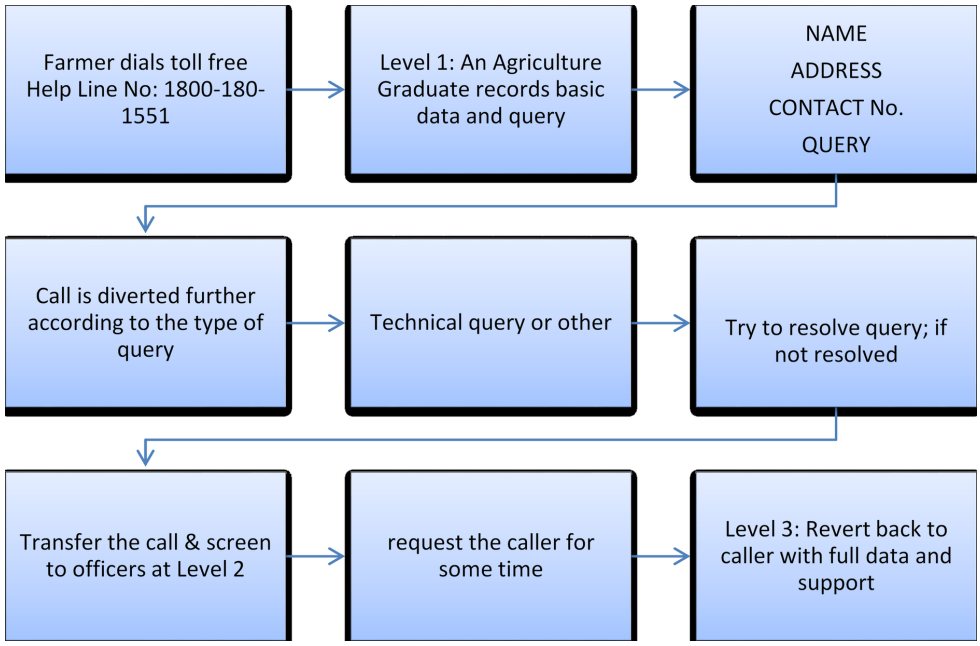
New types of information and services are expected to be included as the system progresses based on the different requirements of farmers. Some of these include:

1. Weather information including forecast
2. Alerts for farming related facts
3. Timely Information regarding disease/pests outbreaks
4. Technology related support for crop cultivation according to local conditions
5. Awareness of new crop variety
6. Market know how
7. Soil fertility reports

THEORETICAL FRAMEWORK

Here we describe the concept and structure of the implemented knowledge based service, also the infrastructure and technology involved in connecting the farmers with the personnel who address their individual queries in their local language. The steps for a typical calling procedure can be seen in Figure 1, below. Each call follows a pre-defined protocol and queries are addressed according to their nature by various levels of representatives, from agriculture graduates, postgraduates equipped with computer

Figure 1. Steps involved in a typical calling procedure
Source: National Institute of Agricultural Extension Management



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systems, Subject Matter Specialists (SMSs) or Subject Matter Experts (SMEs) having sound technical knowledge, and various other but related scientists to promptly assist the farmers with their respective questions and doubts. This way these call centers provide extension services to the farmer community according to the nature of the problem. This is an opportunity for businesses with the existing extension services to grow their network further to help farmers in remote areas of the country adopt better practices.

When a KCC (Kisan Call Center) representative receives a call, he or she addresses the query based on their own knowledge and understanding. Also, the representative has access to a knowledge database containing FAQs, which is updated continuously with every incoming and outgoing call. The different type of calls can be identified as—

Technical Query:

- Crop Production
- Crop Protection
- Horticulture
- Agriculture
- Animal Husbandry
- Marketing

Others include:

- Admin related query
- Regarding Government Schemes
- Subsidy
- Seeds Positioning
- Gypsum, Fertilizers, Pesticides
- Credit and insurance

Farmers can provide feedback on the agriculture services provided by the government and the private sector; this helps in regular monitoring and improvement in services.

These call centers are generally a part of an organization like Research Stations, ATICs, Agriculture Colleges or are outsourced, as per the specific requirements. The objectives of such ATICs are the provision of a single and streamlines delivery system for the services and products to the kisans (farmers) and other FIGs as a continuous process of technology dissemination innovation. They also encourage the callers/users and facilitate them to provide their valuable feedback. The services offered by the call centers usually include customer support, multi-lingual direct assistance and other services. The senior agriculture scientists and experts in the government system are Nodal Officers.

The infrastructure of Kisan Call Centers is divided into three levels:

- **Level I:** A Call Center that is professionally managed including all the basic requirements for a stable network and smooth communication. The call center management dedicated for the KKC services maintains Local Area Network (LAN), Air Conditioning, equipment such as computers, headphones and an Uninterrupted Power Supply.
  Qualification representative: M.Sc. in Agriculture

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The major functions carried out by a Level I representative are being a first point of contact to the farmers, he attends the call with a welcoming message and takes the question down and feeds that into the computer by himself. The operator will be fluent in the local language and in most of the cases he is equipped to answer the question himself.

- **Level II:** A response center handling the services of Subject Matter Specialists for individual problem based query resolution. This contains upgraded and more robust technology setup as compared to Level I.
  Qualification of representative: PhD. In Agriculture, with 10-15 years of experience in relevant sector.
  The Level II representative holds certain responsibilities like answering the questions if the Level I representative couldn't answer the questions posed by the farmer. The Level II representatives comprises of the Subject Matter Specialists who stays at their respective places like educational institutions or the Govt. Offices. Depending on the expertise they hold the specific question will be forwarded to those persons. The expertise basically will be classified depending upon the crop or certain other parameters. In any case if the person is unavailable then there is a callback option where the question poser will be called back in mostly less than 72 hours.
- **Level III:** the Nodal Cell comprising of the Nodal Institutions is also fully equipped with the appropriate logistic support. The senior officers resolve queries and problems using software analysis tools.
  Qualification of manager: Masters in Agriculture, having 5-10 years of experience

For Level II and Level III support, agriculture agents are nominated from various institutions and organizations all over India. Proper training and induction is provided to the nominated graduates.

An important part of this organization is the Human Resource. The personnel attending calls need to possess basic skills to attend to farmers' calls effectively. Few skills identified are

- **Soft Skills**
  - Greeting and facilitation
  - Ability to speak using farmer's language
  - Usage of simple sentences and words
  - Patient listening
  - Probation of the details
  - Diagnosis of the query/problem raised by the farmer
  - Answering at the level of the farmer
- **Communication Skills**
  - Empathizing with the caller
  - Active listening
  - Commitment to assist the caller
  - Assertive responses
  - Relating with local or personal experiences, as need be
  - Polite replies
  - Subtle modulations or transitions in voice
  - Closing the calls with greetings as well

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- **Computer Operating Skills**
  - Basic know how of the mouse and the keyboard
  - Basic know how of the internet
  - Receiving and sending electronic mails

For successful implementation of any system there is always a need to monitor and review the regular performance using methods such as feedback from inside and outside the organization. Storing the data by Nodal Offices on a regular basis lays the foundation of such an extensive knowledge base. Analysis of the collected data takes place at these Nodal Institutions by specialist suitable for the job. The same Nodal Institutions are also responsible for documentation and reporting that help in creating consolidated courses of action for individual farmer's query.

OBJECTIVE

- Study of the concept and mechanism of operation.
- Understanding the ground level function of Kisan Call Centers.
- Analyzing the structure of the scheme.

RESEARCH DESIGN

Based on the learning and research, the elements of survey and data collection were inferred, by focusing on the planning, implementation and management of Kisan Call Centers. Certain Measurement indicators were identified to assess their performance and recommend opportunities for improvement. Parameters that were chosen include

- Number of daily calls received
- Agent quality
- Network sustainability
- Infrastructure
- Utility of software and technology
- Training

The expectations of the government and other stakeholders in the scheme were used to form an understanding about the size of the scheme. Some of the expectations from this scheme:

- Over 500 calls per day
- Technically sound personnel with good communication skills to resolve problems efficiently
- Smooth network quality and reliable connections
- Building regular Database
- Adequate infrastructure matching all technical requirements
- Simple User Interface of software
- Technical training to be continuously provided to representatives

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A strong software tool that has been developed by Telecommunications Consultants India Ltd. (TCIL) supports Kisan Call Centers and ensures instant and continuous connectivity across the entire network. The Management Information System enables technical assistance to farmers and recording of queries to build a database, which is accessible all times to the KCC.

The database mainly consists of questions asked by farmers along with their answers. Report generation software is bought in use by the agriculture graduates having a user interface to generate reports based on specific parameters entered by the agents, according to the requirements of the concerned farmer. The filters used for scanning through database for generation of report are date, location, crop, problem etc. This data is made available over the Internet once the report is generated.

RESEARCH METHODOLOGY

Secondary data was gathered from various sources such as articles, journals and case studies from the Ministry of agriculture. This data was the basis of obtaining an in depth knowledge of the concept leading to a structure for the research.

Primary research was conducted involving site visit of KCC's nodal office in Ghaziabad. Information was gathered on the implementation and response of farmers towards the scheme. The objective of the primary research was to conduct analysis of data collected and inferring the grass root level implementation implications of the scheme. Further, identifying loopholes, if any and providing recommendations based on the learning and findings.

LITERATURE REVIEW

Maximizing the crop productivity is one of the major problems in a country like India where agriculture is the primary occupation. The crop productivity poses a huge problem pertaining to the amount spend on raising the crop and the amount a farmer can earn selling the crop in the market. One among the many reasons for not achieving the desired output is that the expert advice is not reaching the farmers on time. There is a lot of information gap between the research and actual practice. To bridge this gap, the research paper (P. Krishna Reddy and R. Ankaiah, 2005) mentions about a framework. According to the framework mentioned, each farmer will be equipped with Agricultural information dissemination system (AgrIDS) which is cost effective. This helps the farmers to cultivate with the help of both the crops related, location related experts.

The proposed framework mentions the integration of IT services, which grew rapidly over the last few decades, with agriculture. As it was mentioned that all the farmers will be made available, the AgrIDS system, so that the farmers can get the timely advise from the experts. It involves the pictures taken from the fields and then they will be transferred to the experts. They will have a look at those pictures and then will provide the advice analyzing them. The advice definitely will not be based on the received pictures alone but there are lot many details the experts, in their own area of expertise, will suggest the farmers which crops to elect and raise depending upon some of the major factors influencing the agriculture like rainfall, soil type, weather etc. Also financial experts suggest the farmers about the crops which possibly will have high demand in the international or the domestic market which will help the farmers to earn profits. Also production of certain crops in the country is rather scarce when the consumption is taken

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into consideration so government can take steps into providing certain schemes that can motivate the farmers to raise that crop.

The research paper (P. Krishna Reddy and R. Ankaiah, 2005) also mentions about the drawbacks of the traditional system. At present the insights given to the farmers are in a generic and not specific to the certain farmers so for some the advice helps but a lot people might get affected either by not getting the desired productivity nor the profits. It does not cover all the farmers but only a few. There are numerous reasons some being the literacy levels, lack of awareness etc. The traditional process is just a one way process and if the farmers need more information on what they have been farming they couldn't get the information on time. The major drawback being unaccountability – number of advices given and the number of advices that are turned out to be useful. The proposed AgrIDS overcomes these drawbacks to a major extent.

The AgrIDS system will be using the data ware housing technologies, data mining techniques. Saving large amounts of data has become an easy task in the recent years. So all the queries that the system will receive in the form of either text or photos will be recorded along with the answers. This data being saved can be used in the future if the advice is requested for similar kind of problem by a farmer. In the present world extensive information is available online and there are many companies whose business model runs only on the data. With all of this enormous amount of data available it can be analysed and then refined so that the patterns can be drawn using the data mining techniques. Extrapolating the data available simulation models can be developed so that the future possibilities can be drawn from them. For all of this to happen the internet should be made available to all class of people where they can make use of the system proposed.

The system consists of various parts including farmers, coordinators, AEs and Agricultural information system where all of them are integrated using internet. The amount a farmer would invest in receiving the advices is substantially less by using this system. Amount of pesticides and fertilizers to be used for a crop can be moderated based on the actual requirement for high output. Because of lack of experience of the farmers they might not be using the adequate amounts of pesticides or the manure. So making this AgrIDS system available to the farmer, the money a person spends on the fertilizers will be saved substantially.

A research was taken up by a group of researchers from MSSRF (M.S Swaminathan Research Foundation) about the technical advancements in the field of crop husbandry that took place in the country pre – post independence periods and their implications. The research paper (R. Rukmani) mentions about the ICAR system which developed around 3000 hybrids and high yielding varieties related to various crops which promises more productivity and less prone to diseases. Some of these varieties were used in the country to witness a huge increase in the crop productivity. The statistics backs the fact that the growth rate in the 1990^{s} was less compared to 1980^{s} possible reason mentioned was because of the lack of the proactive decisions by the country in that time frame. Also the challenges faced by the government are the Intellectual property rights adoption and the assessment of advances in the biotechnology fields. The policies during the early decades after independence will have to see a significant change to meet the present changes in the field of the crop husbandry.

Considering both the research papers, (R. Rukmani) mentions about how the scientific technology totally shifted the face of agriculture to meet the growing demand and also mentions that some amends to the present policies are required to withstand the changes in this present world. This research paper (P. Krishna Reddy and R. Ankaiah, 2005) mentions about a framework consisting of AgrIDS that will help the farmers. While during the early decades when there was only a limited connectivity among the

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people, the state had taken steps to help farmers use the ICAR developed crop varieties (like Rice, Wheat and some Cereals) and it took decades for the crop productivity to reach to the current state. While taking into account the connectivity among people and the reach of any information in the present day, with advancements in the scientific development and integrating those with the IT models such as AgrIDS will definitely help the increase in the crop productivity.

Kisan call center have been one of the most pioneering initiatives by the Government of India. According to a report published in Asia Pulse, the Kisan call centers in India received 318,106 calls in total. These calls were from farmers who belonged to remote and tribal areas who sought solutions for their problems that varied from agriculture to animal husbandry. The Indian Society of Agricultural Professionals (ISAP) released this data. The ISAP is the organization that sponsors the functioning of the call centers. The article further stated that most of the queries originated from Shivouri and Shajapur districts in Madhya Pradesh. Also, the tribal areas over there also called up these centers to clear their doubts. The number of calls relating to agriculture crops were 173,274, while those about horticulture summed up to 93,299 and 12,802 were from the field of animal husbandry. Currently, the service has been made available from 6 AM to 10 PM, except for Sundays and gazetted holidays. The service is provided beyond these hours by an IVRS system.

There are fifteen subject specialists that are employed and available at the call centers in Madhya Pradesh who work in two shifts to ensure maximum time is available to cater to the queries of farmers. The Kisan call center here is managed and run by National Agricultural Development Project through a private public partnership. The Kisan call centers are equally effective when it comes to solving the problems of farmers in the hilly regions of Himachal Pradesh. A study conducted by Sharma and Singh in 2011 concentrated on two cash crops that are grown in the region, apple and tomato. These crops are grown in the high and medium hills of the state respectively. According to the study, the farmers who used the services of the calls center were more informed about their crops and benefitted from it. The productivity of crops of these farmers was much higher than those who did not used the services. It suggested that the farmers should be educated by the media and government about the call center so that farmers can grow their crops more effectively and scientifically.

Recently, the Government has collaborated with IFFCO Sanchar Limited for the restructuring of the KCC's. The new call centers would be state of the art and shall provide professional assistance as well as well technical innovations to the existing service network. These include call barging that will be handled by experts and officers of the government, video conferencing, dynamic monitoring of the working of the call centers. The books and reference material provided to the employees will also be upgraded to the latest editions of modern agricultural practices. The IKSL (IFFCO Kisan Sanchar Ltd.) has attempted to provide many innovation, interactive and engaging services for the farmers that subscribe to the KCCs. These services and its subscription is absolutely free of charge and includes benefits and activities like free voice messages on a daily basis to every subscriber, on his area of interest, call back facilities, mobile quizzes, common forums and focus groups. Their prime mission is to empower the rural section of the society and the farmers with high quality and germane services and information, through proper telecommunication and other communication channels.

84% of farmers were satisfied with the advice that they received from the call center personnel, as stated by the study conducted by Administrative Stall College of India in 2012. The study further revealed that the advice helped the farmers in efficiently managing their fertilizer and pesticide usage, which reduced the weeds, pests and diseases in crops. Moreover, this initiative is built and structured in a manner to accommodate continuous evaluations and monitoring, that would help the same to grow

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in a more effective manner. After the research, it was also found that TNAU (Tamil-Nadu Agricultural University) formed Farmer's Associations – FIG (Farmer Interest Group) which is essentially an independent and self-managed group of farmers with common goals and interests. The members of this group pool in their resources, so that by uniting their resources, they can work towards the fulfilment of their common goals and objectives and share the consequential benefits.

DATA ANALYSIS

Nodal officers in Delhi and Ghaziabad aided in collection of data, to assess the performance and grass root level implementation of KKCs. The Scheme was launched at the time when BJP government was in power in India and the KKCs received recognition, showing good results and positive response from farmers.

The services provided through KCCs are monitored and reported by these Nodal offices. Although, the offices were equipped with all the facilities claimed by the government, a lackadaisical attitude was observed on our visits to the offices in New Delhi and Ghaziabad. All over the scheme has a total outreach to over 1500 villages and around 30 districts in 17 states of the country. This scheme has also provided employment to over 1800 BPL (Below Poverty Line) youth, living in rural India, by conducting training programs.

The knowledge base has grown immensely since the inception of these call centers. KCCs have enabled spread of knowledge amongst farmers and access to information easy by providing a proper channel supported by the government and private parties. States where the scheme has been most successful, like, Bhopal, Madhya Pradesh have KCCs running in Public Private Partnerships (PPP). A list of call centers across major states can be seen in Table 1.

RESULTS AND FINDINGS

The important findings from the project research are that Kisan Call Centers have:

- Transformed and impacted the lives of more than 1.25 lakh farmer families.
- Provided Specialized Training and job opportunities to over 1800 BPL youth.
- Promoted Entrepreneurial developments to bring in greater avenues for private ventures to agriculture graduates.
- The Bhopal KCC alone has answered up to 5 lakh queries during 2008-11.
- Made effective use of technology. A robust MIS system helps in advisory services and building knowledge base.
- Over 250 graduates, those have been certified as Crop Certified Advisor (CCA).
- Highest calls recorded for the vegetable growers, closely followed by food grain growers and fruit growers. 23.5 percent of the calls were recorded for the information about various diseases in the crops and 6.9 percent of the calls were related to animal husbandry.

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Table 1. Call centers across major states

S.no	*State/ UT*	*KCC Location*	*Language*	*Telephone Lines (Outgoing- incoming)*
1.	Andhra Pradesh	Hyderabad	Telugu	2-3
2.	Bihar	Patna	Hindi	1-2
3.	Jharkhand	Ranchi	Hindi	2-3
4.	Chhattisgarh	Raipur	Hindi	3-4
5.	Delhi	New Delhi	Hindi	2-4
6.	Dadra, Nagar Haveli	Ahmedabad	Gujarati	1-2
7.	Gujarat	Ahmedabad	Gujarati	3-4
8.	Punjab	Chandigarh	Punjabi	2-3
9.	Haryana	Chandigarh	Hindi/Haryanvi	3-4
10.	Himachal Pradesh	Shimla	Hindi	2-3
11.	Jammu & Kashmir	Jammu	Dogri, Kashmiri, Ladhaki	2-3
12.	Karnataka	Bangalore	Kannada	2-3
13.	Kerala	Trichur	Malayalam	1-2
14.	Maharashtra	Nagpur	Marathi	2-4
15.	Uttar Pradesh	Kanpur	Hindi	3-4
16.	Rajasthan	Jaipur	Hindi	2-3
17.	Tamil Nadu	Coimbatore	Tamil	2-4
18.	Uttarakhand	Dehradun	Hindi	NA
19.	Arunachal Pradesh	Itanagar	Adi	NA
20.	Assam	Guwahati	Assamese	NA

*NA—Not Available
Source: Directorate of Extension - KCC

SUGGESTIONS AND FUTURE IMPLICATIONS

The use of technology is critical to bridge the economic gap prevailing in the country, to stimulate growth by building individual capacity to generate value through learning the immense opportunities in agriculture and allied services. A shortcoming in the TOT (Transfer of Technology) model is a prominent challenge for the current private and public extension systems, however, the effective and efficient use of telecommunication channels, relevant technologies and internet, this gap can be bridged by a considerable extent.

After studying and analyzing the concept implemented by the government with the emergence of KCCs, we suggest that more private organizations should show participation in such initiatives, by forming alliances with the government and NGOs. In states where the scheme is to be launched, the mobile carrier partner companies can come up with initial promotional offers for farmers, such as distribution of registered sim cards to them. This would encourage the farmers, make life easier for them and spread greater awareness amongst them regarding KCCs.

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Also, more importance should be given to courses like CCA (Crop Certified Advisor) and the youth, especially in the rural parts of the country, should be encouraged to pursue this as a career option.

Contemporary technology should be leveraged more effectively to facilitate growth. Promotional campaigns using mobile wagons and kiosks should effectively spread the scheme to untouched remote areas of the country.

REFERENCES

Chouhan, R. S., Kumar, Dushyant, & Sharma, H O (2011). Performance of Kisan Call Center: A Case Study of Kisan Call Center of Indian Society of Agribusiness Professionals Bhopal (Madhya Pradesh). *Indian Journal of Agricultural Economics*. Retrieved October 9, 2013, from http://search.proquest.com/docview/912670940?accountid=50136

Dhyani, S. (n.d.). *BPO Caretel announced the achievements of their "Kisan Call Center" project As Kisan Call Center completes its successful 5th Year*. Retrieved October 10, 2013 from http://www.indiaprwire.com/pressrelease/agriculture/2009011718157.pdf

IFFCO Kisan Sanchar Ltd. (n.d.). Retrieved February 12, 2014, from http://www.iksl.in/

KCC: Features, Directorate of Extension. (n.d.). Retrieved October 10, 2013, from http://vistar.nic.in/training/locations.asp

Kisan Call Center. (n.d.). Retrieved May 5, 2013, from http://agricoop.nic.in/policyincentives/kisan-calldetail.htm

Krishna Reddy, P., & Ankaiah, R. (n.d.). *A framework of information technology-based agriculture information dissemination system to improve crop productivity*. Ministry of Communications and Information Technology, Department of Information Technology, New Delhi, India. Retrieved May 17, 2014, from http://www.currentscience.ac.in/php/toc.php?vol=088&issue=12

Mukherjee, A. (2007). Fodder on the Line. *Business Today, 16*(9), 62. Retrieved October 8, 2013, from http://web.ebscohost.com/bsi/detail?sid=62b7dd32-2b33-47ea-9c6f-f67a8b588225%40sessionmgr14&vid=1&hid=19&bdata=JnNpdGU9YnNpLWxpdmU%3d#db=bth&AN=24844647

Over 300,000 MP Farmers Indian used Kisan Call Center: Report, Asia Pulse Pty Ltd. (2010). Retrieved October 10, 2013, from http://search.proquest.com/docview/759359583?accountid=50136

Rahul, A. (2011). *Kisan Call Center: Bridging the information gap*. Retrieved October 10, 2013, from http://www.thebetterindia.com/2304/kisan-call-center-bridging-information-gap/

Rao, S., & Sharma, V.P. (n.d.). *Tele-Agri-Advisory Services for Farmers: a Case Study of Kisan Call Center in Andhra Pradesh*. Academic Press.

Rukmani, R. (n.d.). *Measures of Impact of Science and Technology in India: agriculture and rural development*. Retrieved May 21, 2014, from http://www.currentscience.ac.in/Downloads/download_pdf.php?titleid=id_095_12_1694_1698_0

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Sharma, B. R., Singh, P., & Sharma, A. (2011). *Role of Kisan Call Centers in Hill Agriculture*. Indian Society of Agricultural Economics. Retrieved October 11, 2013, from http://search.proquest.com/docview/912670948?accountid=50136

Tiwari, R. (2012). Government ropes in IFFCO Kisan Sanchar Limited to improve Kisan Call Centers [Agriculture]. *The Economic Times* (Online). Retrieved October 7, 2013, from http://search.proquest.com/docview/1011117854?accountid=50136

User Manual Version 1.0 for Kisaan SMS Portal. (n.d.). Retrieved September 8, 2013 from http://farmer.gov.in/advs/User%20Manual%20for%20Kisaan%20SMS%20Portal_Ver1%200.pdf

KEY TERMS AND DEFINITIONS

AgrIDS: Agricultural information dissemination system, an online system proposed where the entire process of examining the crop and suggesting the productive steps by the specialists can be done online.

ATIC: Agricultural technology information Centre, a place where the information regarding the agriculture can be available.

GAP: Good Agricultural Practices, the best practices that can be adopted to attain the best possible output.

KCC: Kisan Call Center, a call center where farmers can get their queries regarding the agriculture can be answered.

PPP: Public Private Partnerships, a type of partnership where the public, private together is involved to raise the capital and be a part and owner of certain project.

SME: Subject Matter Experts, a part of the KCC where they would be answering the questions addressed to them to their best in order to resolve the farmer's queries.

TOT: Transfer of technology, where the use of technology among the stake holders.

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Chapter 5
Fundamentals of Electrostatic Spraying:
Basic Concepts and Engineering Practices

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ABSTRACT

The desired attributes of electrostatic spraying are uniform deposition onto both directly exposed or obscured crop surfaces which minimize the off-target losses of active ingredients to soil, water, atmosphere and provide more effective and economical pest control. This chapter presents an overview of electrostatic spraying technologies in the field of agriculture emphasizing the key role of advanced electrostatic instrumentation and chronicles the scientific innovations in the parlance of providing cost effective and reliable commercial systems along with an insight on the needs of future research perspectives and directives. It is aimed primarily at a familiarization with spraying concepts and engineering practices. This text is to bridge the knowledge and experience gap among researchers and technology developers and the people involved in electrostatic processes applied to agriculture and food processing. It will also introduce the engineering aspects of design and development of an electrostatic spraying nozzle for agricultural applications.

INTRODUCTION

Air-assisted electrostatic sprayers are advanced agri-instruments for efficient use of pesticides to agricultural crops, orchards, plants, trees etc. The electrostatic spraying technique is all about reducing the use of pesticide by increasing the efficiency and bio-efficacy. Bio-efficacy is a measure of the biological efficacy of an active ingredients of agro chemical such as insecticide etc. The methods used to perform the function of bioremediation are known as bioremediators. Electrostatic spraying is to be the one

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among the available spraying techniques in precision agriculture and food processing. For example, the electrostatic spraying technique can be used for protective biomaterial coatings to fruits and vegetables for resistance towards microbial attacks, to enhance the transportation life, to control spoilage microorganisms, antimicrobial sprays for enhanced food safety etc. It is a method which reduces the environmental pollution by reducing contamination to soil as well as air. In totality, it reduces the chemical consumption which is used indiscriminately through conventional methods such as pedestal-mounted sprayers, the high pressure spray guns, the hand pressure swirl nozzles and the consecutive high volume spraying systems etc. The trans-disciplinary aspects of the embryonic field of electrostatic spraying have provided a major motivation to agricultural and food processing researchers for the development of novel techniques for spraying liquid pesticides to crops and orchards, protective coatings to food and food packaging, in addition to other applications of sprays to industrial, manufacturing and transportation, medical facilities and devices etc. This chapter is to be one among the motives behind the renewed curiosity in the usage of the electrostatics in liquid based spraying.

Although, organic measures for crop protection are being preferred, chemical intervention is still the fastest and most economical way for crop protection. However, due to lack of awareness and ignorance, pesticides are being used indiscriminately leading to side effects on human health and ecosystem. Electrostatic method of pesticide application reduces off-target drift, environmental pollution and human health risks and increases the bio-efficacy and mass transfer efficiency onto the biological surfaces of crops and trees with uniform back deposition. Law, (1978); Jia, Xue, Qui, & Wang, (2013) explained the design and development of induction based electrostatic sprayer for agricultural usage and evaluated the performance. So far, the equipment available in the market are uncontrolled in terms of spraying variability. Pesticide application control, targeted pesticide delivery and variable pesticide spraying are the key to improve operation quality, reduce chemical waste, environmental pollution and operational costs. This entices to develop a sensing mechanism which would discriminate between the presence and absence of pesticide application surfaces. He, Yan, & Chu, (2003) developed the automatic target detecting air-assisted electrostatic orchard sprayer. In this spraying system, the sensing mechanism is based on infrared proximity sensors which determine the presence and absence of target to be sprayed. Other than infrared proximity sensors, ultrasonic sensor mechanism is another substitute for target detection and canopy mapping. Sensory attributes stipulate a good approximation of target and canopy mapping for targeted delivery of pesticides to actual target. Automation and mechanization with respect to agricultural pesticide spraying is one of the naive research topics in the present scenario.

The last decade has witnessed the application of existing electrostatic techniques to various fields accompanied with rapid improvements of the spraying technology. Zhang, Srirama, & Mazumder, (2007) have worked on a new approach in signal processing and sampling which shows that electrostatic applications have gone beyond the earth and reached to Lunar and Mars missions. Space research needs electrostatics in dust and particle control. Mazumder et al., (2006); Hamid, & Atan, (2008); Ghayempour & Mortazavi, (2013); Khan, Maan, Schutyser, Schroën, & Boom, (2013) ; Zhang, Kobayashi, Uemura, & Nakajima, (2013) have shown the numerous applications of electrostatic spraying to various fields such as agriculture, medical, transportation, painting and industrial applications, though agriculture remained the main area of research during the last decade. Electrostatic application to agricultural pesticide spraying has revolutionized agriculture farming scenario by making advances and developments via off-target pest control to increase bio-efficacy and deposition efficiency. There is also an increase in deposition

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efficiency by applying suitable charging techniques, better corrosion resistant material used in electrode design for spray charging and its insulation, liquid atomization methods, post processing of the spray by air assistance, automation of spray system and cost effective compact design and development for the layman in terms of easy-to-handle and simplicity of use. Developing an automated system for greenhouse spraying is the biggest challenge in the current scenario of research, since working environment inside the greenhouse is unbearable and dreadful due to the presence of increased level of humidity, carbon di-oxide and high temperature. Prolonged exposure of greenhouse workers to these conditions leads to a scratchy and hazardous work environment. Significant novel and innovative thoughts also came into existence; however, technical improvements and applications of the electrostatic spraying technique to various fields remain the main focus.

This chapter reviews the advances made in electrostatic pesticide spraying to agriculture and a brief description has also been made for the charge to mass determination, software like Fluent, CFD (Computational Fluid Dynamics) used in hydrodynamics and aerodynamics processes to simulate the electrostatic models with user defined functions and Deposit Scan to measure the percentage coverage, spray deposition rate and distribution of the charged droplets etc. It seeks to give a fundamental understanding of basics of electrostatic spraying to agriculture; along with the intricacies associated with the design and development of such high performance, efficient, efficacious modern advanced agri-instruments. In this chapter, innovative and technical concepts have been summarized and explained in detail that came into existence in electrostatic spraying along with the prevue of future perspectives and needs in the current scenario. However, before getting involved with the intricacies of electrostatic pesticide spraying, one may discuss the need for and applications of electrostatics in spraying.

Purpose of Pesticide Spraying

The use of pesticides to crops, orchards, plants and trees is among the most important pre-harvest facets of precision agriculture to protect the crops and for boosting the food production. Abhilash & Singh, (2009) discussed the importance of pesticides in the process of development of sustainable agriculture and shown that pesticides have become an important tool as a plant protection agent. However, exposure to pesticides both professionally and ecologically causes a number of human health concerns. The application of pesticides is one of the most frequently used methods to protect crops, orchards and trees against diseases and insects in agriculture. Off-target drift of pesticides is a term used for individuals droplets containing the full of life ingredients that are not lay down onto the target area, when spread-over crop protective pesticides to agricultural targets. The droplets most susceptible to off-target drift are usually smaller in size, less than 150μm in diameter (usually indicates the Volume Median Diameter, VMD) and effortlessly moved off the actual target area by wind, gravitational force or other agro-climatic, harsh and transient environmental conditions. The larger droplets settle down on the ground because of gravitational force. For example the conventional spraying statistics for grape growers shows that almost 60-70% of the pesticides have been lost via off-target drift and non-target deposition. Underside of the leaves and hidden areas remain untouched with the sprayed chemicals.

Efficient use of pesticides can protect and optimize the environment and natural resources, since the use of non-renewable pesticides and fertilizers is perhaps irretrievable, and encompasses an environment cost. Crop protection chemicals deposited in undesirable areas raised serious concerns caused by spray

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drift, such as surface water contamination, damage to sensitive neighboring crops, health hazards for living individuals as well as masses and possible adulteration to the target and adjoining areas or possible over application within the target area. Off-target drift destruction can be managed by identifying and regulating the factors that affect it such as environmental conditions, equipment and methods used for liquid spraying etc., later being the most predominant factor to avoid such consequences.

Causes of Spray Drift

Managing spray drift improves pesticide bio-efficacy by guaranteeing that the correct amount of dose reaches at the target. Drift takes away the pesticide from the intended target, making it less effective, and deposits it where it is neither needed nor desired. There may be two kinds of drift in agricultural pesticide spraying:

- Finely divided spray drift is off-target movement of the spray particles.
- Vapor drift is the volatilization of the pesticide segments and their movements away from the actual target.

The pesticide then becomes an environmental pollutant in the off-target areas where it can injure susceptible vegetation, contaminate water, or damage wildlife. A number of variables underwrite to spray drift; these are predominantly due to the spray equipment system and meteorological factors:

- Droplet size and spray height.
- Operating speed, direction and wind velocity.
- Air temperature and humidity.
- Crop protection chemicals and carrier volumes.

Various officialdoms conduct rigorous distribution and drift testing. The reliable data is also very important when conducting drift experiments and it comes from independent testing agencies, such as Food and Environment Research Agency (FERA) in the United Kingdom, the Julius Kuhn Institute (JKI) in Germany and the Centre for Pesticide Application and Safety (CPAS) in Australia. Varieties and consumption of pesticides worldwide have been increasing dramatically as increased human population and crop production. In this process, misuse of pesticide becomes more and more serious, has resulted in heavy environmental pollution and health risk of living beings. Study shows that, even a fraction of percentage of efficiently sprayed protective pest by using advanced spraying equipment such as electrostatic nozzle, is sufficient for the desired biological target as compared to conventional methods.

The charged particle evaporation, droplet instability and its implications to agricultural spraying are justifiably explained and presented theoretically as well as experimentally by Law & Bowen, (1975). The surface energy condition can be drastically altered by the presence of unbound surface charge on an air-borne spray droplet. Evaporating droplet carries no charge as a result an increase in surface charge density is witnessed. This increase in charge per unit area cannot increase infinitesimally; approaches a critical level, called Raleigh limit of charge, at which the liquid surface ruptures and gives birth to small daughter droplets.

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ELECTROSTATICS AND PESTICIDE SPRAYING: THEORETICAL CONCEPTS

Electrostatic force field application in agricultural spraying is a new technique to apply for the protective liquid pesticides and to reduce the off-target drift. It improves the efficiency of the system and bio-efficacy of the biological crops. For example, air-assisted electrostatic spraying, aerial electrostatic spraying system assembled in Helicopter and Tractors, are the modern systems used in agricultural pesticide spraying applications. In electrostatic spraying, finely divided droplets are charged by the application of high electrostatic potential to charging electrode. The system should work at lowest possible applied voltage so that it will work on low power consumption and hence the duration of the power supply. For efficient working of the system, ultimately one has to increase the charge to mass ratio at lower applied voltage as there is a trade off between applied potential and power consumption.

Electrostatic space charge and induced image charge forces enhance the uniformity of spray on the target surface, increase the transfer efficiency, bio-efficacy and adhesion. Electrostatic forces minimize the effect of gravitational force which is the main cause of spray drift and ground fall of the pesticide. The electrostatic forces levitate the charged droplets against the gravitational force; however levitation of the droplet depends upon the droplet diameter, surface tension, applied electric field and density of the liquid. The electrostatic spraying process is a very complex phenomenon which can be divided into three basic regions:

Hydro Electrodynamics

It mainly consists of liquid atomization and finely divided particulate matter charging. Liquid atomization can be achieved through centrifugal, pressure, air, hydraulic, pneumatic or electrostatic forces solely or by a combination of two or more of these forces. Chigier, (2007) showed the Challenges for future research in atomization and spray technology. Droplet charging methods include conduction, induction, tribo-electric, and corona charging; the induction charging is predominant in conductive liquid pesticide spraying.

Aerodynamics

It includes charged particles/droplets transport and charge retention. In the droplet transport region, aerodynamic, inertia, electrostatic and gravitational forces work together to determine the trajectories of the charged droplets.

Electrostatics

It mainly involves the actual spray deposition on the target; either it is conducting or non-conducting target. Electrostatic deposition onto a conductive target relies upon a displacement current to transfer electric charge onto or off the target to a degree appropriate for maintaining it at earth potential in the presence of the approaching charged-particulate cloud. In electrostatic spraying, it is assumed that the charged particulate matter is a slow moving phenomenon and therefore magnetic Lorentz force is negligible in comparison to electrostatic force.

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In electrostatic pesticide spraying, the following fundamental phenomena are of great importance which have to be taken into consideration for the better understanding of the subject:

- Droplet charging methods.
- In-flight trajectory of charged droplet.
- Optimizing the deposition field and transient effects at deposition targets.
- Charge to mass evaluation and hence efficiency and efficacy of the spraying system.
- Understanding the drop size and its measurement.

Droplet Changing Methods

Research approaches to agricultural spray charging have been based upon several distinct principles. Maski & Durairaj, (2010) showed in their previous work that a major portion of the electrostatic pesticide spraying has been in the development of reliable means for droplet charging. Motion of a charged particle can be easily controlled by the electric force, which depends on the charging level. Therefore, it is desirable to charge the particle to as high as possible and the charged droplet must be acted upon by an electric field. Well known and field-proven methods for imparting the necessary and sufficient charge to pesticide spraying droplets are divided on the basis of conductivity of the liquid to be sprayed:

- Ionized-field droplet charging (for both types of conductive as well as non-conductive liquids).
- Electrostatic-induction droplet charging (only for conductive liquids).
- Direct contact charging (for non-conductive liquids).

Law, (1984) presented a thorough consideration of these charging techniques and pros and cons accompanying with each method, accentuating their applicability as dictated by the physical properties of the pesticide-liquid to be electrified. Each method of charging has advantages and disadvantages in terms of liquid conductivity to be electrified, the level of applied voltage, insulation from the rest of the associated device, power consumptions etc. Induction charging is the most predominant method of charge electrification to fine droplets in pesticide spraying.

Ionized Field Droplet Charging

In corona charging, a sharp electrode is held at a high potential resulting in a local electric field high enough to ionize the surrounding air. The positive charges in the ionized air are less mobile than the negative ones and so remain in the vicinity of the electrode long enough to be picked up by a passing liquid stream. It requires a high applied voltage ranging from few thousands to more than a hundred thousand volts, depending upon the geometry of the charging equipment. Either solid or liquid particles, of diameters larger than approximately 0.5 μm, travelling through this ionized-field region can acquire by ion attachment, a saturation charge dependent upon the particles dielectric constant, its surface area, and electrical characteristics of the corona discharge. Ionized-field charging theory has been well developed mathematically by Law, (1984) and can be used to calculate the net electrical charge imparted to an air-born particle as:

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$$q_p = f\left[1+2\frac{K-1}{K+2}\right]4\pi\varepsilon_o E_o r_p^2 \tag{1}$$

where K is the dielectric constant, f is the saturation factor, E_o is the applied electric field and r_p is the radius of the droplet. The fraction of the saturation charge actually attained by the particle depends upon the residence time, and the concentration and mobility of the ion in the charging field. For aqueous-based sprays (K=80) charged to half-saturation (i.e. f=5) in a typical corona-discharge nozzle, droplet charge in coulombs typically attains a value of:

$$q_p \simeq 6\pi\varepsilon_o E_o r_p^2 \tag{2}$$

With an associated charge to mass ratio of $\frac{q_p}{m_p} \simeq \left[\frac{9\varepsilon_0 E_0}{2\delta}\right]\frac{1}{r_p}$ C/kg, where δ represents the surface tension of liquid. While the ionized-field charging method is routinely used in a variety of commercial and industrial processes ranging from xerography to electrostatic precipitation, greater care must be exercised in properly designing the process into agricultural spray-charging devices, in order to maintain long-term charging reliability. Difficulties relate to the fragile nature of the exposed corona electrode, to the elevated ionizing voltage required (typically more than 15kV), and to the onset of reverse ionization from the passive electrode when inadvertently wetted or coated with resistive particles.

Induction Charging

In 1980s, the work led by S. Edward Law at the University of Georgia, developed induction based spray-charging method meeting the engineering design requirements of robustness, simplicity, reliability, energy efficiency, and safety. The electrostatic-induction and the ionized-field spray charging methods are the ones widely used throughout many industrial processes. Agricultural charging based nozzle development has mainly relied upon the induction charging methods. This section presents a detailed consideration of induction spray-charging techniques, emphasizing their applicability as dictated by the physical properties of the pesticide-liquids to be electrified.

Spray liquid is normally electrically neutral. To charge a spray, the normal balance between positively charged protons and negatively charged electrons has to be disturbed so that spray droplets carry either a net positive charge or net negative charge. Droplets with same electrical sign (+ or -) repel while those with opposite charges attract.

Electrostatic induction has proved to be a very satisfactory alternative to the ionized-field method of charging spray droplets for agricultural pesticide applications. Figure 1 indicates the complete picture for understanding the induction charging phenomena. In this method, direct-transfer to the droplet-formation zone of a liquid jet results from electrostatic induction of electrons on to the continuous liquid jet and in order to maintain it at ground potential the presence of closely positioned induction electrode of positive polarity is required. Droplets, formed from the surface of this negatively-charged jet, will depart with net negative charge provided the droplet-formation zone remains subject to the inducing electric field acting between the non-ionizing electrode and the liquid jet.

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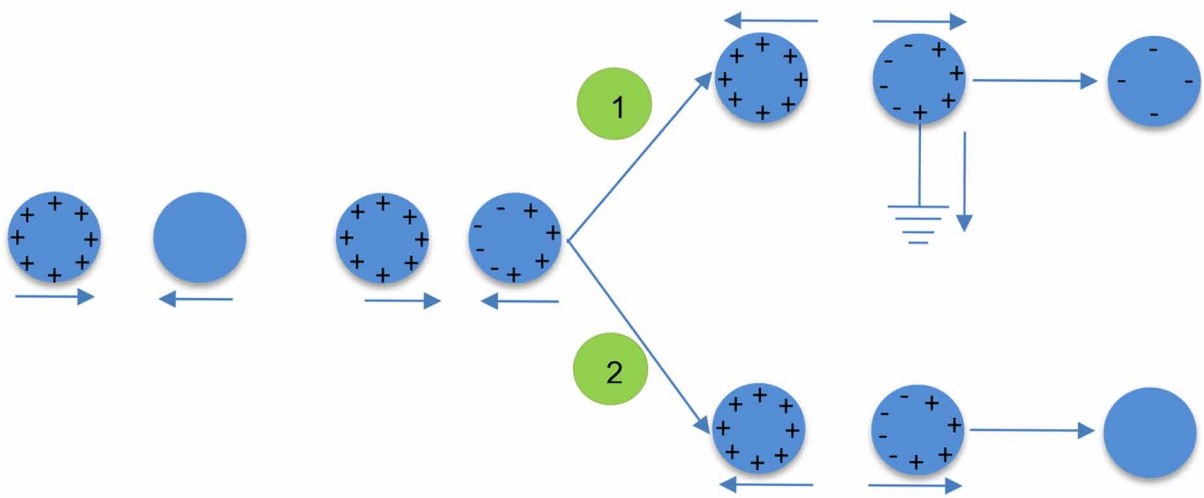
Figure 1. Induction charging of finely divided particulate matter



Gauss's law indicates that maximum droplet charging should occur for the droplet-production zone located at the region which provides maximum field strength at the terminal surface of the liquid jet.

In induction charging of the spray droplets, two time constants are of importance:

1. Time constant of charge-transfer (τ)
2. Droplets formation time constant (t_f)

The level of droplet charge imparted by electrostatic induction depends upon the relative time rate of charge transfer to the droplet-formation zone, as compared with the time required for droplet formation. The charge-transfer capability by induction from a grounded metal nozzle through the issuing liquid jet depends upon the electrical as well mechanical properties of the continuous liquid jet.

The two most important properties of the liquid to be sprayed are:

1. Electrical properties such as conductivity, dielectric constant, permittivity etc.
2. Mechanical properties such as density, viscosity, surface tension etc.

For pesticides, the spray-liquid characteristic may be specified by the charge-transfer time constant, which is a function of the electrical conductivity (σ) and the dielectric constant (K) of the liquid as:

$$\tau = \left(K\varepsilon_0\right) / \sigma \tag{3}$$

If a duration of time t_f, characterizes formation of discrete droplets from the continuous jet, then spray liquids must satisfy the condition $\tau < t_f$, in order to satisfactorily charged by electrostatic induction process. In electrostatic spraying of pesticides, the conductivity of liquid to be sprayed is of inordinate significance and it is to be taken into consideration, when such a system is developed. The system must cover all the ranges of liquid based pesticides used as sprays.

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Conduction Charging

In the case of charging by conduction, the DC electric supply is made by contact with the spraying liquid. In case of the conduction charging, the mechanical energy is used for dispersing the liquid into the droplets and the current that leaks to the power supply and assures a part of the electric energy for charging and accelerating the droplets. Both the mechanical energy and the electrical energy drive the charged drops to the target. The electrical energy depends on the nozzle current and the power supply voltage. Each droplet-charging method possesses its unique advantages as well as disadvantages in relation to technical and engineering requirements of vastly different pesticide-application situation encountered.

Droplet Charge Limit

The amount of charge that each individual drop can carry is limited. There is essentially two physical mechanisms limiting the charge that can be retained on the droplet surface, one is Rayleigh limit and other is Paschen limit. *Rayleigh limit:* In an electrostatic spraying process, as the droplets are charged by induction charging, the saturation charge is reached instantaneously. It takes a finite time for the particle to achieve this saturation charge. When the electrostatic force of repulsion is greater or equal to the attractive force due to surface tension, the droplets disrupt to smaller droplets and produce daughter droplets (Allah, 2002). The process results in a fine mist of highly charged droplets.

It has been shown that for dielectric drops in the presence of significant electric fields, particularly within spray plumes, the maximum charge a drop may hold is less than the Rayleigh limit of charge. The Maximum charge acquired during the induction charging process by a conducting sphere is limited by Rayleigh limit as shown in Equation (4) given by (Shrimpton, 2005):

$$q_{max} = \sqrt{64\pi^2\epsilon_0\delta r^3} \tag{4}$$

where, δ is the surface tension of the droplet and *r* is the radius of the droplet. *Paschen limit*: is another mechanism where the avalanche ionization process and localized electrical discharge can occur at the surface of a charged drop when, the drop charge exceeds the limit and that charge to mass ratio can be given by equation (5):

$$\frac{Q_p}{m_p} = \frac{12\varepsilon_o V_p}{\rho D^2}\ \text{C/kg} \tag{5}$$

where Q_p is the Paschen charge limit, m_p is the liquid mass flow rate, ρ is the density of liquid, D is the diameter of the droplet and V_p is the surface potential.

In-Flight Trajectory of Charged Particulate Matter

The maintenance of charge on electrified clouds of airborne spray enroute from charging nozzles to grounded-plant targets should be maintained. Once the droplets are charged sufficiently, the droplets have to traverse the distance to reach the actual target canopy. Common concern of electrostatic spraying is

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the exploitation of the most favorable force field for achieving the desired motion and the maintenance of droplet charge during the in-flight trajectory of the electrostatic spray. There is no ideal charge to mass ratio for spraying, however higher the ratio, the better is the efficiency of electrostatic spraying. Various studies reported different minimum level of charge to mass ratio i.e. 0.8, 1.2, 2.0 mC/kg etc. Laryea & No, (2004) have shown that these charge to mass ratio values can be used as references, recent studies have shown that these lower values result in an increased spray deposition on the target.

The change in charge to mass ratio is due to the existence of naturally-occurring free charge and electric fields of the earth's atmosphere. In normal air near the earth's surface, ionization by cosmic radiation and background radioactivity typically provide a charge creation rate c_i=1-7 ion pairs per cubic centimeter per second. The recombination coefficient α_i for these positive and negative ions is approximately $1.6*10^{-6} cm^3 sec^{-1}$. Since the rate of ionic recombination depends upon this coefficient as well as upon concentration (n_i) of both positive and negative species, the air's ion pair concentration is governed by the relation, $\frac{dn_i}{dt} = c_i - \alpha_i n_i^2$. Thus, a charged pesticide spray cloud will encounter some degree of neutralization by the following two actions: 1) traversing a region of ionized air; and 2) causing migration of oppositely charged air ions into the region of charged sprays. Spraying distance and its consequences on the performance of the nozzle has been discussed by Robson et al., (2013), at Federal University of Vicosa, Minas Gerais Universidade Federal de Vicosa, Vicosa- Minas Gerais and it has been concluded that for the liquid deposition, the electrostatic system was affected by the target orientation and spraying distance.

Optimizing the Deposition Field and Transient Effects at Deposition Targets

While inverse-square image-charge forces are significant for achieving deposition at millimeter droplet-to-target spacing, only the space-charge field is relevant for electrically driving charged droplets over greater distances within shielded plant canopies. Significant research effort has therefore been directed toward managing the space-charge electric field for enhanced target deposition. Findings have important practical implications regarding improved designs of portable, human-carried, electrostatic sprayers. A further strategy to enhance pesticide droplet deposition, under constraints limiting the dielectric breakdown of the space-charge field has been theoretically developed. In contrast to deposition benefits derived from surface-charge accumulation on plastic films under and above crops, charge buildup on the actual target plants must be avoided so that they will remain near ground potential. A target's inherent charge-relaxation time constant must accommodate this charge transfer i.e., displacement current to earth as charged conductive droplets impinge Law, (2001).

Charge to Mass Evaluation and Hence Efficiency and Efficacy of the Spraying System

The use of pesticides should be performed efficiently and judiciously to increase the bio-efficacy of the biological plants and trees, since its application without the appropriate technology can cause contamination of the soil and environment, leaving residues in food with an increased risk of farm workers' health. Numerous experimental tests have been conducted over the past quarter century which validate electrostatic crop-spraying technology as currently practiced by various field machines. Spray mass-

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transfer results by many researchers, both in the laboratory and the field; have generally verified 2-8 fold increase in target deposition, as well as improved spatial distribution on plant surfaces, greater deposition density, attributable to electrostatic forces.

Charge to mass ratio is a key term defining the performance of spray equipment in electrostatic spraying applications. Charge to mass ratio determination may vary as the field of application changes such as agricultural pesticide spraying, medical, powder coating and painting, however, the basics behind the measurement of charge to mass ratio is same. The effectiveness of various electrostatic applications depends directly or indirectly on this parameter. It is a critical measure that needs to be determined in order to accurately predict the behavior of a particle exposed to inertial, electrical and gravitational forces. A brief review has already been given by Toljic, Adamiak, & Castle, (2008) for the determination of particle charge to mass ratio distribution in electrostatic applications. Brown, (1997) divided charge to mass ratio measurement techniques into two categories. First, a static method of charge measurement, measures the amount of charge present in droplets directly. Second, the dynamic method for calculating the charge to mass ratio by observing the particle motion parameters in the presence of external electric field.

Static Method

In static method of charging, Ye, & Domnick, (2003) present a numerical method for the calculation of electric field with space charge in electrostatic powder coating with a corona spray gun and used a suction-type Faraday cup apparatus to measure the charge to mass ratio. An extended commercial Computational Fluid Dynamics (CFD) code was used for numerical simulations. Their calculated charge to mass profile based on Pauthenier theory showed a good agreement with the experiment for particles with radius less than 60μm. This is a good agreement with surface area theory. For particles with larger diameter, the experimental charge to mass values stayed constant which is in disagreement with theoretical knowledge. They conclude that this was probably due to the experimental uncertainty for the large particles. From the obtained results, it was evident that the sensitivity of this instrument decreased with increasing mean particle diameter.

In agricultural pesticide spraying the common mathematical method for measuring charge is based on charge to mass ratio that is characterized by measured spray current and mass flow rate.

There are two methods of measuring the charge to mass ratio and hence performance of the spraying system:

- Faraday cage method
- Conductive plate method

In both the methods, the charged liquid spray was collected at a specific time and weighed. The spray current was divided by the mass flow rate to determine the charge to mass ratio. Both the performance measuring methods are nicely explained by Mamidi, Ghanshyam, Patel, & Kapur, (2013); Patel, Ghanshyam, & Kapur (2012b) in their previous research work conducted at CSIR-Central Scientific Instruments Organisation, INDIA. In these methods of charge to mass ratio measurement, the spray strikes onto the target, due to potential gradient the current flows and this current can be measured by an electrometer connected to the Faraday cage or conductive plate electrode as shown in Figure 2.

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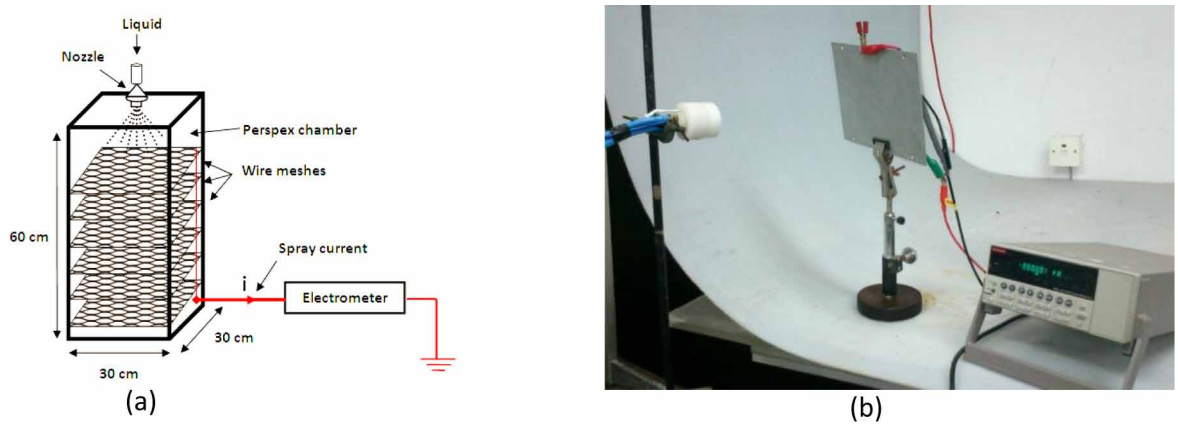
Figure 2. Common methods to measure the charge to mass ratio (a) Faraday cage (b) Conductive plate



Dynamic Method

The dynamic method for calculating the charge to mass ratio by observing the particle motion parameters in the presence of external electric field involves the Phase Doppler Anemometry (PDA) technique, a nonintrusive optical method for simultaneous measurement of the size as well as the velocity of spherical particles. Kulon, Malyan, & Balachandran, (2003) discussed that it is a noninvasive method of measurement of the charge level on a population of particles by combining the Phase Doppler Anemometry technique and high-resolution computer-controlled traversing system.

The principle of the Phase Doppler Anemometry (PDA) is based on light scattering from two-plane light beams incident on the particle. The intersecting coherent and polarized laser beams form a small measurement region of light and dark fringes within the spray. The phase shift between the signals from different detectors is proportional to the size of the spherical particle for reflection represented by Equation (6),

$$\Phi = \frac{2\pi d_p}{\lambda} \frac{\sin\theta \sin\varphi}{\sqrt{2\left(1-\cos\theta\ \cos\varphi\ \cos\psi\right)}} \tag{6}$$

where, λ is the wavelength of the laser light, d_p is the inter-planar distance, θ is the angle between the incoming laser beams, φ is the scattering angle and ψ is the elevation angle. The velocity measurement is based on the Doppler Effect. As a droplet passes through the measurement region it scatters light at a frequency based on its velocity normal to the fringes and its spacing. A receiving device measures the frequency of the scattering signal and the spacing of the fringes is determined based on the wavelength of the laser light and the angle between the beams. Knowing the Doppler frequency f_d, frequency of the scattered signal f_s and the spacing of the fringe d_f, the particle velocity v can be calculated as follows in Equation (7):

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$$f_d = \frac{f_s + v}{d_f} = \frac{f_s + v2\sin \pi/2}{\lambda} \tag{7}$$

The PDA system was used to track the motion of charged particles in air in the presence of a dc electric field within the space between the parallel-plate electrodes. Charged particles exposed to the external electric field and situated in a viscous medium experience two types of force exerted on them: external electrical force and drag force as a result of a relative motion of a particle in the air. After the relaxation time, a particle attains mechanical equilibrium and reaches a steady state velocity relative to the medium.

Laser Velocity Meter (LDV), an important part of the Electronic Single Particle Aerodynamic Relaxation Time (ESPART) analyzer, is used extensively in non-invasive measurements of fluid flow, turbulence characteristics, and particle dynamics. ESPART analyzer can measure the statistical charge and size distribution of charged particulate simultaneously and it is widely used in industrial applications for the analysis of toner particles, drug powders, oil droplets, dust particles, pesticides charged particulate. In ESPART analyzer, the particle motion in an electric field is analyzed in noncontact manner using LDV or by image analysis. The ESPART analyzer is based on the motion of particles suspended in a gaseous medium when the particles are subjected to an external electric field. The measurements of size and charge of the particles, derived from their relative motion in the gaseous medium, are based on the assumption that the particle motion is within Stokes regime, which is valid only when the Reynolds number of the particles motion in less than 0.1. Some specifications of ESPART analyzer are:

Particle Charge Range

The ESPART analyzer can measure electrostatic charge on each particle in the range from zero to its saturation value, limited by many factors like breakdown strength of the surrounding medium, Rayleigh limit etc., with positive or negative polarity.

Particle Count Range

The maximum count rate will be limited to less than 500 counts per second when signal-to-noise ratio of the Doppler signal is high. At an excitation frequency higher than 2.0 kHz, the maximum count rate depends upon the minimum time required by signal and data processing circuitry for real-time size and charge analysis.

Particle Size Range

ESPART analyzers have been built based on both LDV measurements for small particles (diameter < 50μm) and with image analyzers for larger particles (20μm $<d_a<$100μm). ESPART analyzer is capable of measuring particle size and charge distributions in different atmospheric conditions.

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Understanding the Drop Size and Its Measurement

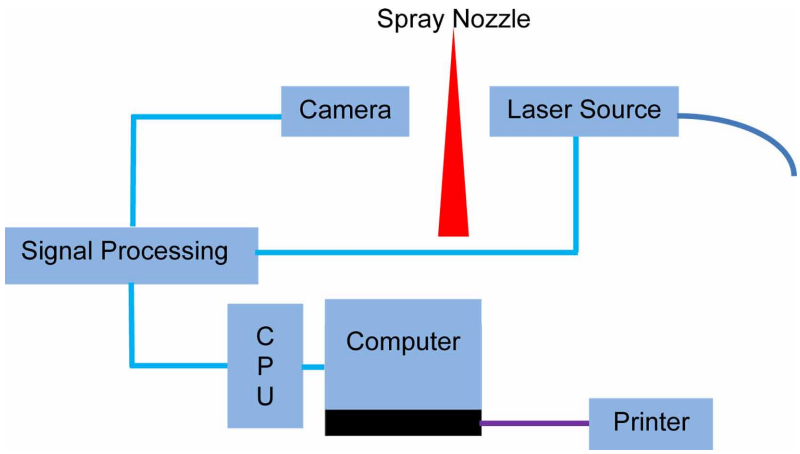
Optical Image Analyzer

Among available methods of droplet size and to visualize the detailed time-resolved structure of electrospray, a simple and sophisticated system i.e. optical image analyzer can be used to study the different mode of spray with the increase in applied voltage and other parameters. A schematic of a typical optical image analyzer is shown in Figure 3. The measurement range of these instruments varies from 1µm with no definite upper bound restriction as the system optics determines the upper range. In such kind of measurements, a high speed camera is implemented to visualize the detailed time-resolved structure of electrospray. The measurement records the shadow images of the droplets by the high speed camera at fraction of micro second intervals. The size of the droplet is determined from the recorded images with the high-speed camera.

Deposit Scan

Zhu, Salyani, & Fox, (2011) developed a portable scanning system to measure the spray coverage and deposition quality feedback information, a system that could quickly evaluate spray deposit distribution and coverage area on deposit collectors such as water sensitive paper or Kromekote card. The system is integrated with a handheld business card scanner, deposit collector, a laptop or computer, and a custom-designed software package entitled "Deposit Scan". Deposit Scan also called ImageJ is a Java-based image-processing program used for the acquisition and analysis of images. It is developed by the National Institutes of Health (NIH), USA and is now available to open access. ImageJ can be used to measure an area and count number of spots in the user-defined areas or throughout the entire image. The shape of selected areas could be rectangular, elliptical, or irregular. It also quickly gives the deposits per centimeter square area of the image.

Figure 3. Droplet characterization and size measuring system through optical imaging



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A Shift From Micro to Nano Scale Measurement

Stark, Zhang, Sharma, & Mazumder, (2008) developed a mathematical model using MATLAB/SIMULINK to measure the charged nanoparticle (particle size distribution ranges from 2 pm to 20 pm and charge to mass ranges from 2 to +24 pC/kg), a modification of the older ESPART analyzer that was restricted to measurement of sub-micron particles i.e. in printing industry applications, space applications, and in applications to distinguish between different types of bacteria. ESPART analyzer at present can measure nanoparticles, which requires measuring signals with a low SNR (Signal-to-Noise Ratio). Resolution of particle size relies heavily on the frequency of the exciting signal, which causes the particle to experience oscillatory motion. With an increase in the exciting frequency, smaller particles experience motion at high frequencies with greater changes. It can be inferred that a higher frequency exciting signal can be used to resolve smaller particle sizes at the limits of the light collection methods and devices such as silicon photodiodes and photomultiplier tubes. Amplitude of oscillation of the particle in the applied AC electric field charges up the particle. The magnitude of oscillation compared with the magnitude of the applied electric field gives the particle net charge.

FLUENT to Model Electrostatic Spraying Processes

The recent development of Computational Fluid Dynamics (CFD) software makes it possible to model the mechanical spraying process with ease. FLUENT is one of such powerful software tools to model the air flow in the continuous phase and the droplet motion in the discrete phase. However, it does not have a direct solution for the electrostatic field formed by the charged droplets. Fortunately, it offers user-defined functions (UDF) and user-defined scalars (UDS) as an extension to suit different needs for various applications.

Numerous studies have been carried out on the charged particle motion under electrostatic space-periodic field in crossed-field systems. In this study, changed particle trajectory was considered in crossed-field systems under periodical electrostatic distribution. Many parameters affect the process such as atomizing air pressure, liquid flow rate, nozzle-to-target distance, droplet size, charge to mass ratio, etc. The mechanical portion can be directly modeled with the computational fluid dynamics software. The droplet trajectories are computed under the discrete phase model. In this mode, the equation of motion is solved by the Lagrange approach where the droplets are tracked by the stochastic tracking (random walk) model in turbulent gas flow. The electrostatic force on the charged droplets due to space charge is incorporated into the FLUENT solver as a component of the droplet body force. The air flow and the droplet discrete phase can be directly modeled in FLUENT.

In practice, the Poisson equation of the electrostatic field is analogous to the general scalar transport equations within FLUENT. In this way, modeling of the electrostatic liquid spraying process can be performed solely by FLUENT without compiling a separate computer program to solve the Poisson field which calls for a vast amount of data exchange. The key of this technique is to find the space charge density for different charging models.

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ELECTROSTATICS AND ITS APPLICATIONS TO AGRICULTURAL SPRAYING

The application of pesticides is one of the most frequently used methods to protect crops and trees against diseases and insects in agriculture and agricultural products for the sustainable agricultural development. Laryea & No, (2003) showed that more than 90% of the pesticides are applied as liquid sprays providing more accurate metering and on-site particle-size control but the sprays are highly drift-prone and it is mostly performed by using hydraulic and conventional spray nozzle systems, pedestal-mounted sprayers, high pressure spray guns, hand pressure swirl nozzles and the consecutive high volume sprayers. Sande et al., (2008) showed in their previous work that due to non-uniformity of droplet size and off-target drift, target deposition efficiencies less than 30% is very common in agricultural pesticide spraying. The work was mainly on different spraying techniques and how to optimize spray deposition and minimize spray drift. The smaller droplets are lost in airborne drifts and the larger ones are lost due to gravitational settling by the soil. Off-target drift, aerial spraying losses and uneven deposition are very common in pesticides application that leads to damage of non-target microorganisms, soil quality and environmental pollution. Further, Sayinci & Bastaban, (2011) also worked on spray distribution uniformity of different types of nozzles and discussed the parameters of spray deposition mainly for potato plant. Numerous scientists and researchers have been working on measurement and evaluation of off-target drifts and aerial spraying losses from the target.

Electrostatic force field applications to agricultural pesticide spraying is one of the most efficient and economic methods to protect the crops and trees from insects and diseases (Ru, Zheng, & Zhou, 2007a). Law, (1983) and his students have done a remarkable work in the development of electrostatic pesticide-spraying processes and prototyping devices at the University of Georgia from 1970 to the present-day's commercialization of the technology. Electrostatic technique in spraying has already been commercialized and being used in countries such as USA, China, South Korea etc. In developing countries such India, a small portion of the agriculture farming is being performed in large scale, however, the major chunk of farming is done in small scale. Therefore, the spray equipment available in the market are not viable to developing economies especially in Indian scenario. Mamidi, Ghanshyam, Patel, & Kapur, (2012) have highlighted that the demands of the spraying equipment are very much different in developing economies than developed economies, where the farming is carried out in large scale. On the other hand, earlier electrostatic spray systems are motorized and mounted on tractors, helicopters or any other vehicles because of the complexity and heaviness, bulky which lead to the economic burden to the small scale farmers. Literature shows that a large number of publications and patents are coming from developing economies in today's scenario and these publications are mostly based on simplifying the complex and sophisticated systems to small scale farming such as hand pressure based electrostatic nozzles.

The goal of pesticide spray application is not only the effective deposition onto the target, but also economical, available at the lowest cost. This means that in order to develop a technologically feasible and economically attractive system, more research at both the experimental and theoretical level is needed (Law, 1995). Even though many parameters are involved in an induction charge based electrostatic spray systems, all the investigations carried out thus far have demonstrated the intricacies of the electrostatic-spray phenomena (Ru, Zheng, & Zhou, 2007b). In this section, the different applications of electrostatics in agriculture spraying and related areas have been discussed in details.

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Antimicrobial Sprays for Enhanced Food Safety

Antimicrobial agents are the biomaterials used to sanitize contact surfaces of the food production, processing and supply chain at various stages. The objective of the work 'Food Safety' at University of Georgia by Law and associates was to experimentally establish and control the mass-transfer efficiency and antimicrobial efficacy of the air-assisted induction charged electrostatic spraying process for spread over decontaminator liquids to various surface alignments and compositions commonly come across in food handling and processing operations specifically reconnoitering whether the lower volume of spray carrier liquid put down on the target surface would provide sufficient contact time for microbial cell death, as well as determining adequacy of target charge transfer for various electrically insulating versus conductive food-contact materials (Lyons, Harrison, & Law, 2011). They developed an air-exhausted biosafety chamber, an air-assisted induction charged electrostatic sprayer, commercially provided by Electrostatic Spraying Systems (ESS) Inc., was operated and compared to a conventional hydraulic-atomizing sprayer to determine mass transfer of active ingredient deposited onto the actual targets. Fluoroanalysis of AAIC (air-assisted induction-charged) electrostatic sprayer has given good agreement with theoretical considerations in terms of significant increase in deposition efficiency and surface sanitizing bio-efficacy. This provides backside deposition with greater efficiency and bio-efficacy. The deposition of active ingredients onto backside of the target was 29-times better than any conventional sprayer. However, in these kinds of microbial sanitizing techniques, it is to be noted that the sanitizing media should be biocompatible to food materials.

Postharvest Control of Fruits and Vegetables Spoilage Microorganisms

Maintaining the quality and desired sensory attributes of fruits and vegetables between farm and market is one among the major challenges. It is also called post-harvest treatment of biological commodities. This entices the application of waxes and water-loss barriers onto the surfaces of perishable food product. Law & Scherm, (2005) reported the development of an efficient electrostatic spray application method and processing-line prototype created specifically for postharvest protection of foodstuffs. They developed a prototype electrostatic sprayers unit utilizing an oscillating array of air-assisted induction-charging nozzles for postharvest treatment of fruits and vegetables on processing and packing lines. Example was the demonstration of prototype of Banana packing, a 1 m x 1 m shallow plastic tray containing 16-18 clusters of 5-7 bananas each is pushed along the process roller-line into the treatment chamber ejecting the previously treated tray of fruits. Experimental results of extensive evaluations of electrostatically applied protective sprays onto bananas for international shipment, where both microbiological and mass-transfer data document typically showed the 2-3 fold deposition improvements for food protection.

High Range Electrostatic Sprayers

To develop an electrostatic spraying system for high range spraying, such as defendable forest, shelter trees in urban areas, fast growth forest, field net forest and shelter trees on highways etc., is the current issue to be taken into considerations since performance of such systems deteriorate as the travel distance of charged droplets increases. Also greater the distance between the spray tip and the target area, the greater impact wind velocity can have on drift (Ru, Zheng, & Zhou, 2007c). Charge to mass ratio is one among the parameters which decide the performance and efficiency of electrostatic spraying systems,

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a process of neutralization due to naturally occurring radioactive phenomena's in ambient atmosphere. It is also very important because in recent years, it has been observed that there are more and more tall trees in worldwide, as forest covering area become wider. Ru, Zheng, & Zhou, (2005) authenticated that to improve the effective spraying range; it should be considered such features of sprayers as spraying height and application efficiency. The work led by Zhou, Professor at the Nanjing Forestry University, China, designed and developed a system to apply liquid sprays to very high trees to control the forestry diseases. The high range spraying systems are commercialized recently and available in the market.

Aerial Spraying Systems

Based on the theoretical analysis and practical experiments and the requirements for the large area forest pest control and farming performed in large scale, Zhou, Ru, Shu, Zheng, & Zhu, (2008) developed an aerial electrostatic spraying system assembled on a helicopter, a hydraulically assisted flight control. The study addressed issues associated with inefficiencies in disease and pest control, including pesticide overuse, spraying difficulties and labor intensity. The spraying system includes electrostatic generator and two sets of nozzles. An electrostatic generator with two high-voltage power levels can output positive and negative high-voltage simultaneously and was used to deliver voltage of 24-36V into a high-voltage generator with output voltage of 10kV in common use and 20kV in maximum and mounted on the aircraft. On the basis of field tests and experimental results, it was observed that combining aerial spray technique with electrostatic spray technique, the invented aerial electrostatic spraying system applied in R44 was provided with scientific design, rational structure, convenient operation, high productivity and high efficiency and had no harmful effects to all the airborne equipment and instruments of R44. It was completely suitable for the safe flight and spraying of R44 helicopter. Electrostatic spraying, which accords with the demands of flight safety and spraying procedures; can evenly distribute droplets while reducing pesticide use that leads to environmental and soil pollution.

Equipment for Improved Deposition in Cotton

Air-assisted electrostatic and hydraulic sprayers have been developed in recent years to improve pesticide penetration and coverage within the plant canopy and to increase the efficiency and bio-efficacy of the biological surfaces of the crops and trees. These sprayers need to be evaluated to determine their effectiveness when compared with conventional sprayers. Sumner, Herzog, Sumner, Bader, & Mullinix, (2000) compared within-canopy penetration and leaf side coverage of spray materials applied using the following spray technologies: (a) air-assisted sprayer (b) over-the-top hydraulic nozzles plus drop nozzles (c) electrostatic air-assisted sprayer (d) over-the-top hydraulic nozzles; (e) over-the-top nozzles plus shielded drop. The results showed that the air-assist nozzles are better than hydraulic and other sprayers in term of coverage and penetration of the canopy of the plant.

Automatic Target Detection and Electrostatic Spraying

The recent work by Xiongkui, Aijun, Yajia, & Jianli, (2011) was based on an infrared sensor detection system to discriminate between the presence and absence of trees for which spray is not needed, when the detecting devices detect the target, an automatic control system activates the spraying system to spray toward the target. Similarly, when the automatic control system receives the signal of a gap between the

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trees from the "electronic eye", the spraying system shuts off. Infrared sensor detecting techniques have been adopted in automatic target detecting orchard sprayers to discern targets and control the spraying system automatically. The important engineering aspects to keep in mind while developing such systems, is the matching of the electrostatic spray nozzles and sensor actuation. The microcontroller response and response of different sensors should be matched because of the fast actuation of electromagnetic valves. The actuation of controlling devices should be matched for exact target detection along with sensitivity, accuracy etc. An infrared detector is utilized in the automatic target detection system along with electrostatic nozzle and air assistive fans. Multi-sensor fusion techniques can be utilized for this kind of spraying systems.

FUTURE RESEARCH DIRECTIVES IN ELECTROSTATIC PROCESSES APPLIED TO AGRICULTURE AND AGRICULTURAL RELATED AREAS

Real Time Monitoring and Pesticide Delivery

As the population is growing day by day, the demand of nutritious and healthy food is increasing. Therefore, there is a tremendous increase in green house farming to fulfill the demands of billions of people. In greenhouses, it is very difficult to work in the presence of high temperature, increased carbon dioxide and humidity level. Therefore, there is a possibility of automation and mechanization in agricultural pesticide spraying. The automation in pesticide spraying involves majorly three steps: sensor package to sense the target and to map the plant canopy (target detection and canopy mapping), data acquisition to calculate and store the data and the last is navigation to monitor the movement of an automated spraying system. By using sensory attributes, the pesticide dose can be decided as per requirement of the plant canopy and disease.

Pesticide application control and variable pesticide spraying is the key to improve operation quality, reduce chemical waste, environmental pollution and cut down the cost of production. Other factors which have to be considered in pesticide spraying are target detection, quantity and quality of spraying control, directionality of spray, efficient treatment with low pesticide doses, operator safety, ease of use and reliability, flexibility and economic and cost effective spray system.

Characterization of Electrode Material for Spray Charging

Appropriate electrode material selection for spray charging and dimensional design and specifications are very important that need further study. Right electrode material and its insulation may enhance the chargeability of liquid sprays. So far the materials used as an electrode for spray charging were copper, brass and stainless steel. Recently nickel has been reported as a new electrode material for spray charging by Patel, Ghanshyam, Mamidi, Kapur, (2012a). Nickel increases the corrosion efficiency and enhances the performance of the system, since Nickel is assumed to be inert in standard temperature and pressure. This may enhance the charge to mass ratio and hence the performance of the electrostatic nozzle system.

Figure 4 shows the performance of the different material electrodes for spray charging in electrostatic spraying processes (Patel, Ghanshyam, Mamidi, Kapur, 2013). It shows that nickel (Ni) electrode has more spray current and hence the charge to mass ratio than rest of the electrodes because of availability of more electron surface density. Here the Fermi energy and work function of the charging electrode

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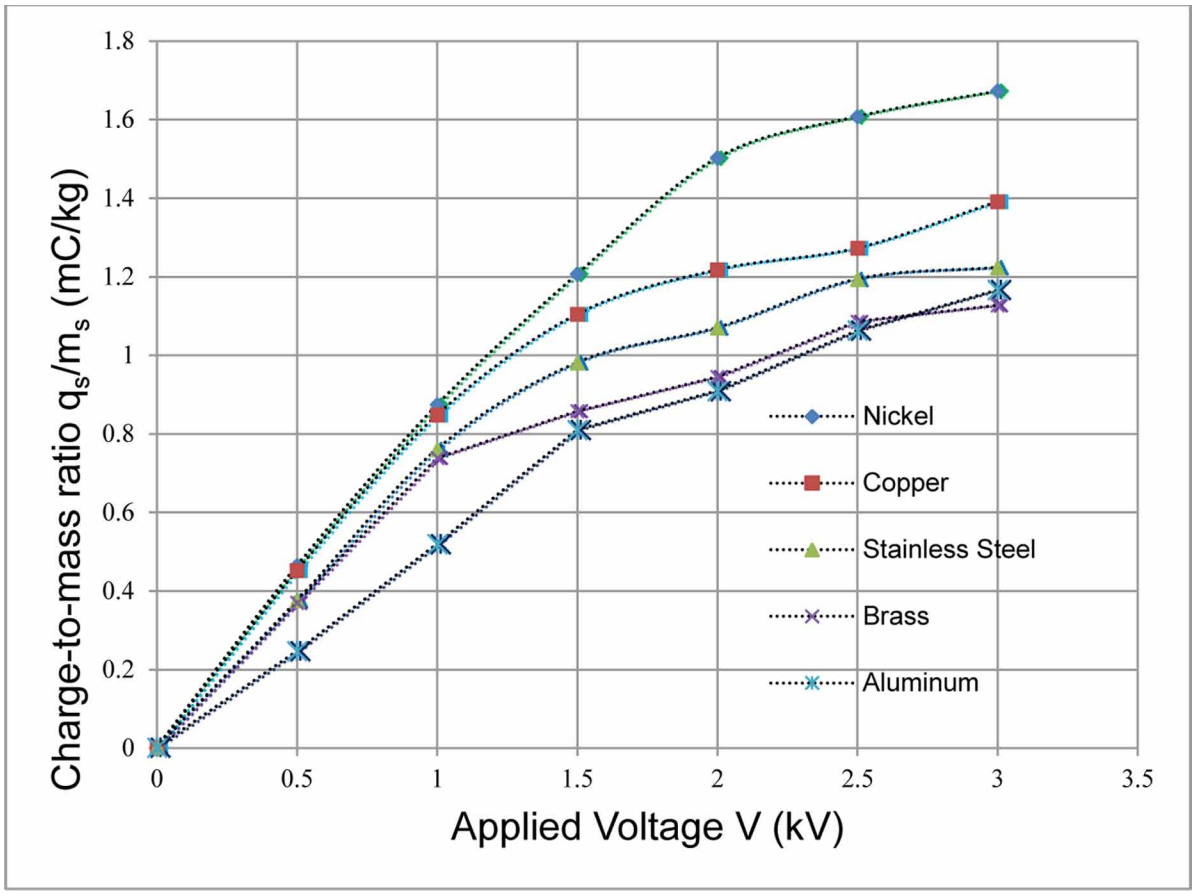
Figure 4. Charge to mass ratio for different material electrodes in spray charging



material are playing a key role. The performance and characterization of different electrode materials for spray charging is still a naive and unexplored area which requires furthers innovation in material synthesis to work at lower applied voltage for the same performance.

Electrostatic Sprays for Ratnagiri Mangoes to Enhance the Transportation life

Ratnagiri is the largest producer of quality mangoes such as Alphonso, Kesar etc. a Southern part of India. The life of the storage and transportation of these mangoes is about 7-10 days which is very short. The pest level on these varieties is reported by the European Union. This is because, pesticides are being used indiscriminately, affecting the export of perishable commodities, and as a result economic balance is affected. The European Union imposed a ban from May 1, 2014, on import of mangoes, after alleging to have found unwanted pests such as “non-European fruit flies” in some consignments. These mangoes are easily attacked by microbial and affected by ambient conditions. There is a possibility of electrostatic sprays or coatings on the surface of these mangoes to protect them from microbial attacks and ambient conditions and also to increase the self-life of transportation.

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The electrostatically coated material on the surface of mangoes should be biocompatible so that it will not affect the human being and consumer of the products. The biomaterial should be soluble in water or other solvents so that it can be sprayed as liquid.

Protective Coatings to Apples for Resistance Towards Microbial Attacks

An excellent technique for applying protective thin coatings on fruits such as apples, to protect from microbial attacks has been proposed. Further improvements can be done by combining a processing and packaging line with the treatment chamber for automated online processing. An array of nozzles spraying different solutions can be used for applying simultaneous coatings such as waxes and fungicides. These electrostatically coated fruits are more resistive to the ambient conditions and can be stored for a long time.

Ultra High Electric Pulses to Preserve the Liquid Beverages/Foods

Technological advances in food processing industry have evolved various instruments, ranging from simple to complex equipment. These are either processing equipment or preserving equipment. Preservation of food item calls for new techniques, which involve various thermal and non-thermal methods. Pulsed Electric Field (PEF), which is a non-thermal method offers freshness, flavor and nutritional value and is used to improve the shelf-life of liquid food. In this technique, a short pulse is given to foodstuffs for a short duration for effective inactivation of microbes. Method of pulse generation is a still great concern of research, which needs further modifications and improvements. This generator may require power MOSFET, high voltage switching circuit, and microcontroller, to generate high voltage pulses of less than microsecond duration. The instrument should be equipped with data acquisition system and display system for proper and easy operation. Virtual Instrumentation could be used for data acquisition and control purposes.

Air-Assisted Electrostatic Nozzle for Variable Canopy Coverage

In the case of electrostatic spraying, the droplet size is normally in the range of 30-60μm or less and the droplets in this range are most susceptible to spray drift. The electrostatic repulsion among droplets is also the cause of spray drift. Presence of wind is another cause of spray drift and presently available sprayers cannot be used even in normal wind. It can be achieved by shielding the fine electrostatic spray from these harsh wind conditions. It may be simple mechanical means of shielding. The air-assistance forms an envelope around the spray to protect the finely generated charged particles. It also reduces the interaction of charged droplet cloud to naturally occurring charged ionic environment already present and hence applicable for higher range of spraying. The naturally occurring ions are present due the cosmic and radioactive activities. Air-assistance may provide virtual path to the finely divided charged droplets to reach actual target.

Automation in Switching ON/OFF of Power Supply

In the manual operation of the complex and sophisticated electrostatic sprayers, the probability of errors is very high, and calls for automation in the switching (ON/OFF) of the power supply to charge the small droplets in the design of the spraying nozzle systems. There should be an orderly and proper sequence

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to be followed from the different inputs for the efficient working of the electrostatic spraying nozzle system. A novel idea in the design of an automated circuit is to switch (ON/OFF) the high voltage power supply in electrostatic nozzle system, using the inherent property of water grounding, can be used. This can be achieved with the use of simple electronic and electrical components. Other way to achieve the goal is by using pneumadyne switch to control the high voltage power supply.

CONCLUSION

The aim of this chapter is to provide a basic understanding of an electrostatic spraying processes and the entry of charge to the liquid atomized as well as uniform deposition onto the surfaces of crops and orchards. This chapter has established a theoretical foundation for understanding the basics relying on electrostatic spraying, and relative effectiveness of the electrostatic forces. It emphasized the fundamentals behind the different charging mechanisms along with the charge retention and charge-loss phenomena and underlined the difficulties associated with each method, since it has always been a great challenge to inject the charge into the finely divided liquid droplets. The heart of the charge injection technique is being balance between hydrodynamics and electrodynamics, may generate flow instabilities which leads to turbulence. This requires co-design of the atomizer internal geometry from both hydrodynamics and electrical perspectives, the optimization of which leads to a maximum in the generated spray charge per unit volume contained by the spray.

This chapter links several research areas together to provide an integrated summary of the knowledge relevant to air-assisted electrostatic spraying and electrostatically assisted atomization of electrically conductive liquid specially an attention has been given to pesticide spraying. The emphasis of the review leans towards explanation of physics and description of experimental work, interactions between space charge gradient and electric field produced which in turn can generate instability throughout the bulk of the continuum. It also discussed the interaction between finely divided charged particulate matters and naturally occurring ions present in the atmosphere, leads to neutralization of the charged droplets and hence deteriorates the performance of the spraying system.

This chapter highlighted the various applications of electrostatic spraying to different fields of agriculture, engineering trends and food processing industry along with the future perspectives of the electrostatic spraying. Electrostatic spraying technique can be used for protective biomaterial coatings to fruits, vegetables and perishable food products for resistance towards microbial attacks, to enhance the transportation life, to control spoilage microorganisms, antimicrobial sprays for enhanced food safety etc. However, the biomaterial should be soluble in conducting liquids such as water and other liquid solvents. It is one among the bioremediators since it reduces the pesticide use and ensures the minimum residue level (MRL), an indication of pesticide residue in consumer commodities. Controlled and targeted delivery of pesticides is one of the current fields of interests in pesticide spraying, an automated system which is intelligent enough and trained properly to spray without interventions of human operator. Currently, the fabrication of electrostatically sprayed particles and liquid spray at industrial and user scale (e.g., ESS Technology, Inc.) is feasible. However, advanced research on electrostatic spraying techniques in the field of food processing and preservation is recommended to enable the applications workable at the industrial scale.

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REFERENCES

Abhilash, P. C., & Singh, N. (2009). Pesticide use and application: An Indian scenario. *Journal of Hazardous Materials*, *165*(1-3), 1–12. doi:10.1016/j.jhazmat.2008.10.061 PMID:19081675

Allah, M. H. O. (2002). Rayleigh-Taylor instability with surface tension, porous media, rigid planes and exponential densities. *Indian Journal of Pure and Applied Mathematics*, *33*, 1391–1403.

Brown, R. C. (1997). Tutorial review: Simultaneous measurement of particle size and particle charge. *Journal of Aerosol Science*, *28*(8), 1373–1391. doi:10.1016/S0021-8502(97)00034-7

Chigier, N. (2006). Challenges for future research in atomization and spray technology. *Atomization and Sprays*, *16*(7), 727–736. doi:10.1615/AtomizSpr.v16.i7.10

Ghayempour, S., & Mortazavi, S. M. (2013). Fabrication of 684 micro–nanocapsules by a new electrospraying method using coaxial jets and examination of effective parameters on their production. *Journal of Electrostatics*, *71*(4), 717–727. doi:10.1016/j.elstat.2013.04.001

Hamid, A. H. A., & Atan, R. (2008). Spray characteristics of jet–swirl nozzles for thrust chamber injector. *Aerospace Science and Technology*, *13*(4-5), 192–196. doi:10.1016/j.ast.2008.10.003

He, X. K., Yan, K. R., & Chu, J. Y. (2003). Design and testing of the automatic target detecting, electrostatic, air assisted, orchard sprayer. *Transactions of the Chinese Society of Agriculture Machinery*, *19*(6), 78–80.

Jia, W., Xue, F., Qui, B., & Wang, Z. (2013). Design and Performance of Inductive Electrostatic Sprayer. *Research Journal of Applied Sciences. Engineering and Technology*, *5*(21), 5102–5106.

Khan, M. K. I., Maan, A. A., Schutyser, M., Schroën, K., & Boom, R. (2013). Electrospraying of water in oil emulsions for thin film coating. *Journal of Food Engineering*, *119*(4), 776–780. doi:10.1016/j.jfoodeng.2013.05.027

Kulon, J., Malyan, B. E., & Balachandran, W. (2003). Simultaneous Measurement of Particle Size and Electrostatic Charge Distribution in DC Electric Field Using Phase Doppler Anemometry. *IEEE Transactions on Industry Applications*, *39*(5), 1522–1528. doi:10.1109/TIA.2003.816460

Laryea, G. N., & No, S. Y. (2003). Development of electrostatic pressure-swirl nozzle for agricultural applications. *Journal of Electrostatics*, *57*(2), 129–142. doi:10.1016/S0304-3886(02)00122-5

Laryea, G. N., & No, S. Y. (2004). Spray angle and breakup length of Charge-injected electrostatic pressure swirl nozzle. *Journal of Electrostatics*, *60*(1), 37–47. doi:10.1016/j.elstat.2003.11.001

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Law, S. E. (1978). Embedded-electrode electrostatic-induction spray charged nozzle: Theoretical and engineering design. *Transactions of the American Society of Agricultural Engineers*, *21*(6), 1096–1104. doi:10.13031/2013.35448

Law, S. E. (1983). Electrostatic pesticide spraying: Concepts and practice. *IEEE Transactions on Industry Applications*, *19*(2), 160–168. doi:10.1109/TIA.1983.4504176

Law, S. E. (1984). Physical properties determining chargeability of pesticide sprays. In H. B. Scher (Ed.), *Advances in Pesticide Formulation Technology* (pp. 219–230). Washington, D.C.: American Chemical Society. doi:10.1021/bk-1984-0254.ch017

Law, S. E. (1995). Electrostatic atomization and spraying. In J. S. Chang, A. J. Kelly, & J. M. Crowley (Eds.), *Handbook of Electrostatic Processes* (pp. 413–440). New York: Marcel Dekker Publishing.

Law, S. E. (2001). Agricultural electrostatic spray application: A review of significant research and development during the 20th century. *Journal of Electrostatics*, *51-52*, 25–42. doi:10.1016/S0304-3886(01)00040-7

Law, S. E., & Bowen, H. D. (1975). Theoretically predicted interactions of surface charge and evaporation on air-borne pesticide droplets. *Transactions of the American Society of Agricultural Engineers*, *18*(1), 35–39. doi:10.13031/2013.36519

Law, S. E., & Scherm, H. (2005). Electrostatic application of a plant-disease biocontrol agent for prevention of fungal infection through the stigmatic surfaces of blueberry flowers. *Journal of Electrostatics*, *63*(5), 399–408. doi:10.1016/j.elstat.2004.11.008

Lyons, S. M., Harrison, M. A., & Law S. E. (2011). Electrostatic application of antimicrobial sprays to sanitize food handling and processing surfaces for enhanced food safety. *Journal of Physics Conference Series,* 301(1).

Mamidi, V. R., Ghanshyam, C., Manoj Kumar, P., & Kapur, P. (2013). Electrostatic hand pressure Knapsack spray system with enhanced performance for small scale forms. *Journal of Electrostatics*, *71*(4), 785–790. doi:10.1016/j.elstat.2013.01.011

Mamidi, V. R., Ghanshyam, C., Patel, M. K., & Kapur, P. (2012). Electrostatic Hand Pressure Swirl Nozzle for Small Crop Growers. *International Journal of Applied Science and Technology Research Excellence*, *2*(2), 164–168.

Maski, D., & Durairaj, D. (2010). Effects of electrode voltage, liquid flow rate, and liquid properties on spray chargeability of an air-assisted electrostatic-induction spray-charging system. *Journal of Electrostatics*, *68*(2), 152–158. doi:10.1016/j.elstat.2009.12.001

Mazumder, M. K., Simsa, R. A., Birisa, A. S., Srirama, P. K., Saini, D., Yurteri, C. U., & ... (2006). Twenty-first century research needs in electrostatic processes applied to industry and medicine. *Chemical Engineering Science*, *61*(7), 2192–2211. doi:10.1016/j.ces.2005.05.002

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Patel, M. K., Ghanshyam, C., & Kapur, P. (2013). Characterization of electrode material for electrostatic spray charging: Theoretical and engineering practices. *Journal of Electrostatics*, *71*(1), 85–90. doi:10.1016/j.elstat.2012.11.019

Patel, M. K., Ghanshyam, C., Mamidi, V. R., & Kapur, P. (2012a). Selection of electrode material for spray charging in electrostatic nozzle. *Journal of Instrument Society, India*, *42*(4), 272–275.

Patel, M. K., Ghanshyam, C., Mamidi, V. R., & Kapur, P. (2012b). Performance and Characterization of Different Material Electrodes in Electrostatic Pesticide Spraying Nozzle System. *International Journal of Applied Science and Technology Research Excellence*, *2*(2), 158–163.

Robson, S. S., Mauri, M. T., Haroldo, C. F., Paulo Marcos de Barros, M., & Denílson, E. R. (2013). Parameters of electrostatic spraying and its influence on the application efficiency. *Revista Ceres*, *60*(4), 474–479. doi:10.1590/S0034-737X2013000400005

Ru, Y., Zheng, J. Q., & Zhou, H. P. (2005). Research and Outlook on air assisted electrostatic spraying technique for prevention and control of forest pest. *World Forest Research*, *18*(3), 38–42.

Ru, Y., Zheng, J. Q., & Zhou, H. P. (2007a). Design and experiment of double-nozzle of aerial electrostatic sprayer. *Transactions of Chinese Society of Agricultural Machinery*, *38*, 58–61.

Ru, Y., Zheng, J. Q., & Zhou, H. P. (2007b). Theoretical Studying On Improve Corona Charging Effect of Droplet. *Journal of Agricultural Mechanization Research*, *149*(9), 38–40.

Ru, Y., Zheng, J. Q., & Zhou, H. P. (2007c). Design and test study on double acicular electrostatic device of High-range Electrostatic Sprayer. *Journal of Nanjing Forestry University*, *31*(6), 87–90.

Sayinci, B., & Bastaban, S. (2011). Spray distribution uniformity of different types of nozzles and its spray deposition in potato plant. *African Journal of Agriculture Research*, *6*(2), 352–362.

Shrimpton, J. S. (2005). Dielectric charged drop break up at sub Rayleigh limit conditions. *IEEE Transactions on Dielectrics and Electrical Insulation*, *12*(3), 573–578. doi:10.1109/TDEI.2005.1453462

Stark, J., Zhang, J., Sharma, R., & Mazumder, M. K. (2008). Mathematical Simulation Study of Digital Signal Processing of the ESPART Analyzer for the Nanoparticle Size Range. *Particles and Modeling Techniques*, 1-4.

Sumner, H. R., Herzog, G. A., Sumner, P. E., Bader, M., & Mullinix, B. G. (2000). Chemical Application Equipment for Improved Deposition in Cotton. *The Journal of Cotton Science*, *4*, 19–27.

Toljic, N., Adamiak, K., & Castle, G. S. P. (2008). Determination of Particle Charge to Mass Ratio Distribution in Electrostatic Applications: A Brief Review. *Proceedings of ESA Annual Meeting Electrostatic Minneapolis*. Minnesota. Society Publications.

van de Zande, J. C. V., Huijsmans, J. F. M., Porskamp, H. A. J., Michielsen, J. M. G. P., Stallinga, H., Holterman, H. J., & de Jong, A. (2008). Spray techniques: How to optimise spray deposition and minimise spray drift. *The Environmentalist*, *28*(1), 9–17. doi:10.100710669-007-9036-5

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Xiongkui, H., Aijun, Z., Yajia, L., & Jianli, S. (2011). Precision orchard sprayer based on automatically infrared target detecting and electrostatic spraying techniques. *International Journal of Agriculture and Biological Engineering*, *4*(1), 35–40.

Ye, Q., & Domnick, J. (2003). On the simulation of space charge in electrostatic powder coating with a corona spray gun. *Powder Technology*, *135-136*, 250–260. doi:10.1016/j.powtec.2003.08.019

Zhang, J., Srirama, P. K., & Mazumder, M. K. (2007). ESPART Analyzer for Mars Mission: A New Approach in Signal Processing and Sampling. *IEEE Transactions on Industry Applications*, *43*(4), 1084–1090. doi:10.1109/TIA.2007.900475

Zhang, X., Kobayashi, I., Uemura, K., & Nakajima, M. (2013). Direct observation and characterization of the generation of organic solvent droplets with and without triglyceride oil by electrospraying. *Colloids and Surfaces. A, Physicochemical and Engineering Aspects*, *436*, 937–943. doi:10.1016/j.colsurfa.2013.07.032

Zhou, H., Ru, Y., Shu, C., Zheng, J., & Zhu, H. (2008). Design and experiments of aerial electrostatic spraying system assembled in helicopter.

Zhu, H., Salyani, M., & Fox, R. D. (2011). A portable scanning system for evaluation of spray deposition distribution. *Computers and Electronics in Agriculture*, *76*(1), 38–43. doi:10.1016/j.compag.2011.01.003

ADDITIONAL READING

Agoramoorthy, G. (2008). Can India meet the increasing food demand by 2020? *Futures*, *40*(5), 503–506. doi:10.1016/j.futures.2007.10.008

Ahluwalia, M. S. (2011). Prospects and Policy Challenges in the Twelfth Plan. *Economic and Political Weekly of India–XLVI*, *46*(21), 88–105.

Ahmad, K., Scott, S. H. T., & Esmaeil, E. (2014). Electric field induced sheeting and breakup of dielectric liquid jets. *Physics of Fluids*, *26*, 1–14.

Balachandran, W., Hu, D., Yule, A. J., Shrimpton, J. S., & Watkins, A. P. (1997). Electro-statically produced fuel sprays for combustion applications. *Fuel and Energy Abstracts*, *38*(6), 421–422. doi:10.1016/S0140-6701(97)82143-1

Cobine, J. D. (1958). *Gaseous Conductors: Theory and Engineering Applications*. New York: Dover Publications.

Ezhilarasi, P. N., Karthik, P., Chhanwal, N., & Anandharamakrishnan, C. (2013). Nanoencapsulation techniques for food bioactive components: A review. *Food and Bioprocess Technology*, *6*(3), 628–647. doi:10.100711947-012-0944-0

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Ghanshaym, C., Bagchi, S., & Kapur, P. (2013). Optimization of spray parameters in the fabrication of SnO_2 layers using electrostatic assisted deposition technique. *Journal of Electrostatics*, *71*(1), 68–76. doi:10.1016/j.elstat.2012.10.001

Hoffmann, W. S., & Hewitt, A. J. (2005). Comparison of three imaging systems for water sensitive papers. *Applied Engineering in Agriculture*, *21*(6), 961–964. doi:10.13031/2013.20026

Huang, Y., & Tomson, S. J. (2012). Characterization of spray deposition and drift from a low drift nozzle for aerial applications at different application altitudes. *International Journal of Agriculture and Biological Engineering*, *4*(4), 28–33.

Jackson, J. D. (1998). *Classical Electrodynamics*. USA: Hamilton Press.

Kacprzyk, R., & Lewandowski, M. (2011). Post-dispersion electrification of droplets in a system with pneumatic atomization. *Journal of Physics Conference Series,* 301(1).

Kourmatzis, A., Allen, J., & Shrimpton, J. S. (2010). Electrical and spray characteristics of a multiorifice charge-injection atomizer for electrically insulating liquids. *Atomization and Sprays*, *20*(4), 269–280. doi:10.1615/AtomizSpr.v20.i4.10

Krupa, A., Jaworek, A., Sobczyk, A. T., Marchewicz, A., Szudyga, M., & Antes, T. (2013). Charged spray generation for gas cleaning applications. *Journal of Electrostatics*, *71*(3), 260–264. doi:10.1016/j.elstat.2012.11.022

Milind, S. R., Jograj, A., & Manglik, M. (2012). Liquid Jet Breakup at Low Weber Number: A Survey. *International Journal of Engineering Research and Technology*, *6*, 727–732.

Ministry of Agriculture. (2006). Quantity of pesticides imported according to their kind during the period 1984-2007. Department of Extension and Agriculture Service, Ministry of Agriculture, Saudi Arabia.

Moore, A. D. (1973). *Electrostatics and Its Applications*. New York: John Wiley & Sons Inc.

Pascuzzi, S., & Cerruto, F. (2015). Spray deposition in “tendone” vineyards when using a pneumatic electrostatic sprayer. *Crop Protection (Guildford, Surrey)*, *68*, 1–11. doi:10.1016/j.cropro.2014.11.006

Ratya, A., Nur, B., & Budi, S. (2013). Effect of marketing efficiency improvement in Indonesia. *Russian Journal of Agricultural and Socio-Economic Sciences*, *19*, 13–21.

Sasaki, R. S., Teixeira, M. M., Fernandes, H. C., Monteiro, P. M., Rodrigues, D. E., & Alvarenga, C. B. (2013). Parameters of electrostatic spraying and its influence on the application efficiency. *Revista Ceres*, *60*(4), 474–479. doi:10.1590/S0034-737X2013000400005

Stern, R. W. (2003). *Changing India*. United Kingdom: Cambridge University Press. doi:10.1017/CBO9780511803239

Zhu, K., Ng, W. K., Shen, S., Tan, R. B. H., & Heng, P. W. S. (2008). Design of a device for simultaneous particle size and electrostatic charge measurement of Inhalation drugs. *Pharmaceutical Research*, *25*(11), 2488–2496. doi:10.100711095-008-9660-x PMID:18592352

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KEY TERMS AND DEFINITIONS

Bio-Efficacy: In agrochemical, bio-efficacy is a measure of the biological efficacy of an active ingredients of agrochemicals such as insecticide etc. Bio-efficacy of an insecticide is determined by the minimum dose required for maximum control of the disease. For an agrochemical, the bio-efficacy of an insecticide is determined by the minimum dose required for complete kill of the insects or diseases.

Charge to Mass Ratio: Experimentally the performance of the air-assisted electrostatic nozzle can be evaluated in terms of charge to mass ratio, which signifies the chargeability of the spray droplets by the charging electrode. It also signifies the efficiency and performance of the spraying system, higher the charge to mass ratio, better the performance. Charge to mass ratio depends on electrical and mechanical properties of the liquid as well as material of the charging electrode.

Electrode Material: The amount of charge present in the fine droplet depends on many parameters, the one is electrode material. Appropriate and suitable electrode material and its dimensional specifications may enhance the chargeability of finely divided particulate matter. Selection of electrode material for spray charging is as much important as other parameters such as electrical and mechanical properties of liquid to be sprayed. So far, most frequently used materials for electrode in electrostatic nozzle systems are nickel, copper, stainless steel and brass.

ESPART Analyzer: Electronic Single Particle Relaxation Time (ESPART) analyzer is an instrument which is used in many applications to determine both size and charge of micrometer sized particles in electrostatic spraying processes. ESPART analyzer consists of two major units: Laser Doppler Velocimeter (LDV) and particle relaxation apparatus which measures the velocity of a particle and aerodynamic diameter passing through the intersection of two coherent light sources, such as lasers and the signal processing unit, a simulation model for the ESPART analyzer to measure the time lag. The ESPART analyzer can measure the statistical distribution of particle size and charge in electrostatic spraying processes.

Faraday Cage: Faraday cage, a specially designed wire mess like structure which is called a cage, commonly used to collect the charged droplets coming out from the spraying system. The contact of the charge droplets onto the wire meshes of Faraday cage and transfer of the charge to the earth caused an electrical current which is detected by a microampere meter, the charged liquid spray is then collected at a specific time and weight. Then the spray current is divided by the mass flow rate to determine the charge to mass ratio.

Induction Charging: Induction charging is the most commonly used method to charge the finely divided particulate matter in electrostatic spraying processes. In electrostatic induction charging, direct charge-transfer to droplet formation zone of a liquid jet results from electrostatic induction of electrons on to the continuous jet and in order to maintain it at ground potential the presence of a closely positioned electrode of positive polarity is required. Induction electrification process reduces the chances of shock and hazardous to operators of the nozzle system.

In-Flight Trajectory: The path followed by the charged particulate matter in the presence of many forces including electrostatic force is called in-flight trajectory. Once the droplets have been charged inductively, the charged spray-cloud has to travel in a harsh and transient environment, and thus, a charged spray-cloud will encounter some degree of neutralization. The charged droplets are governed by many forces such as gravitational force, force due to surface tension, electrostatic forces, drag force etc.

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Rayleigh Limit of Charge: A drop can hold a maximum charge, defined by the Rayleigh limit, or a limit defined by electrical breakdown strength. The maximum limits of charge that can charge mother droplet carry without rupture into the daughter droplets.

Volume Median Diameter: It also refers to average volumetric size or mean size. The Volume Median Diameter (VMD) refers to the midpoint droplet size, where half of the volume of spray is in droplets smaller, and half of the volume is in droplets larger than the mean. For example, A VMD ($DV_{0.5}$) of 50μm, indicates that half of the volume is in droplet sizes smaller than 50μm, and half the volume is in droplet sizes larger than 50μm.

Wraparound Effect: In electrostatic spraying, the pesticide deposits uniformly onto both directly exposed or obscured crop surfaces. The deposition of pesticide onto the backside of the crop surface is called wraparound effect. The wraparound effect occurs due to electrostatic phenomena takes place during the spraying.

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Chapter 6
Aggressions of the Socio-Economic System on the Natural Capital

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ABSTRACT

Nearly 250 million years ago, the Earth was shaken by the amplest extinction known so far, which led to the extinction of up to 96% of all the marine species, 70% of the vertebrate species, and almost all the insects. This extinction affected the whole range of biodiversity so much. Nature took almost 10 million years to recover after this event. Life was really in danger on our planet at that moment, due to the dismal conditions that were created, and the current research shows that these dire conditions continued to occur, in the natural environment, after that, triggering numerous outbreaks that occurred for five to six million years following the initial crisis, triggered by the carbon rise and the repeated shortages of oxygen, the increased warming and other such adverse effects, which, once initiated, were uncontrollable and had disastrous effects. When life returned to normal and, gradually, after several million years, a new beginning was possible, the significant elements that caused the disaster - global warming, acid rain - sound strangely familiar to us today.

MAN'S BELONGING TO NATURE

In time, for a very long period, nature in general, but especially forests, have been considered empty areas, some even hostile, which could become valuable only when the trees were turned into timber and/or the land freed (evidently, deforested) acquired a deforested land, acquired an agricultural use, or settlements or infrastructure elements were built on it.

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Human perception and attitude to nature and its components is a key element for understanding the relations between nature, mankind and culture. This perception, aware or not, guides the attitude, the actions and the ecological footprint of different individuals, groups or cultures, on the environment in general and especially on nature. Yet, at the same time, this perception has consequences on man himself, directly influencing his mental and physical health.

Unfortunately, often science and, on these grounds, also education, tend to intellectualize, in the sense of complicating, the feeling of nature and implicitly man's relation to nature.

The genetic information related to man's ancestral belonging to nature comes back intuitively or culturally and produces feelings, often contradictory ones, in the relations between man and nature and even in relation to human naturalness.

In is almost unanimously acknowledged that the increase of the human population, accompanied by the growth of the needs for goods and services of the members of the different communities are the main drives of the human society's development, which determined the diversification, the improvement and the increased capacity of the means and technologies of access and use of the resources and services provided by the natural systems.

The concept of structural unity between biocenosis and the physical and chemical components of the area it occupies anticipated and actually substantiated the concept of "organization" in a given space, which is much more comprehensive and constitutes the backbone of the ecology theory. In this way, it has been possible to integrate the study of the populations in the study of the ecosystems - basic productive units.

The research carried out on the energetics of the ecosystems and, implicitly, on the energetics of the natural populations, highlighted the need to research the circulation of the mineral elements and, first of all, of carbon, nitrogen and phosphorus, to be able to explain the primary output dynamics.

From this new perspective, the bioindividuals, the populations or the species, interconnected in biocenoses, and also the structural entities resulting from their interaction with the abiotic environment, become integrated units, functioning based on cybernetic principles and self-regulable (Popescu C., 2008).

PRODUCTIVE CAPACITY AND CARRYING CAPACITY

This conceptual progress permitted to investigate and know the productive and carrying capacity of ecosystems or ecosystems complexes. Errors have also been committed, like those of the period 1960-1985, when, without a sufficiently consolidated basis, a series of sub disciplines were differentiated, such as: ecophysiology, ecotoxicology, biochemical ecology, biophysical ecology, agroecology, urban ecology, human ecology etc., which, operating each with many, often conflicting concepts, created confusions, undermining the coherence and credibility of ecology as a science.

During the same period, the theoretical basis of ecology was consolidated and completed with dynamic systems mathematics, attaining during the last two decennia of the 20th century the systemic conception that gave ecology the force and means necessary to perceive and interpret the physical and biological environment as a hierarchy of complex ecosystems, dynamically influencing one another. At the same time, the passage from the analythical method to systemic analysis allows identifying ecological systems as real entities and identifying, at the same time, ways of investigating them and of describing their behavior.

Systemic analysis supposes an integrated holistic approach both in the research and especially in the management of natural ecological systems and of those dominated by the human species.

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During the present stage, after the conceptual clarification of ecology as science of the ecological systems, an ample process of identification of the ecosystems organized in hierarchies, from simple to complex, also comprising anthropized systems, has been started, to be able to project and then develop support information systems and especially organize their integrated management.

This is how for us, forest administration people, understanding climate change as a direct effect of deforestation was unfortunately the first practical evidence of the accuracy of the systemic approach (Popescu C., 2008).

The many conflictual states created in the world in relation to the forests are caused by the fact that, unfortunately, people have understood too late that when forests vanish they do not lose only wood but first of all the effects of their first functions.

The very ample studies of the American researchers coordinated by professor Robert Constantza (University Professor of Sustainability in the Institute for Sustainable Solutions at Portland State University, 1997) demonstrate that the environmental services of the world's natural ecosystems go even over the world GDP and, under these conditions, during the last 200 years, about 3 billion hectares of forests have disappeared, namely almost half of the forests covering back then the Earth's land.

The increasing conflicts related to forests and forest lands and highlighting their implications on the political and managerial decision is part of the new arena delineated by the complex interaction between public processes and phenomena and between them and local ones, which are getting more numerous and call for solutions.

The topicality of the subject is also accentuated by the fact that, increasingly more, the relations citizen-administration will be defined by new directions and implications related to natural resource management, and only the integrated approach will be the one able to solve them competitively (Constantza, R., 1997).

The great ecological accidents, as well as the ecological crisis we are going through, are first of all due to the anthropocentric economic conception according to which plants, animals, forests, waters and ecological systems in general are important only to the extent to which they are the object of the interests of human communities.

The deeply negative effect of such an approach is that very few restrictions have been imposed on the way people deal with the environment in general and especially with forests. Practically, since times out of mind, and apparently even today here and there, in their relation with nature, the only limit of those people mastered by the desire of overexploitation of the natural resources has been only the result of their interplay with the interests of other individuals.

This is why the next step in the direction of a deeper approach was considered as "huge"; it is a step by which ethics has been extended to the analysis of all the areas and not just of those dominated by man. This is how the concept of "Earth ethics" was launched by the American forester and ecologist Aldo Leopold even since the middle of the 20th century.

Leopold's principles are today acknowledged by an increasing number of specialists in the theory of ecology and not just by them, as these principles have introduced new values:

- Nature and the environment have an intrinsic value, just as any value put in the service of man, or even in opposition to this
- Not just people and the projects put in their service carry value
- Something is correct when it tends to preserve the integrity, stability and beauty of the biotic community, and incorrect if, on the contrary, it has a different orientation

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- Earth ethics simply extends the boundaries of the community, also including the soils, the water, the plants and the animals from all over the Earth
- The ethical community is therefore extended so that it overlaps the ecological community.

Starting from these concepts, the Norwegian Arnei Naess issued in 1978 the postulate according to which mankind is inseparable from nature. In other words, nature as a whole has moral value—not the human individuals or other living organisms, taken separately.

The conclusion of such an approach is that the environmental issues will be solvable only by those able to emit judgements of value, beyond the narrow limits of human interests.

GOODS AND SERVICE PRODUCTION

Continuing this logic, today, is unanimously accepted the thesis according to which "the goods and services production increase, in order to answer, on the one hand, the basic needs of the population, and, on the other hand, the increasing "desires" manifested in the developed countries have always been assured based on the absorption of matter and energy resources or services, assured by primary producers. In other words, it is admitted that the socio-economic system is strictly dependent on the energy performances of the natural and seminatural ecological systems.

Primary producers – the populations or species of plants and photosynthesizing and chemosynthesizing bacteria, concentrating solar energy and chemical energy, produce biomass that, after the decrease of their own consumption of energy, constitute an energy source for the heterotrophic species that are part of the structure of a biocenosis or human population.

Here, in Table 1, we see the gross primary production of the main ecological systems on our planet (Popescu C., 2008; Vădineanu, A. 1998).

Table 1. Gross primary production of the main ecological systems

Categories of Ecological Systems	Area ($10^6 km^2$)	PPB kcal/m^2/year	% of ecosphere PPB
Planetary ocean (depths > 200 m)	326	800	30
Desert and tundra	40		
Coastlines (altitude < 200 m)	34	4000	32
Grazing fields	42		
Coniferous forests	10		
Temperate forests	10		
Waters and wet temperate forests	5		
Traditionally managed agrosystems	10		
Estuaries, deltas, reefs	2	18000	38

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Therefore, natural and seminatural ecological systems produce biological resouces (concentrated energy) and recycle the raw matter needed by the biological production, using solar energy. The processes by which goods (renewable resources) and also services (water quality, soil formation and protection, carbon absorption and climate control etc.) are produced are relatively costly in point of energy, yet, solar energy, which is free, is the source covering these expenses. Consequently, it results that natural and seminatural ecological systems are the most efficient dissipative structures.

Dissipative structures accumulate, concentrate, transform and dissipate energy, the result being an increasingly complex organization, namely they behave antienthropically, and their main outcomes are the production of renewable resources and services.

It is precisely the increase of the organization degree and the productive capacity that are assured by the specific of biological systems, which are part and parcel of the ecological systems. It results, therefore, that natural and seminatural ecological systems are the only productive units and carrying units for life on the planet.

Unlike in them, in the systems transformed and controlled by man (agrosystems, farms, intensive aquaculture etc.), energy expenses are realized from considerable subsidies obtained by burning energy stocks concentrated in fossil fuels, constituted in time, via long geological processes.

The systems created by human populations (urban systems, industrial complexes), as energy are parasite systems, depending on the concentrated energy and raw matter stocked in natural systems.

Recycling raw matter needed by primary producers to absorb and concentrate solar energy in organic matter by photosynthesis, or chemosynthesis, is the most important ecological process on earth.

The recycling compartment, represented by the trophic structure of the biological systems, taken as parts of the ecological systems (beginning with biocenoses and ending with the biosphere) is closely interconnected with the elements of the hydrogeomorphological units (soil, lithosphere, water) forming the toposphere. In their turn, these components are interconnected by physical-chemical mechanisms and phenomena and constitute the support of the local, regional and global biogeochemical circuits.

The productivity of any ecological system depends on both the stock of macro and microelements available in the mass of water and sediments of acquatic systems, or in the soil and water of terrestrial systems, and on recycling speed of the respective stock by the ecological systems' biological elements.

Under these circumstances, the ecological systems availing themselves of relatively small stocks of macro and microelements, especially nitrogen and phosphorus, but having a very dynamic recycling system, realize great productivities of goods and services.

Such are the forests, the most productive biocenoses of our planet, which beside profitably using the lands that are poorest in micro and macroelements, often totally impossible to be used for other uses, provide fundamentally important services for the key components of the ecosphere, such as: lithosphere, hydrosphere or troposphere, namely they become carrying units of life.

It has been demonstrated in this way that the deterioration of the vegetal layer by deforestations and overgrazing, along with draining, damming, channaling, soil compaction through intensive agriculture have modified the amplest essential phenomenon on the planet: the water circuit in nature.

The development of the socio-economic system has been and will be dependent on the hydrological circuit, but it is regrettable that it is precisely many human activities that have significantly affected the key mechanisms of this circuit.

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EVALUATION OF THE RISK DETERMINED BY CLIMATE CHANGES

On Risk and Uncertainty

The consequences of most human activities are almost unforeseeable, because we often do not know the nature of these consequences. Here we have in view the extreme case of uncertainty regarding future events. As our knowledge improves we can express our uncertainty by the probability of occurrence of such consequences, namely we can transform our uncertainty into risk. Consequently, risk can be defined as measurable uncertainty.

Many ecological processes are, however, insufficiently understood so far, so that one cannot precisely foresee the impact of the economic activities on them and implicitly on the environmental components. One can understand and foresee the type of potential impact, but not its amplitude or the moment when it is going to occur. Particularly difficult is the anticipation of the possible impact of an event triggering a chain reaction. Irreversible effects, such as the disappearance of a species, damages on the ozone layer or landscape changes have become main concerns for the ecologists.

In order to face uncertainty, one can act in several ways:

- Stimulating investments in information
- Presenting eventual consequences and their probabilities of occurrence (evaluating risk)
- Carrying out analyses on the perceptions and preferences of the decision-maker and/or the public concerning the risk (the perception of risk and subjective preferences)
- Determining the rules regarding decision-making and investment strategies

Risk evaluation is the process by which uncertainty is turned into risk and answers questions such as:

- "How risky is the situation?"
- "What are the risks associated to the different ecological problems?"

Complementarily, risk management answers questions such as:

- "What should be done in this situation?"
- "What solutions can be found to reduce the risks associated to the various ecological problems?"

The aim of risk evaluation consists in analyzing and hierarchizing the risk levels associated to some ecological problems, based on the best information and scientific judgements available.

Ecological problems can represent a risk both for people, and for the ecosystems; they can also lead to the degradation of the quality of life. Each risk category is important and must be analyzed separately. For example, the heating of the atmosphere induces the heating of the waters, which has a negative impact not just on the biocenoses of the ecosystems, but also determines a loss of some recreational opportunities of the communities (diminishing the quality of life). For this reason, it is important to look at the ecological problems from all the perspectives: of the risks for human health, for the ecosystems, and for the quality of life.

Comparative Risk Evaluation (CRE) is also a useful tool for hierarchizing the priority actions in environmental protection. For this reason, the solving of the global environmental problems, such as

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climate changes or irreversible biodiversity loss, has to be approached, if not simultaneously, at least according to the order of their priority.

CLIMATE CHANGE

Indices of the Impact of Climate Changes

The average air temperature worldwide has risen by 0.3-0.6o C since the end of the 19th century. In the year 1997 (the hottest year), the average temperature was 0.43 degrees higher than the average recorded during the period 1961-1990. Europe has been confirmed as matching the global trend, the 1990s being the hottest years. According to the estimates, the average temperatures of the year 2010 will be two degrees Celsius higher than those of the 1990s. At the same time, in Europe, it is estimated that the warming is going to be more significant in the northern than in the southern areas (Allan, D., 1994).

Global warming has been dilating the seas and oceans and accelerating the melting of the icecap. All these have led to an increase of the seas and oceans' level of 10-25 cm during the last 100 years. The estimates indicate the fact that in the year 2020, the sea level will be 50 cm higher than the level of the 1990s (with a variation ranging between 15 and 95 cm), the uncertainty degree being increased by the lack of knowledge regarding the contribution of the polar ice.

The increasing sea level can have consequences such as:

- Flooding and dislocating the marshy or low lands
- Increasing salinity in estuaries
- Deteriorating the potable water sources

From this perspective, the riskiest areas are deltas, beaches, islands and estuaries. In Europe, they include the coastlines of the Netherlands, Germany, the Balkan States, Ukraine, Russia and some Mediterranean deltas.

Coastal areas can also be affected in other ways than just by the rising of the sea level. For example, in the Netherlands, a 10% storm intensity rise, accompanied by changes in the wind direction, could bring more damage than a 60 cm sea level rise.

The cost of the adaptation and protection against a one-meter sea level rise has been estimated to US$12,300 million for the Netherlands, US$1,400 million for Poland and US$23,500 million for Germany.

Precipitations

In the Europe of the 20th century, the precipitations regime has been changing continually. Thus, precipitation quantities have grown, in general, in the Northern half of Europe and have decreased in its Southern half.

While in Northern Scandinavia, precipitations have increased by 5%, the southern parts of Italy and Greece have recorded, since the year 1900 till now, a decrease of about 5%.

All the attempts of modelling the climate modifications forecast an increase in the average annual precipitations; at the same time, global warming influences soil humidity, by accentuating water evaporation. The modelling of these processes suggests the fact that, in Europe, soil humidity is going to decrease.

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Hydrology and Water Resources

Even since the middle of the 19th century, the glaciers of the Alps have begun to "withdraw" (it is estimated that during the next hundred years, global warming will melt up to 95% of the glaciers of the Alps), which will influence the seasonal pattern of the river courses (Constantza, R., 1996). During the last decennia, their volume increased in Northern Europe, which agrees with the precipitations growth observed.

The climate change will probably accentuate the "hydrological stress" of some already sensitive European areas: the Mediterranean region, the Alps, Northern Scandinavia, the coastlines and central and Eastern Europe. The consequences of the hydrological cycle changes are hard to estimate; they include a possible increase in the frequency and intensity of flooding and a possible water quality decrease, by the infiltration of salty water in the underground water of the coastal areas.

Agriculture and Forest Ecosystems

The ecosystems' reaction to the changes of temperature, precipitations and soil humidity and of other factors that change along with the climate is hard to forecast.

The main impact on the species will be concretized in the modification of their geographic distribution. A one-degree Celsius rise of the annual average temperature is equivalent to a shift northwards of 200-300 km or in altitude of 150-200 m. A two-degree Celsius temperature rise in 50 years in Europe would lead to a shift of the climate zones northwards at a faster pace than the migration ability of most plant species. Moreover, in the alpine areas, the plants' location will be forced upwards, yet there may be no room available for their migration. Besides, the possibilities of migration in many parts of Europe are limited due to the intensity of the land use.

Climate change can have various effects on agriculture and forestry, namely on the plants' periods of growth and productivity. The growing variability of the climate can endanger certain crops due to the occurrence of late frosts. Some studies and especially simulation and modelling have shown that climate changes can trigger richer crops in large areas of Europe (Leopold, A., 1949).

CLIMATE CHANGE REASONS. MAIN GREENHOUSE GASES: EMISSION SOURCES, CONCENTRATIONS

Carbon Dioxide

The greatest anthropic source of CO2 is the burning of fossil fuels for the production of electricity, heat, in transports and industry. The natural ecosystems emit and absorb, by photosynthesis and respiration, large quantities of CO2.

In time, these processes have been balanced and have not given rise to extra emissions on either side. Human activities and the socio-economic system in general have disturbed, however, these balances, when they generated and as they continue to generate important supplementary net emissions. For example, by the destruction of the forests, carbon is freed, and this evil could be remedied, generating a significantly higher net absorptions, for example if deforested areas were reforested or if forests were allowed to reach greater ages and sizes.

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On a global level, the main CO2 sources are fossil fuel burning (77%), industrial processes such as cement production (2%) and modification of the land use (21%). In Europe, the contribution of these sources is slightly different: fossil fuel burning (98%), industrial processes (2%), while the land use can actually be a sponge absorbing 13% of the carbon dioxide emitted in Europe. At present, Europe generates 29% of the global carbon dioxide emissions.

CO2 emissions depend on the economic development degree of the different countries. Thus, the CO2 emissions level per GDP unit in the year 1994 shows that, excepting some parts of the former Yugoslavia and Albania, this indicator is considerably higher in Central and Eastern Europe (3.3 tons/US$) and in the new independent states (2.4 tons/US$), than in Western Europe. The numbers reflect the inefficient use of energy and the predominance of the heavy industry, consuming significant quantities of energy, in Eastern Europe.

Methane

The global anthropic emissions of methane total 375,000 tons/year, out of which 27% result from the use of fossil fuels. European emissions represent about 11% of this total. The main sources are: leaks from gas transport and distribution networks, coal extraction and agriculture - especially ruminants breeding and rice fields. Natural sources (e.g., marshes) contribute by about 20% to the global methane emissions.

Nitrogen Protoxide

The global anthropic emissions of N2O range between 3 and 8,000 tons/year. The existing uncertainties regarding the evaluation of these emissions results from the insufficient understanding of the processes involved and of their distribution around the globe. Worldwide, the greatest emissions are generated by the fertilization of the agricultural lands. In Central and Eastern Europe, N2O emissions in agriculture have decreased due to the reduction of the use of fertilizers; to a lesser extent, due to the restructuring process, the emissions coming from the industry have also recorded a decrease (the production of nitric acid and nylon).

Halogenated Gases

The emissions of halogenated gases, such as CFC, are rapidly decreasing due to their suppression according to the protocol of Montreal. Consequently, the emissions of replacing gases, especially HCFC and HFC, both greenhouse gases, have been growing. The data on these emissions are too limited to establish their evolution in time, yet their long-term remanence in the atmosphere and their high global warming potential, can increase their importance.

The contribution of greenhouse gases to global warming, and therefore their influence on the sea level, precipitations and ecosystems, depends on their concentration and period of remanence in the atmosphere and their efficiency in retaining radiations. For example, although CFCs are present in the atmosphere in very small concentrations, they are important because their period of remanence is around 100 years, and each molecule determines a greenhouse effect many times higher than one of CO2. To be able to compare the impact of various gases, the indicator called global warming potential relative to CO2 has been used, carbon dioxide being attributed the value one. The dimensions of this indicator depend on the time horizon considered. Examples of such values calculated for a period of 100 years are: 21 for CH4,

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310 for N2O and several hundred for halogenated compounds. The measurement units of these emissions, which take into account the values of the global warming potential are called equivalent (carbon).

Moreover, the tropospheric ozone can contribute to global warming, the estimates showing that they add 16% to the total effect caused by the anthropic greenhouse effect gases mentioned.

The aerosols, which can be emitted directly (primary aerosols), or formed in the atmosphere out of SO2, NO and NH (secondary aerosols), have a cooling effect, both directly, through the dispersion of the sunlight, and indirectly, by modifying the features of the clouds. The size of the cooling effect is not known for sure; it has been estimated that aerosols annihilate almost half of the warming triggered by greenhouse gases. However, unlike the main greenhouse gases, aerosols have a short period of remanence in the atmosphere. Their effect is therefore regional and short-term and appears especially over Europe, USA and China. As in Europe the level of SO2 and NO emissions is decreasing, the quantities of secondary aerosols generated are also decreasing, simultaneously to their cooling effect.

The great variations of the duration of remanence in the atmosphere of the various greenhouse gases shows a contribution in time to global warming that can vary from 20 to several thousand years. Consequently, there is a considerable temporal gap between the period when the emissions reduction takes place and the stabilization of their concentration in the atmosphere. Therefore, the actions undertaken today will need a long time to have some effect.

Global warming is not, however, the only effect that greenhouse gases can trigger. Thus, the actions meant to control the climate changes can have beneficial or negative side-effects on the environment:

- The reduction of CFC emissions meant to protect the stratospheric ozone also diminishes their greenhouse effect
- The decrease of the methane emissions meant to slow down the global warming phenomenon is concomitantly lowering the level of the tropospheric ozone
- The diminution of the SO2, NOX and NH3 emissions will reduce acidification

On the other hand, a side-effect will be the decreasing production of sulphate and nitrate aerosols, which have a regional cooling effect (Lester, R. Brown, et al., 1997).

OBJECTIVES AND POLICIES OF GREENHOUSE GASES REDUCTION

The Decision no. 406/2009/EC of the European Parliament and of the Council of 23 April 2009 regarding the effort of the Member States of reducing the greenhouse gas emissions so that they may respect the Community's commitments to reduce greenhouse gas emissions until 2020 is the central document regulating the position and the commitments of the EU States in relation to greenhouse gas emissions reduction.

The supreme objective of the UN Framework-Convention on Climate Change (UNFCCC), approved on behalf of the European Community by the Decision 94/69/EC of the Council JO L 33, 7.2.1994, p. 11, consists in the stabilization of greenhouse gas concentrations in the atmosphere at a level preventing any anthropogenic disturbance of the climate system (Popescu, C., 2011).

According to the opinion of the Community, expressed most recently especially by the European Council of March 2007, in order to be able to attain this objective, the global increase of the average annual temperature on the ground should not go over the preindustrial levels by more than 2°C, which

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means that the world greenhouse gases emissions ought to be reduced, until 2050, by at least 50% compared to the levels recorded in 1990.

The Community's greenhouse gas emissions, regulated by the present decision, ought to continue to be reduced annually after 2020, as part of the Community's efforts of contributing to this global emissions reduction goal.

The developed countries, including the EU Member States, ought to continue to constitute an example, committing to reduce, until 2020, their greenhouse gas emissions by up to 30% compared to the levels recorded in 1990. They ought to realize the same thing in order to attain the collective goal of emissions reduction of 60% to 80% until the year 2050, compared to the levels recorded in 1990.

All the economic sectors ought to contribute to the realization of this emissions reduction goal, including the international transport by sea and the aviation sector. The aviation sector contributes to these reductions by its inclusion in the EU' emission quota trading system (henceforth called "Community system"). If, until 31 December 2011, no international agreement including the emissions coming from the international transportation by sea among its reduction goals is approved by the Member States in the framework of the International Maritime Organization or by the Community in UNFCCC, the Commission ought to submit a proposition coming into force until 2013 and including these emissions in the frame of the Community's commitment of emissions reduction. Such a proposition ought to reduce any negative impact on the Community's competitiveness, while considering the eventual benefits for the environment.

At the same time, in order to attain this objective, the European Council of March 2007 reiterated the community objective of reduction by 30% compared to the levels of 1990 of the greenhouse gas emissions until 2020, as a contribution to the conclusion of a global and comprehensive agreement for the period following the year 2012, on condition that other developed countries should also commit to realizing comparable emissions reductions, while the developing countries with a more advanced economy ought to contribute adequately, according to the responsibilities and capacities of each of them.

The European Council of March 2007 highlighted, at the same time, the Community's pledge of transforming Europe in a highly energy-efficient economy, with low greenhouse gases emissions, and decided that, until the conclusion of a global and comprehensive agreement for the period following the year 2012 and without affecting its position in the international negotiations, the Community takes on this firm and independent commitment of realizing a reduction of at least 20% compared to 1990 of the greenhouse gas emissions until the year 2020.

An improved energy-efficiency is an essential element for the accomplishment by the Member States of the present decision's demands. In this context, the Commission ought to closely monitor the progresses recorded in order to attain the objective of energy consumption reduction by 20% until 2020 and propose further actions in case of insufficient progress.

Directive 2003/87/CE

The Directive 2003/87/CE of the European Parliament and of the Council of 13 October 2003, instituting a greenhouse gas emissions trading system in the Community (JO L 275, 25.10.2003, p. 32) has created a greenhouse gas emissions trading system in the Community, which regulates certain sectors of the economy (Allan, D., 1994).

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Paris 2015

The main objective of the conference is to sign a treaty by which all the participant countries will take on to reduce their polluting gas emissions. So far, the only document of this type was the Kyoto protocol, of 1997. Only a few industrialized countries have committed, however, to respect the provisions of this protocol. Meanwhile, these countries produce only 15% of the greenhouse gas emissions worldwide. Moreover, the Kyoto protocol expires in 2020.

Here are the main results of the final agreement of the Paris Climate Change Conference of December 2015:

- Limiting global warming to maximum 2 degrees Celsius compared to the average temperatures of the preindustrial epoch
- Checking all the commitments assumed by the signatory States every 5 years
- Financial help for developing countries, especially for those in the south, from the developed ones

The text of the agreement explicitly mentions a limitation of the global average temperature growth to up to maximum 2 degrees Celsius and a continuation of the efforts of lowering this increase limit down to maximum 1.5 degrees Celsius. The objective of 2 degrees Celsius, related to the preindustrial epoch, was established in 2009, in Copenhagen, and imposes a drastic reduction of the greenhouse gas emissions (GGE) and also energy saving measures and investments in renewable energies, as well as afforestation plans for large areas.

Numerous countries, especially Island States, which are the first threatened by the perspective of the rise of the planetary ocean, are in danger if average global temperatures rise by more than 1.5 degrees Celsius.

Out of the 195 States represented at the Conference of Paris, 186 announced measures meant to limit or reduce their greenhouse gas emissions until the horizon 2030. But even if these measures are respected perfectly, they would lead to an increase of the global average temperature of about 3 degrees Celsius.

To attain the objective of 2 degrees Celsius, the text proposes a peak of the greenhouse gas emissions as low as possible and the adoption, as fast as possible, of rapid pollution diminutions to attain a balance between the emissions resulted from anthropic activities and those that can be absorbed, a possible reference to the forests, but also to the new technologies meant to capture and store carbon dioxide.

One of the key provisions of the agreement refers to the constitution of a voluntary mechanism checking the respect of national commitments. Such a check-up will take place every 5 years and will "represent a continuation of the previous report". A first obligatory revision is to take place in 2025, after a collective action assessment foreseen for the year 2023. Meanwhile, a first discussion on the actions undertaken and the measures taken is foreseen for the year 2018.

The UN Climate Convention of 1992 introduced a strict distinction between the developed and the developing countries regarding the sharing of the obligations in this domain. Industrialized countries, such as the USA, want to fragment this clear separation line, and developing countries, such as India, refuse to accept the renunciation to this delineation in the name of their right to development and of the historical responsibility of the northern hemisphere for excessive pollution and climate changes.

Regarding the greenhouse gas emissions reduction, this "differentiation" remains active: the developed countries "need to be about to adopt objectives of polluting emissions reduction in absolute value",

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while developing countries "must continue to improve their efforts" in the fight against global warming, according to their national situation.

Another important provision is that of granting financial aid to the countries of the austral hemisphere. In 2009, the developed countries promised they would discharge 100 billion dollars a year, starting with 2020, for funding climate policies in developing countries. The latter asked for a progressive increase of this sum and a greater clarity concerning the means of implementation of this provision.

On the other hand, the developed countries do not wish to bear these costs on their own and ask for contributions from countries in full economic expansion, such as China, South Chorea and Singapore or from the countries with rich oir reserves. The formula proposed is: "developed countries ought to assure financial resources to help developing countries" adapt to the effects of climate change and take measures to reduce their greenhouse gas emissions (Constantza, R., 1997).

THE PREMISES OF A NEW ENDEAVOR

In Paris, the participants have tried to conclude a new global climate treaty, entering into force in 2020. The 2009 Climate Summit of Copenhagen failed in a similar attempt. Experts like Christophe Balls are, however, more optimistic regarding the summit of Paris.

"Political will is much greater than in Copenhagen", as the political leader of the NGO German watch declared for DW. "Second, negotiations are more advanced than in Copenhagen. Third: the real world evolutions are much better than before Copenhagen. Last year, for example, the polluting emissions caused by energy production no longer increased, even though there was a little economic progress worldwide."

All the economy sectors ought to contribute to attaining a 20% reduction of the greenhouse gas emissions, compared to 1990, until the year 2020, in a cost-efficient way. Consequently, the Member States ought to implement further policies and measures in their effort of limiting even more the greenhouse gas emissions from other sources than those regulated by the Directive 2003/87/EC.

Each Member State's effort ought to be established in relation to the level of the greenhouse gas emissions recorded in the year 2005 nationally, which are under the influence of the present decision; this level ought to be adjusted to exclude the emissions in the atmosphere of the installations that existed in 2005 and which were included in the community system for the period 2006-2012. The annual level of emissions allocated for the period 2013-2020 expressed in tons of carbon dioxide equivalent ought to be established based on analyzed and verified data.

The Member Sates' emissions reduction efforts ought to rely on the principle of solidarity between the Member States and on the need of a sustainable economic growth throughout the territory of the Community, considering the Member States' GDP per capita. The Member States recording, at present, a relatively low level of the GDP per capita and, consequently, important expectations regarding the increase of their GDP, ought to be authorized to increase their greenhouse gas emissions level in relation to 2005, but also to limit this growth so as to contribute to respecting the independent commitment of Community emissions reduction. The Member States recording, at present, a relatively high level of their GDP per capita ought to reduce their greenhouse gas emissions levels in relation to 2005.

To be able to continue to assure an equitable distribution of the Member States' efforts of contributing to the implementation of the Community's independent emissions reduction commitment, no Member State should be obliged to reduce its greenhouse gas emissions until 2020 by more than 20% compared to the levels recorded in 2005, nor should it be authorized to increase its greenhouse gas emissions until

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2020 by more than 20% over the levels of 2005. The greenhouse gas emissions reduction ought to be attained in the period 2013-2020. Each Member State ought to be authorized to transfer from the following year a volume of up to 5% of its annual level of emissions allocated. When a Member State's emissions are lower than its annual level of emissions allocated, the respective Member State ought to be authorized to transfer to the following year the emissions reduction supplement.

To balance the Member States' emissions reduction costs differences, which would offer a greater geographic flexibility and at the same time improve the general efficiency of the costs incurred by the total community commitment, any Member State ought to have the possibility to transfer to other Member States a part of its annual level of emissions allocated. The transparency of these transfers ought to be assured by the notification of the Commission and by the recording of each transfer in the registers of both Member States involved. The respective transfers can be realized by a procedure convenient for both parties, including by tender, by market intermediaries acting as agents, or by means of a bilateral agreement.

The European Union ought to record a significant reduction of its greenhouse gas emissions. The use of credits coming from project activities ought to be limited, in order to complete the internal actions. The Union renews its pledge to continually improve its Clean Development Mechanism (CDM) and will try to improve it via adequate international procedures. It is important for the credits coming from the project activities used by the Member States to represent real, supplementary and permanent, verifiable emissions reductions, to present net advantages for sustainable development and no significant negative impact on the social or environmental level. The Member States, at the same time, ought to report on the qualitative criteria they apply for the use of such credits.

To grant the Member States a certain flexibility in the accomplishment of their pledges, to promote the sustainable development of third countries, especially of developing countries, and to offer security to investors, the Community ought to continue to recognize a certain number of credits from greenhouse gas emissions reduction projects undertaken in third countries before the adoption of a future international agreement on climate change (henceforth called "the international climate change agreement"). The Member States ought to make sure that the national policies of acquisition of these credits facilitate an equitable geographic distribution of the projects, especially by the increase of the Certificate Reduction Emissions (CER) ratio bought from the Least Developed Countries (LDC) and from Small Island Developing States (SIDS) and the conclusion of an international climate change agreement.

Consequently, the Member States ought to use the greenhouse gas emissions reduction credits granted for reduction realized during the period 2008-2012 and resulting from types of projects eligible for use in the community system during the respective period. At the same time, the Member States should be able to use greenhouse gas emissions reduction credits for the reductions realized after the period 2008-2012, resulting from projects recorded in the period 2008-2012 and from types of projects eligible for use in the community system during the respective period.

In the least developed countries, a very small number of CDM projects have been implemented. Considering the support given by the Community to the equitable distribution of CDM projects, including by means of the Global Climate Change Alliance, established by the Communication of the Commission of 18 September 2007 entitled "Building a global climate change alliance between the European Union and poor developing countries most vulnerable to climate change", it would be good to guarantee the acceptance of the credits coming from projects launched after the period 2008-2012 in the least developed countries, for types of projects eligible to be used in the community system during the period

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2008-2012. Such an acceptance ought to continue until 2020 or until the date of the conclusion of an agreement with the Community, if this date comes earlier than 2020.

To assure a greater flexibility to the Member States and to promote the developing countries' sustainable development, the Member States ought to be able to use supplementary credits coming from projects based on agreements concluded by the Community with third countries. In the absence of an international climate change agreement, establishing the quantity attributed to the developed countries, Joint Implementation (JI) projects cannot continue after 2012. The greenhouse gas emissions reduction credits resulting from these projects could continue to be recognized, however, in the framework of agreements with third countries.

The Member States' continual capacity of using credits in the framework of CDM is important, contributing to the assurance of a market for the respective credits after 2012. In order to assure such a market and new greenhouse gas emissions reductions in the Community, encouraging, in this way, the realization of the community goals in the domain of energy from renewable sources, energy efficiency, safe energy provision, innovation and competitiveness, it is proposed to authorize an annual use, by the Member States, of the credits coming from greenhouse gas emissions reduction projects carried out in third countries, within the limit of a volume representing 3% of the greenhouse gas emissions of each Member State non-regulated by the Directive 2003/87/CE in the year 2005, or undertaken in other Member States, until the adoption of an international climate change agreement.

The Member States ought to be authorized to transfer the unused part of this volume to other Member States. Certain Member States recording a negative limit or a positive limit of maximum 5%, according to the present decision, should be authorized to use, beside the above-mentioned credits, supplementary credits of 1% of their emissions checked in 2005 coming from projects undertaken in LDC and in SIDS, under the reserve of their respect of any of the four conditions foreseen in the present decision.

The present decision should not affect more stringent national objectives. If, to accomplish a more stringent objective, the Member States limit the greenhouse gas emissions level regulated by the present decision more than the obligations assumed based on the present decision, the limits imposed by the present decision regarding the use of greenhouse gas emissions reduction credits should not apply to the supplementary emissions reductions realized in order to attain the national objective.

The United Nations' Green Climate Fund has raised for the moment only US$ 2.3 billion, out of which one billion promised on Tuesday by France", as the Secretary-General of the United Nations declared in the conclusion of the reunion. This sum is far from the objective proposed, of 10 billion dollars until the end of this year, to reach 100 billion per year beginning with 2020.

The United Nations' high official also announced that private banks have pledged to issue green bonds worth 20 billion dollars and the insurers intend to "double their green investments" by 2015, reaching 82 billion dollars.

The American president called, from the summit's pulpit, to the conclusion of an "ambitious" agreement at the Conference of Paris of the end of 2015, promising that the United States will take on their part of contribution in "the urgent and increasing climate change threat".

In his turn, the French president affirmed that France will contribute with a billion dollars to the Green Fund, created in 2009 to aid developing countries in their efforts of facing climate change. Germany had announced, even since July 2015 a contribution of a billion dollars.

The Chinese Vice Premier declared that his country – one of the greatest polluters, along with India and the United States – "will collaborate with other states for the edification of a better future". He reaf-

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firmed, however, that the industrialized countries need to "respect their obligation to support, by their finance and technology, the developing countries".

China and India sent to the New York summit lower rank representatives, casting a shadow over this reunion, exceptional by the number and diversity of its participants: 120 heads of state or government, over 200 companies and numerous NGOs.

The reactions to the announcements of financial support from some countries were prudent. Oxfam-France appreciates that the billion announced by the president Hollande "is a first timid step that risks being insufficient"' and "there are many details still in suspense". Greenpeace considers that the announcement is "an important signal of support to the most vulnerable countries", yet regrets the fact that "the details remain unclear". The organization also regrets that "the Obama administration continues to allow the industry to prospect and exploit coal, oil and gas on public land".

According to a survey made by Chicago Council for Global Affairs and published on Tuesday, half of the Americans interviewed appreciate that the government does not make enough efforts in relation to climate change.

The Secretary-General of the United Nations, Ban Ki-Moon, who asked the participants to the opening of the summit to "demonstrate leadership", received support from the actor Leonardo DiCaprio, who took the floor and said that "clean air and a liveable climate are inalienable human rights" and that investing in renewable energies is "a good economic policy". DiCaprio, called by the UN "messenger of peace" for the climate, recommended the heads of state or government "to answer the greatest challenge of our existence with courage and honesty".

THE OBJECTIVE OF GLOBAL TEMPERATURE INCREASE OF JUST 2 DEGREES CELSIUS

Even if a new treaty is signed, including new climate protection measures, it is very likely to miss the objective of limiting global warming until the end of the century to just 2 degrees Celsius over the level previous to industrialization, although the international community had adopted this objective at the Cancun Climate Summit of 2010.

The consequences of a global warming of maximum 2 degrees Celsius are considered still moderate and controllable. The physicist Anders Levermann from the Postdam Institute for Climate Impact Research warns: "With increasing warming, some physical systems or ecosystems may be at risk. If we continue as we have begun, until the end of the century, our global temperature will be 5 degrees Celsius higher. This means the loss of most alpine glaciers. The Arctic Sea Ice will also disappear. Corals, determining for the existence of 600 million people worldwide, will also die."

According to the UN calculations, even if all the pollution reduction measures discussed were applied, the planet will grow warmer by 2.7 degrees Celsius until the end of the present century.

NEED FOR IMPROVEMENTS

Some States are asking that the summit of Paris ought to give birth to a process of revision and improvement of the climate goals every five years. The German chief-negotiator Karsten Sach is expecting tough

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discussions on this topic. According to him, the EU would like the environment goals to begin to be reviewed already starting with 2020, while other countries, however, would like this process to begin later.

Controversial are also the regulations that ought to be adopted in this dynamic revision and improvement process. The head of German watch Bals draws the attention on the different calculation standards: "Some countries take into account the forests in their estimates; others do not." "The countries also have different factors regarding the polluting emissions for different fossil sources of energy."

EU negotiators are asking for more transparency on a global level, which bothers some, especially among the great emerging economies. "China and India are not the greatest friends of transparency and taking on responsibilities", says the speaker of the evangelical association "Brot für die Welt", Sabine Minninger.

NATURAL CAPITAL FROM THE PERSPECTIVE OF ECOLOGICAL ECONOMY

It has been demonstrated that what supports the sustainable development of the socio-economic system is the natural capital and biodiversity.

Practically, the natural capital of a country, region or of the planet, in general, is the network of ecological systems operating in a natural and semi natural regime and the anthropized systems, constructed through the transformation and simplification of the first two categories.

For this reason, renewable natural resources, including water and the soil, and non-renewable ones on the time scale at which the development assured by the natural capital elements is projected, are key factors of the economic system's production function and support of sustainable development.

Continuing this logic, the natural capital becomes part and parcel of the diversity of the ecological and biological systems and includes, beside the components operating in a natural regime, the human species, as part of the biosphere, together with their environment.

Therefore, natural capital has a certain productive capacity that has to be known by the economic activities' managers, in order to avoid overexploitation, namely a certain carrying capacity – an essential parameter, necessary in the process of dimensioning the anthropic pressure, namely of the human society, avoiding the degradation of the environment.

It logically results that, to guarantee a sustainable socio-economic development, it is absolutely necessary to assure the conservation of a diverse and balanced natural capital structure and a use of the resources and services produced by it within limits bearable for the natural capital components.

Beginning with the years 1970, when the Club of Rome began discussions on the limits of growth, for the first time, the issue of the need of modifying and transforming the economic growth model was brought up, in the sense that this growth cannot be unlimited.

A series of theories followed, concerning the concept of economic growth and the way of quantifying the degradation of the environment, differentiated by the theories that generated them:

The general economic theory interprets the natural capital either as a circulating monetary fund, or as a stock of technical means existing at a certain moment, which can be reproduced and diversified to support a goods and services flow necessary to development. The so large interpretation of the monetary capital in monetary and physical terms led to the conclusion according to which the natural capital might be a metaphor harder to quantify and use in designing an economic development model.

The neo-classic economic theory characterizes the economic systems as being designed and developed based on the principle of their independence to the environment, in the sense that the environment is not

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a factor limiting the development of the socio-economic system, because resources are renewable and can be assured endlessly, while the resulting wastes can be absorbed without restrictions. The theory was soon fought against and amended by its very supporters, as soon as they noticed that the deterioration of the environment is a reality, directly connected to the economic development. The supporters of a growth at all costs tried to argue that the resources provided by the natural ecosystems can be gradually replaced by those produced by the components of the environment created by man, based on the technological progress, namely the world can exist as well without natural resources.

In other words, a series of theories that had the gift of encouraging the economic development based on the maximization of the profit and on the relation demand-offer, tried to find arguments to support a development at all costs, going even up to modalities of substituting the natural capital. They supported either the direct substitution, when a component of the capital created can assure a service equivalent to that provided by the natural capital or an indirect one, generically defined as "efficient growth through technological progress".

The two modalities were impossible to defend except by a new approach – the systemic approach of the environment – which will be able to demonstrate that the environment is a hierarchy of simple systems or grouped systems that develop based on a stability hierarchy.

NATURAL CAPITAL FROM THE PERSPECTIVE OF SYSTEMIC ECOLOGY

The definition of the natural capital through the prism of the way the physical, chemical and biological environment is perceived, as representing the totality of the natural and semi natural ecological systems, permits a new approach of the ecological systems' management.

Natural ecological systems are, in this case, interpreted as self-regulatory systems with no or very limited direct anthropic influence (generally activities meant to meet the 1st order needs of the local population, research needs, and, more recently, ecotourism).

Semi natural ecological systems are represented by systems that, although bearing a direct anthropic influence (especially by the industrial exploitation of renewable resources), preserve their structural and functional features, by which they maintain themselves and develop themselves.

The basic feature of the natural and semi natural ecological features is that their productivity and stability does not require any supplementary input of energy produced in other systems.

The direct activities of exploitation of the resources from semi natural systems or of control of certain command factors, call for a current management process.

These ecological systems operating in a semi natural regime are represented by:

- Agro systems responsible for producing cereals, vegetables, fruits, technical and fodder plants
- Secondary forests or forest plantations for wood production
- Farms for the production of animal-based foods and raw matter for the leather industry, farms for aquaculture, in general, and for intensive fisheries, in particular
- Storage lakes created for the exploitation of the hydro energetic potential, renewable water source and exploitation of fishing potential etc.

The anthropic intervention is direct both during the stages of creation of these types of ecological systems by removing or totally eliminating the components of the natural ecosystems and affecting some

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physical and chemical environments and especially the bio-geo-chemical mechanisms starting with the sawing or plantation stages, species improvement, fertilization, pests fight etc.

We shall underline the fact that the semi natural ecological systems produce resources and services, by concentrating the solar radiant energy and maximizing the density of the energy flow. For example, wet areas are ecological systems with intermediary position, between the terrestrial systems and the aquatic ones and characterized by their capacity to purify surface waters, due to mechanisms such as: periodically or permanently the soil is covered by hygrophyte species in which a specific fauna develops, able to recycle nutrients.

Practically, the natural capital is therefore made up of natural and semi natural ecological systems and anthropized ecological systems.

All systems making up the natural capital preserve the productive function of resources and services based on fundamental ecological processes. For this reason, the energy flow from the radiant solar energy which is free, and the recycling of nutrients—the fundamental mechanism for maintaining the bio-geo-chemical circuits – are defining elements of the natural capital structure.

At the same time, we consider that maintaining the spatio-temporal organization, the productive function, and controlling the dynamics of these ecological systems can be realized only if the human populations' direct and significant intervention is assured permanently and non-destructively.

Practically, anthropized systems are characterized by a strict dependence on the human populations' direct and complex intervention, associated to a flow of auxiliary energy, produced in other systems, such as those for energy conversion.

Consequently, one can state that these ecological systems have specific structural and functional features and, as a result, we can consider them an essential part of the socio-economic systems.

In essence, a third of all agrosystems, for instance, are intensive and super intensive production structures, calling for a very large auxiliary energy input, of up to 10 kcal/m^2/year. For this reason, such ecological systems are assimilated to anthropic capital components (built by human populations).

Finally, we consider this last category of ecological systems as representing natural capital (NC) components dominated and controlled by human populations and, consequently, one can state that these ecological systems are subordinated structurally and functionally to the socio-economic system's development strategies, actually proving that they are practically integrated in the socio-economic system (SES).

Moreover, we consider that the weight of this category of ecological systems increased exponentially during the last century, as the population and the 1st order needs of the members of the human societies increased, and the numerical growth of these systems is the result of a process of substitution of the natural and semi natural systems.

Therefore, we do not exclude the possibility of substituting, between certain limits, some components of the natural capital, by others, in order to increase productivity, yet the massive substitution of the ecosystems functioning in a natural and semi natural regime, producing for free renewable resources and services, by anthropized ones (super intensive cultures, urban centers, transportation infrastructure elements etc.), which cannot function except based on the significant increase of the energy flow produced in other systems is not allowed.

The comments on the so controversial issue concerning, on the one hand, the possibility and opportunity of substituting the natural capital components by components created by the human populations, and on the other hand, the obligatory need to guarantee complementariness, must lead to the conclusion that, always, the normal progress is towards the harmonization of the spatial relations and the matter and energy flows circulating between the natural capital and the socio-economic system.

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We reiterate the fact that all the components in a natural and semi natural regime and the anthropized ones are dissipative systems, maintaining and maximizing the energy flows and recycling raw matter, producing resources and services.

Thus, all the ecological systems are dynamic on large geological time scales and develop by going through different growth stages, depending on which they produce resources and services. It logically results that on ecological and geological time scales (over 100 000 years), all resources are renewable.

Practically, however, the socio-economic systems' management is based on strategies emitted for much smaller time scales (5-15 years); in this case, their management cannot be operated based on a comparison to the scales at which resources are renewable.

For this reason, in the category of renewable resources we cannot include anything else but the vegetal and animal biomass, most soil and water reserves and partially the mineral resources usable as building materials, for example.

Ores and fossil fuels (coal, oil, gas) have a replacement time of the order of hundreds of thousands or millions of years, which determines their inclusion in the category of non-renewable resources.

Managerially, the distinction between renewable and non-renewable resources is extremely important, as it leads to the conclusion that renewable resources need strategies meant to preserve their functional integrity and the productivity of the natural capital components, maintaining the exploitation rate under or very close to the rate at which these resources are produced or regenerated (Lester, R. Brown, et al., 1997).

For non-renewable resources, however, flexible strategies are needed, involving measures limiting the exploitation rates, identifying alternative sources and especially, technical measures of bio-geo-chemical recycling of the products obtained and of the residues.

One of the essential features of the natural capital, almost always neglected, is its structural and functional diversity.

The presentation of the problems up to this stage is giving us the possibility to highlight the structural and functional aspects of the ecological systems, which are actually arguments in the substantiation of the new model of socio-economic development: sustainable development.

Thus, Sustainable Development does not suppose only the need to maintain the natural capital as ratio over a critical level, but supposes especially the need for it to preserve a maximum level of structural and functional heterogeneity, on which long-term development opportunities will actually depend.

Thus, the issue of preserving biological and ecological diversity is not a collateral problem representing just a small defect for the political decision factor, but is the very issue of preserving the natural capital as development support and sustainability guarantee.

The last 3-4 decennia of the past century were marked, incomparably more than any other period in the history of mankind, by the evident process of deterioration of the perceptible environment, via the toxic, often lethal effects, of the by-products and final products resulted from the processes of the socio-economic system. These products have come together and have become concentrated in the major compartments of the environment (troposphere, lithosphere, hydrosphere) and have affected the taxonomic hierarchy of the biosphere, degrading at the same time the abiotic environment.

The reactions to the tendencies of degrading the environment by damaging anthropic activities have diversified as the effects were seized, assessed and linked to a series of concrete human activities.

Consequently, actions delimiting the pollution effects, and, very recently, actions meant to diminish and prevent pollution, have been designed and have increased in diversity.

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Compared to the alarmingly growing tendency of the process of elimination of various plant and animal species, a phenomenon generating the worrying narrowing of biodiversity, the answer was mainly actions of identification of the vulnerable and endangered species and the elaboration of special protection programmes.

At the same time, for endangered habitats, the answer was ecological reconstruction actions, consequently also avoiding the elimination process.

The real process of erosion of biological diversity following the aggressions of the socio-economic systems could not be stopped by sectorial protection actions regarding certain species or the reconstruction of some endangered habits. For this reason, organisms such as E.U. or U.N. have found themselves obliged to adopt regional or global conventions on biodiversity protection, climate change, reducing greenhouse emissions etc.

Two mentions are needed, helping us to make a distinction between biodiversity in a broad sense and in a restrained sense, the latter being promoted by those supporting a "development at all costs":

- For a long time, this concept designated only the richness of species without taking into account the diversity of the structural and functional units of the abiotic environment.
- The socio-economic systems, which include a great diversity of the social, cultural and patrimonial capital, were not taken into account when biodiversity was discussed.

BIODIVERSITY AND ECOSYSTEM SERVICES AS FUNDAMENTS OF SUSTAINABLE DEVELOPMENT

While in its broad sense the concept of biodiversity includes the totality of the organized units constituting the natural capital, including the human species and the totality of the capital created by them, it results that the syntagm "diversity of the ecological and biological systems" would be more adequate for the concept of biodiversity in a broad sense.

Diversity needs to be analyzed and quantified at least on four distinct levels

- Of the species and species hierarchy
- Of every development level along the hierarchic line
- Of each system with supraindividual organization
- Of each genetic structure (Popescu C., 2003)

Consequently, biodiversity conservation ought to be designed and realized based on strategies, programmes and methods, pursuing on the one hand a sustainable use, namely within the limits of the carrying capacity of the natural capital components, and, on the other hand, a management of the development of the socio-economic system, namely of the capital created by the human populations.

Therefore, the diversity of the biological and ecological systems ought to be analyzed at least on these levels:

- Diversity as support of life
- Diversity of the biological systems in the species' hierarchy
- Diversity of the genetic structure of the population and of the species, including of Homo sapiens

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- Ethno-cultural diversity of the socio-economic systems

The extension and operationalization of the biodiversity concept was necessary given the numerous attempts of reducing the diverse biodiversity forms, by supporting new ecosystem degradation techniques.

Governmental experts, as well as those of important financial organisms, still have the tendency, even to this day, of interpreting biodiversity restrictively, stating that affecting the environment is a natural process of technological development, and the solution is possible by new developments.

We need to mention that the 2002 Johannesburg meeting is a proof that the political decision factors have understood that they need to give up on speculative arguments and have seen themselves obliged to adopt, at least formally, clear measures meant to prevent environmental degradation.

Political decision factors and managers have had to admit that important for long-term development is the creation of the conditions needed for a sustainable development and implicitly for preserving biodiversity.

The large recognition of this need has been supported at least by the following arguments:

- The effort for preserving biodiversity cannot focus only on the ecological systems, arguing that they would integrate almost all the species, of which the great majority are unknown.
- It is equally necessary to preserve the habitats assuring the complex ecological-fundamental processes, and, naturally, to avoid the elimination of certain species.

Out of the total of about 50,000,000 species existing on Terra, over 90% are invertebrate species (fungi, bacteria), not yet studied, whose salvation would not be needed, since their contributions to the functioning of the ecological systems have not been quantified yet.

Conserving or maintaining the structural-functional integrity within the stability domain of a given natural or semi natural ecological system involves, to the same extent, maintaining the trajectory of the abiotic compartments' dynamics and the dynamics of the biotic compartments' trajectory, but also the interactions between them.

Thus, the term interconnectivity is introduced, representing the necessity of permanent intercommunication of the components, in the sense of support of life, one for the other.

When analyzing the development of each ecological system as a complex long-term process, the general tendency is to assure the mechanisms by which the number of species or populations can increase, without considering the necessity that, within them, specializations and interactions need to intervene, able to intensify the environmental services, such as maximizing the energy flow, recycling nutrients, and regulation, balance and stability mechanisms etc.

The result of such a process appears, therefore, in the extension of the stability domain on a spatial level, while the analysis on a time scale specific to large systems would be obligatory.

Therefore, one cannot at all speak about the existence of useless species within a complex model, but in different growth stages, the functioning of the ecosystem relies successively on some or the other of the species comprised in the taxonomic hierarchy.

Consequently, even though, at the same time, not all the elements composing the ecosystem on the spatio-temporal scale of analysis are equally important, each species has its distinct role.

It logically results that to preserve the ecological structures on the level of the national and macro regional complexes, one has to take into account the maintaining of a mosaic of natural and semi natural systems, to include all the types of ecosystems and preserve at least half of their surface. The conserva-

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tion of the ecological systems therefore involves their interconnectivity, assured via natural corridors or, where they do not exist, the technological and ecological reconstruction of such corridors is needed (Popescu C., 2003).

The connectivity of the natural and semi natural systems is an essential condition for the dispersion of the species within their area, for their movement, for the directions of the new gradients modified given the climate change, the consideration of the elements highlighted having to be done in fact by operative policies and strategies, on each State or State Union level.

The European Council established, on the occasion of the environmental ministers' summit of Sofia, in 1996, that on the level of Europe it is necessary to create a European network of ecological systems interconnected through management programmes, comprising the conservation of the natural and semi natural systems specific of their different European regions, the reconstruction of some endangered habitats, the rehabilitation of certain ecosystems and their reconnection, and special programmes of sustainable management for the anthropized systems.

All these are necessary since the biological systems' diversity actually holds a huge genetic fund (an immense genetic information bank), a fund assuring, on the one hand, the natural process of species dynamics and, on the other hand, information for the technological research concerning the correct dynamics of the anthropized systems and the correction of their trajectories, imitating nature.

Very recently, the syntagm bioindustrial development has emerged, in the sense of avoiding the negative tendencies generated by the idea that man masters nature. It is acknowledged in this way that the anthropic factor, though being the command subsystem, is part and parcel of the ecosystem.

Moreover, during the last decennium, there emerged the idea of creating a complementariness between the high-performance industries of the developed countries and the diversity of the genetic resources of the underdeveloped countries, in the sense that by the "Convention on Biodiversity" the developed states are obliged to return at least 20-25% of the profits obtained by exploiting the genetic patrimony to the underdeveloped countries.

These financial resources would have the role of funding the increase of the territories called "protected areas", namely precisely of preserving this invaluable genetic patrimony, the main support of life on our planet.

REFERENCES

Allan, D. (1994). *Stream Ecology*. Oxford.

Brown. (1997). State of the World and our Resources. New York: W.W. Norton & Company.

Constantza, R. (1996, October). Gross world product from International Monetary Fund (IMF). *World Economic Outlook*.

Constantza, R. (1997). The Development of Ecological Economics. London: Academic Press.

Georgescu-Roegen, N. (1979). Legea entropiei si procesul economic. Publishing House Politică.

Kumari, K. (1996, November). Sustinable Forest Management: Myth or Reality? Exploring the Prospects for Malaysia. *Ambio*.

Leopold, A. (1949). A Sound Country Almanac. Oxford.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Pimentel, D. (1997). L'écologie des fôrets. Ed. did. Paris.

Popescu, C. (2003). *Economia protectiei mediului*. Târgovişte: Editura Bibliotheca.

Popescu, C. (2008). *Stări conflictuale generate de exploatarea abuziva a pădurilor lumii*. Editura Bibliotheca.

Popescu, C. (2011). La durabilité en qualité de nouveau projet civilisateur. 57éme Congrès "Refondation financière, sorties de crise et nouvelles stratégies de croissance économique, Croatia.

Popescu, C. (2014). *Reconsidering the Relationship Between Socio-Economic System and Natural Environment*. The 2nt International Conference ESPERA 2014 – Economic Scientific Research Theoretical, Empirical and Practical Approaches organizată de National Institute for Economic Research, Bucharest, România

Vădineanu, A. (1998). *Sustainable development*. Press University of Bucharest.

Vădineanu, A., Negrei, C., & Lisievici, P. (1999). *Sustainable development*. Press University of Bucharest.

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Section 2

Development and Design Methodologies

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Chapter 7
Appropriate Extension Methodologies for Agricultural Development in Emerging Economies

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ABSTRACT

Over two-thirds of the world's poorest people are located in rural areas and engaged primarily in agriculture and agricultural-related activities for their livelihood. Therefore, the future of most underdeveloped and developing nations depends on agriculture. Most African Countries have agricultural dependent economies that are hinged to rain-fed agriculture and based on smallholdings. These countries are referred to as countries with emerging economies and characterized as having low to middle per capita income and represent 20% of the world's economies. This chapter discusses; concepts of agricultural extension methodologies assessed from past to present, appropriating extension methodologies to encourage agricultural development, identifying roles of agricultural extension activities in agricultural development and factors influencing the choice of appropriate extension methodologies in emerging economies. It concludes with the constraints to sustainable agricultural development and extension methodologies which if removed will have the potential for progression towards economy development. Developing countries should fashion a sustainable extension system that will be socially acceptable and culturally compatible, economically viable and environmentally friendly.

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INTRODUCTION

More than two-thirds of the poorest of the poor populations of the world are located in rural areas and derive their livelihood from the rural environment. More than 70% of such people in developing nations are engaged in agriculture and agricultural-related activities. Therefore, the future of most underdeveloped and developing nations depends on agriculture. Most African nations have agricultural dependent economies that are hinged to rain-fed agriculture and based on smallholdings. The smallholders depend mostly on traditional tools which, though easily maintained, are energy sapping and make agricultural production laborious. Many of the innovations that are developed by researchers, especially in the universities and research institutes, are wasting away on their shelves. Agricultural Extension agencies that are tasked with disseminating the developed innovations, are either moribund, the innovations/technologies have not been transferred to them or innovations are inappropriate. In some instances, scientists are not ready to release their innovations because they think that the extension agencies that disseminate the innovation to farmers will take their glory. All ofthese contribute to continued poverty among farmers.

Extension is a service or system which assists farm people, through educational procedures, in improving farming methods and techniques, increasing production efficiency and income, bettering their levels of living and lifting the social and educational standards of rural life (Maunder,1973). Agricultural extension can be defined simply as the transfer of useful information from a source to the farmers or rural dwellers. Swanson et al. (1997) defined agricultural extension as the extending of relevant agricultural information to people. Piercell and Anderson (1997) defined agricultural extension as a process of assisting farmers to be aware and adopt improved technology from reliable sources to enhance production efficiency, income, and welfare of farmers. The main goal of agricultural extension is to improve the socio – economic condition of farmers and rural dwellers. As a discipline, it finds itself articulating appropriate knowledge and decision-making capacity to determine how factors of production can be best utilized to improve the standard of living of rural dwellers through appropriate extension methodologies (Famuyiwa, 2013).

The general objectives of extension are to:

1. Assist farmers to discover and analyze their problems and identify their felt needs.
2. Develop leadership among farmers and help them in organizing groups to solve their problems.
3. Disseminate research information of economic and practical importance in a way farmers would be able to understand and use.
4. Assist farmers in mobilizing and utilizing the resources which they have and to identify what they need from outside.
5. Collect and transmit feedback information for solving management problems.

Agricultural extension, therefore, provides the indispensable elements that farmers need to improve their agricultural activities. This has made agricultural extension to be a crucial input in agricultural development, especially in Nigeria.

Most developing nations of the world especially in Africa have implemented various agricultural extension methodologies. Most of the methodologies are transferred from a country where it has been successfully implemented, to other countries regardless of the farming system and culture of the country. In addition, some funding agencies also sponsor and fund agricultural extension methodologies in developing countries. As soon as the funding ceases, the project also ceases. A good example is Agricultural

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Development Project (ADP) which was jointly funded by the World Bank, Federal and State governments in Nigeria. The ADP operated the Training and Visit (T&V) agricultural extension approach in Nigeria. This project was implemented between 1985 and 1995. But, after the cessation of the World Bank counterpart funding in 1995, technology delivery by the ADP progressively declined to the extent that State's ADPs found it difficult to pay salaries and to provide funding for other operating transaction costs (Agwu &Chukwuone 2005). This decline in the World Bank funding according to Havnevik et al. (2007) was not limited to Nigeria, it was part of the Structural Adjustment Policy of the Bank that adversely affected Africa. Though successes were recorded during the implementation of the project, it was not economically viable. If developing nations could create sustainable technologies, these would support their systems over a long period.

In the light of this, developing countries should fashion a sustainable extension system that will be socially acceptable and culturally compatible, economically viable and environmentally friendly. It has been discovered that most agricultural extension approaches and methodologies that were borrowed or sponsored by external agencies in developing countries did not involve farmers in a participatory process. Any sustainable agricultural extension approach or methodology to be adopted in developing countries, must guard against the above mentioned issues if rapid growth in agriculture is to be delivered and to enhance food security.

It might be useful at this point to differentiate between the terms 'approaches' and 'methods' in agricultural extension as used in this chapter.

Approaches: An approach in agricultural extension connotes the way or avenue to get things done. It can also be seen as the manner in which a problem is solved. Anandajayasekeramet al. (2002) referred to the concept "approach" as the "essence of agricultural extension system". They added further that "approach is the style of action within a system and embodies the philosophy of the system". In an agricultural extension system, an approach is the framework and structure of the system which serves as the pathway that guides in a program of action.

Method: This refers to the process and techniques used by extension agencies to get a task done. Examples include visits by extension agents to a group or a family, demonstration of skills to a group by extension agent and so on.

This chapter reviews the past and present agricultural extension approaches and methods. The understanding of these along with an in-depth view of their success and failures will assist in building appropriate and sustainable agricultural extension approaches and methods for the future. These will bring rapid development to the wellbeing of farm families, agriculture and the environment.

FACTORS INFLUENCING CHOICE OF APPROPRIATE EXTENSION METHODOLOGIES IN EMERGING ECONOMIES

Emerging economies are defined and characterized as economies having low to middle per capita income and represent 20% of the world economies. However, they can further be described as countries having low levels of human capital, high levels of poverty and under-nutrition, and high population growth rates. There are also the predominance of agriculture, low levels of industrialization, and urbanization but rapid rural-to-urban migration, dominance of informal sector, underdeveloped labor, financial, and other markets (Kumar, 2015 and Wikiversity, 2015).

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For easy dissemination and diffusion of innovation, some cogent factors have to be appropriately considered in choosing the method to be used among the array of methods available for extension activities. The majority of agricultural projects and programs that are extension based, fail or are moribund because some of these factors are not carefully considered.

Technological Applicability

Technology improvement is an indication of development. However, challenges are faced in the areas of applicability, adaptability, and acceptability into the system. Before now, dissemination of innovation was undertaken using a top-down approach which makes diffusion difficult and adoption almost impossible. The alternative Farmers' Participatory Approach (FPA), has so far yielded better results. This approach promotes the involvement of the target group, the farmers or the end-users, right from the conception of the idea through to the completion. This approach is being employed in National Fadama programs implemented in Nigeria. This approach empowers the target group to input their ideas for sustainable adoption of the innovation. The general aim is to see if the innovation fits into their felt needs.

Economic Feasibility

Economic feasibility of a method is very important for agricultural development. The final goal of development has to do with the cost effectiveness of the method and its approach. A sustainable method is the one that is market and farmer driven; meeting the needs of consumers and profitable to the farmers. In the case of technology or innovation to be adopted by farmers, it will only be appropriate if it adds to the income of farmers, either by cost reduction or by yield increase.

Another area of economic feasibility advanced by Campbell and Barker (1998) asks the question: Do farmers have financial resources to implement the innovation, in order to derive the benefit that will accrue? In the case of drying cocoa beans, this has been a very serious problem in developing countries that produce 75% of the world cocoa. Does the individual farmer have the financial capability to buy a Simona dryer, which was developed as an alternative and useful method for drying cocoa beans in humid areas?

Environmental Safety

There are inter dependencies in the systems that make up an environment; the social system and the ecosystem (Marten, 2009) as shown in Figure 1. These two systems interact with each other and they both transmit energy, materials and information to each other. The social system is represented as the human activities, while the ecosystem is made of biotic and abiotic organisms. These interactions need to be guided through appropriate methods to enhance environmental safety.

Serious environmental issues have developed in emerging economies because of farmers' low income, high population, and high illiteracy level. Indiscriminate use of pesticides and other chemicals on the farm have been identified by different studies (Sosan and Akingbohungbe, 2009; Ogunjimi and Farinde, 2012 and Famuyiwa, Torimiro, and Adesoji, 2013). The diagram below as described shows the interaction between environmental elements; social system and ecosystem.

Technology in the social system brought about the use of pesticides for the control of pests on cocoa farms. Farmers, because of lack of knowledge on the use of pesticides or their anxiety to increase yields,

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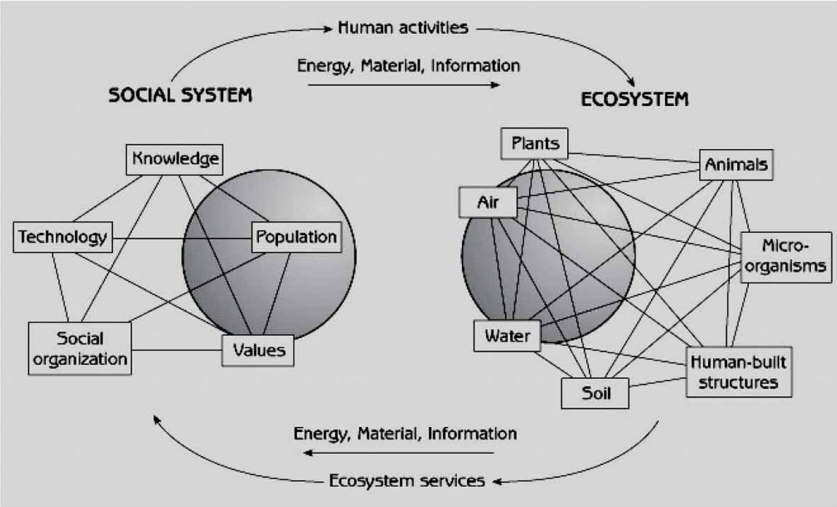
Figure 1. Interaction of the human social system with the ecosystem (Marten, 2009)



tended towards the indiscriminate use of pesticides. The indiscriminate use of chemical/pesticides which is a human activity from the social system consequently pollute the ecosystem and brings about chemical residue in farm products like cocoa beans that are made into chocolate and consumed by human beings. These chemical residues have been identified as causative agents of diseases such as cancer.

The goal should, therefore, be to carefully design dissemination methods of non-pesticide procedures or organic farming approaches to increase farmers' yield and the marketability of their farm produce.

Socially Acceptable

A social system is an interrelationship between the linkages that exist among all the elements of a society namely; individuals, groups, and institutions that make these elements form a whole. Since these elements are knitted together, moving the society from the status of developing to developed, will require methods that will be acceptable to them. However, introducing a paradigm shift needs a well-designed methodology to achieve acceptability.

Culturally Acceptable

The cultural system is located within the larger society or the social system. It is defined as interrelationship of six elements namely; traditions and norms; language; arts and literature; religion and belief systems; forms of government; and economic systems. Agricultural productivity that leads to development depends largely on how knowledge is adequately managed, shared and applied. Early theorists emphasized that behavioral change among farmers is a prerequisite of the agricultural modernization process. Hence, in order to achieve development in emerging economies, the method of dissemination and appropriate diffusion of innovation need to be carefully chosen. No matter how beautiful an innovation is, if it is not culturally acceptable the required adoption level will not be attained. This factor is highly considered in designing extension programs.

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Sustainably Suitable

Sustainability is the ability to undertake a project or process using the present resources, without compromising the future resources. ICCO (2008), posited that practices of cocoa farming should be considered as sustainable in terms of economic, environmental and social. However, the United Nations (2015) in its meeting (25^{th} – 27^{th} September 2015) deliberated on 17 points Sustainable Development Goals (SDGs) by member countries, the majority of which are emerging economies. The goals SDGs discussed include the issues of;

1. No poverty
2. Zero hunger
3. Good health and well-being
4. Quality education
5. Gender equality
6. Clean water and sanitation
7. Affordable and economic growth
8. Decent work and economic growth
9. Industry, innovation, and infrastructure
10. Reduced inequalities
11. Sustainable cities and communities
12. Responsible consumption and production
13. Climate action
14. Life below water
15. Life on land
16. Peace, justice and strong institutions
17. Partnerships for the goals

Audience Configuration

A proper understanding of the audience is another key factor in program development. Messages need to be specific as audiences are also specific. There is divergence in culture, gender, education and access to resources. The International Food Policy Research Institute (IFPRI, 2011), identified that gender relations are culture and context specific. It was specifically stated that addressing gender issues is one of the most effective ways of achieving development and reducing poverty in the society.

Content Relevance

The content flow between research and farmers is termed “information”; information about methods, innovation or advice. Information to meet the competitiveness of the stakeholders in agricultural development has to be content-specific to achieve desired sustainable economic growth. Studies according to Adedeji et al. (2013), and Mwangi and Kariuki, (2015), showed that the adoption rate of most technological innovations disseminated in emerging economies is low. The majority of these failures (low adoption rates) are attributed to inappropriate methods of extension delivery of the technology; innovations are not economically feasible, socially acceptable, technologically adaptive, culturally compatible, environ-

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mentally compliable and hence the innovations are not sustainably practiced. Technology in isolation, without regular guidelines by the extension professionals and the use of appropriate methodologies, cannot help in enhancing the productivity of any economy. Hence, it has to be content relevant to the specific environment where it is to be promoted.

Role of the Agricultural Extension in Agricultural Development

The role of agricultural extension in the past was to transfer new technologies from researchers to farmers. This role has not been able to meet the developmental challenges in developing countries.This is because most of the technologies disseminated to farmers have not been able to solve farmers' production problems. Agricultural extension's role in the recent past in most developing countries was seen to help farmers make their own decisions. Extension only increases the number of options from where the farmers can choose and also highlights the consequences of each option. At this point, it is the role of extension to answer questions that may arise when the knowledge of the farmers is limited. In a way, extension still guides in decision making.

Agricultural extension promotes and enhances the learning process among farmers. Farmers have many avenues by which they can learn. For example, people say, 'experience is the best teacher'. Farmers learn from their past experiences, from neighbours, from extension demonstrations as well as discussions with other experienced farmers. Agricultural extension must assist farmers in this learning process. Farmers are known to be knowledgeable in their area of production; extension should not look down on the farmers, but should be able to also learn from the farmers.

For extension to achieve its own set objectives, it is important to do what other agencies have left undone. For example, extension should include sources for agricultural inputs as well as marketing information in their programs or activities. It will be a waste of time and effort for an extension agent to introduce the use of fertilizer to a group of farmers who do not know the source of the input, fertilizer. Also, it will not be helpful for both the extension agent and the farmer to have a bountiful harvest without a market for the harvest. Providing guidance to the farmers in this regard would afford credibility to the extension agent and hasten the economic development of the farmers. Extension may also assist in supervising the appropriate use of loan/ credit and ensuring regulation adherence.The approach of the Cocoa Research Institute of Nigeria (CRIN) in solving coffee farmers' problems is designed as market and farmer driven approach to change farmers' attitude towards coffee cultivation. When farmers' problems are addressed with effective solutions, it is always easy to adopt innovations.

It has been observed that valuable local knowledge and resources are underutilized. Extension should harness the knowledge of 'indigenous' and rural people that are often termed as 'primitive' or 'unscientific', then pass them to researchers to transform and improve. This is important because what the farmers know and believe can develop them.

Appropriateness and Selection of Extension Methodologies for Agricultural Development

Extension is an ongoing process of getting useful information to people and then assisting those people to acquire the necessary knowledge, attitudes and skills (ASK) to utilize this information or technology for the purpose of improving their quality of life. The term, 'agricultural extension', narrows the focus

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and defines the area to which the extension process is applied. Without extension, the farmers would lack access to the support and services required to improve their livelihoods and other productive activities.

Extension is not concerned directly with generating knowledge. This is done in specialized institutions such as agricultural research centres, agricultural colleges, and Universities of agriculture.

Researchers neither have the time nor are they equipped and trained for the job of ascertaining from the farmers their field problems and of persuading farmers to adopt technologies. Similarly, it is not always practical for the farmers to visit the research stations and obtain first-hand information. Thus, there is a need for an agency that could interpret the findings of research to the farmers and to carry the problems of the farmers to researchers for solutions. This process is guided and supported by Extension Agents of the extension agency who work at the field levels and have direct contact with farmers and their families. The task of extension personnel is bringing scientific knowledge to farm families in the farms and homes. The objective of the task is to improve the efficiency of agriculture.

AGRICULTURAL EXTENSION SYSTEMS/ APPROACHES IN NIGERIA

A number of systems have been developed and applied in the process of agricultural development through various programs and projects with extension outfits in Nigeria. The extension system/approaches are categorized into two:

1. General Clientele Approach: These include a variety of approaches such as
    a. Ministry-based general extension
    b. Training and visit extension (T&V)
    c. Integrated (Project) approach
    d. University-based extension
2. Selected Clientele Approach: These include:
    a. Commodity based extension
    b. Commercial extension service
    c. Client-based and client-controlled extension

In an attempt to realize the expectations of increase in food production for the teeming population, successive governments in Nigeria have, at one time or the other, put in place many agricultural policies and programs as well as projects. Such programs that were implemented include, as shown in Box 1.

Box 1.

The National Accelerated Food Production Programme (NAFPP, 1972); First generation Integrated Agricultural Development Projects (1st generation ADPs, 1975); Operation Feed the Nation (OFN, 1976); River Basin Development Authorities (RBDAs, 1976); National Committee on Green Revolution (NCGR, 1979); the World Bank Assisted Agricultural Development Projects (2nd generation ADPs, 1986); Better Life Programme (BLP, 1989); National Agricultural Land Development Authority (NALDA, 1991); Family Support Programme (FSP, 1992); Family Economic Advancement Programme (FEAP, 1997); Fadama Development Programme (FDP, 1982); National Special Programme on Food Security (NSPFS, 1994) and the Poverty Eradication Programme (PEP) since 1999. Other efforts of note are the involvement of young school leavers and graduates in agricultural production through programs such as Farm Settlement Scheme (FSS, 1957); National Directorate of Employment (NDE, 1986); School to Land and Back to Land programme (SLBLP, 1985), National Economic Empowerment and Development Strategy (NEEDS, 2004) and recently the Farmer fields School (FFS) and Growth Enhancement Scheme (GES) under the Agricultural Transformation Agenda (ATA) (Olaniyi, 2010).

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All these programs and projects were targeted at enhancing food security and improving the standard of living of farmers through the use of various agricultural extension approaches and methodologies.

Extension Methods Incorporated in Various Agricultural Development Programs in Nigeria

Successes recorded in Nigeria in relation to agricultural development, could be traced to the implementation of agricultural programs with extension components and coupled with the selection of appropriate extension methodologies. Agricultural Extension has two dimensions (a) Educational and (b) Communicational. Both of these dimensions must be incorporated into agricultural development programs to achieve successful results.

The *educational dimension* involves the change agent (extension worker) attempting to build human capacity through the use of effective teaching methods to improve knowledge and develop the skills of the clientele (farmer) along with acquiring knowledge on improved practices to enhance production and marketing activities (Williams et al.1981). The purpose of education is for immediate action or to solve a problem, hence it is different from the formal education.

The *communicational dimension***:** This involves dissemination of information to the clientele on new technologies or innovations. It also involves exchange of ideas that could provide the basis for research or feedback on the use of previous innovations. Therefore, extension is involved in dissemination of useful information using the appropriate methods.

With various extension approaches, the choice of the communication channel or method generally depends on the number and location of the target audience and the time available for communication. The extension methods are categorized into: individual methods, group methods, and mass methods. Each of these methods has both advantages and limitations. The extension agent has to choose a particular appropriate method or combination of methods according to the needs of the situation. Let us now look at different extension methods in detail and their importance for small farmers in developing countries.

Individual Methods

Individual methods, also known as face-to-face methods, are the most universally used extension methods in both developed and developing countries especially in Nigeria. The extension agent meets the farmer at home or on the farm and discusses issues of mutual interest, giving the farmer both information and advice. The atmosphere of the meeting is usually informal and relaxed, and the farmer is able to benefit from the agent's individual attention. Individual meetings are probably the most important aspect of all extension work and are invaluable for building confidence between the agent and the farmer.

Learning is very much an individual process and, although group methods enable the agent to reach a greater number of farmers, personal contact and the individual attention of the extension agent are important supports for a farmer. The personal influence of the extension worker can be a critical factor in helping a farmer through difficult decisions, and can also be instrumental in getting the farmer to participate in extension activities. A farmer is often likely to listen to the advice given by the extension agent and will be grateful for this individual attention.

The individual contact method between the extension agent and the farmer may take a number of forms. These include:

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Farm and Home Visits

Farm and home visits are the most common form of personal contact between the agent and the farmer and often constitute over 50% of the agent's extension activities. Because they take up so much of the agent's time, it is important to be clear about the purpose of such visits and to plan them carefully. Farm and home visits can: familiarize the extension agent with the farmer and family; enable provision of specific advice or information to the farmer; build up the agent's knowledge of the area, and of the type of problems which farmers face; permit explanation of a new recommended practice or follow up and observe results to date; arouse general interest among the farmers and stimulate their involvement in extension activities.

The following are involved in Farm and home visits.

1. **Planning for the Visit:** This include: extension agent makes an appointment with farmers if possible, decide the purpose of the visit; review previous records and information; prepare specialized subject matter that might be required; and schedule the visit into the overall work plan.
2. **Making the Visit:**
    - Be punctual for the visit.
    - Greet the farmer and family.
    - Praise the farmer's work.
    - Encourage the farmer to explain and discuss any problems.
    - Provide any technical or other information required.
    - Record the details of the visit.
    - Plan with the farmer the time and purpose of the next meeting.
3. **Recording and Follow-Up:** The purpose of farm and home visit will be lost if its content and conclusion are not recorded and no follow-up action taken. Therefore, record the purpose of the visits and decision resulting from visit; arrange for any follow-up information or advice to be sent and schedule the next visit to the farmer.

Advantages and Limitations of Farm and Visits

Farm and home visits are perhaps the single most important aspect of the agent's work in terms of establishing rapport with the farmers in their area and of building the trust and confidence that are vital to the success of their work. However, farm visits take up a lot of time and only a few farmers can be reached. Farm visits are, therefore, a costly extension method and for this reason they must be carefully thought out and planned. The visits must make an impact and must lead to positive agricultural development if they are to justify their cost. Finally, the agent should beware of visiting some farmers repeatedly. This would not only severely limit the range of activities, but could also arouse the resentment of other farmers who might feel excluded.

When is the methodology for personal contact used? It is worthy to note that individual methods are useful when there is sufficient time or in the slow periods of farming. Also, when the farm family is operating as a production unit.

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Office Calls

Along with the extension agent visiting the farmer, it is expected that from time to time the farmer will visit the agent in the office. Such a visit is often a reflection of the interest which the agent may have aroused among the local farmers. The more confidence local farmers have in an extension agent, the more likely they are to visit the extension office. Such office visits are less time consuming for the extension worker, and offer some of the advantages of a farm visit. While no extension agent would wish to be overwhelmed by such visits every day, farmers should be encouraged to drop in, if it is convenient, for them to make the exchange of visits two-way. As with farm visits, office visits similarly have to be prepared. Although the agent may not know when a farmer is likely to drop in, the extension office can be arranged in such a way that the visitor feels at ease and can understand the activities of the office.

Telephone Calls

The deployment of information and communication technology in extension delivery service makes the use of mobile telephones relevant. Telephone calls and office visits serve a similar purpose. It is improbable that the extension worker will deal with many of the farmers in the area (if at all) by telephone. If the telephone is used, however, it should not be for long discussions but for passing on specific advice or information. Whatever the reason, it is important for the agent to speak clearly, to note the main points discussed and to enter them on the farmer's record.

Group Methods of Extension

The extension agent should consider the use of the group approach in work with farmers. The use of groups in extension has become more common over the past decade, and indeed, a number of new ideas have emerged about how groups may be used most effectively. For example, the widespread Small Farmer Development Programme (SFDP) in Southeast Asia was based upon group methods and has produced two manuals which detail the approach of group extension work. Furthermore, in Latin America, work with extension groups in Brazil and Colombia has shown the usefulness to extension of the formation of extension groups, and how these groups can support extension activity. Empirical evidence shows that a group of 5–7 members usually works best for achieving optimum productivity and participation. However, due to cost constraints, normally a group is formed comprising around 20–25 members. Some situations, such as microcredit, input acquisition, and marketing, may demand a larger group for initiatives to be cost effective. Various projects indicate that optimum membership ranges between 20 and 50 people, but groups of less than 20 farmers can also function well as reported by Sanginga et al. (2001), and Pretty, (2003). It is worthy to note that as with any social unit, conflicts within groups may arise. What matters most is how conflict is managed (Anandajayasekeram et al. 2008). Conflict, depending on the types, may be harmful or beneficial to the group. Generally, it is poor management of conflicts that weakens groups as it may lead to dissatisfaction of members, withdrawal or total collapse of the group. This is also applicable to extension work in many countries of the world.

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Advantages of Group Methods

It has been seen that individual extension methods can be costly both terms of time and scarce extension resources, and that they reach only a limited number of people. There is also the danger that too much emphasis upon individuals can lead to undue concentration on progressive farmers to the detriment of the poorer farmers. The group method has advantages in the following aspects.

Coverage

The group method offers the possibility of greater extension coverage, and is therefore more cost-effective. Using the group method, the extension worker can reach more farmers and in this way make contact with many more farmers who have had no previous contact with extension activities.

Learning Environment

Extension groups offer a more reflective learning environment in which the farmers can listen, discuss and decide upon their involvement in the extension activity. The support of the group helps an individual farmer to make decisions and determine a course of action. The group creates a supportive atmosphere, and individual farmers can gain greater self-confidence by joining others to discuss new ideas and try out new practices.

Action

The group method brings together farmers with similar problems. Often, these problems demand concerted action (tackling the erosion of a hillside, for example), and such action can be taken more effectively by a group rather than by an individual, who may be overwhelmed by the enormity of certain problems.

Types of Group Extension Methods

Group Meetings

Calling the members of a group or the inhabitants of a local community together for a meeting is the most common group extension method. Although there may be an air of informality about such meetings, they will nevertheless need to be carefully thought out and planned. The group or community meeting is a useful educational forum where the agent and farmers can come together, and ideas can be openly discussed and analyzed. The agent may have information about a new government policy, or agricultural idea or practice. The agent will want to introduce this new information, to seek the opinions of community members and gain their support for extension activities. Indeed, there are a whole range of objectives for such community or group meetings:

Planning the Meeting

There are two important decisions to make regarding the time and location. A date and time for the meeting must be decided and announced. The time should be convenient to all concerned and should

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Table 1. Forms of group meetings in agricultural extension systems in developing economies

Types/ Form of Group Meetings	Description	Purpose
Information meetings	The agent calls the group or community together to communicate specific new information which is thought will benefit them and upon which their advice is sought.	Review a particular problem, suggest a number of solutions and decide upon a course of action.
Special interest meetings	Topics of specific interest to a particular group of people (e.g., horticulture, bee keeping, or dairy farming) are presented and discussed in detail at a level relevant to those participating.	Discuss specific issues that are related to particular interest group based on their needs.
General community meetings.	Men, women and young people of a community are invited to attend and discuss issues of general community interest. It is important to hold such general meetings occasionally so as to avoid any community group feeling that it is excluded from extension activities. Whatever the case, however, the agent should only call a meeting if it can be useful. If farmers feel that their time has been wasted in coming to a meeting, they may refuse to come to subsequent meetings and thus frustrate the agent's work. The agent should make careful preparations and check a number of important arrangements which will be necessary to ensure a successful meeting.	Mainly for the purpose of general community interests especially as the situation demands..
Smaller meeting	Smaller meetings are more likely to meet the specific needs of those who attend. When plans are to be made or decisions taken, a small number of representatives will usually achieve more than a large gathering of all community members. On other occasions, it will be important for the meeting to be open to as many people as possible.	Ad-hoc committee to proffer solutions to a particular problem for a group of people.
Lecture and Discussion	A lecture or talk allows the agent (or other speaker) to convey a detailed, well-prepared message to the audience on a specific issue; for example, a new piece of technology, can be presented in this way, and illustrated by visual aids. It should be remembered, however, that the lecture is a particularly tedious approach to meetings and care must be taken to ensure that the audience will not get bored. Alternatively, in a discussion, many people are able to express points of view and ask questions. Discussions may be completely open and unstructured, or based on a prepared agenda of discussion points.	Presentation and deliberation of specific issues.
Formal Meeting	A formal meeting, with a chairperson, agenda and written record of proceedings. The chairperson keeps the meeting to the central issues, and the decisions of the meeting are recorded accurately so that they cannot be disputed later.	Appropriate when specific business/ issues has to be dealt with or decisions are to be reached for a particular group of people.
Informal Meeting	In an informal meeting, people feel free to express their own point of view and less dominated by the structure and formality of the proceedings. However, an open, unstructured discussion, although it allows all to participate, may result in a few people dominating the proceedings.	The same as for formal meeting

Source: Oakley & Garforth (1997)

avoid clashes with other events or activities. The meeting-place should be well-known, easy to access and appropriate for the form of meeting. The meeting-place should also be comfortable and have the necessary facilities. An extension agent should never hold a meeting at midday, on a very hot day, in the open sun. Such a meeting could be disastrous, as well as cause considerable discomfort.

After the above two issues have been considered, it may be useful for the agent to draw up a list of other arrangements to be made in preparation for the meeting. Such a check-list could include:

- Publicity for the meeting
- Seating arrangements

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- Audio-visual equipment and material, or other educational aids
- Agenda, and order of events
- Guest speakers or other specialists who will contribute to the meeting
- Chairperson to take charge of the meeting; should be elected by the community
- Refreshments for speakers and, where necessary, other participants.

Conducting the Meeting

Even the most carefully prepared meeting can fail if it is not conducted in the right manner. While the above arrangements are important, the way the actual meeting proceeds will determine whether it will be a success or not. The agent must be conscious that interaction is with adults who do not want to sit for hours listening to a speaker talk endlessly. The agent should try to vary the agenda of the meeting: for example, a short talk, accompanied by visual aids, followed by comments and questions.

Variety of content, as well as a chance for the farmers to participate, will be important. In addition, the meeting must not extend too long. One-and-a-half hours are probably sufficient for a group or community meeting. It is better to have a highly productive, short meeting than one which rambles and loses effect.

The agent's role in the meeting should also respond to the circumstances. The agent should encourage the community to appoint a chairperson and should allow the chairperson to conduct business. The agent's role should be to inform and support, but not to dominate the meeting. Furthermore, the meeting should not resemble a class-room with the agent as teacher and the farmers as pupils. The agent should make every effort to ensure that during the proceedings the community members feel that it is their meeting and that they have a role.

As a guide to the proceedings of the meeting, the agent should keep the following points in mind. Start the meeting on time, then welcome community members and special guests, explain the purpose of the meeting and the programme to be followed, and begin the programme. Later, the agent should encourage questions and discussion, and be prepared to summarize the main points and note important decisions. The meeting should be closed with thanks to all concerned.

As the most commonly used form of group extension method, the group or community meeting will be most effective if carefully thought out and planned. After each meeting, the agent should make a brief record of the proceedings and the principal decisions taken and should also take any prompt follow-up action that has been decided.

Demonstrations

Farmers like to see how a new idea works, and also what effect it can have on increasing their production. Both purposes can be achieved by means of a farm demonstration. A good, practical demonstration is an invaluable method in extension work. The demonstration is a particularly powerful method to use with farmers who do not read easily. A demonstration will give such farmers the opportunity to observe, at first hand, the differences between a recommended new crop practice and traditional practices. The strength of the demonstration should lie in its simplicity and its ability to present the farmers with concrete results.

There are two principal types of demonstration used by extension agents - method demonstration and result demonstration.

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Method Demonstration

Method demonstrations show and explain to farmers detailed procedures for implementing a technology. In the method demonstration, the farmer is shown step by step how, for example, to plant seeds in line, to use a mechanical duster to control insects, or to 'top' tobacco. The agent will probably be dealing with farmers who have already accepted the particular practice being demonstrated, but who now want to know how to do it themselves.

The main advantage of the method demonstration is that the extension agent can explain simple farming skills to a large number of people, thus increasing the impact of extension work. Moreover, as farmers are able to participate, there is a greater chance that they will benefit from the demonstration than if they were passively hearing it in a lecture.

The main limitation of a method demonstration is that, if there are too many farmers present, only a few get a chance to see, hear and do. The agent must be conscious that the demonstration is a learning experience and prepare the event accordingly. It is also vital that the demonstration be well thought out and competently conducted.

Result Demonstration

The main purpose of a result demonstration is to show local farmers that a particular new recommendation is applicable and beneficial under local conditions. Comparison is the important element in a result demonstration, for example, comparison: between using compost and no compost, between poor seed and selected seed, or between use of fertilizer and no fertilizer. "Seeing is believing" is an age-old expression, but one appropriate to a result demonstration. Until a farmer has actually seen the results of, for example, the application of a fertilizer, he will not be convinced by the agent's recommendation. By showing tangible results of a new practice recommended by the extension service, the agent can help to create confidence among the farmers and can greatly encourage them to try the practice themselves.

A result demonstration is an ideal way to present to farmers a comparison between traditional and new practices. It can also help to establish confidence in more scientific farming methods and increase the farmers' confidence in ideas originating from research stations. It shows proof of the value of a new practice. A result demonstration is also a useful tool that an agent can use to establish confidence among farmers in a new area.

Its major limitation is that it takes a long time to come to fruition and is thus a costly use of extension resources. If, in the end, for whatever reason, the new practice should fail, it could have disastrous consequences. Often such failures (for example, because of lack of rain) are outside the control of the agent.

Both method and result demonstrations are extension activities that require a lot of thought, careful planning and efficient execution. Although the two demonstrations differ somewhat in their purposes, they share a lot of common points and, in terms of their preparation and execution, they can be considered together.

Basic Principles for Demonstrations

Before the agent begins to plan and prepare for a demonstration, clarity about a number of key points will guide preparation and handling of the demonstration.

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Participation. Where possible, demonstrations should be carried out on local farms with farmers' participation rather than on an extension plot or research station. Farmers will have more confidence if a demonstration is held on a neighbour's land, or if a new practice is shown by a fellow farmer, than if it is carried out by agents on extension's land. The more the local farmers can be involved in the whole process of a demonstration, the greater will be their self-confidence and readiness to learn.

Simplicity. Simple, clear-cut demonstrations of a single practice or new idea will be far more effective than ambitious and over-complex demonstrations that demand too much of the farmer. It is better to proceed step by step with a number of demonstrations than to try do to everything at once.

Learning.The demonstration is a learning environment and should be conducted in such a way that the farmers do in fact learn. A demonstration is a type of class-room, and the agent must be conscious of classroom requirements in terms of space, time, equipment and the teaching method to use.

Preparation. An extension agent should never contemplate holding a demonstration without careful planning and preparation. A demonstration hastily given could have disastrous consequences.

Planning the Demonstration

When the agent decides that a demonstration would be useful, time should be dedicated to planning and preparing for it. In this respect, a number of questions should be considered.

- What is the objective of the demonstration?
- Why is the demonstration the most suitable extension method?
- What would be the usefulness of the new idea to be demonstrated?
- When should the demonstration be held? When is the most convenient date and time both for the farmers and in terms of the application of the new idea?
- Where is the demonstration to be held? Which suitable location is the most convenient for the farmers?

The agent should work out in some detail answers to the above questions before proceeding any further. It is very important that the reasons for the demonstration be appropriate and clearly understood and that there is a realistic expectation that the demonstration will be of benefit to the farmers involved.

Preparing the Demonstration

The more carefully the agent can prepare all the details of the demonstration, the greater the likelihood that it will run smoothly. The following are the key areas of preparation.

1. Consult the local people and seek their help and advice in the preparation of the demonstration.
2. Prepare a detailed plan of the demonstration, the main issues to be covered, the sequence of events, the resources needed and the contributions required from other people.
3. Collect information and material available on the new idea or practice to be demonstrated, and make sure that the topic is familiar and that questions can be answered.
4. Check that all the support material is ready (for example, audio-visual aids, implements).
5. Select those farmers who will take part in the demonstration and brief them on the outline of events.

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6. Ensure that the demonstration has been publicized and that the farmers know exactly when and where it is to take place.
7. Visit the demonstration site beforehand to make sure that all is in order and that the site is appropriate.

Supervising the Demonstration

During the demonstration, the agent's role should be to supervise but not to dominate. Actively support the farmer who may be assisting in the demonstration, and encourage the others to participate as much as they can. The agent should be keen to ensure that all those present benefit from the demonstration. During the demonstration, therefore, the agent should:

Welcome the participants, make them feel at ease and ensure that they have all they require to benefit fully from the demonstration.

Explain the purpose of the demonstration, what is hoped to be achieved, and outline the various stages to be followed. Distribute any literature or other material which was prepared as a guide for the participants.

Conduct the demonstration in person or be ready to help the demonstrator farmer. Proceed at a pace the farmers can follow, and be prepared to repeat explanations or answer questions from participants. Emphasize key points and explain the practice step by step in simple words. In a method demonstration, ensure that all those who wish to do so, have a chance to practice the technique themselves.

Summarize the main issues or points which have arisen, encourage questions from the farmers and make sure that the participants have had every opportunity to try out or examine the practice being demonstrated.

Conclude the demonstration with a vote of thanks to all concerned, and with a few comments about any follow-up activities planned.

Follow-Up

It is important that any interest generated, or decisions taken at the demonstration be followed through. Farmers will feel let down if the agent does not do so. This follow-up will be useful for the agent as well. Demonstrations can often result in good contacts with local farmers, and the agent may be able to enlist their support for future activities. It is also important that the agent reflect upon the demonstration and evaluate its effectiveness. The agent should, therefore, write a report and prepare a record of the demonstration, noting the names of the participants, the effect achieved and personal impressions of the usefulness of the demonstration.

Field Days

Field days are usually opportunities to hold method or result demonstrations on a slightly larger scale, and are usually run in a more informal and less highly structured manner. The purpose is often to introduce a new idea and a new crop, and to stimulate the interest of as many farmers as possible. Experimental stations or other government centers may be used for field days, but it is more usual and profitable for them to be held on the land of a local farmer. There is a greater chance of making an impact if the field day is held on a farmer's land, and if the farmer plays a part in running it and explaining the purpose. Field days can range in size from a small group to annual events attracting hundreds of farmers. Since

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the aim is a general introduction to some new idea, there is less need to be concerned about limiting the numbers. The extension agent's role on the field day is to support the farmer on whose land it is being held, to offer general guidance to ensure that things run smoothly and to be available to answer questions and queries. It is probably better not to over-organize the field day but to try to create an atmosphere in which visiting farmers can inspect, inquire, question and generally get to know what is available. Although the agent will try to encourage an open and informal atmosphere for the field day, there is still a considerable amount of preparation needed to ensure that it runs well. The issues which the agent must consider are very similar to those noted under demonstrations and will not be repeated here. It may be useful, however, to bear a few additional points in mind.

- ***Limit*** the numbers to the capacity of the field, to avoid overcrowding.
- ***Ensure*** a good layout of field-day activities, with easy access and facility of movement around the field.
- ***Encourage*** the demonstrator farmer to take most of the initiative; give support but do not take over the field day.
- ***Provide*** suitably large visual material and also, if necessary, a loudspeaker, to ensure that all can hear. Check that extension literature and other material are available for information.
- ***Conclude*** the field day by bringing all the participants together, reviewing the day's proceedings and the main items seen and discussed, and explain any future relevant extension activities. A field day is a day out for farmers and is often a welcome relief from their daily hard work. The agent should, therefore, provide an interesting and well-presented exhibition, suitable refreshments and points of rest, and generally create an atmosphere in which the farmers will feel at ease and will be eager to know what is going on.

Tours

Farmers like to visit farms in other districts to see how they operate, what they grow and what kinds of problems the farmers there are facing. A tour is a series of field demonstrations on different farms, or at different centres, and can often attract a lot of interest from local farmers. The tour should give local farmers a chance to see how other farmers cultivate their land, and to exchange ideas and experiences with them. It is important, therefore, that the area to be visited be in some way similar agriculturally to that of the visiting farmers.

As with all other forms of extension, tours have to be well thought out, planned, prepared and conducted. The five stages of; determining the objective, planning the content, preparing the arrangements, conducting the tour and arranging for appropriate follow-up, will be a guide to the extension agent. However, it may be useful to add these points:

- ***Visit*** the area first to become familiar with local conditions, the farms to be visited, the route and road conditions
- ***Limit*** the tour to what is possible. It is better to do a short tour in which visitors can have a good look at local farms than to arrange an ambitious tour and be pressed for time. Don't tire the visitors out.
- ***Encourage*** the host farmers to do all the explaining and to take charge of the tour.

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- ***Arrange*** for food and drink during the tour
- ***Conclude*** the tour with a short summary of the main events and note any comments or conclusions.

A field tour is an ideal method of involving farmers and of stimulating genuine interest in extension activities. It is also very useful in bringing farmers together to discuss common problems, and to gain useful experience of other areas.

Advantages of Group Methods (Based on the Experience of the Authors)

1. Enables Extension Agent to have face-to-face contact with a larger number of people at the same time.
2. Enables the Extension Agent to reach a selected part of the target group.
3. Facilitates sharing of knowledge and experience and thereby strengthen learning of the group members.
4. Reaches relatively large number of people, also offers more opportunities for interaction and feedback.
5. Satisfies the basic urge of people for social contacts.
6. Motivates people to accept change due to group influence. More effective than mass method in stimulating action. Less expensive than individual method owing to wider number of people reached at a time (Refer to Table 2).

Limitations of Group Methods

1. Wide diversity in the interest of group members may create a difficult learning situation.
2. Holding the meeting may be regarded as an objective itself.
3. Vested interests, power groups and village factions may hinder free interaction and decision making by group members.

Mass Methods

When Are Mass Methods Used in Extension?

Mass methods are used to

- Provide farmers with new awareness and draw their attention to certain new technology.
- Sharing experiences among successful farmers to other farmers in the community.

In this method, the Extension Agent communicates with a vast and heterogeneous range of people, without taking into consideration their individual and group identity. The method is used when a large and widely dispersed audience is to be communicated within a short time. There may be a few communicators and Subject Matter Specialists involved. The size of the audience may vary depending on the technique used.

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Advantages

1. Suitable for creating general awareness among people.
2. Helps in transferring knowledge and, forming and changing opinions.
3. Large number of people may be communicated within a short time.
4. Facilitates quick communication in times of emergency.
5. Reinforces previous learning.
6. Cost effective due to large coverage.

Limitations

1. Less intensive method.
2. Little scope for personal contact with the audience.
3. Little opportunity for interaction with and amongst the audience.
4. Generalized recommendations hinder their application by individuals.
5. Little control over the responses of audience.
6. Difficulty in getting feedback information and evaluation of results.

CONSTRAINTS TO SUSTAINABLE AGRICULTURAL DEVELOPMENT AND EXTENSION METHODOLOGIES

Emerging countries are usually faced with constraints which are consequences of the factors that identified them as developing countries as earlier highlighted. More importantly, the 17 Sustainable Development Goals of the United Nations can only be achieved if the majority of the constraints are concertedly

Table 2. Summary of extension methods used in developing countries: Characteristics and functions

Characteristics	Individual Methods (Farm and Home visits, telephone calls, office calls)	Demonstrations (Method and Result)	Mass Media (radio, Television, Newspapers, Magazine, Bulletins)	Group Methods (group meetings, Lectures)
Creating Awareness of Innovation	0	0	XXX	0
Creating Awareness of own problems	XXX	XX	0	XXX
Knowledge transfer	XXX	XX	XXX	XXX
Behavioral change	0	0	0	XXX
Activating Learning processes	XXX	XX	0	XXX
Cost per farmer reached	AAA	AA	A	AA

(Van den Ban and Hawkins 2002)

0 --- Indicates Unsuitable X----The number of crosses indicates suitability

A ---- The number of As indicates level of cost incurred.

N.B. The points outlined in the Table 2 are based on research results (Olaniyi et al. 2006; Chaudhry et al. 2006; Cho and Boland, 2004) rather than the ordinary impression and opinions of individuals.

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attended to by member countries. Conclusively, the way forward to solving the challenges facing the emerging countries will only be attained through the Sustainable Development Goals which are embedded in the issues stated below. These are the major constraints jointly summarized by the authors based on their experiences and studies; affecting extension activities in Nigeria.

1. **Lack of Strategic Planning that Indicates Future Directions:** Madukwe (2008) in his Professorial inaugural lecture describes agricultural extension in Nigeria as 'practice without policy'. This situation makes it difficult for extensionists to operate effectively since the majority of their activities are not legislated.
2. **Inadequate Monitoring and Evaluation Systems:** Effective monitoring and evaluation bring about performance and early indication of deviation from program objectives. The majority of federal and state agricultural programs such as ADP, OFN, Green Revolution, NAFPP and RBDAs became moribund due to lack of effective monitoring and evaluation.
3. **Top-Heavy, Bureaucratic Procedures:** A lot of bureaucratic bottle necks and red tape entangle activities by delaying, while waiting on instructions that may not come at the right time
4. **Insufficient Resources for Effective Implementation of Priority Research:** Resources in the form of capital, equipment and humans are either, insufficient, inadequate or are not released to meet timeliness of priority research. Agricultural projects are time and season specific, so that efforts should be made by agricultural policy makers to be conscious of the importance of time and season
5. **Lack of Effective External Linkages:** A perfect linkage system involving the research-extension-farmers, results in solving pressing issues in the agricultural sector. The Nigeria story has a linkage system called Weak research-extension-farmers-inputs-linkage system which needs effective performance of all the stakeholders in the linkage system for better coordination.
6. **Inward Looking Attitude:** For progressive performance of agriculture in developing countries, all stakeholders along the agricultural value chain must demonstrate effective attitudes in every stage of agricultural production in which they operate.
7. **Lack of a Culture of Evaluation of Performance:**The majority of projects die within a short period, because of lack of evaluation to improve performance. The problem of not having performance indicators to evaluate, before commencement of a project leads to project failure.
8. **Decreasing Investors' Confidence:** Decreasing attitude of the investors sets in when researchers work more on basic research rather than applied research. On this note the targets of researchers and investors are at variance. While some researchers concentrate on basic research for self-aggrandizement and publication recognition, investors are interested in problem solving research that can address their needs; which is applied research. This brings about low private sector participation in research activities
9. **Policy:** Without a well-defined Agricultural policy by the Federal Government, Agricultural practices in the country looks like a journey without a destination
10. **Infrastructural**
    a. Equipment. There is inadequate modern equipment to work with.
    b. A good Research environments needs stable electricity, regular water supply and uninterrupted internet services

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11. **Information Dissemination**: Extension plays important roles in creating innovation platform conducive for establishing an interactive linkage between research and End-Users (Roling, 1997). However, this unit is faced with many challenges in performing this role
    a. Lack of modern equipment to disseminate information
    b. Insufficient manpower to meet the increasing End-Users requests
12. **End-Users – Challenges faced by Research Institute are;**
    a. Poor participation and cooperation of End-Users in research activities
    b. Lack of adequate stakeholders participation and responsiveness
13. **Inadequate Training for Extension Agents:** There is need for on-the-job training of extensionists to bring about better job performance. The majority of the extensionists never attended on-the-job training. Extensionists should be exposed to the use of Geographical Information System (GIS), web Social Media for development, photographic and video equipment and open broadcast van, to mention few. All these will put value to extension work and make dissemination easy. More importantly, there is need to note that at every point of diffusion level, there are specific skills and approach in the use of equipment to facilitate adoption.

CONCLUSION

This chapter discussed several concepts of agricultural extension methodologies assessed from past to present and actions taken to make extension methodologies more appropriate to encourage agricultural development. It also identified roles of agricultural extension activities in agricultural development and the factors influencing the choice of appropriate extension methodologies in emerging economies. It concluded with the advice that developing countries should fashion a sustainable extension system that will be socially acceptable and culturally compatible, economically viable and environmentally friendly. Such an extension system will help hasten agricultural development in emerging economies.

REFERENCES

Adedeji, T.O., Nosiru, M.O., Akinsulu, A.A., Ewebiyi, I.O., Abiona, B.G. & Jimoh, T.S. (2013). Adoption of new rice for Africa (NERICA) technology in Ogun State, Nigeria. *Journal of Development and Agricultural Economics, 5*(9), 365-371.

Agwu, A. E., & Chukwuone, N. A. (2005). Funding of Agricultural Extension in a Democratic and Deregulated Economy: The Cost Sharing Approach. *Journal of Agricultural Extension*, *8*, 90–98.

Anandajayasekeram, P., Puskur, R., Workneh, S., & Hoekstra, D. (2008). *Concept sand practices in agricultural extension in developing countries: A source book.* Nairobi, Kenya: International Livestock Research Institute.

Anandajayasekeram, P., Torkelsson, A., & Dixon, J. (2002). *Emerging participatory approaches to technology development and transfer. What is new? Occasional paper*. Harare, Zimbabwe: FARMESA.

Campbell, D. A., & Barker, S. C. (1998). Selecting appropriate content method in program delivery. In Improving agricultural extension: A reference manual. FAO.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Chaudhry, K. M., Muhammad, S., & Ashraf, I. (2006). Alternative Extension Approaches to Technology Dissemination for Sustainable Agriculture in The Punjab, Pakistan. *International Journal of Agriculture and Biology*, *8*(6), 832–835.

Cho, K. M., & Boland, H. (2004). *Education and Extension for Multi-Functional Agriculture: Extension Concepts for Sustainable Agricultural Development in Myanmar*. Dublin, Ireland: AIAEE.

Famuyiwa, B. S. (2013). *Assessment of Environmental hazards associated with cocoa farming in Nigeria.* (Unpublished Ph.D. thesis). Department of Agric., Extension and Rural Development, O.A.U. Ife.

Famuyiwa, B.S., Torimiro, D.O., & Adesoji, S.A. (2013). Determination of Cocoa Farmers' Knowledge on Environmental Hazards Associated with Cocoa Farming Operations in Nigeria. *International Journal of Knowledge, Innovation and Entrepreneurship*, *1*(1-2), 58-70.

Havnevik, K., Bryceson, D., & Birgegard, L.-E. (2007). *African agriculture and the World Bank: development or improvement?* Retrieved from www.eldis.org/go/topics&id=34737&ttpe=Document#.Vws_DjY1gwg

ICCO. (2008). *Manual of best known practices in cocoa production. Version 1*. Consultative Board on the world cocoa economy sixteenth meeting Berlin, Germany.

IFPRI. (2011). *Priority setting Research & extension adoption evaluation; Engendering agricultural research development, and extension*. doi:10.2499/9780896291904as

Kumar, A. (2015). *Lecture 2 Major characteristics of developing countries.* Retrieved from http://web.uvic.ca/~kumara/econ420/characteristics-dev.pdf

Madukwe, M.C. (2008). *Practice without policy: The Nigeria agricultural extension services*. 30th Inaugural Lecture of the University of Nigeria.

Marten, G. G. (2009). *Human ecology*. Earthscan Publications.

Maunder, A. H. (Ed.). (1973). *Agricultural extension: A reference manual*. Rome: Food and Agriculture Organisation of the United Nations.

Mwangi, M., & Kariuki, S. (2015). Factors determining adoption of new agricultural technology by smallholder farmers in developing countries. Journal of Economics and Sustainable Development, 6(5), 208-217.

Oakley, P., & Garforth, C. (1997). Extension methods. In *Guide to Extension Training*. FAO. Retrieved from www.fao.org/docrep/t0060e/T0060E07.htm#5

Ogunjimi, S. I., & Farinde, A. J. (2012). Farmers' Knowledge Level of Precautionary Measures in Agro-Chemicals Usage on Cocoa Production in Osun and Edo States, Nigeria. International. *Journal of Agriculture and Forestry.*, *2*(4), 186–194. doi:10.5923/j.ijaf.20120204.10

Olaniyi, O. A. (2010). *Assessment of Utilization of Agricultural Information on Selected Arable crops among Rural youth in Oyo and Osun states, Nigeria*. (Unpublished Ph.D Thesis). Department of Agricultural Extension and Rural Development, Ladoke Akintola University of Technology, Ogbomoso, Nigeria.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Olaniyi, O. A., Ogunleye, Y. K., & Eniola, P. O. (2006). Extension Delivery Methods Preferred by Women Farmers in Oyo State, Nigeria. *Journal of Agricultural Extension Management*, *7*(2), 1–6.

Pretty, J. (2003). *Social capital and connectedness: Issues and implications for agriculture, rural development and natural resource management in ACP countries*. Review paper for CTA. CTA Working Document Number 8032.

Purcell, D. L., & Anderson, J. R. (1997). *Agricultural Research and extension: Achievementand problems in national systems. World Bank Operations Evaluation Study*. Washington, DC: World Bank. doi:10.1596/0-8213-3878-1

Roling, N. (1997). *Extension Role in Sustainable Agricultural Development in Improving Agricultural Extension a Reference Manual*. FAO Rome.

Sanginga, P.C., Lilja, N. &Tumwine, J. (2001). *Assessing the quality of participation in farmers' research groups in the Highlands of Kabale, Uganda.* PRGA; CGIAR, Future Harvest. Working document/PRGA 19.

Sosan, M. B., & Akingbohungbe, A. E. (2009). Occupational Insecticide Exposure and Perception of Safety Measures among Cacao Farmers in Southwestern Nigeria. *Archives of Environmental & Occupational Health*, *64*(3), 185–193. doi:10.1080/19338240903241077 PMID:19864221

Swanson, B., Bentz, R., & Sofranko, A. (1997). *Improving agricultural extension: A reference manual*. Rome, Italy: Food and Agriculture Organization of the United Nations.

United Nation. (2015). *Sustainable Development Goal*. Retrieved from http://www.un.org/sustainabledevelopmentas

Van den Ban, A. W., & Hawkins, H. S. (2002). Agricultural Extension (2nded). Blackwell Science publishers.

Wikiversity. (2015). *Characteristics of developing countries*. Retrieved from https://en.wikiversity.org/wiki/Characteristics_of_developing_economies

Williams, S.K., Fenley, T.M., & Williams, C.E. (1981). *A Manual for Agricultural Extension Workers in Nigeria*. Academic Press.

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Chapter 8
Agropreneurship Among Gen Y in Malaysia:
The Role of Academic Institutions

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ABSTRACT

Despite great concerns regarding food security and the need to maintain a continuous food supply for an ever-increasing population, the agriculture sector remains an unattractive employment option, especially among younger generations. The big question is, "who should play a greater role in giving this sector young talents that are needed for successful agriculture and how it should it be acquired? Research has shown that this sector is dominated by an aging community of farmers who lack the innovative skills that is needed for running a new and modern agricultural industry. This chapter provides a brief overview of the importance of the agriculture sector and agropreneurship and is followed by why the involvement of the Gen Y segment is crucial for the growth and development of this sector. Since the basis for agropreneurship development among today's youth is based on training and inculcating an agropreneurship work culture at the university level, the authors proposed roles an academic institution could play in instilling positive an agropreneurial attitude among Gen Y graduates.

AGRICULTURE SECTOR AND WHY IT MATTERS?

In many parts of developing world, agriculture production is recognized as a strategy to improve a nation's standard of living, particularly to increase income, reduce hunger, and contribute to the improvement of other measures of well-being (Owens, Hoddinott, & Kinsey, 2003). Agriculture is also acknowledged to contribute significantly to economic growth in many countries (Bairwa, Lakra, Kushwaha, Meena, &

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Kumar, 2014; Diao, Hazell, Resnick, & Thurlow, 2007; Razak et al., 2015). Furthermore, agricultural growth is seen as precursor to the industrial revolutions that spread across the temperate world, from England in the mid-18th century to Japan in the late 19th century. Higher agricultural productivity that generates an agricultural surplus open to partial taxation and is used to finance industrial development as well as enabling lower food prices for the masses underpinned the success stories of industrial and structural transformation.

Agriculture also plays a substantial role in providing employment opportunity and poverty reduction. It accounts for 32 percent of total employment globally and 39 percent of employment in developing countries of Asia and the Pacific (International Labour Office, 2014). The sector has been acknowledged to be a major contributor to poverty reduction, as is found in countries such as Brazil, Cameroon, Chile, Costa Rica, Dominican Republic, Egypt, Mali, Mexico, Nicaragua, Panama, Tunisia and, not forgotten, Malaysia (Cervantes-Godoy & Dewbre, 2010) among others in Asia and the Pacific (International Labour Office, 2014; Kuldilok, Dawson, & Lingard, 2013). Similar scenario is also seen in many developed countries such as the United States, the United Kingdom, Japan, and Australia, where agriculture sector does not only play a significant role in contributing the countries' food supplies but also provides other benefits such as improved physical and mental health, improved aesthetics, community building, employment opportunities, improved local land prices, and etc. (Mok et al., 2014).

On reflection, agriculture today is no longer a sector for poor people only. For instance, Thailand has gained its competitive advantage by dominating world exports of canned tuna with a market share of around 40 percent, which is at least four times higher than any other exporter (Kuldilok et al., 2013). Many other developing countries have benefited from agriculture not only to have sufficient food to maintain normal health for a growing population but also to increase the nation's economic standing (Bairwa et al., 2014; Diao et al., 2007; Razak et al., 2015). There seems to be no compelling reason to argue for the economically inferior state of agriculture sector in shaping the country's economic condition. With agribusiness' increasing technological sophistication, as is found in developed countries, agriculture can appeal to younger generations.

OVERVIEW OF AGRICULTURE SECTOR IN MALAYSIA

For many years, agriculture sector has been standing high as the backbone of Malaysian economy through the production of agricultural products for domestic consumption and also as the earner of foreign exchange (Abu Dardak, 2015). Agriculture plays an important role in the development of the Malaysia's economy including providing employment opportunity, uplifting the income of the populations and ensuring national food security (Siwar, Yasar, Ghazali, & Mohd Idris, 2013). Since its independence in 1957, agriculture has become a significant contributor to Malaysia's economy. For example, agriculture has contributed 38 percent of the country's GDP in 1960 as compared to 9 percent contributed by the manufacturing sector in the same year. In mid-1980s however, agriculture contribution to GDP has declined significantly due to the slow growth in the production of commodity and fluctuations in agricultural commodity prices (Selamat & Nasir, 2013). The declining trend keeps on continuing for decades. Even though it went up to 10.09 percent in 2010, it went back down for years after (Malaysian Department of Statistics, 2016). Despite this unstable trend faced by Malaysia, the country has observed an increased in total agriculture value added from RM18.7 billion in 2000 to RM21.6 billion in 2005. Albeit the performance of Malaysian economy experienced a rapid growth where the GDP has increased from RM11.8

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billion in 1970 to RM751.5 billion in 2012, the contribution of agriculture sector showed a declining trend since 1970 (30.8 percent) to 2012 (7.3 percent) (Abu Dardak, 2015; Malaysian Department of Statistics, 2016). Although its contribution increased to 3.0 in 2014 but it has decreased by 4.7 percent during the first quarter of the following year (Bank Negara Malaysia, 2015; Ministry of Finance, 2013).

The agriculture sector in Malaysia is an area where employment opportunity is offered to the population. In 1960, this sector contributed 60 percent of total employment in the country. The contribution however dropped in 2000 and 2005, where total employment contributed by the agriculture sector accounted only 15.3 and 12.9 percent, respectively. In 2010, agriculture, forestry and fishing has made up 13.3 percent of country's total employment and has provided employment for 11.1 million people in Malaysia (Jala, 2013, September 30). Even though its contribution to the country's total employment has been decreasing, the agriculture sector in Malaysia still continues to be a major contributor to the development of the country's economy (Selamat & Nasir, 2013). Because of this, the Malaysian government takes a serious attitude toward the decline in employment potential, where a total of RM6 billion is allocated for the agriculture sector in the 2014 national budget. Despite the growth in the services sector, which has taken over the manufacturing sector as the main contributor to the country's economic growth, the agriculture sector is not going to be ignored because it is the main source of income for many for farmers, fishermen and agro-based industries.

Recently there has been renewed interest in the agriculture sector as people begin to understand that the sector plays a crucial role in providing food and reducing the nation's poverty level, especially in rural areas. Against this background observation, the notion of sustainable agricultural development in relation to national food security and a continuous food supply is quickly gaining importance because the government has outlined it in the country's New Economic Model (NEM). A country's resourcefulness in developing its agricultural sector is an indication of its ability to provide sufficient food for its population. According to the Economic Planning Unit (EPU), agriculture consists of producing industrial and food commodities that include crops (plantation and food), horticulture (olericulture, pomology, floriculture, nursery crop culture and landscape horticulture), aquaculture (marine and freshwater), and livestock husbandry. In conjunction with the NEM, which has striven to reduce poverty among 40 percent Malaysians who earn less than RM1500 a month, agriculture and the agro-based sectors are seen to have potentials in realizing the government plan.

In Malaysia, agriculture stands as the third pillar of the country's economy and follows behind the service and manufacturing sectors (Selamat & Nasir, 2013). Entrepreneurship, on the other hand, is acknowledged as one of the best strategies for the development of economic growth for a country and is a useful tool to sustaining a country's competitiveness in today's increasing trend of globalization. This is because it indirectly creates political and social stability through the creation of job opportunities and initiates innovations that lead to technological change and productivity growth (Ahmad, Wan Yusoff, Mf Noor, & Ramin, 2012; Lim, Lee & Cheng, 2010). Therefore, an integration of both has given birth to the concept of 'agropreneurship', a new and promising dimension of the agriculture sector. Research findings show that agropreneurship has a profound impact on growth and survival (Baron & Shane, 2008; Poornima, 2009; Verhees, Kuipers, & Klopcic, 2011), not only on the individual, but also on the society and country altogether. The development of agropreneurship also contributes to the growth of small and medium-sized enterprises (SMEs) through the creation of small and medium-sized agro-based enterprises (SMAEs). Given the significant role played by SMEs in making a substantial contribution to the global economic growth (Jutla, Bodorik, & Dhaliwal, 2002), the development of agropreneurship is a worthy subject to be examined.

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Comparing agriculture sector in Malaysia to that of the neighbouring countries such as Thailand, Vietnam and Indonesia, the agriculture sector's contribution to the Malaysian economy is still relatively low and lags behind these regional peers in percentage contribution to GDP due to lack of scale, production-driven farming and low-value products (Ramachandaran, 2010). For example, according to a report by the World Bank, agricultural contribution to the country's GDP in Thailand, Vietnam and Indonesia was 10.5 percent, 17.7 percent and 13.3 percent respectively. However, in Malaysia, the sector's contribution to the country's GDP in the same year was 8.9 percent only. This highlights that Malaysia need to strive hard to be at least at par with its closest neighbours.

Therefore, in view of the growing world population, it is imperative that sustainable agriculture and food security and nutrition be part of the new sustainable development agenda in 2016 and beyond. A way to achieve this plan is by encouraging Malaysians, especially the younger generation, to venture into agropreneurship business activities. With full and strong support from the government, the agriculture industry in Malaysia, with its enormous prospects and prosperous business potential, creates a large and attractive chance for entrepreneurs (D'Silva, Mohamad Shaffril, Uli, & Abu Samah, 2009). Slowly, Malaysians have immense investment prospects with quick and high returns in agropreneurship business activities (Abdullah & Naem Sulaiman, 2013).

AGROPRENEURSHIP: THE NEW DIMENSION IN AGRICULTURE SECTOR

The concept of agropreneurship, is gradually getting attention in both agriculture and entrepreneurship areas of study, especially in redefining new and modern agriculture. Recent studies show that agropreneurship as a concept and practice is not wishful thinking and exageration: it has a profound impact on business growth and survival (Verhees et al., 2011). According to Nagalakshmi and Sudhakar (2013):

Agricultural companies increasingly have to adapt to the vagaries of the market, changing consumer habits, enhanced environmental regulations, new requirements for product quality, chain management, food safety, sustainability, and so on. These changes have cleared the way for new entrants, innovation, and portfolio entrepreneurship.

This have conclusively shown that the emergence of the free market economies globally has resulted in the development of a new spirit of enterprise "Agropreneurship" and the increased individual need for responsibility for running their own businesses (Alex, 2011).

The concept of agropreneurship is being promoted to encourage setting up of enterprises related to the farm sector in the effort to modernise the agriculture sector. There are various definitions of agropreneurship in the literature. An early definition by Ahmed, Hasan, and Haneef (2011) refers to agropreneurship as an employment strategy that leads to economic self-sufficiency of rural people. Nagalakshmi and Sudhakar (2013), on the other hand, define agropreneurship as sustainable, community-oriented, and directly marketed agriculture. A more recent definition by Bairwa et al. (2014) indicates that agropreneurship is a profitable marriage between agriculture and entrepreneurship which turns a farm into an agribusiness establishment in agriculture and allied sectors. Similarly Azer, Mohamad, Abdullah, and Mustapha (2014) describe agropreneurs as individuals who involve the agricultural aspects into business. Agropreneurship could also be understood as the classification of all activities where farmers adjust a free market economy as entrepreneurial (Soumiya Devi, 2015). Despite the various definitions

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given to explain agropreneurship, the authors did agree on one aspect, which is that agropreneurship involves activities of producing, distributing and marketing of agricultural products to generate income and contribute to a sustainable community.

Agropreneurship is indeed seen to contribute at both individual and national levels. At the individual level, agropreneurship contributes to improving performance of an individual by reducing one's poverty level as a result of employment opportunity creation and allowing creativity and innovativeness to exist in meeting consumer demands (Bairwa et al., 2014; Nagalakshmi & Sudhakar, 2013; Osikabor, Adesope, Ibrahim, Babayemi, & Olatunji, 2011). At the national level on the other hand, agropreneurship has the power to improve economic viability (Osikabor et al., 2011) and to make agriculture a more attractive and profitable venture that contributes largely to national income by providing direct employment and income to the large, lower socioeconomic strata of society (Bairwa et al., 2014). Agropreneurship is now viewed to be an important agent of rural economic development (Mohd Yusof & Raja Abd Rahman, 2007). Agropreneurship's importance has also captured the attention of the country's important parties with the rise of the concept, 'agriculture is business' (Rezai, Mohamed, & Shamsuddin, 2011). With this concept, people in Malaysia are encouraged to become agropreneurs, not only to create wealth for themselves, but at the same time to contribute to the sustainability of society. This shows that communities also believe that agropreneurship indeed plays a significant role in contributing towards national economic growth and individual well-being. Therefore, future agropreneurs should be groomed, especially among youth.

THE IMPORTANCE OF AGROPRENEURSHIP IN ECONOMIC GROWTH AND DEVELOPMENT

Department of Statistics Malaysia revealed that in 2013, 76 percent of active companies in the agricultural sector were SMEs through the establishment of SMAEs. This shows that the success of agricultural projects depends largely on the success of SME's operation. Based on the findings, it is reported that SMEs and SMAEs play a significant role in and make substantial contributions toward national economies. This is evidenced by reports that 80 percent of global economic growth is attributable to SMEs (Jutla et al., 2002). In 2013, SMAEs drove 3 percent and 2.1 percent of Malaysian SME GDP growth and the country's overall GDP growth, respectively (SME Annual Report 2013/2014). Undoubtedly, agropreneurship activities play a significant role in contributing to the country's economic development by contributing to the supplies of food, job opportunities for people, earnings from exports and have also become major suppliers for agro-based industries (Hassan, Shaffril, Azril, Abu Hassan, & D'Silva, 2009; Okezie & Baharuddin, 2012; Siwar et al., 2013).

Even though the agriculture sector has recorded a more moderate growth (National SME Development Council, 2013), the country still expects the sector to improve, and this was supported by the higher output of crude palm oil from the maturing of new trees as well as being supported by food commodities, especially livestock and vegetables. The Third Industrial Master Plan (IMP3) highlights the need to push small entrepreneurs to become major players in agropreneurship and agro-based business activities with potential areas in resource based manufacturing SMAEs, such as herbal and traditional medicines, palm oil-based products, and food and beverages, including convenience foods for the halal market (Ministry of International Trade and Industry, 2006). Agro-based activities such as the agro-processing sector, which includes not only agro-related industries but also distribution services and trading activities, would roughly account for more than one-third of the GDP of Indonesia, Chile, Brazil and Thailand, and between

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20 and 25 percent of GDP in sub-Saharan countries. The entire food system, including the production of primary goods and commodities, marketing and retailing, accounts for more than 50 percent of the GDP in developing countries (Jaffee, Kopicki, Labaste, & Christie, 2003). Furthermore, in developed countries such as in the United States of America (USA), agropreneurship activities contributes 13 times more to GDP than pure agricultural activities (Jaffee et al., 2003).

Due to the world's concerns about food security and continuous food supplies for people, agropreneurship has greatly captured the attention of multi-lateral organizations, policy makers and civil society (Food and Agriculture Organization of the United Nations, 2009). Hence, agropreneurship is a mechanism that provides an off-farm link in agrofood value chains. It supplies valuable inputs such as innovative information to the farm sector and at the same time connects the farm sector to the final consumers via the handling, processing, transportation, marketing, and distribution of agricultural products. These connections show strong cooperation between agropreneurship business activities and the performance of the agriculture sector. Indeed, vigorous agropreneurship business activities could encourage tremendous growth of this sector. At the same time, strong connection between agropreneurship and smallholders opens opportunity for the community to live a better life because it contributes to employment generation, poverty reduction and human resource development (Ahmed et al., 2011).

Agriculture today is no longer a sector for poor people only. Instead, given full and active supports from the government, it is now a sector where chances exist for businesses to prosper (D'Silva, Mohamad Shaffril, Uli, & Abu Samah, 2010). Hence, this offers significant opportunities for entrepreneurs to take advantage of opportunities and generate wealth. In fact, the focus of agropreneurship development is not only for the purpose of food security. Its importance also covers the transfer of knowledge, skills, techniques, expertise to the rest of the population via job creation and employment opportunity.

AGROPRENEURSHIP DEVELOPMENT IN MALAYSIA

Since the third era of industrialisation that took place between 1990 and 2005, it is only until recently that the focus on agropreneurship has started to regain momentum in Malaysia. Agropreneurship is now viewed to be an important agent for rural economic development (Mohd Yusof & Raja Abd Rahman, 2007). Because of that, the 9th Malaysian Plan outlined an RM 511.9 million budget allocation that aimed to produce 260,928 agropreneurs (Mohamed, Rezai, & Shamsudin, 2011). In this national development plan, the government placed great emphasis on the enrichment of the modern agriculture sector, outlining the way forward for it and to reenergize the sector to become one of the main contributors to the country's economic growth. The plan not only covers the commercial and biotechnology aspects of agriculture, but also on agriculture as a business. Consequently, small agricultural entrepreneurs in the country need to be pushed forward to become major players in SMAEs, as outlined in the Third Industrial Master Plan (IMP3). Based on the SME Annual Report 2012/2013, SMAEs that are run by agropreneurs rank number four of overall SMEs in this country. Table 1 summarizes the Malaysian SME establishment, as compared to other sectors in 2011. Even though SMAEs represent only 1 percent of the overall SME establishment in Malaysia, its contribution to GDP is still significant. As of 2012, SMAEs contribute 3.3 percent to Malaysia's GDP (Malaysian Department of Statistics, 2016).

In Malaysia, agropreneurship is becoming increasingly important. It offers opportunities for generating revenue and creating a future that straightforward subsistence farming often struggles to provide. In the 2003, the Ministry of Agriculture and Agro-Based Industry allocated and spent RM500 million on

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Table 1. Number of SME establishments by sector

Sector	Micro	Small	Medium	Total SME
Manufacturing	21,619	13,934	2,308	37,861
Services	462,420	106,061	12,504	580,985
Agriculture	3,775	1,941	992	6,708
Construction	8,587	6,725	3,971	19,238
Mining & Quarrying	57	126	116	299
Total SMEs	496,458	128,787	19,891	645,136

Source: Economic / SMEs Census 2011 by Department of Statistics, Malaysia.

entrepreneurial development programs with aims to transform traditional farmers to visionary agropreneurs (Abdul Halim, Alias, Che Hamid, & Zakaria, 2011). Government's effort to promote agropreneurship did not just stopped there. The effort to promote modern agriculture and agropreneurship was also led by government agencies such as Department of Agriculture in collaboration with government linked companies (GLCs), such as Khazanah Nasional Berhad's subsidiary, Blue Archipelago. Realizing that agropreneurship is a very important activity among SMAEs specifically and its contribution to SMEs generally, the National Food Security Policy (FSP), which was approaching its expiration in 2011, was finally extended. Furthermore, the Fourth National Agricultural Policy (NAP4), a policy under which RM5.6 billion was allocated for agricultural development, was also executed in the same year (Adnan, 2011).

Moving forward, the government's support for agropreneurship and SMAEs was also clearly outlined in the national policies and development plans, such as Economic Transformation Program (ETP, 2011-2020), IMP3 (2006-2020), 10th Malaysian Plan (10MP) and SME Masterplan (2012-2020). In order to translate SME development strategy into reality, the National SME Development Council (NSDC) was established in 2004 to provide strategic direction for government policies on SME development and to ensure coordination and effectiveness of government programs. One of the key initiatives developed by NSDC is the National SME Development Blueprint, an annual action plan for SME development. Two types of government support for the development for agropreneurship and SMAEs are financial and non-financial support. Included under the first category are property loans, working capital and grants that are channelled through the Agro Bank with aims to provide agropreneurs a continuous working capital via overdraft facility. With the purpose to strengthen SMEs, the government has launched a Shariah-compliant SME Financing Fund of RM2 billion. The scheme is currently managed by 13 Islamic banks with the government providing a 2 percent profit rebate. Another initiative to assist agropreneurs with the capacity and potential to sustain their businesses is the SME Revitalisation Fund. The government also established an RM10 million SME Emergency Fund to assist SMEs that are affected by natural disasters. This fund channels soft loans up to a maximum of RM100 thousand to affected SMEs through the Small and Medium Enterprise Corporation Malaysia (SME Corp. Malaysia) and the Malaysian Industrial Development Finance Berhad (MIDF). On the other hand, the latter category (non-financial) of support includes advisory, marketing, management, networking, research and development and technical support.

Equally important, various government agencies such as Palm Oil Research Institute of Malaysia (PORIM), Rubber Research Institute of Malaysia (RRIM), Malaysia Cocoa Board (MCB), Malaysia Agricultural Research & Development Institute (MARDI), Forest Research Institute Malaysia (FRIM)

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have also participated by expressing their support and commitment to grow agropreneurs and SMAEs to be economic champions by conducting research and development (R&D), activities in agriculture and providing agricultural training programs. Agencies like the Federal Agricultural Marketing Authority (FAMA) on the other hand, plays its role in securing market base and looking for market potential for local produce, particularly fruits and vegetables, as well as internationally promoting horticultural products such as fruits and flowers.

In order to promote the involvement of youth in producing modern agriculture and promoting the growth of agropreneurship, the government introduced the My *Kampung* My Future (MKMF) program. Huge amounts of funding were allocated for the success of this program with a goal of generating future agropreneurs. Today, as one of the government's effort to reduce graduate unemployment, RM50 million was allocated under the Graduate Entrepreneurship Fund, which is managed by SME Bank. The fund provides soft loans of up to RM500 thousand at an annual interest rate of 4 percent. To show that the government is very serious about building local agriculture industry, the sum of RM6 billion was allocated to implement high value-added and commercially-viable agriculture programs that requires human capital input from the youth sector ("Budget 2014: Support for SME plans," 2013). In order to further instil interest towards agriculture among the young segment and also to grow young agropreneurs with high income, the government has established the Young Agropreneur Unit through the aspirations of the Minister of Agriculture in September 2013. Mainly targeted for individuals under the age of 40, the aim of this program is to assist and encourage agropreneurship business activities among this group by involving in agricultural activities such as crops, livestock, fisheries, marketing, technology and innovation, as well as special projects such as agro-tourism and agro-based industry. Additionally, the implementation of this program is hoped to facilitate in shifting youth's paradigm towards this sector whereby the government is focussing in changing the traditional held belief regarding negative perception of agriculture sector.

As innovativeness was proven as being impacted by education (Yusoff, Ahmad, & Abdul Halim, 2016), the Agriculture Youth Entrepreneur Incubation Programme (AYEIP) with an aim to provide education, training and practices intended for youth who are interested in agriculture field was developed. The programme outlines provide agriculture coaching and offer a 'hands-on' experience on farming knowledge. The AYEIP programme was conducted in the Department of Agriculture (DOA) in four centres across the country. The programme was developed particularly for young (18-35 years old) agriculture institute graduates, university graduates, youth and any general Malaysian citizen, and police retiree or pension army personnel. The incubation consists of eight months full time programme which was fully funded by Malaysian government under the Ninth Malaysian Plan. At the end of the incubation programme, participants who passed stringent training together with good entrepreneurial qualities will be granted with a space for starting agropreneurship business activities.

Furthermore, to enhance youth agriculture interest and entrepreneurial skills, various activities and programs were provided by the Malaysian government through its agricultural departments. such as trainings that covers various business aspects that include production, marketing, advertising and promotion (Performance Management and Delivery Unit, 2010). The Malaysian Agriculture, Horticulture and Agro-tourism (MAHA), through its active promotion of agricultural products with its motto "Agriculture is business", was also one of the government's initiatives that opened important opportunities for youth to get ideas to create new products (Performance Management and Delivery Unit, 2010).

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Finally, the government through its Ministry of Higher Education (MOHE) strives to assist SMEs in expanding their business through the introduction of Public-Private Research Network (PPRN) programme. Demand-Driven Innovation Project by PPRN endeavours to identify entrepreneurs with technological problems and researchers with viable research-based solution. Under PPRN programme, entrepreneurs who face difficulties in their venture could join the PPRN programme and begin describing their problems. In responding to that, PPRN subsequently develop a team of experts and scientists in the area to readily develop new technologies and taking appropriate action to assist in solving the entrepreneur's problem. Besides helping the entrepreneurs, this approach also aims to develop close cooperation between academics and entrepreneurs in producing innovative, high quality, competitive and unique products. Furthermore, in order to solve the problem, the entrepreneurs will be provided with a grant. A fund up to RM50,000 for every problem solved with the cooperation of entrepreneurs and academics will be granted.

AGROPRENEURSHIP SUPPORT THROUGH EDUCATION

Becoming an agropreneur is not a career path to be undertaken lightly. Agropreneurs have to prepare themselves to take calculated risks, be creative, innovative and resourceful, ready to put in long hours of hard work, cope with stress, and weather the bleak periods as well as the good ones. Realizing these needs, an agropreneur incubator program was established. It is a six-month course developed and aims to produce more agropreneurs with exposure to the realities of the entrepreneurial world who are confident and competitive. Agropreneurship training and education is actually not something new in Malaysia. Indeed, agropreneurship education: which is embedded in entrepreneurship education in Malaysia, began as early as lower secondary level in high school when the Integrated Living Skills (ILS) curriculum was introduced in 1991 (Mohamed, Rezai, Shamsudin, & Mahmud, 2012). Later when the students moved to the upper secondary level, students may choose subjects that relates to entrepreneurship such as Commerce as an elective course. At a much higher level, entrepreneurship education is even more emphasis. Through its Basic Student Entrepreneurial Program (BSEP) that started in 2003 and with early participation from 19 local and one private higher education institutions, the government aims to provide training to final year students who are interested in becoming entrepreneurs.

Subsequently, agropreneurship education and training in producing skilful agricultural talents cannot be given any less attention. Realizing the contribution of agriculture to the country's economic growth, the Malaysian government has been promoting both formal and informal agropreneurship education. For example, agropreneurship education has been promoted as early as primary school for children where most primary schools in the country encourage their students to sell foods during the *Canteen Day,* an entrepreneurship day of which students sell things during school hours. Other examples of government efforts to promote agropreneurship education can also be seen in common activities offered by various organizations, along with the formal entrepreneurship education offered at higher education institutions such as conferences, seminars, short courses and training on agropreneurship. Furthermore, realizing the importance of agropreneurship, the Malaysian government through its public and private universities and colleges has put in several academic programs and training at tertiary level to cultivate graduate feasibility and desirability for agropreneurship. At the university level, programs are typically offered by faculty of agro-based industries, faculty of agriculture or faculty of applied science.

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WHY FUTURE GENERATION NEEDS TO CONCENTRATE ON AGROPRENEURSHIP?

In Malaysia, Chan, Selvadurai, and Hamid (2009) have raised concerns and highlighted the issue of small number of young entrepreneurs. According to the authors, the involvement of youth in entrepreneurship in Malaysia is not up to the expected level despite the huge efforts put forth by the government. The same issue was highlighted by Mohammad Nor, Nik Mohd Masdek, and Maidin (2015). The authors stressed that participation of youth in entrepreneurial activities was very low. Indeed, the growth percentage of entrepreneurs in Malaysia (youth and elderly) did not even exceed 26 percent (Mohammad Nor et al., 2015). Supporting this claim, a survey conducted by the Ministry of Education (MOE) in Malaysia revealed that among 22,016 working graduates, only 2.8 percent is self- employed and only 1.4 percent of 11,313 diploma holders are self-employed (Zainal Abidin and Irsyad, 2012).

Furthermore, a few of previous researchers have expressed their concern regarding youth unemployment in Malaysia (Abu Samah, D'Silva, Shaffril, & Uli, 2011; Mohammad Nor et al., 2015; Shamsuddin, Mohmad Isa, Aziz, Mohamed Mahfol, & Alagari, 2013). According to Abu Samah et al. (2011), the unemployment rate among youth was 4 percent in 2011. The rate kept on going up where in 2015, the youth unemployment rate was reported to be around 10 percent (Ministry of Finance, 2016; Mohammad Nor et al., 2015). Additionally, the current report by the Ministry of Finance showed that up to 40 percent of the total unemployed in Malaysia are youth especially the university graduates (Ministry of Finance, 2016). Furthermore, the report revealed that over 90 percent of those unemployed are aged between 15-29 years old.

Given this unfavourable situation, many researchers have called for agropreneurship activities as an approach in dealing with the overwhelming rate of youth unemployment as well as to increase the number of graduate entrepreneurs (Abdullah & Naem Sulaiman, 2013; Abdullah, Abu Samah, & Othman, 2012; Hock-Eam, Ahmad, & Jan, 2015; Mohammad Nor et al., 2015). Besides that, it was found that majority of graduate entrepreneurs were involved in wholesale and retail trade; services, real estate activities, and the manufacturing sectors (Hock-Eam et al., 2015). Hence, there is an urgent call for the involvement of young entrepreneurs to enhance and strengthen the agriculture sector in Malaysia via agropreneurship activities (Abdullah & Naem Sulaiman, 2013; Abdullah et al., 2012; D'Silva et al., 2009, 2010). Therefore, given the issue of small number of young entrepreneurs and an overwhelming rate of graduate unemployment in Malaysia, it is imperative for future generation to concentrate on agropreneurship as one of the tools to cater these issues.

THE CHALLENGE: GEN Y INVOLVEMENT IN AGROPRENEURSHIP

With the surge of interest in sustainable development, agropreneurship has now been earmarked as an important business activity for the country's economic development. However, the development of modern agriculture and agropreneurship endeavours will not be a success without an involvement of the young people, especially the Gen Y segment. Because of this, the Malaysian government endeavours to develop agropreneurial skills among this population. The local government has also placed great emphasis on encouraging and motivating them to become agropreneurs with the objectives of ensuring increasing and continuous supplies of food for the nation as well as decreasing the youth unemployment rate (Abdullah, Abu Samah & Othman, 2012; D'Silva et al., 2009). This can be seen through government highlights

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in the Third Industrial Master Plan (IMP3) to push small agropreneurs to become major players in the agro-based industries (Ministry of International Trade and Industry, 2006).

Yet, despite the considerable critical attention that was paid to the issue of food security and continuous food supplies in the country, Malaysians relatively show a lack of interest in agriculture sector when, compared to other sectors, only 11.8 percent of country's total employment comes from the agriculture sector (Abdullah et al., 2012). At the same time, the country is also facing the issue of an ageing agricultural community. The Performance Management and Delivery Unit (2010) reported that the average age of paddy farmers is above 60 years and 40 percent of fruit farmers are above 55 years of age. Supporting this report, a major finding in agriculture also showed that over 66 percent of people in agriculture are over 50 years old where the young are not interested and do not want to be involved in agriculture perhaps due to the view of low profitability held on this sector (Alam, Siwar, Murad, Molla, & Toriman, 2010; Jala, 2013, September 30; Zainal Abiddin & Irsyad, 2012). Later findings also showed the same phenomenon. It was revealed that 45 percent of farmers in Malaysia are 55 years old and above and this situation has caused retardation in production improvement (Abdullah & Abu Samah, 2014; Che Abdullah & Mustapha, 2009; Siwar, Idris, Yasar, & MOrshed, 2014). This phenomenon highlights that the agriculture sector in Malaysia is experiencing a shortage of young agricultural talent (Zainal Abiddin & Irsyad, 2012). Additionally, Movahedi, Latifi, and Sayyar (2013) emphasized that agropreneurship activities in Malaysia suffer from a lack of educated and skilful workforce and entrepreneurial spirit due to aging agricultural community. Until today, the issue of youth involvement in agriculture remains a big question mark. Their involvement in agropreneurship activities is still discouraging where young agropreneurs (aged 18 to 40 years) accounts for only 26 percent of all agricultural community (Abdullah et al., 2012). This figure is still far below despite the strong encouragement from the local government.

Notwithstanding the huge efforts put forth by the government, the involvement of youth in entrepreneurship in this country is still not up to the expected level (Chan et al., 2009). Possibly due to the instability of the agriculture sector, the youth in this country are more inclined to work in the manufacturing sector because they believe the sector brings them a better image, higher income and more advanced urban infrastructure (Che Abdullah & Mustapha, 2009). The great challenge therefore is to see how to get Malaysian youth, specifically the Gen Y segment, to venture into agriculture given the stigma associated with agriculture and farming. Researchers have expressed their concern regarding youth unemployment and suggesting venturing in agropreneurship and become agriculture self-employed as one of the solution (Abdullah & Naem Sulaiman, 2013; Abdullah et al., 2012). Hence, there is an urgent call for the involvement of young entrepreneurs to enhance and strengthen the agriculture sector in Malaysia via agropreneurship business activities (Abdullah & Naem Sulaiman, 2013; Abdullah et al., 2012; D'Silva et al., 2009, 2010).

WHY GEN Y INVOLVEMENT IN AGROPRENEURSHIP IS IMPERATIVE

Considering the significant role played by SMAEs in developing the country, Malaysian Gen Y are encouraged to become agropreneurs to meet both new career opportunities and also to ensure an increase and continuous supply of foods in the future (Abdullah et al., 2012; Zahrom, 2012, December 13). Besides its objective to enhance income distribution and reduce the nation's poverty level, many countries nowadays are gearing toward producing young entrepreneurs that possess many optimistic characteristics as one of the solutions to decrease the youth unemployment rate (Abdullah et al., 2012; D'Silva et al.,

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2009). Together with fast growing current technology and innovation, the agriculture sector definitely demands fresh and innovative ideas from the young segment, especially those with agropreneurship education, knowledge and skills.

Equally important, as SME Masterplan 2012-2020 outlines it's vision to develop globally competitive SMEs across all sectors that enhance wealth creation and contribute to the social well-being, the Malaysian Prime Minister encouraged high investment in youth as he believes "…the youth of today are an asset… who will take Malaysia to greater heights". Approximately, 38 percent of the Malaysian population consists of youth (SME Master Plan 2012-2020). In the same way, it has been suggested to create a "productive society" especially among the young population (those between the age of 18 to 40 years old) (Ahmad, Ramayah, & Tuan Muda, 2013). Agropreneurship activities should be cultivated among the young people because as individuals get older, they become less willing to invest time in activities that do not produce quick returns, including starting a new business (Lévesque & Minniti, 2006). In addition, the productivity level among this population must be kept high in order to spur economic growth and thus energize entrepreneurial spirit that drive first generation entrepreneurs (Ahmad et al., 2013).

Globally, the Gen Y population totals approximately 70 million, which is double the size of Gen X (Hewlett, Sherbin, & Sumberg, 2009). In Malaysia, Gen Y accounts for 40 percent of the country's total population and is the fastest growing segment of the workforce today. Even though there exists a contrary view that ageing or the third-age entrepreneurs (those between the age of 50 to 64) possess high working experience, know-how, and great financial means for entrepreneurship (Baucus & Human, 1994; Singh & DeNoble, 2003), and hence are better off in their entrepreneurial pursuits, the Gen Y cohort is more appropriate to be the key to drive a sustainable economy of long term growth that a nation can depend on because they are characterized by many optimistic values needed by agropreneurs in today's modern agriculture environment, such as being technology savvy, independent, self-reliant, entrepreneurial thinkers, well-educated, confident, passionate, upbeat, ambitious, result-oriented and socially conscious with high integrity (Geyzel, 2009; Martin, 2005; Sox, Kline, & Crews, 2014), as well as vibrant, energetic and high productivity (Joseph, Adanma, & Chinonso, 2012; Onwumere & Ukpebor, 2011). Evidence from the United States of America by the Kauffman Foundation (2012) reveals that 29.4 percent of entrepreneurs were 20 to 34 years old, and roughly 160,000 start-ups a month were led by Gen Y in 2011. Similarly, Pugh (2014) reports that more than half of Gen Y (54 percent) either want to start a business or have already started one. Thus, the Gen Y segment is the best candidate to venture in agropreneurship in order to realize the government plan in creating agriculture as a promising economic sector for the country's development. Based on those arguments, agropreneurship venturing among the Gen Y agropreneurs has recently grown in importance and is seen to be a practical concern to be investigated further in future research.

PROMOTING GEN Y AGROPRENEURSHIP: THE ROLE OF ACADEMIC INSTITUTIONS

It has been discussed extensively in the entrepreneurship literature that entrepreneurship is indeed a discipline of traits that can both be learned and taught (Vanevenhoven, 2013). Relying on the assumption that "entrepreneurs can be made", it is the role of academic institutions to take initiatives to promote agropreneurship among graduates by offering agropreneurship courses and programs and also via agropreneurship support mechanisms. Academic institutions emerged as a place where 'critical tools'

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for the development of future entrepreneurs are offered. The 'critical tools' here implies all efforts the institutions take in contributing to the development of future entrepreneurs. Furthermore, young agropreneurs have been postulated to have the risk taking and innovative attributes in undertaking a business enterprise (Mohamed et al., 2012; Zainal Abiddin & Irsyad, 2012). Therefore academic institutions are expected to produce young talents who are confident, motivated, proactive, innovative, take up entrepreneurship challenges as well as have a substantial skills to work in a team (Sánchez, 2013). The engines of agropreneurship development among youth are based in training and inculcating agropreneurship work culture (Mohamed et al., 2012) during their study at the university. Therefore, the role of academic institutions is paramount, as it is a centre that make contribution to the development of agropreneurship by creating an extent of business opportunities and equipping students with innovative business skills (Mohamed et al., 2012).

Specifically, in order to promote youth agropreneurship from academic institution perspective, the following suggestions are put forth.

1. **Stimulate Awareness and Positive Agropreneurial Attitude:** Firstly, academic institutions should stimulate students' awareness and form a mental picture and experience of the viability of agropreneurship as a career choice via formal agropreneurship courses and programs. Agropreneurship education must appear to enable students to acquire a set of knowledge and skills needed for successful performance along the entrepreneurial process (Matlay, 2008). This set of skills can facilitate future agropreneurs, especially for opportunity discovery and as well as promoting agroepreneurship desirability and feasibility and thus increase the formation of intention to become self-employed (Peterman & Kennedy, 2003; Saeed, Yousafzai, Yani-De-Soriano, & Muffatto, 2015; Solesvik, Westhead, & Matlay, 2014). Furthermore, young agropreneurs are postulated to have the risk-taking and innovative attributes needed in undertaking a business enterprise (Mohamed et al., 2012; Zainal Abiddin & Irsyad, 2012). Therefore, students who are supplied with agroepreneurship education and were enrolled in agroepreneurship courses are expected to be confident, motivated, proactive, innovative, and willing to face agroepreneurship challenges, as well as have the substantial skills to work in a team (Sánchez, 2013). Students who have participated in agropreneurship education are expected to be more entrepreneurially oriented, thus having a higher intention to become agropreneurs. This can be achieved by formulating detailed and meaningful curriculum and content that leads to students' adoption of appropriate attitudes that will cultivate their interest and desire in learning activities as well as developing their skills and competencies (Heinonen, 2007; Muhammad, Ismail, & Eh Rak, 2013).
2. **Provide Agropreneurship Education via a More Holistic Approach:** Secondly, academic institutions should provide agropreneurship education at the individual level with emphasis on the interaction between young agropreneurs and opportunity. It is true that developing positive attitude toward a certain behaviour is necessary, but positive attitude alone is insufficient. Students also need to be assured that the behaviour is feasible to achieve in real world (Baden & Parkes, 2013; Florin, Karri, & Rossiter, 2007). Notwithstanding positive outcomes derived from implementation of the entrepreneurship education programs that were reported, some however showed a contradictory discovery. Surprisingly, entrepreneurship education was found to exhibit negative outcomes too. For instance, students who engage in entrepreneurship education were found to show a somewhat declination in their intention to become entrepreneurs despite the significant positive effect on their self-assessed entrepreneurial skills (von Graevenitz, Harhoff, & Weber, 2010). This, possi-

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bly, is due to individuals' learning dissimilarities as students learn at different rates, have different motivations, start with different bases of knowledge and experience, and have access to different resource networks (Vanevenhoven, 2013). Therefore, what academic institutions could do is to pay more attention to finer variables such as pedagogical methods. In educating future agropreneurs, academic institutions could look at how individual interaction with the agropreneurship environment is emphasised. This approach is known as experiential learning. This technique is acknowledged to have the capability in producing entrepreneurs just the way it produces other people, such as professionals (Dhliwayo, 2008). Furthermore, in a different research setting, experiential learning in agricultural economics was revealed to be superior than traditional classroom learning (Parcell & Sykuta, 2003). An implementation of agropreneurship education with the presence of experiential learning in a supportive environment could affect students' perception of agropreneurship feasibility by allowing them to see themselves to be real agropreneurs. Rather than just learning theory, experiential learning is about action and thus it unlocks one's capabilities (Jennings & Wargnier, 2010) and give opportunities to students to see themselves as real entrepreneurs rather than pretending to be one (Vincett & Farlow, 2008). Experiential learning as an approach of discovery learning was acknowledged to have an ability to create the right learning atmosphere, allow articulations and interactions of ideas, offers synergistic learning among different participants and creates new meanings on students' knowledge, skills and experience (Smith, Collins, & Hannon, 2006) Additionally, Moore, Boyd, and Dooley (2010) indicated that true learning is the product of experiences which students collect throughout their learning process, as well as its evaluation and reflection.

3. **Create Large Agropreneurship Business Opportunities:** At the same time, agropreneurship education should also be tailored to contribute to the development of agropreneurship by creating large business opportunities (Mohamed et al., 2012). Hence, academic institutions could offer action-based agropreneurial programs. This is necessary for an acquisition of higher quality and quantity of education, relevance and current real-life experience from the external resources, network acquisition, and the availability of role models that can contribute to the movement of actual business start-up (Rasmussen & Sørheim, 2006). The reason for this is because effective entrepreneurial development programs must be based in a real work setting, encompassing a "learning-by-doing' element through outside classroom activities such as internships, so that the learning outcomes can be better implemented (Dhliwayo, 2008; Henry, Hill, & Leitch, 2005). Accordingly, academic institutions should extend their programs by offering more experiential programs such as internships to provide students with some exposure on the actual entrepreneurship environment as they learn on the ground (Vanevenhoven, 2013). Besides that, real-life agropreneurship exposure can also be gained by allowing students to be trained by real agropreneurs who had encountered challenges, or even failure, during their enterprise founding journey (Kuratko, 2005). Agropreneurship education offered should allow students to be actively involved in real business opportunity because it could lead to a birth of an enterprise (Rasmussen & Sørheim, 2006). Through action-based agropreneurial programs, future agropreneurs as the experiential learners are able to establish multiple set of skills that are cognitive, emotional and physical and in which the learning experience is heightened while at the same time developing capabilities to solve real-world problems (Baden & Parkes, 2013). Experiential learning through internship or trial firms may develop relevant entrepreneurial skills and enhance the feasibility and desirability to become entrepreneurs (Davey, Plewa, & Struwig, 2011).

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4. **Instil the Sense of Agropreneurship Desirability and Feasibility:** Next, offer opportunities for students to view agropreneurship more feasibly and desirably. Since an academic institution is the place where students formally acquire necessary entrepreneurial abilities and skills and systematically learn how to become successful agropreneurs, such institutions are also the right and best place in providing students with training and experiences to embark on an entrepreneurial career (Ghazali, Ibrahim, & Zainol, 2012), it should also be the place where students turn for support needed for initial agropreneurship venture creation. According to Ismail et al. (2013), the development of early entrepreneurial competencies is a significant result of the entrepreneurial role played by the educational institutions. Indeed, both the academic institutions and their instructors (i.e. professors) are important institutional key players in promoting entrepreneurial spirit, cultivating entrepreneurial capabilities and inspiring self-employment among the students through innovative programs and a research oriented culture (Ismail & Ahmad, 2013; Rae & Woodier-Harries, 2013; Souitaris, Zerbinati, & Al-Laham, 2007). Furthermore, students' intentions to become entrepreneurs was evidenced to positively and significantly relate with academic institutions environments (Md Rasli, Khan, Malekifar, & Jabeen, 2013; Trucker & Selcuk, 2009). In fact, many business enterprises, particularly in the developing world such as Malaysia, have been initiated at academic institutions (Ghazali et al., 2012). The supportive environment of an academic institution could lead to entrepreneurship development, particularly in intensifying students' entrepreneurial intention. The possibility of students to become self-employed is more likely to increase if the institutions provide adequate education and aspiration. By furnishing an entrepreneurially supportive environment and infrastructure, academic institutions are actually playing a part in increasing students' perceived self-efficacy and their involvement in entrepreneurial activities (Hashemi, Hosseini, & Rezvanfar, 2012) and thus changing students' perception on entrepreneurship feasibility.

Youth agropreneurial aspirations may be hindered due to inadequate preparation, such as insufficient business knowledge and lack of risk taking preparation. Because of this, agropreneurship may not be seen to be feasible or even desirable to students. In fact, stronger entrepreneurial promotion by academic institutions is needed by students to assist their enterprise foundation process (Venesaar, Kallaste, & Küttim, 2014). One way to supply adequate preparation to students is by fostering a supportive institutional environment, such as supplying resources like initial capital for business creation, inclusion of role models, and giving one-to-one support. With regard to a developing country such as Malaysia, academic institutions are expected by students to be supportive by providing networks, workshops, idea development for starting a business and entrepreneurship focus projects (Davey et al., 2011). These types of supports may increase students' confidence levels to take risk and thus initiate the new venture creation.

5. **Play an Active Role in Connecting Gen Y to the Network Circle:** Finally, since performing agropreneurial activities and founding an agropreneurship business cannot be done in isolation (Rutten & Boekema, 2007), academic institution should become an agent for networking development between students and potential suppliers, customers and capital providers. Indeed, it was found that the unavailability of social network and lack of resources were hurdles to entrepreneurship (Sandhu, Sidique, & Riaz, 2011) and contribute to hiccups along the agropreneurial process. Nascent agropreneurship businesses cannot be realized unless agropreneurs are able to acquire those resources (Sesen, 2013). In order for agropreneurs to successfully operate their business, the importance of resources available to them and knowledge is undeniable. Networks can be

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a source of necessary resources needed to start an entrepreneurial behavior (Fernández-Pérez, Alonso-Galicia, del Mar Fuentes-Fuentes, & Rodriguez-Ariza, 2014; Gutiérrez & Pérez, 2010; Najib & Kiminami, 2011; Quan, 2012; Rampersad, Troshani, & Plewa, 2012; Sequeira, Mueller, & Mcgee, 2007; Sesen, 2013; Slotte-Kock & Coviello, 2010), such as information regarding the applicable laws, necessary permits, reference, potential sources of financing and emotional support to provide agropreneurs with distinctive resources and knowledge (Sequeira et al., 2007). Valuable, distinctive and unique key resources supplied by networks improve the effectiveness of entrepreneurs (Slotte-Kock & Coviello, 2010) by greatly allowing them to experience positive outcomes as distinctive and unique resources contribute to greater and remarkable returns (Chiu & Lee, 2007; Rutten & Boekema, 2007). Since becoming an agropreneur, and also other kinds of entrepreneurs, they are challenged with limited resources (Sequeira et al., 2007) and uncertainty, encouragement, information, support, and access to key resources provided by networks greatly influence students' intention to become agropreneurs in a favorable manner. Agropreneurs who are capable of developing meaningful networking are entrepreneurs that gain rewards from networking, which enable them to make decisions quickly, build confidence, save lots of valuable time and necessary cost as well as learn greatly from the experiences of others (Liñán & Santos, 2007; Rampersad et al., 2012; Sequeira et al., 2007). At the initial state of the agropreneurship venture creation process, potential agropreneurs can benefit from networking in at least two ways. First, agropreneurs can make use of networks to recognize business opportunities and chances. Second, being surrounded by networking allows agropreneurs to get access to resources that can range from financial to human such as skilled labours. Therefore, an academic institution that is actively involved in arranging and introducing the students to the appropriate network circle will minimize the hiccups in the agropreneurship process. Academic institutions should take proactive actions to closely link students with potential business and social networks, which may be accomplished by conducting a seminar and providing focus group development with real world entrepreneurs, capital providers, and motivators.

CONCLUSION

In summary, the development of Gen Y creating a future that traditional subsistence farming often struggles to provide. Since an individual spends almost 18 years in getting formal education with 7 seven years at the tertiary level, an academic institution is undoubtedly a very salient agent in producing young agropreneurs. Academic institutions should pay more attention to what they could offer to develop more young agropreneurs by contributing to the development of integrated entrepreneurial skills, capabilities and competencies. With adequate agropreneurship education coupled with extensive agropreneurship supports programs received, it is believed to help Gen Y graduates to nourish creativity and innovation, especially in developing a novel agropreneurship product and useful ideas. Future research in agropreneurship area should focus on the impact of Gen Ys' skills and competencies developed by academic institution, and it is used along the agropreneurial business creation process as well as how these accumulated assets could impact the business performance. Another dimension that future research could focus is on the benefits the Gen Y could get from the network circle created by the academic institution in assisting the development of agropreneurhsip business activities among this unique cohort.

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REFERENCES

Abdul Halim, M. A. S., Alias, M., Che Hamid, A., & Zakaria, Z. (2011). An inter-relationship of entrepreneurial personality, commitment and self-independent in a Terengganu agriculture industry. *International Journal of Business and Social Science*, *2*(23), 274–281.

Abdullah, A. A., & Naem Sulaiman, N. (2013). Factors that influence the interest of youths in agricultural entrepreneurship. *International Journal of Business and Social Science*, *4*(3), 228–302.

Abdullah, F. A., & Abu Samah, B. (2014). Factors influencing inclination toward agriculture entrepreneurship among students in agriculture learning institute. *Asian Social Science*, *10*(2), 273–278.

Abdullah, F. A., Abu Samah, B., & Othman, J. (2012). Inclination towards agriculture among rural youth in Malaysia. *Journal of Basic and Applied Scientific Research*, *2*(11), 10892–10894.

Abu Dardak, R. (2015). *Transformation of agricultural sector in Malaysia through agricultural policy*. Malaysia: MARDI.

Abu Samah, B., D'Silva, J. L., Shaffril, H. A. M., & Uli, J. (2011). The impact of female university students' acceptance towards agriculture contract farming on Malaysian economy. *African Journal of Business Management*, *5*(15), 6625–6631.

Adnan, H. (2011, April 9). Food security policy may be extended. *The Star Online*. Retrieved from http://www.thestar.com.my/story.aspx/?file=%2f2011%2f4%2f9%2fbusiness%2f8445971

Ahmad, A. R., Wan Yusoff, F. W., Md Noor, H., & Ramin, A. K. (2012). Preliminary study of rural entrepreneruship development program in Malaysia. *Journal of Global Entrepreneurship*, *2*(1), 1–8.

Ahmad, N. H., Ramayah, T., & Tuan Muda, S. A. D. (2013). Unlocking the entrepreneurial propensity among prime-age Malaysians: Multi-ethnic analysis. *Journal of Arts. Science & Commerce*, *4*(1), 1–6.

Ahmed, T., Hasan, S., & Haneef, R. (2011). Entrepreneurial characteristics of the agripreneurs under the Scheme of Agriclinics & Agri-business Centres. *Journal of Community Mobilization and Sustainable Development*, *6*(2), 145–149.

Alam, M. M., Siwar, C., Murad, M. W., Molla, R. I., & Toriman, M. E. (2010). Socioeconomic profile of farmer in Malaysia: Study on integrated agricultural development area in North-West Selangor. *Agricultural Economics and Rural Development. New Series*, *7*(2), 249–265.

Alex, L. (2011). *A review and analysis of policies on farmers' entrepreneurship development*. PELUM Association Retrieved from http://api.ning.com/files/mBFEJqp6LPA6uws0UOvKYJD594rw5TqjU-WCb6e5tQ*x02SZslAqcSAQNJIAirsnn3b6LLN7QbTlhi602siwc0PPbcR26h4v/Farmerentpolicystudy.pdf

Azer, I., Mohamad, S. A., Abdullah, N. S., & Mustapha, M. (2014). Agro-preneurial obstacles among students in the Faculty of Plantation and Agrotechnology, UiTM Pahang. *Social and Management Research Journal*, *11*(1), 1–8.

Baden, D., & Parkes, C. (2013). Experiential learning: Inspiring the business leaders of tomorrow. *Journal of Management Development*, *32*(3), 295–308. doi:10.1108/02621711311318283

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Bairwa, S. L., Lakra, K., Kushwaha, S., Meena, L. K., & Kumar, P. (2014). Agripreneurship development as a tool to upliftment of agriculture. *International Journal of Scientific and Research Publication*, *4*(3), 1–4.

Bank Negara Malaysia. (2015). Economic and financial developments in Malaysia in the first quater of 2015. *Quaterly Bulletin.* Retrieved Jun 20, 2016, from http://www.bnm.gov.my/files/publication/qb/2015/Q1/1Q2015_fullbook_en.pdf

Baron, R. A., & Shane, S. A. (2008). Entrepreneurship: A Process Perspective (2nd ed.). Mason, OH: Thomson South-Western.

Baucus, D. A., & Human, S. E. (1994). Second-career entrepreneurs: A multiple case study analysis of entrepreneurial processes and antecedent variables. *Entrepreneurship Theory and Practice*, *19*(2), 41–71.

Budget 2014: Support for SME plans. (2013, October 26). *The Star Online*. Retrieved from http://www.thestar.com.my/Business/Business-News/2013/10/26/Support-for-SME-plans-Hafsah-says-activities-will-help-to-achieve-goals.aspx/

Cervantes-Godoy, D., & Dewbre, J. (2010). Economic importance of agriculture for poverty reduction. *OECD Food Agriculture and Fisheries Working Papers, 23*. doi:10.1787/5kmmv9s20944-en

Chan, K. L., Selvadurai, S., & Hamid, B. A. (2009). Malay youth entrepreneurship in Malaysia: An empirical update. *Geografia: Malaysian Journal of Society and Space*, *5*(2), 61–68.

Che Abdullah, N., & Mustapha, R. (2009). Kajian kes usahawan tani industri kecil sederhana (IKS) bumiputera di Negeri Terengganu. *Jurnal Pendidikan Malaysia*, *34*(2), 143–165.

Chiu, S.-K., & Lee, Y.-I. (2007). Strategic resources, network competence, and sustainable competitive advantages - An empirical study on Taiwan led firms. *International Journal of Electronic Business Management*, *5*(1), 70–78.

D'Silva, J. L., Mohamad Shaffril, H. A., Uli, J., & Abu Samah, B. (2009). A review of contract farming and factors that impinge youth's acceptance to contract farming. *European Journal of Soil Science*, *11*(2), 328–338.

Davey, T., Plewa, C., & Struwig, M. (2011). Entrepreneurship perceptions and career intentions of international students. *Education+ Training, 53*(5), 335-352.

Dhliwayo, S. (2008). Experiential learning in entrepreneurship education: A prospective model for South African tertiary institutions. *Education+ Training, 50*(4), 329-340.

Diao, X., Hazell, P., Resnick, D., & Thurlow, J. (2007). *The Role of agriculture in development: Implications for Sub-Saharan Africa*. Washington, DC: International Food Policy Research Institute. Retrieved from http://www.ifpri.org/sites/default/files/pubs/pubs/abstract/153/rr153.pdf

DSilva, J. L., Mohamad Shaffril, H. A., Uli, J., & Abu Samah, B. (2010). Socio-demography factors that influence youth attitude towards contract farming. *American Journal of Applied Sciences*, *7*(4), 603–608. doi:10.3844/ajassp.2010.603.608

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Fernández-Pérez, V., Alonso-Galicia, P. E., del Mar Fuentes-Fuentes, M., & Rodriguez-Ariza, L. (2014). Business social networks and academics entrepreneurial intentions. *Industrial Management & Data Systems*, *114*(2), 292–320. doi:10.1108/IMDS-02-2013-0076

Florin, J., Karri, R., & Rossiter, N. (2007). Fostering entrepreneurial drive in business education: An attitudinal approach. *Journal of Management Education*, *31*(1), 17–42. doi:10.1177/1052562905282023

Food and Agriculture Organization of the United Nations. (2009). *How to feed the world in 2050*. Retrieved from http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf

Geyzel, M. V. (2009). Working with generation. Retrieved from http//vangeyzel.com/2009/08/20working-with-gen-y/

Ghazali, Z., Ibrahim, N. A., & Zainol, F. A. (2012). Factors affecting entrepreneurial intention among UniSZA students. *Asian Social Science*, *9*(1), 85–93. doi:10.5539/ass.v9n1p85

Gutiérrez, L. G., & Pérez, V. F. (2010). Managerial networks and strategic flexibility: A QM perspective. *Industrial Management & Data Systems*, *110*(8), 1192–1214. doi:10.1108/02635571011077834

Hashemi, S. M. K., Hosseini, S. M., & Rezvanfar, A. (2012). Explaining entrepreneurial intention among agricultural students: Effects of entrepreneurial self-efficacy, and college entrepreneurial orientation. *Research Journal of Business Management*, *6*(3), 1–9.

Hassan, M. S., Shaffril, M., Azril, H., Abu Hassan, M., & D'Silva, J. L. (2009). Developing agriculture in Malaysia: Internet utilization among Malaysian youth agro-businessman. *European Journal of Soil Science*, *11*(2), 215–224.

Heinonen, J. (2007). An entrepreneurial-directed approach to teaching corporate entrepreneurship at university level. *Education+ Training, 49*(4), 310-324.

Henry, C., Hill, F., & Leitch, C. (2005). Entrepreneurship education and training: can entrepreneurship be taught? Part I. *Education + Training, 47*(2), 98-111.

Hewlett, S. A., Sherbin, L., & Sumberg, K. (2009). How Gen Y & Boomers will reshape your agenda. *Harvard Business Review*, *87*(7/8), 71–76. PMID:19630257

Hock-Eam, L., Ahmad, S. A., & Jan, S. J. (2015). *The inferring predisposed factors for graduate agropreneur in Malaysia: Mismatch?* Paper presented at the 9th Asia-Pacific Business Research Conference, Singapore.

International Labour Office. (2014). *Global employment trends 2014: Risk of a jobless recovery?* Geneva, ILO: Document and Publications Production, Printing and Distribution Branch (PRODOC), ILO. Retrieved from http://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_233953.pdf

Ismail, K., Ahmad Anuar, M., Wan Omar, W. Z., Aziz, A. A., Seohod, K., & Akhtar, C. H. (2013). *Entrepreneurial intention, entrepreneurial orientation of faculty and students towards commercialization*. Paper presented at the 3rd International Conference on Leadership, Technology and Innovation Management, Istanbul, Turkey.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Ismail, M. Z., & Ahmad, S. Z. (2013). Entrepreneurship education: An insight from Malaysian polytechnics. *Journal of Chinese Entrepreneurship*, *5*(2), 144–160. doi:10.1108/JCE-02-2013-0003

Jaffee, S., Kopicki, R., Labaste, P., & Christie, I. (2003). *Modernizing Africa's agro-food systems: Analytical framework and implications for operations* (Africa Region Working Paper Series, No. 4). Retrieved from http://www.worldbank.org/afr/wps/wp44.pdf

Jala, I. (2013, September 30). Agriculture is a sector that is still important to Malaysia's economy. *The Star Online*. Retrieved from http://www.thestar.com.my/Business/Business-News/2013/09/30/Agriculture-is-a-sector-that-is-still-important-to-Malaysias-economy/

Jennings, C., & Wargnier, J. (2010). Experiential learning – A way to develop agile minds in the knowledge economy? *Development and Learning in Organizations*, *24*(3), 14–16.

Joseph, O., Adanma, N. J., & Chinonso, E. H. (2012). Wealth allocation and determinants of venture capital among poultry agribusiness entrepreneurs in Abia State, Nigeria. *Journal of Economics and Sustainable Development*, *3*(14), 188–196.

Jutla, D., Bodorik, P., & Dhaliwal, J. (2002). Supporting the e-business readiness of small and medium sized enterprises: Approaches and metrics. *Internet Research: Electronic Networking Applications and Policy*, *12*(2), 139–164. doi:10.1108/10662240210422512

Kuldilok, K. S., Dawson, P. J., & Lingard, J. (2013). The export competitiveness of the tuna industry in Thailand. *British Food Journal*, *115*(3), 328–341. doi:10.1108/00070701311314174

Kuratko, D. F. (2005). The emergence of entrepreneurship education: Development, trends, and challenges. *Entrepreneurship Theory and Practice*, *29*(5), 577–598. doi:10.1111/j.1540-6520.2005.00099.x

Lévesque, M., & Minniti, M. (2006). The effect of aging on entrepreneurial behavior. *Journal of Business Venturing*, *21*(2), 177–194. doi:10.1016/j.jbusvent.2005.04.003

Lim, Y.-M., Lee, T.-H., & Cheng, B.-L. (2012). Entrepreneurial inclination among business students: A Malaysian study. *The South East Asian Journal of Management*, *6*(2), 113–127. doi:10.21002eam.v6i2.1318

Liñán, F., & Santos, F. J. (2007). Does social capital affect entrepreneurial intentions? *International Advances in Economic Research*, *13*(4), 443–453. doi:10.100711294-007-9109-8

Malaysian Department of Statistics. (2016). Retrieved 2 April 2014, from http://www.statistics.gov.my

Martin, C. A. (2005). From high maintenance to high productivity: What managers need to know about Generation Y. *Industrial and Commercial Training*, *37*(1), 39–44. doi:10.1108/00197850510699965

Matlay, H. (2008). The impact of entrepreneurship education on entrepreneurial outcomes. *Journal of Small Business and Enterprise Development*, *15*(2), 382–396. doi:10.1108/14626000810871745

Md Rasli, A., Khan, S., Malekifar, S., & Jabeen, S. (2013). Factors affecting entrepreneurial intention among graduate students of Universiti Teknologi Malaysia. *International Journal of Business and Social Science, 4*(2), 182-188.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Ministry of Finance. (2013). *Gross domestic product by kind of economic activity at constant 2005 prices (RM million) 2013-2013*. Retrieved 21 June, 2016, from http://www.treasury.gov.my/pdf/ekonomi/dataekonomi/2013/timeseries/GDPbySector2013_2014.pdf

Ministry of Finance. (2016). *Economic performance and prospects Economic Report 2015/2016. Kuala Lumpur*. Malaysia: Ministry of Finance.

Ministry of International Trade and Industry. (2006). *IMP3: Third Industrial Master Plan 2006-2020, Malasia: Toward global competitiveness*. Retrieved from http://mset.org.my/myraig/pdf/Industry/MasterPlan3/Review-MITI%20IMP3.pdf

Mohamed, Z., Rezai, G., & Shamsudin, M. N. (2011). The effectiveness of entrepreneurship extension education among the FOA members in Malaysia. *Current Research Journal of Social Sciences*, *3*(1), 17–21.

Mohamed, Z., Rezai, G., Shamsudin, M. N., & Mahmud, M. M. (2012). Enhancing young graduates' intention towards entrepreneurship development in Malaysia. *Education + Training, 54*(7), 605-618.

Mohammad Nor, N. A. A., Nik Mohd Masdek, N. R., & Maidin, M. K. H. (2015). Youth inclination towards agricultural entrepreneurship. *Economic and Technology Management Review*, *10a*, 47–55.

Mohd Yusof, A. B., & Raja Abd Rahman, R. R. (2007). *Green lifestyle: Evaluating new business and income enhancement through agripreneurship development*. Paper presented at the The USM-UPM-PETA Conference, Penang, Malaysia.

Mok, H.-F., Williamson, V. G., Grove, J. R., Burry, K., Barker, S. F., & Hamilton, A. J. (2014). Strawberry fields forever? Urban agriculture in developed countries: A review. *Agronomy for Sustainable Development*, *34*(1), 21–43. doi:10.100713593-013-0156-7

Moore, C., Boyd, B. L., & Dooley, K. E. (2010). The effects of experiential learning with an emphasis on reflective writing on deep-level processing of leadership students. *Journal of Leadership Education*, *9*(1), 36–52. doi:10.12806/V9/I1/RF3

Movahedi, R., Latifi, S., & Sayyar, L. Z. (2013). The factors affecting agricultural students' attitude towards self-employment and entrepreneurship. *International Journal of Agriculture and Crop Sciences*, *5*(16), 1813–1819.

Muhammad, M., Ismail, A. A., & Eh Rak, A. (2013). Competency of agriculture graduates in Malaysian public universities. *International Journal of Enhanced Research in Educational Development*, *1*(1), 1–9.

Nagalakshmi, T., & Sudhakar, A. (2013). Agri-preneurs: A case study of Dharmapuri farmers. *International Journal of Science and Research*, *2*(8), 208–214.

Najib, M., & Kiminami, A. (2011). Innovation, cooperation and business performance: Some evidence from Indonesian small food processing cluster. *Journal of Agribusiness in Developing and Emerging Economies*, *1*(1), 75–96. doi:10.1108/20440831111131523

National SME Development Council. (2013). *SME annual report 2013/2014: Transitioning for productivity-led and innovation-driven growth*. Sentral, Malaysia: SME Corporation Malaysia. Retrieved from http://www.smecorp.gov.my/vn2/node/1475

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Okezie, C. A., & Baharuddin, A. H. (2012). Risk and poverty in agriculture: Expanding roles for agricultural cooperatives in Malaysia. *Geografia: Malaysian Journal of Society and Space*, *8*(4), 1–11.

Onwumere, J., & Ukpebor, P. O. (2011). Evaluation of earning performance of female owned leather-based enterprises in Aba Metropolis, Abia State, Nigeria. *Journal of Agriculture and Social Research*, *11*(2), 120–127.

Osikabor, B., Adesope, A. A., Ibrahim, A. G., Babayemi, O. F., & Olatunji, B. T. (2011). Animal-agriculture based entrepreneurship: Descriptive norms, perceived economic viability and behavioural intention among final year agriculture related students in Ibadan, Nigeria. *Asian Journal of Agricultural Sciences*, *3*(2), 87–93.

Owens, T., Hoddinott, J., & Kinsey, B. (2003). The impact of agricultural extension on farm production in resettlement areas of Zimbabwe. *Economic Development and Cultural Change*, *51*(2), 337–357. doi:10.1086/346113

Parcell, J., & Sykuta, M. (2003). *Undergraduate perceptions of the need for an agricultural entrepreneurship curriculum*. Paper presented at the Agricultural Economics Association Annual Meeting, Denver, CO.

Performance Management and Delivery Unit. (2010). *Economic transformation programme: A roadmap for Malaysia*. Putrajaya, Malaysia: Performance Management and Delivery Unit (PEMANDU). Retrieved from http://www.moa.gov.my/documents/10157/c65bb64f-da6c-4e83-bb51-40a1a55b9954

Peterman, N. E., & Kennedy, J. (2003). Enterprise education: Influencing students perceptions of entrepreneurship. *Entrepreneurship Theory & Practice*, *28*(2), 129–144. doi:10.1046/j.1540-6520.2003.00035.x

Poornima, S. C. (2009). Motivating through satisfaction: An on-going effort of HR in organisations. *IUP Journal of Management Research*, *8*(5), 26–37.

Pugh, M. (2014). Why millennials should become entrepreneurs now? *Entrepreneur.* Retrieved 28 April, 2014, from http://www.entrepreneur.com/article/230886

Quan, X. (2012). Prior experience, social network, and levels of entrepreneurial intentions. *Management Research Review*, *35*(10), 945–957. doi:10.1108/01409171211272679

Rae, D., & Woodier-Harris, N. R. (2013). How does enterprise and entrepreneurship education influence postgraduate students' career intentions in the New Era economy? *Education + Training, 55*(8/9), 926-948.

Ramachandaran, G. (2010). Excerpts of the Government Transformation Programme (GTP) & Economic Transformation Programme (ETP): Key thrusts to power the nation towards 2020. *RSM Startegic Business Advisor*. Retrieved 22 April, 2014, from http://www.rsmi.com.my/WebLITE/Applications/productcatalog/uploaded/Docs/Government%20Transformation%20Programme%20&%20Economic%20Transformation%20Programme%20Article%205.10.10.pdf

Rampersad, G., Troshani, I., & Plewa, C. (2012). IOS adoption in innovation networks: A case study. *Industrial Management & Data Systems*, *112*(9), 1366–1382. doi:10.1108/02635571211278974

Rasmussen, E. A., & Sørheim, R. (2006). Action-based entrepreneurship education. *Technovation*, *26*(2), 185–194. doi:10.1016/j.technovation.2005.06.012

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Razak, M. I. M., Abas, N. M., Yaacob, N. J. A., Rodzi, S. N. A. M., Yusof, N. M., & Azidin, R. A. (2015). An overview of primary sector in Malaysia. *International Journal of Economics*. *Commerce and Management*, *3*(2), 1–13.

Rezai, G., Mohamed, Z., & Shamsuddin, M. N. (2011). Informal education and developing entrepreneurial skills among farmers in Malaysia. *International Journal of Social*. *Human Science and Engineering*, *5*(7), 146–153.

Rutten, R., & Boekema, F. (2007). Regional social capital: Embeddedness, innovation networks and regional economic development. *Technological Forecasting and Social Change*, *74*(9), 1834–1846. doi:10.1016/j.techfore.2007.05.012

Saeed, S., Yousafzai, S. Y., Yani-De-Soriano, M., & Muffatto, M. (2015). The role of perceived university support in the formation of students entrepreneurial intention. *Journal of Small Business Management*, *53*(4), 1127–1145. doi:10.1111/jsbm.12090

Sánchez, J. C. (2013). The impact of an entrepreneurship education program on entrepreneurial competencies and intention. *Journal of Small Business Management*, *51*(3), 447–465. doi:10.1111/jsbm.12025

Sandhu, M. S., Sidique, S. F., & Riaz, S. (2011). Entrepreneurship barriers and entrepreneurial inclination among Malaysian postgraduate students. *International Journal of Entrepreneurial Behaviour & Research*, *17*(4), 428–449. doi:10.1108/13552551111139656

Selamat, Z., & Nasir, A. M. (2013). Efficiency measurement of Malaysian agriculture firms. *International Journal of Trade*. *Economics & Finance*, *4*(2), 79–85.

Sequeira, J., Mueller, S. L., & Mcgee, J. E. (2007). The influence of social ties and self-efficacy in forming entrepreneurial intentions and motivating nascent behavior. *Journal of Developmental Entrepreneurship*, *12*(03), 275–293. doi:10.1142/S108494670700068X

Sesen, H. (2013). Personality or environment? A comprehensive study on the entrepreneurial intentions of university students. *Education+ Training, 55*(7), 624-640.

Shamsuddin, A., Mohmad Isa, K. H., Aziz, M. N., Mohamed Mahfol, N. Z. N., & Alagari, T. (2013). Graduate unemployment: The awareness and perception of graduates towards government's initiatives. *International Journal of Business*. *Economics and Law*, *3*(1), 15–24.

Singh, G., & DeNoble, A. (2003). Early retirees as the next generation of entrepreneurs. *Entrepreneurship Theory & Practice*, *23*(3), 207–226. doi:10.1111/1540-8520.t01-1-00001

Siwar, C., Idris, N. D. M., Yasar, M., & Morshed, G. (2014). Issues and challenges facing rice production and food security in the granary areas in the East Coast Economic Region (ECER), Malaysia. *Research Journal of Applied Sciences*, *Engineering and Technology*, *7*(4), 711–722.

Siwar, C., Yasar, M., Ghazali, Z., & Mohd Idris, N. D. (2013). Vulnerability and sustainable livelihood of paddy farmers in the North Terengganu Integrated Agriculture Development Area (IADA KETARA), Malaysia. *Prosiding Perkem*, *8*(2), 778–789.

Slotte-Kock, S., & Coviello, N. (2010). Entrepreneurship research on network processes: A review and ways forward. *Entrepreneurship Theory & Practice*, *34*(1), 31–57. doi:10.1111/j.1540-6520.2009.00311.x

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

SME Annual Report. (2013/2014). Retrieved 17 November 2015, from http://www.smecorp.gov.my/vn2/sites/default/files/chapter2-SME%20Development%20and%20Outlook_0.pdf

SME Master Plan. (2012-2020). Retrieved 22 April, 2014, from http://www.chinesechamber.org.my/html/themes/chinesechamber/images/content/bulletin343/SME%20MASTERPLAN%202012-2020.pdf

Smith, A. J., Collins, L. A., & Hannon, P. D. (2006). Embedding new entrepreneurship programmes in UK higher education institutions: Challenges and considerations. *Education+ Training, 48*(8/9), 555-567.

Solesvik, M. Z., Westhead, P., & Matlay, H. (2014). Cultural factors and entrepreneurial intention: The role of entrepreneurship education. *Education+ Training, 56*(8/9), 680-696.

Souitaris, V., Zerbinati, S., & Al-Laham, A. (2007). Do entrepreneurship programmes raise entrepreneurial intentions of science and engineering students? The effect of learning, inspiration and resources. *Journal of Business Venturing*, *22*(4), 566–591. doi:10.1016/j.jbusvent.2006.05.002

Soumiya Devi, M. K. (2015). A study on the influencing factors for a literate youth to take up agricultural entrepreneurship. *International Journal of Management and Commerce Innovations*, *3*(1), 692–700.

Sox, C. B., Kline, S. F., & Crews, T. B. (2014). Identifying best practices, opportunities and barriers in meeting planning for Generation Y. *International Journal of Hospitality Management*, *36*, 244–254. doi:10.1016/j.ijhm.2013.09.009

Trucker, D., & Selcuk, S. S. (2009). Which factors affect entrepreneurial intention of university students? *Journal of European Industrial Training*, *33*(2), 142–159. doi:10.1108/03090590910939049

Vanevenhoven, J. (2013). Advances and challenges in entrepreneurship education. *Journal of Small Business Management*, *51*(3), 466–470. doi:10.1111/jsbm.12043

Venesaar, U., Kallaste, M., & Küttim, M. (2014). Factors influencing students venture creation process. *Procedia: Social and Behavioral Sciences*, *110*, 678–688. doi:10.1016/j.sbspro.2013.12.912

Verhees, F. J. H. M., Kuipers, A., & Klopcic, M. (2011). Entrepreneurial proclivity and farm performance: The cases of Dutch and Slovenian farmers. *International Journal of Entrepreneurship and Innovation*, *12*(3), 167–177. doi:10.5367/ijei.2011.0039

Vincett, P. S., & Farlow, S. (2008). Start-a-Business: An experiment in education through entrepreneurship. *Journal of Small Business and Enterprise Development*, *15*(2), 274–288. doi:10.1108/14626000810871673

von Graevenitz, G., Harhoff, D., & Weber, R. (2010). The effects of entrepreneurship education. *Journal of Economic Behavior & Organization*, *76*(1), 90–112. doi:10.1016/j.jebo.2010.02.015

Yusoff, A., Ahmad, N. H., & Abdul Halim, H. (2016). Entrepreneurial orientation and entrepreneurial intention among Malaysian agricultural students: The impact of entrepreneurship education. *Advances in Business-Related Scientific Research Journal*, *7*(1), 77–92.

Zahrom, B. (2012, December 13). Generasi Y digalak sertai industry tani. *Berita Harian*. Retrieved from http://www.bharian.com.my/bharian/articles/GenerasiYdigalaksertaiindustritani/Article/index_html

Zainal Abiddin, N., & Irsyad, S. (2012). The involvement of graduates youth in commercial agriculture: Issues and challenges. *International Journal for Educational Studies*, *5*(1), 15–24.

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KEY TERMS AND DEFINITIONS

Academic Institutions: Higher educational institutions dedicated to education and research, which grants academic degrees the students.

Academic Institution Agropreneurship Support: The tangible and intangible assistance provided by the academic institution in fostering agropreneurship business activities among students including concept development support and perceived business development support.

Agriculture: The broad field that includes efforts of farming, planting, fisheries, and downstream agro-based and agro-processing industries. In Malaysia, agriculture involves plantation and food crops, horticulture, aquaculture, livestock husbandry and all other related activities.

Agropreneurship: Entrepreneurship activities practised by individuals who own goals to create wealth by applying innovative skills within the agriculture industry.

Agropreneurship Education: Formal pedagogical agribusiness programmes or process of education for agropreneurial attitude and skills which involves certain personal agropreneurial qualities.

Gen Y: Young people who were born between 1977 and 2000. Also known as Millennials, Nexters or the Nexus Generation, or Echo-Boomer.

Graduate Entrepreneurship: Entrepreneurship business activities that are run and managed by graduates who have graduated from higher education institutions.

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Chapter 9
Application of Information Communication Technologies for Agricultural Development Through Extension Services: A Review

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ABSTRACT

This chapter outlines the role that Information Communication Technologies (ICT) play in the global context and in Africa, agricultural extension and Agricultural development. The role of and use of ICT by extension officers, the trends of ICT in agricultural information management, how ICT bridge the digital divide as well as the types of ICT tools used by extension officers such as radio, television, computers and internet. It also gives the perspective about the factors that influences use of ICT by extension officers which are seen as playing an important role human development.

INTRODUCTION

ICT and the Global Context

According to Roy (2005), the use of Information Communication Technologies is expanding rapidly. ICTs comprise of a diverse set of technological tools and resources to create, disseminate, sore and manage data and information. Traditional ICT tools such as television, radio and telephone have proven their effectiveness in promoting development in marginalized areas. The emergence of computers, the internet

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and wireless communication technology, along with powerful software for processing and integrating text, sound and video into electronic media comprise modern ICTs. The spread of the global electronic network of computers popularity referred to as the internet and wireless telephony has generated an unprecedented global flow of information, product, capital and ideas. Furthermore Adesope, Asiabaka and Agumagu (2007), states that the advent of the computer gave a new direction to the information and communication technology industry. This is evident in the use of technologies such as electronic mail (e-mail), electronic commerce (e-commerce) and more recently mobile phone, which Salihu (2000) referred to as Palm assistant, because of its palm-size nature. Information communication technologies such as electronic mail and electronic conferencing provide scientists, administrators and information staff with rapid and reliable communication, while increasing productivity and decreasing communication costs by reducing the physical means of communication channels (Kerrigan, Lindsey & Novak, 1994).

ICT and Africa

Agriculture has and will be the backbone of the African economy contributing to the livelihoods of rural communities. The prospects of African globalization cannot be separated from the nature of its historical incorporation in the world economy, the ensuing commodity based export structure, unequal terms of trade and declining position in the world economy. Globalization demands driven re-casting critical questions on the role of state and NGO's to steer economic development through the use of ICTs. In Africa, most farming communities rely on the public Agricultural Extension services for technical farming advice and information. Information communication Technology can be the instrument for stimulating the growth and by ushering in unique forms of national and transnational exchange relationships between producers and consumers, for instance, the scope of widening markets, profitability and investments and the choice of diverse range products, services and facilities (Roy, 2005).

Africa, like the rest of the world, needs to attain the United Nation's Millennium Development Goals (MDGs) and the World Food Summit (WFS) goals to reduce the number of hungry people from 790 million to 400 million by 2015. To reduce poverty by 50% by 2015, the African economies need to grow at 7% per annum. Another target requires that a national strategy for sustainable development be in place in every country to ensure the reversal of current trends in the loss of environmental resources at both national and global levels by 2015. Several factors are responsible for the numerous challenges facing the continent. First, there has been underinvestment in the rural areas. Inadequate access to markets and unfair market conditions also continue to be major stumbling blocks. These challenges, coupled with the crippling impact of limited access to advanced technologies, weak infrastructure, high production and transport costs, present the image of a continent that will be poverty stricken for many years to come (ECA, 2005).

Richardson (1997) points out that ICTs are considered to be drivers of change for rural and agricultural development, as they are efficient tools for reaching rural and remote communities and for improving agricultural productivity. Due to this factor, ICTs can speed up the extension of development services in areas that include healthcare, education and agriculture. Furthermore, ICTs can be instrumental in strengthening partnerships and in providing a framework for shared learning. It is not surprising, therefore, that ICTs have led to increased use of a networked information environment and the development of platforms for better sharing and exchange of information and knowledge (Van Audenhove, 2003).

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ICTs, Agricultural Extension, and Agricultural Development

Agricultural Extension and advisory services in the field of agricultural development has seen many changes in the past decades. The first trend is the change in philosophy and rationale behind extension services towards more participatory approaches and participatory technology development (PTD), a shift has been made in thinking about the role of extension services in broader information and knowledge sharing processes (Leeuwis, 2004). A second trend in extension services, situated at a less conceptual level and a more professional level, seems to be the development towards 'extension-plus' which means that extension and advisory services plays an expanded role because extension has long been primarily associated with 'transferring technologies to farmers' (Sulaiman, 2003).

According to Munyua (2008), Information and knowledge play a central role in rural agricultural development. In describing the role of women and men in agricultural and rural development, information and knowledge are essential if women and men are to respond to opportunities and major challenges of the coming century. In emphasizing the role of information and knowledge, information and knowledge is described as prime productive resources. The Food and Agriculture Organization of the United Nations (2000) advances a corresponding view to this perspective in its assertion that "information and knowledge play a key role in ensuring food security and sustainable development". World Bank (2002, cited in IICD 2006), also takes the position that "information and communication technologies are a key input for economic development and growth".

Munyua (2008) states that Africa has a cumulative body of agricultural information and knowledge, know-how and practices that need to be shared continent-wide and applied for improved livelihoods and sustainable development. Although there is a lot of information relevant to small-scale farmers, this is scattered and hard to find. Most of the institutions implementing initiatives on ICTs and small-scale agriculture in Africa have developed local agricultural information and knowledge resources in English, and in some cases, in local languages. Bertolini (2004) notes that most farmers in Africa rely on intermediaries such as nongovernmental organizations (NGOs), extensionists and producer organizations to access and exchange information on innovations in crop varieties, pest management, soil fertility, weather forecasting and irrigation among others. Wider access to such information and in a more cost effective manner ought to be given priority.

There seems to be recognition that extension should merge with, or at least should incorporate, other fields such as improved access to markets, research, advice, credit, infrastructure, farmer organization development and business development services. "Research and extension strategies should emerge out of a broader livelihood analysis organized through a wider consultative exercise." Next to these developments in fundamental thinking in the academic and professional worlds, a third global economic trend from public services to private services can be identified. Although, for instance in India, the state Department of Agriculture (DoA) continues to dominate extension provisions, initiatives towards privatization and public-private partnerships do exist (Sulaiman, 2003).

Effective agricultural development requires access to information on all aspects of agricultural production, processing and marketing and it seems likely that if anything this need is increasing (Jones, 1997). ICT is already showing the potential to play an important role in the delivery of this information to this sector in both developed and developing countries. In most cases the base technology is universal, rather than being specific to agriculture, and hence usage evolves from existing designs and practices (Zijp, 1994).

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The agricultural communications industry will change in the future because the agricultural industry itself is changing dramatically. There is more information but perhaps less knowledge than ever before in agriculture and that is a huge opportunity for extension officers. At the same time, the emergence of the internet as a communications medium, as well as the convergence of many other traditional communications vehicles like print, radio, television and database marketing, has a direct impact on extension officers approach their jobs (Boone, Meisenbach & Tucker, 2000).

According to Boone et al. (2000) today agriculture holds a unique position in society. As more and more of the world's population moves from rural to urban areas, agriculture as a way of life is changing. Although its role in food production has not changed, however, and more and more of the world's food production is centered on agriculture with fewer and fewer people engaged in production farming. The gap between rural and urban society has narrowed. Media and popular culture have changed the way that farmers work, live and interact with other parts of society. Depending on the commodity in which a farmer specializes, information and technology is critical for efficiency and fiscal success. Technology is not limited entirely to the production aspects of agriculture. Farmers, as has much of society have adopted personal computers technologies into their farm operations; therefore computer technology is built into most equipment in use on farms today. Specialty crops and specialty farming operations are also tied into advanced technology.

Role of ICTs in the Extension Service

Information and communicative technologies are key enablers of globalization. They allow for the efficient and cost-effective flow of information, products, people and capital across national and regional boundaries. ICT is not a panacea for rural development problems, but it has the potential to help the rural poor to leaping some of the traditional barriers to development, by improving access to information, expanding the market base, enhancing employment opportunities and making government services work better (Swanson & Rajalathi, 2010).

According to Leeuwis (2004),the conventional method of training and information dissemination through the extension channel has been based on cascade model: master trainers are trained, they in turn train the trainers who go to the field to conducting training of extension officers / workers; extension agents carry information to the final recipients. This model has obvious disadvantages such as loss of information, degradation of quality of training, long lead times and high costs. In fact, the lead time of such a training cycle is so long that by the time one training cycle is completed, the second is overdue. There is therefore a great need to speed up the extension process and enhance its quality. It is in this area where the use of ICTs amongst extension officers plays an important role and with the Participatory Programme Extension Approach, the gap that exists in the information flow between the end users will be addressed.

Effective ICTs strategies must provide the basic infrastructure for connectivity and access, develop human capacity, offer affordable demand-driven ICT services and involve local stakeholders and beneficiaries in project design and implementation. Liberalization of the telecommunications sector can dramatically expand connectivity and reduce costs, but the strategic government investment or regulatory measures are needed in disadvantaged areas where the private sector does not provide services. Community- based telecenters offer a way of providing affordable access to ICT services in rural areas and this will assist agricultural extension officers to disseminate required farming information that will increase the agricultural productivity (van Veldhuiven, et al, 1997).

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The diffusion of ICTs is fundamental to enable developed and developing countries to stimulate socio-economic development and usher in structural change. The term digital divide has been coined to capture the bias in the patterns of access to ICT in terms of the levels of use on the internet (region, sector, socio-economic group), the ownership of computers or public facilities, and the availability of telecommunications (telephone lines), the nature of use (e-mail, using the World Wide Web), and the institutions (public and private) offering ICT facilities (Roy, 2005)

ICTs are in addition are considered to be drivers of change for rural and agricultural development as they are efficient tools for reaching rural and remote communities and for improving agricultural productivity. Due to this factor, ICTs can speed up the extension of development services in areas that include healthcare, education and agriculture. Furthermore, they can be instrumental in strengthening partnerships and in providing a framework for shared learning (Richardson, 1997).

Uses of ICT's by the Extension Service

The ICT sector as a whole (telecommunications, broadcasting, computer hardware and software, and related technologies) has emerged as a strategically important sector driving social and economic change. The paradigms shift in development concept towards participation and sustainability coupled with revolutions in the information and communication technology has provided opportunities for extension and rural communities to move into the information age. Extensive review of literatures in agricultural development showed that there is a direct relationship between research and the utilization of research findings. This is a strong linkage complimented by flawless information flow enhanced by the effective use of ICT by the extension services significantly boost agricultural production and improve rural livelihoods in developing countries. Front line extension workers, who are the direct link between farmers and other actors in the agricultural knowledge and information system, are well positioned to make use of ICT to access expert knowledge or other types of information that could facilitate the accomplishment of their day-to-day activities (Aboh, 2008).

The important role played by agricultural extension services in providing linkages and support to agricultural research information and technology transfer for farmers and farming communities has been crucial to agricultural success. Strong criticism of public agricultural extension services has circulated in recent years. This criticism is due to agricultural extension top-down approach, which has been supply- driven, technically weak, patronizing, and catering only to large farmers and providing insufficient coverage of and contacts with farmers (FAO,2004).

IFAD (2002) reached the conclusion that extension services in Africa have failed to address the needs of small-scale farmers. In another study, Richardson (2006) argues that agricultural extension services that provide agricultural information do not work effectively in Africa. These shortfalls may be due to changes in the extension process that have resulted in the shift to the facilitation and brokerage of information, communication and advocacy services. This range of services, meant to improve rural livelihoods, can benefit from the applications of ICTs. It has been found for instance that the technologies could be used to restructure extension services. For example, they can be used to disseminate information and advisory services to farmers to improve their efficiency. More specifically, agricultural information on input supply, use, product marketing, and value addition could be transmitted through ICTs, thus cutting down the number of visitations by extension workers. ICTs could also free time for extension workers if greater use is made of telecentres and other public access points.

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It is true that public extension services unfortunately have been ineffective in reaching farmers and farming communities with information and technologies needed to ensure food security and sustainable development. Farmers have managed to obtain information from other sources where agricultural extension services have been insufficient. These preferred sources include other farmers, private sector agricultural marketing and sales providers (of seeds, fertilizers and agrochemicals) or from NGOs and civil society organizations. There is substantial literature providing evidence to this fact. What is clear from many studies, however, is the continued need for information by farmers and farm communities- thus necessitating continued improvement in ways and means to provide the extension support that farmers and farm communities require and demand.

According to FAO, (2004) given the reality of an interconnected world, the recent trend currently confronting agricultural extension globally are also manifesting regionally and nationally. These include the responses to the effects of globalization, privatization, increasing commercialization of agriculture, increased democratization and participation, environmental degradation, increasing incidences of natural disasters, improved communications including the availability of information technology, the need to address the HIV/AIDS epidemic, preferences for multidisciplinary approaches and holistic development and criticism of extension itself. The faces of globalization and privatization on extension, for instance, are probably most pronounced in the highly competitive, market – driven orientation of agribusiness. However, most extension services are ill prepared to deal with the changes due to extension agents' lack of knowledge and skills in those areas.

The twin challenge for developing country agriculture, then, is to harness the power of ICTs to compete in complex and rapidly- changing regional and global markets while empowering poor smallholders with information and communication assets and services that can increase their productivity and income and protect their food security and livelihood.

New technologies, new applications and new business modes and their wider availability and affordability are enabling widespread innovation in addressing the needs of the poor farmer and farming communities. The uses of ICTs are driving changes in agriculture that make it even more urgent to understand their potential and pitfalls. The dramatic and rapid expansion in global information and communications networks in the past decade, and the concomitant proliferation of new information and communication devices, applications, services and business models pose significant new opportunities and new challenges for developing subsistence agriculture and for rural poor populations. Globalised food markets have both opened new market opportunities for developing country agriculture and created new risks and volatility, including new challenges to food security, and risks of marginalization from agricultural value chains that increasingly depend on technical sophistication for speed, customization and food safety.

Agriculture Technology Dissemination

According to (Nagasri, 2000; Aizaki, Nakashima, Ujie, Takeshita & Tahara, 2010), all agricultural extension and farmer programs face major challenges which are ensuring cost effective outreach, designing solutions tailored to needs of individual farmers and cultivating an image that is farmer friendly. Any change in technology, the economic impact of ICT occurs through improvements in efficiency and increasing productivity. This can take place in different ways including improving efficiency in resource allocation, reducing transaction costs, and technical improvements that result in an outward shifting of the production function. In particular, through the provision of information from a source that is relative affordable, accessible and broadly available, ICT can contribute to the reduction of uncertainty in activi-

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ties and transactions, reduce the extent to which markets are thin, missing or incomplete, and reduce the extent to which information asymmetries can be exploited by the relatively informed to extract rent when transacting with the relatively uninformed.

Most of the farming communities, particularly in the rural areas, do not have access to the huge knowledge base acquired by agricultural extension centers and businesses. ICT can provide vital access to information, markets by connecting the rural poor and marginalized to the worlds information resources and opportunities. The inequality in opportunities presented by ICTs is widest between commercial and subsistence farmers, urban and rural groups, rich and poor, men and women, and the educated and uneducated. Despite this, ICTs use in rural areas is increasing, such as the internet and cell phones and the individual, community ad national benefits they bring by making information available at the fingertips are forever emerging. A productive sector depends on a fruitful and fair interaction between the diverse actors-communication and information flows are critical to this process. The technology and socioeconomic context of the farmers determines the selection of ICT in terms of content, media and form of communication.

According to FAO (2006), there are numerous instances where improved production and market information is important to farmers who are often a particularly vulnerable group. These might include extension and research on adoption of new crop varieties, mechanization, pests and weed control, processing and the care of livestock. A further observation was made by FAO (2006) that, technology and what can be accomplished with it has implications for rural communities and producers of all sizes, whether these are larger commercial producers who need to understand global market situations that affect them or subsistence producers concerned with local input markets. This is particularly relevant in the agriculture sector which is an activity that is often highly dependent on externally determined requirements. Government, parastatals and private sector agri-business frequently regulate commercial agricultural production by placing requirements on quality, safety, logistical arrangements and even quotas. Inputs to the agricultural sector may be similarly affected, including seed, fertilizers, pesticides and herbicides as well as livestock feed and veterinary services (FAO, 2006).

The development of agricultural producers can be enhanced by using ICT is though what is known as site-specific management, also called precision agriculture. This refers to a knowledge intensive management strategy that involves the application of information technology to crop production. The literature provides many examples of ICT applications in this domain, including uses in the application of chemical samples, application of fertilizers, application of herbicides, application of liquid fertilizers, application of pesticides, and so forth, as well as activities for efficient resource management such as livestock movement regulations (FAO, 2006).

Farmer Education

According to FAO (2004) strengthening and upgrading rural education and training is a sure means for addressing the knowledge, skills and information gaps that currently exist for farmers as well as extension agents. Today's farmers seem to be more innovative and extension services have become laggards. The important role that rural education institutions can play in this is vital and will require policy changes and commitment and support by governments, donors and communities, as rural schools and institutions are often given lower priority compared to urban institutions and are thus under - resourced and underutilized. Strengthening of education's linkages with extension is a needed component.

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Extension personnel are unable to creatively respond to the change taking place in the environment and remain duplication and tradition bound. Farmers need dynamic information relating to agricultural rural development. There is presently a gap between farm families need by way of generic and dynamic information in what the conventional extension agencies are able to provide. Therefore, to satisfy the need s of farmers and farming communities, information and communicative technologies would be very effective. ICTs can play a major role in updating the farming community by ensuring information flow through agri-websites, enabling the industry to take an updated, uniform database of farming practices to the individual villages, with the data customized to individual agro-climatic zones (Bhatnagar & Schware, 2000; Acker & Gasperini, 2008).

There is potential to bring about transformation in agriculture, through the enhancement of education and research. Perhaps the most straight-forward way in which this can occur is through the conventional agricultural extension system. Traditional Training and Visit extension is a comparatively costly approach requiring the preparation, printing and dissemination of training material, large numbers of trained extension officers who carry the messages to be conveyed, and the risk that messages may become distorted when they are eventually conveyed. Extension officers who are connected through ICT will be better able to update their knowledge on a continuous basis than in the past, avoiding the criticism that the information provided by these services is often irrelevant or out-of-date. This approach does not require any ICT capacity on the part of the farmer, and as a result, may be relatively simple to implement in many countries. However when farmers are digitally literate a range of new opportunities become available.

According to FAO (2006), ICT can be used for agricultural research surveys and censuses completing a 'virtuous circle' of information exchange and can also be used to build what have been termed Knowledge Digital Libraries which can include the collection of indigenous knowledge about crops and cultivation practices specific to local contexts. Through participatory research strategies that place farmer's and communities at the centre of the research process, a network for small scale development projects can foster the exchange of information, experiences, expertise and solutions to technical problems and adapt the often generic nature of information accessed by ICT to local conditions. Such appropriately supported ICT strategies have the potential to enhance access to information and information technologies as well as access to channels and other modes of communication.

Prize Realization

The benefits of using ICTs can be broadly categorized as personal and commercial. On the personal front ICTs can be used to enable farmers to keep in touch with their relatives and friends whereas commercially, farmers can use them to obtain information on the prices of agricultural inputs and marketing their products. Most farmers sell their produce to middlemen or in the nearest markets where the middlemen decide on price. The farmers have virtually no interaction with the buyer nor do they know the prices ruling at nearby markets. By making commodity prices and market information on a real time basis available on the internet, the farming community can be provided with choices that they lack today. This will ensure better price realization and stimulate a drive towards better productivity. The role of extension services becomes increasingly important in ensuring that the use of ICTs is more relevant and effective.

Furthermore the use of ICTs amongst extension officers can also enormously benefit farmers who grow cash crops by providing forecasted information on future process of commodities. This will prevent the tendency of farmers to jump a decision on the basis of ruling price levels and later discover that the

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process have crashed when they are ready to sell their produce at the end of the season. Information on likely future process of commodities can avert this disaster to a large extent (Nagasri, 2000)

According to Rivera and Sulaiman (2009) in India, Reuters Market Light provides information on market prices, weather conditions, agricultural policy news, and tips on farming cycles via SMS to fee-paying subscribers in India. Information can be personalized based on the type of crop, region of the country, and local language. The service employs a staff of 300 full-time content professionals to provide news and data on more than 250 crop types, 1,000 markets, and weather forecasts for 2,500 locations.

Back-Up Services

An important task in the process of development is that of carrying information on the latest agricultural concern to rural areas. It is not sufficient for extension officers to provide farmers exhaustive information through web portals, their specific queries have to be replied though on-line chats, they have to be provided with early warning systems regarding pest onset and weather forecasts to their local areas. Digital data storage appeared on the scene much later than long distance communication. While telephones and telegraphs revolutionized the transfer of information, traditional analog methods like pen and paper were still considered sufficient enough to keep track of production. Bookkeeping had become an art by then, and farmers simply did not have enough time to learn the ins and out of computerization.

However, as the volume of information increased dramatically over the years, the limitations of old methods became increasingly clear. They first became apparent in central organizations like Ministries of Agriculture which had to keep track of production on an exceedingly vast scale and maintain the information indefinitely. The vulnerability of paper and the massive amounts of record to track meant that digital storage quickly went from being a novelty to a necessity. The use of ICTs amongst extension officers will attract large number of farmers; lot of new industries interested in providing services like transportation ad mechanized farm operations like pest control will get created (Gurstein, 2000).

Enhancing Agricultural Production

Swanson and Rajalahati (2010) reported that most countries have somewhat similar agricultural extension systems, but most systems differ in terms of their respective management structure, including how extension priorities are set, how extension programs are planned and by whom, and how extension programs are actually organized and implemented. Farmers especially emerging ones often face threats from soils, drought, erosion and pests. Key areas where ICTs can help improve this is by providing up to date information about pest and disease control, early warning systems, new varieties, new ways to optimize production and regulations for quality control.

Capacity Building and Empowerment

The meaning of the term capacity building seems to vary according to the user, but there seems to be no doubt that ICTs are capable of helping to achieve it. There are many definitions, but they all carry the same theme concerning developing an organization's or individual's core skills and capabilities to help them achieve their development goals. This definition suits the context of ICTs as it assumes knowledge of the existence of development goals, without which ICTs are unlikely to be of much value (Marker, McNamara & Wallace, 2002).

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It is widely accepted today that the information society is going to lead the knowledge society where individuals as well as institutions are valued and judged according to what they know and how much they know. The farming population needs new knowledge and new skills to understand, to feel at ease with, to take advantage of, to benefit from, and to operate ICTs efficiently. The sped of change of ICTs means that acquisition of this new knowledge and skills needed to operate ICTs is becoming a never ending process.

Marker et al. (2002), further states that capacity building also relates to the accumulation of social capital, which refers to those features of social organization such as networks, norms, and social trust that facilitate coordination and cooperation for mutual benefit and establishing networks for mutual benefit that can be nurtured and extended through the use of ICTs. ICTs can help create and sustain online and offline networks that introduce and interconnect people who are working toward similar goals. Many NGOs can use ICTs as an advocacy tool to champion their courses.

ICTs can be used strengthen communities and farmer organization to strengthen their own capacities and better represent their constituencies when negotiating input and output prices, land claims, resource rights and infrastructure projects. Rural communities are able to interact with others via the use of ICTs which reduces social isolation that they would otherwise be facing. Besides, ICTs are able to make processes like law-making and land title approvals more transparent (FAO, 2004).

In the past senior subject-matter specialists were needed to provide technical support to field extension staff about key crops, livestock, fisheries, and other commodity areas. In the future, it may be possible to make more of this technical and marketing information available electronically to the field extension staff, given the complexity of problems being addressed. The goal should be to enhance the capacity of the field extension staff to make available a wide range of technical and market information to the different group of farmers being served, especially small-scale men and women farmers through the use of ICTs (Swanson et. al, 2010).

According to Flor and Hazelman (2004) in Thailand, it is mandatory for the field extension staff of the DOAE to undergo training on Basic Computer Applications and Web Tools. The DOAE ICT Center conducts both training courses on a regular basis. However, secondary data from the 2001 UNDP Human Development Report reveal that computer literacy in the rural areas is still quite low. Generally, Thai extension workers are computer literate and proficient in using the World Wide Web. Their role may go beyond plain users but as contributors to and developers of online knowledge products. Thus, training programs on Web technologies (i.e., Web writing, html, and interface design) might be in order.

Knowledge Base

A knowledge base is a portal –type application that can centralize many major sources of information into one searchable reference library. The sources of information could include government websites, universities, document archives, the Internet, economic reports, historical data and others. The information may have different security levels depending on who is looking at the information, but in general would be open to browsing or searching by topics and keywords. Internet information would be filtered and categorized for more accurate and valuable results. Information in the knowledge base include: technology, seeds, livestock, veterinarian resources, best farming practices and natural language sources (Richardson, 2006).

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AGRICULTURE KNOWLEDGE MANAGEMENT

Knowledge sharing, exchanging and dissemination are elements in a broader theme which is knowledge management. The central purpose of knowledge management is to transform information and intellectual assets into enduring value. The basic idea is to strengthen, improve and propel the organizations by using the wealth of information and knowledge that organizations and its members collectively possess. It has been pointed out that a large part of knowledge is not explicit but tacit. This is true for knowledge in agriculture where a lot of good practices are transferred without being well documented in books, papers or extension documents. To manage the knowledge properly, ICTs are needed. In effect, there are many information technologies that can be used for knowledge management (Said, Rafea, El-Beltagy & Hassan, 2009).

Content management system in its wider sense including data bases and multimedia, *is* the core technology of information and knowledge management. This technology can be used in different applications: Building a national agriculture research information system (NARIS) which needs to include research outcomes, projects, institutions and researchers in every country, and a regional research information system that works as a portal for all the NARIS. An example NARIS has been developed at the agriculture research center in Egypt, developing an information system of indigenous agricultural practices can enable researchers to examine this knowledge and decide on its usefulness for sustainable development. Such a system will also keep this knowledge for future generations before it disappears as a result of advanced technologies, developing an information system recording matured technologies that on a trial basis have proven successful and success stories that have achieved economic growth will strengthen the interaction between inventors and innovators. This will lead to an innovation-driven economic growth paradigm, storing and retrieving images, videotapes and audiotapes related to different agricultural activities (Said et al. 2009).

Said, et al. (2009) further states that geographic information systems (GIS) are needed to store databases about natural resources with a graphical user interface that enables users to access these data easily using geographical maps. Furthermore decision support system techniques are needed in many applications such as simulating and modeling methods can be used to build computer systems that can model and simulate the effect of different agricultural production policies on the economy and the environment to help top management make decisions, using expert systems technology to improve crop management and track its effect on conserving natural resources is elaborated in This technology may also be appropriate for keeping indigenous knowledge. Expediting the expert systems development by generating agriculture specific tools to overcome the well-known problem of knowledge acquisition and enhancing the explanation capabilities of expert systems developed for agriculture.

Agricultural Information Needs

The effectiveness of information transfer process depends on the effectiveness of the communication system through which the transfer is to take place, and that, in turn, depends on whether the target audience has access to the medium and can understand the message which it conveys (Feather,1994). In light of the constraints of human and financial resources and geographical distances, the media and ICT are being promoted as valuable tools in the delivery of extension information. Increasingly, ICT is being regarded as a tool for sustainable development and poverty reduction. The extent and rate of change now occurring in the development of ICTs have opened the way for significant change in crop production

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management, agricultural decision-making and information dissemination. The farmers may depend on extension personnel to get the proper advice to cultivate the crop. The information needed relate to different schemes, crops, technologies, seeds, fertilizers, pesticides, availability of fertilizers, seedlings, biopesticides, soil fertility, pest and disease diagnosis and many more.

The agricultural marketing information is essential for farmers to increase their profits. Information such as price details of seeds, fertilizers, pesticides and availability of these products in the market enables the farmer to take decision in choosing right seed, fertilizer and pesticide required for the better farming. The vital information that flows from the agricultural policy maker's desk, such as fixation of procurement price, procurement targets and policy relating to exports helps to farmers to get maximum profits.

In India, Reuters Market Light provides information on market prices, weather conditions, agricultural policy news, and tips on farming cycles via SMS to fee-paying subscribers. Information can be personalized based on the type of crop, region of the country, and local language. The service employs a staff of 300 full-time content professionals to provide news and data on more than 250 crop types, 1,000 markets, and weather forecasts for 2,500 locations (Rivera & Sulaiman, 2009).

The delivery of information, technical advice and agricultural skills training for farmers rests with national extension services. However, in the Pacific extension activities are typically given a low priority. Extension work continues to face challenges because of the scarcity in human, financial and physical resources. The need 'to do more for less' is a realty, and partnering with the media can help enhance extension services (SPC, 2011).

Agriculture Support

Research suggests that increasing agricultural productivity benefits the poor and landless through increased employment opportunities. As the vast majorities of poor people lives in rural areas and derive their livelihoods directly or indirectly from agriculture, support for farming is a high priority for rural development. ICTs can deliver useful information to farmers in the form of crop care and animal husbandry, fertilizer and feedstock inputs, drought mitigation, pest control, irrigation, weather forecasting, seed sourcing and market prices. Other uses of ICTs can benefit farmers, enabling them to participate in advocacy and co-operative activities.

Vulnerable and Marginalized Groups

According to Marker et al. (2002), women in developing countries particularly, face difficulties in using ICTs, as they tend to be poorer, face greater social constraints and are less likely to be educated or literate than men. They are likely to use ICTs in different ways, and have different information requirements, to men. Women are less likely to be able to pay for access to ICTs, either because of an absolute lack of funds or because they lack control of household expenditure. Constraints on women's time or their movement outside of the home can also reduce their ability to access technologies. Such groups usually require special assistance and attention in order to benefit from programmes that are targeted at poor people.

Munyua (2000) further notes that, in any farming system it is important to recognize the various roles of men, women, youth, and children. Women in rural areas have very little access to information. They are mostly poor, illiterate, and unable to afford even the very most basic forms of ICTs, such as radios and telephones. Nevertheless, rural women actively seek and disseminate information. So ICTs

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must be appropriate to enable women to gain access to information efficiently and cost-effectively. Gender considerations have, however, not received the attention they deserve in the design and use of information services or in the application of ICTs. Therefore the types of information required to meet the needs women express, to determine the information gaps, and to select the ICTs and services to best close these gaps must be identified.

The lack of reliable and comprehensive information for rural female farmers is a major hindrance to agricultural development. They require information on agricultural inputs; market prices; transportation systems; product potential; new environmentally sound production techniques and practices; new agricultural technologies; new markets; food processing and preservation; decision-making processes; the resource base; trade laws; and trends in food production, demand, and processing. Women also need to exchange indigenous knowledge. However, most available local information is packaged in a raw form and therefore difficult to access or use .The situation is compounded because women do not know where to find this information. Moreover, current mass media and communication systems have not been used to maximum effect in development. Information should be accessible to female farmers at selected sites, with various ICTs to facilitate easy access to relevant information and information exchange to meet the information needs of rural female farmers (Munyua, 2000).

Trends in Agricultural Information Management

According to Ballantyne (2009), the world of agricultural information and communication is changing, as agricultural innovators become active creators and managers of information and knowledge and information managers become innovators. These effort calls for greater investment in knowledge creation, information access, and the wider use of information technologies. There is an exploration on what the renewed interest might mean for information and communication specialists working in agricultural environment. Starting from an "innovation systems" perspective which looks across the agricultural information for development landscape and highlighting some items on the agenda of information and communication specialists working area. The widening recognition of the value of farmers knowledge, growing used of information and communication information and communication technologies to enable different agricultural development activities, concerns to ensure that public investment result in public goods whose benefits can travel, related efforts to ensure that agricultural content is open and accessible, the discovery and increasing use of a 'social' web, and some emerging new roles for agricultural library information and information centers to meet changing demands.

Virtual Community

Satyanarayana, Reddy, Balasubramani, Sharma, and Bhaskar (2008) defines a virtual community, e-community or online community as a group of people that primarily interact via communication media such as letters, telephone, email or usenet rather than face to face. If the mechanism is a computer network, it is called an online community. Virtual and online communities have also become a supplemental form of communication between people who know each other primarily in real life. Many means are used in social software separately or in combination, including chartrooms and forums that use voice, video and/ or text.

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Virtual Information Networks

A number of virtual information networks with the objective of linking agricultural institutions for facilitating better access to information resources have been initiated successfully. While some of these network agricultural institutions within a country, link to agricultural institutions around the globe.

Agriculture Network Information Center

Agriculture Network Information Center (AgNIC) is an Internet based network of public and private agricultural libraries and information centers, coordinated by the National Agriculture Library (NAL), USA. The network aims to provide global access to agricultural information. AgNIC Members represent 40 land-grant universities and other national and international partners including universities and research institutions, government agencies, and a non-profit organization. Through its website the network provides access to a network of electronic sources on research and teaching in agriculture, food, renewable natural resources, forestry, and physical and social sciences. AgNIC is a distributed discipline-oriented source of agricultural information in electronic form on the Internet. The goals are to: identify major collections of agriculture-related information; provide mechanisms to facilitate access/ retrieval from these information resources; create mechanisms to encourage organizations to collaborate in creating/ using AgNIC. AgNIC partners select important information sources for inclusion in the system (Satyanarayana et al. 2008).

Services include: Resource database with web sites, image collections, lists of publications, documents, databases, and other resources; Calendar of events which includes meetings, seminars, national and international symposia and conferences, conventions, and workshops in agricultural and related sciences; News items; Specialized Services – such as Plant Disease Announcements; discussions on emerging plant diseases around the world; Expertise where specialists respond to individual questions. There are partnerships between libraries and United States Department of Agriculture (USDA) Cooperative Extension programs; between libraries and academic departments within colleges; between states and between technologists and librarians. Member participants take responsibility for small segments of agricultural information and develop Web sites and reference services in their specific subject areas. Nearly all participating AgNIC institutions have developed partnering relationships with a variety of internal and external institutions, groups, and agencies to develop content and tools for their respective Web sites.

Agricultural Libraries Network

The Agricultural Libraries Network (AGLINET) coordinated by the Food and Agriculture Organization of the United Nation (FAO), is a world-wide, voluntary network of international agricultural libraries with regional/country coverage and other comprehensive or specialized subject resource collections. All member libraries provide, upon request, access to the literature originating in the country or region or for a given specialization. AGLINET aims at combining resources for mutual and rational use through delivery of primary documents, by means of inter library loan provision of reproductions, bibliographic information; with appropriate regional and subject specialization. Member libraries include Agricultural libraries of national or regional importance with comprehensive collections and strong regional cover-

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age; Libraries in special subject fields within the broad domain of agriculture with worldwide coverage. AGLINET Network members include Libraries from Argentina, Australia, Belarus, Belgium, Benin, Botswana, Brazil, Bulgaria, Brazil, Canada, China Costa Rica, Czech republic, Denmark, Egypt, Estonia, Ethiopia, Finland, France, Germany, Hungary, India, Indonesia, Italy, Japan, Jordan, Kenya, Korea, Latvia, Lithuania, Malawi, Malaysia, Mexico, Netherlands, Nigeria, Norway Philippines, Poland Portugal, Russia, Slovenia, South Korea, Sprain, Sri Lanka, Sweden Syria, Thailand, UK, Uruguay, USA, West Indies and Zambia (Satyanarayana et al. 2008).

International Information System for Agricultural Sciences and Technology

The Food and Agriculture Organization (FAO) of the United Nations initiated agricultural information networking through AGRIS. Established in 1974, AGRIS facilitates information exchange and brings together world literature dealing with all aspects of agriculture and related subjects. AGRIS is a cooperative system in which 240 national, international and intergovernmental centers in participating countries input references to the literature produced within their countries and draw on the information provided by the other participants. The new vision of AGRIS, in response to the needs includes: a decentralized approach with greater emphasis on national partnerships, improved linkages between the AGRIS network and other FAO initiatives; focus on management of documents in agricultural science and technology in full text; information about activities, organizations, and people in agricultural science and technology (FAO, 2006).

Agrigate

Coordinated by the National Library of Australia is a project of the libraries of the Universities of Melbourne, Adelaide and Queensland, and the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia. This is a subject information gateway for resources, both online and offline, in agricultural research. The purpose is to support the identification and dissemination of quality research materials selected by an editorial review process consisting of members of the agricultural research community. The content covers agriculture and related areas of value to the Australian agricultural research community. The resources selected have been reviewed by subject specialist librarians. The majority of resources identified in the database are available online.

AGROWEB CEE Network

Satyanarayana et al. (2008) states that AGROWEB CEE network has been established by organizations and individuals involved in agricultural and rural development in Central and Eastern Europe. This collaborative network is maintained by representatives of participating countries, and facilitated by International Association of Agricultural Information Specialists (IAALD) and FAO. Twenty-five countries from the Balkan region, New Independent States, Baltic States, Caucasus region, Central Asia, and European Union are participating in the network. National web pages have been established as portals for the countries in the region, which provide access to information about agriculture-related institutions - ministries, libraries, information centre's, universities, research centre's, NGOs, agro-marketing organizations and other organizations. The Agro Web national portals provide Internet links,

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to these national institutions and to other relevant national web sites. In addition to the national portal pages, cross-cutting subject areas have been identified and a number of thematic sectors of the network are being coordinated by regional focal points.

Asia-Pacific Association of Agricultural Research Institutions (APAARI)

Information exchange among the Asia-Pacific national agricultural research systems is one of the primary objectives of the Asia-Pacific Agricultural Research Information System (APARIS). Components of APARIS include Management Information System (MIS) Tools viz.: Regional Research Networks (RRN) Database, NARS Database, etc.; information on regional events; access to scientific publications generated by agricultural research in the region; electronic Forums to facilitate dialogue among stakeholders of Agricultural Research for Development (ARD) in the region on issues of strategic importance; gateway/portal service - portal to RRNs, websites of NARS Institutions in the Asia/Pacific region, web-enabled information on key topics/themes of ARD; Knowledge Networks on ARD in the APAARI region; information dissemination through APAARI web site and publications. The web site has linkages to various national, regional and international institutions, networks, and other organizations (Satyanarayana et al. 2008).

The Consultative Group on International Agricultural Research

According to FAO (2006), The Consultative Group on International Agricultural Research (CGlAR) is a research network of fifteen international agricultural research centers. The 15 centers supported by the CGIAR are independent institutions, each with its own charter, international board of trustees, director general, and staff. The institutions are Africa Rice Center (WARDA), Biodiversity International, Centro Internacional de Agricultura Tropical (CIAT), Center for International Forestry Research (CIFOR), International Maize and Wheat Improvement centre (CIMMYT), International Potato center (CIP), International Center for Agricultural Research in the Dry Areas (ICARDA), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), International Food Policy Research Institute (IFPRI), International Institute of Tropical Agriculture (IITA), International Livestock Research Institute (ILRI), International Rice Research Institute (IRRI), International Water Management Institute (IWMI), World Agro-forestry Center (ICRAF) and World Fish Center (WFC).

Thirteen of the 15 CGIAR Centers are located in developing countries and the knowledge gathered is shared and disseminated across the world. The CGIAR website gives access to a Virtual Information Center and Library. One can tap into agricultural information databases, including online libraries of the CGIAR Centers and the Core Collection Database. The CG Library gives access to databases and e-journals and facility to go directly to the full text of publications. One can search CGIAR libraries/ other agricultural libraries/by specific topics. The Virtual Information Center provides information on various topics mentioning the source against each topic. Each institutional library is the source for/ and responsible for providing information on specific subject areas viz.,: Agriculture in the Dry Areas- ICARDA library; Agriculture in semi arid tropics- ICRISAT library; Agro-forestry- ICRAF library; Aquaculture and fisheries -WFC library; Food policy- IFPRI library, Agricultural biodiversity – IPGRI library; Water Management-IWMI library; Wheat - CIMMYT library(FAO,2006).

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DAINet: German Agricultural Information Network

The German Agricultural Information Network (DAINet) is a catalogue of Internet sources in the field of nutrition, agriculture and forestry. DAINet was established in 1995 to guide people interested in subject specific information to sources on the Internet. DAINet has about 7,500 references to information sources and about 800 web links to agriculture-related organizations. Three sections cover, 'information', 'service' and 'dialogue'. The 'information section' organized by subjects, structures worldwide existing agricultural information under 'subject fields', 'user groups' and 'topics'. The 19 'subject fields' cover various topics of agriculture. The division into five user groups caters to the specific needs of farmers, economists, scientists, educators and journalists. The 'service section' is structured according to types of data. The 'dialog section' is used for professional communication through Internet. 'Information' and 'service' sections offer links to databases and web pages and also give access to newsgroups and mailing lists (Satyanarayana et al. 2008).

ELIN: Entomology Library and Information Network

According to Satyanarayana et al. (2008), the ELIN project hosted by the Natural History Museum, London, aims to establish a global Entomology Library and Information Network to provide entomologists with a co-ordinated and structured electronic information resource including a gateway to a wide range of entomological information. A mailing list was launched in 1998 and has over 100 members from libraries and information centre's from around the world, which has encouraged international communication between specialists working with entomological information. The ELIN project provides up-to-date, detailed information about entomological libraries around the world. ICTs.

Information Network on Post-Harvest Operations

Information Network on Post-Harvest Operations (INPhO) is an FAO databank project of the Post-Harvest Management Group. It is an international collaborative effort by the FAO, GTZ and CIRAD which aims to support the collection and dissemination of information on proven technologies and products in post-harvest systems. Components of the network include a comprehensive collection of information on post-harvest issues, communication/interactive services; links with other databases. The website includes full text documents of training and technical publications, country profiles, crop profiles (main focus is on cereals and grains, fruits and vegetables, oil seeds, roots and tubers). Recipients of this information include people working in the agricultural production and marketing sector viz., producers, researchers, policy makers, private investors and donors (FAO, 2006).

Philippine Agricultural Libraries and Information Services Network

Philippine Agricultural Libraries and Information Services Network (PhilAgriNet) aims to create and maintain a central electronic database of Philippine technical agricultural literature and make this accessible to agricultural scientists worldwide. Membership is open to agricultural institutions. The database intends to cover all technical publications on agriculture, generated by member institutions, both published and unpublished, and written in any language or dialect, regardless of format. Affiliation is open

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to libraries of Government agencies and corporations engaged in agricultural research; state colleges and universities, whose curriculum includes agriculture and independent or private agricultural agencies.

Virtual Extension Research Communication Network (VERCON)

Virtual Extension and Research Communication Network (VERCON) established by FAO aims to use the potential of the Internet and apply it to strengthening and enabling linkages among the research and extension components of the national agricultural knowledge and information system. VERCON aims at improving linkages between and within agricultural research and extension institutions through human and technological components. The human component is a network of staff of research and extension institutions, faculty of agricultural education, NGO workers, in some cases agro producers committed to strengthening collaboration, communicating, sharing information and supporting improved agricultural production. In order to link the human component there is the technological component, which allows members of the network to communicate and develop, share, store and retrieve information (FAO, 2006).

Network members can engage in two-way horizontal communication to address problems, discuss solutions and coordinate local, regional and national agricultural activities. An illustration of how VERCON functions: A farmer visits an extension office with an insect that is causing heavy damage to his cotton crop. The extension worker identifies the insect by consulting a database of digital photographs of various cotton pests that have been photographed in the area and scanned. Using a chat room, a number of integrated pest management specialists are consulted simultaneously about how to accurately identify and control the pest. Relevant information is quickly compiled from research results, pest distribution maps, publications and the photo file into a Fact sheet using a template. A message with the fact sheet attached is sent to all extension officers in the region, warning about the presence of the pest and providing recommended integrated pest management measures. This is communicated to farmers through IPM farmer field schools, facilitated by extension.

In 2000, the Virtual Extension and Research Communication Network (VERCON) project was funded by the FAO Technical Cooperation Program (TCP) to develop a Web-based information system to strengthen the link between research and extension. The Egyptian Government established a pilot VERCON to support research and extension interaction and the flow of information between research, extension and farmers in Egypt. This network has been extended to include other stakeholders, and other services through a project funded by Italian Debt Swap Program and executed by FAO in collaboration with Central Laboratory for Agricultural Expert Systems (CLAES). Several expert systems have been made available on this network in addition. In collaboration with other stakeholders, CLAES has developed three regional expert systems for wheat, faba and barley. Furthermore CLAES also developed the National Agricultural Research Management Information System (NARIMS) through a project funded by FAO/TCP (FAO, 2003).

Web-Based Information Service for Agricultural Research for Development

Web-Based Information Service for Agricultural Research for Development (WISARD) is a web-based information platform that provides searchable information on experts, organizations, outputs and projects in the fields of ARD, Natural Resource Management (NRM) and Sustainable Development (SD) from the mid-nineties till date. The system can be used at organization, network, national and international levels. WISARD allows decentralized data input and management through focal points at organization,

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network or national level. A module has been added for depositing outputs of research and another is under development for 'Technologies and Best Practices'. Present partners include among others, CGIAR, IPM-Europe, and Rice-Wheat Consortium for the Indo-Gangetic Plains, FAO, donor agencies, international and national NGOs and European agencies and national agricultural research systems of India, Pakistan, Nepal and Bangladesh.

Bridging the Digital Divide with Technology

The emergence of digital divide lies in the acknowledgement of the existence of an environment that sustains, unequal and unaffordable access to digital and network resources; enormous disparities in the ICT endowment/infrastructure and the lack of suitable local digital content. Digital divide cuts across international borders and goes beyond the gap between developed and developing nations to include the unequal participation of women, youth and marginalized communities, as well as the lack of local culture and content. The concept applied to reflect the disparity in access to information that is growing within nations, namely, between the rich and poor and between urban and rural communities. In recent years, as ICTs have become a more important part of the global information economy, more attention has been given to the gap in access to ICTs between developed and developing nations, and also within countries (Alao, 2010).

E-Agriculture

The FAO defines e-Agriculture as an emerging field in the intersection of agriculture informatics, agricultural development and entrepreneurship, referring to agricultural services, technology dissemination and information delivered or enhanced through the Internet and related technologies. More specifically, it involves the conceptualization, design, development, evaluation and application of new (innovative) ways to use existing or emerging information and communication technologies (ICTs)" (FAO 2006). E-Agriculture is intended to promote the integration of agricultural stakeholders and technology with multimedia, knowledge and culture, and aims to improve communication and learning processes.

According to FAO (2006) e-Agriculture is an emerging field focusing on the enhancement of agricultural and rural development through improved information and communication processes. E-Agriculture also addresses the 8th Millennium Development Goal, and the target to make available the benefits of new technologies, especially information and communication technologies to the fight against poverty. More specifically, e-Agriculture involves the conceptualization of design, development, evaluation and application of innovative ways to use information and communicative technologies in the rural domain, with a primary focus on agriculture. All stakeholders of agriculture industry need information and knowledge about the phases of agriculture, for example: water management, fertilizer application, food safety and food marketing and how to manage them efficiently. Any system applied for getting information and knowledge for making decisions in any industry should deliver accurate, complete, concise information in time or on time. The information provided by the systems must be in user friendly form, easy to access, cost effective and well protected from unauthorized accesses. ICTs can play a significant role in maintaining the above mentioned properties of information.

The World Summit on the Information Society (WSIS) Plan of Action emphasizes two key areas on e-Agriculture, namely:

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- Ensuring the systematic dissemination of information using ICTs on agriculture, animal husbandry, fisheries, forestry and food in order to produce ready access to comprehensive, up-to-date and detailed knowledge and information, particularly in rural areas.
- Establishing public-private partnerships that seek to maximise the use of ICTs as tools to improve production, marketing and food safety standards (FAO 2006).

Electronic Publishing in Agriculture

Satyanarayana et al. (2008) states that Electronic Publishing (e-Publishing) is quickly becoming an important part of publishing mainstream. Recent innovations in this area have made it possible to publish on the information super highway. E-document can be accessed at the computer. It makes much easier for readers to search the information. It is very quick and easy for a reader to browse the table of the contents of previous issues, to jump directly to a particular section of a document or even particular section of an article. E-Publishing (EP) difference lies in the new levels of value it provides through features not possible in traditional media. EP products may differ to an even greater degree than print products. Nevertheless, there are some common features to distinguish EP from print Publishing in terms of value to end-users.

Satyanarayana et al. (2008) further states that EP products create additional value for the user with regard to following three dimensions: content availability, content transparency and interactivity and content format. Content availability means that EP products can be delivered and accessed with more independence of time and place than can be traditional print products and that their delivery is less limited with regard to quantity. Content availability includes: time of delivery - available any time; location of delivery - consumption anywhere; amount of information - end of traditional boundaries imposed by paper volume and price. Content transparency and interactivity refers to new tools and opportunities concerning information navigation The main features are: Interactivity- contextual hyperlinks open new dimensions of information retrieval and lead to new types of information behavior: browsing, etc. the possibility to integrate content and services; and search tools across one or thousands of documents - interactive information processing.

For example, Electronic Publishing in Agriculture in India, The Directorate of Information and Publications of Agriculture, (DIPA), New Delhi, is the official publication wing of the ICAR through which the research and other activities are revealed to the world. DIPA brings out a variety of publications in English and Hindi languages for the use of scientists, researchers, students, policy planners, extension personnel, farmers and the general public. The e-publications of DIPA include - "Handbook of Horticulture", ICAR Research Projects Information – Research Project Files (RPF) Database, ICAR Vision 2020 Document etc. Some other important institutions bringing out e-publications in Agriculture in India include, National Institute of Agricultural Extension Management (NIAEM), Indian Agricultural Research Institute (IARI), New Delhi, Indian Farmers Fertilizer Cooperative Limited (IFFCO), Krishak Bharati Co-operative Limited (KRIBHCO), National Bank for Agricultural and Rural Development (NABARD) National Agricultural Co-operative Marketing Federation of India Ltd. (NAFED) Indian Agricultural Statistics Research Institute (IASRI), and State Agriculture Universities of Tamilnadu, Uttarakhand, Punjab, Haryana and Andhra Pradesh. Two major open universities namely Indira Gandhi National Open University (IGNOU), Delhi and Yeshwantrao Chavan Maharashtra Open University (YCMOU), Nashik and National Institute of Agricultural Extension Management, MANAGE, have taken open and distance

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learning in Agriculture on a national scale, and all these institutions are in the process of bringing out a number of e-publications in Agriculture (Satyanarayana et al. 2008).

E- Commerce

Harris (2004) indicates that m-commerce using wireless mobile phones and PDAs to sell goods and services has been growing rapidly. It is the case however, that most countries cannot make payments online due to national ICT policies, security risks and inadequate infrastructure such as low bandwidth to support e-commerce. Other bottlenecks have been created by inadequate skills to use e-commerce, the legal status of e-mail communication and the high telecommunication costs. Not surprisingly therefore, in Africa, e-commerce has been insignificant in the agricultural sector. Thus, a number of transactions have to be conducted off-line (Tregurtha & Vink 2002). Some of the reasons given for not adopting e-commerce include: lack of applicability and little incentive to change business models when returns are not clear; poor trust in e-transactions; privacy considerations; shortage of ICT-skilled labour (Qiang, Clarke & Halewood, 2006).

The findings of a survey on e-commerce that was conducted in South Africa there are a number of challenges to using e-commerce such as: the need for face-to-face interaction; data privacy and security issues; hesitance of customers to use the technology; inadequate staff with e-commerce expertise; costs of implementing e-commerce; unwillingness to make organisational changes; low levels of Internet usage; non-supportive business laws; inadequate legal protection (Qiang et al, 2006).

Types of ICT Tools Used by Extension Service

Increasing diversity and complexity of global agriculture, and the seed of global innovation in ITC tools, services and business models, requires in turn a flexible approach to policies and investment choices that focuses not on 'choosing winners' among ICT options but on maximizing conditions for local innovation and creative public –private partnerships to expand ICT access and services. According to Obayelu and Ogunlade (2006), ICTs consist of various collections of resources and technical tools that are used for connecting, spreading, storing and managing information. ICT represents the collection of hardware and software that is used for producing, preparing, transferring and storing data via devices such as computers, radios, televisions, etc., and it includes an extensive scope of traditional and modern media.

In general, ICTs can be classified into three groups: New ICTs: This group consists of computers, satellites, one-on-one connections, wireless phones (mobile), the internet, e-mail, the web, internet services, video conferences, CD-ROMs, personal computers (PC), distance control systems, informational-geographical systems, global positioning systems (GPS), electronic cameras, databases, etc. The hidden concept behind these technologies is that they are not automatically considered to be new, but their common and inexpensive availability has resulted in them being regarded as new; Old ICTs: This group consists of radios, televisions, telephones, telegraphs, audio and video cassettes, films and slides. This group of technologies have been used for several decades; Very Old ICTs: These groups of technologies have been used for several centuries and includes newspapers, books, photo albums, posters, theater, human interactions, markets and plays (Obayelu & Ogunlade,2006).

According to FAO (2006), combining traditional information and dissemination methods with new forms of extension of extension delivery will promote information access by farmers and farming communities. The ICT tools that have great potential for use in agricultural extension include radio,

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television, telephone (GSM), the web, search engines, packet digital assistants, cameras, video, email, computer, contact data bases and system, CD-ROM, DVD, current awareness, group ware, rural radio, etc. regardless of the tool, the focus must be on the people who will use the technologies and the content rather than the technologies themselves. Farmers depend on multiple sources of information and technologies. In most societies, face- to- face contact is still the preferred mode of communication. Given the large populations to be served by extension agents and the dispersed and distant locations, face-to-face communication is not always possible and thus to combine strategies and communication channels to include traditional information sources, such as radio, print, video and television, together with new forms of delivery such as through ICT.

Rivera and Sulaiman (2009) states that different approaches to delivering farm extension services via ICT channels in a sustainable (i.e. without on-going donor support, although often with government support) and scalable ways (i.e., to reach tens of thousands or millions of farmers) have been identified. Often, more "high tech" ICT channels such as mobile phone services are combined with an older ICT channel, like radio, that has been used well for many years in sub-Saharan Africa and for decades in the US and elsewhere. Strengthening the use of ICT to close the gap between those who have access to extension services and those who do not, along with the strategies use of traditional media, is an opportunity that needs to be harnessed. Use of ICTs is now increasingly available and becoming more affordable. Linking ICT tools and other traditional mediums is also advocated, with choices dependent upon the local situation and realities. ICT provide information access and networking, which are two areas where the current extension systems are weak- between research and extension and between extension and farmers.

According to Lie (2006) the renewed interest in ICTs for agricultural development is remarkable and triggers the question: "What is the difference between the classic mass media attempts and the 'new' attempts to use ICTs as instruments for bringing about change?" The first thing that seems to be different relates to the shift in paradigmatic thinking about change and development in general and the role of ICTs in development in particular. This change is often framed under the heading 'from modernization to multiplicity'. The new paradigm emphasizes non-linear bottom-up perspectives and local cultural relevance. The second thing that seems to be different and is more specific is that the new ICTs, such as internet and mobile phones are not only and primarily used to reach the masses as the mass media were supposed to do. The new ICTs can also cater for small and specific audiences, which opens up possibilities for sharing more relevant and even tailor made information.

As the mass media mainly aimed at national development, the new ICTs can also be appropriate instruments for aiming at local, community levels. The implementation of any technology needs to be participatory and sustainable in its very nature. Although difficult to implement, the new ICTs have the potential of becoming a more democratic medium than traditional media such as national television that is often operating in a national power driven environment. So, an important difference between then and now seems to lie in the possibilities of the technology itself. The possibilities of the ICTs have changed towards more flexibility as it is related to speed, convergence of media forms; interactivity and specificity (Lie, 2006).

Furthermore, Lie (2006) states that in the area of 'agricultural extension systems' or 'agricultural knowledge and information systems' (AKIS) one of the changes taking place is the integration of new information and communication technologies. The mainstream focus of bringing ICTs to rural areas seems to be lying on (multi-purpose) telecentres or information kiosks as they are called in India. Two mainstream ICTs in the debates seem to be the use of the internet (including email) and the use of mobile phones, although mobile phones seem to get far less attention. Besides these two 'new' ICTs, radio

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remains one of the most important communication and information technologies for rural areas, but also the overall paradigmatic thinking about agricultural extension has changed.

The present systems no longer think in terms of 'adoption and diffusion of innovations', but talk about 'agricultural knowledge and information systems', emphasizing social learning and negotiation, participation and interactivity, the sharing——instead of transmissions——of all kinds of knowledges, knowledge markets and networks and continuous change. Within this paradigm shift from 'extension' to 'communication for change' in the agricultural sector, there is also a growing recognition of the importance of cooperation and integration of the natural sciences and the social sciences, in case of the communication sciences. Without intrinsic trans disciplinary cooperation, ICTs would only have a limited chance of being successful in an appropriate and sustainable way (Lie, 2006).

Radio

Radio has achieved impressive results in the delivery of useful information to farmer and farming communities. One of its strengths is its umbiquity. For example, a recent survey of 15 villages in Nepal found radios in every village, with farmers listening to them while working in their fields. Another survey of 21,000 farmers enrolled in radio-backed farm forums in Zambia found that 90 percent found radio programmes relevant and more than 50 percent credited the programmes and forums with increasing their crop yields (Dodds, 1999).

Community radio projects have indicated how extension officers and farming communities can use ICTs tools appropriate for their own purposes. For example, in Nepal, two-community radio stations were established, radio Lumbini in Manigram in western Nepal and Radio Madan Pokhara in Palpa District. Village development committee of the communities held a license and a community group holds the other. Both services have proven to be very popular. Ownership of radio receivers in the coverage areas has shown an increase of 68 percent in the use of community radio station for agricultural information. Programmes include valuable development messages; the Kothmale community radio station in Sri Lanka *p*rovides an interface between smallholder farmers in remote regions. In daily agricultural programmes presenters accepts requests for information from community members and browse the Internet live in response to listeners' requests, the information accessed is explained, and communities are enabled to develop their own websites which are then hosted on the station's server and searches the internet for answers, which it then broadcasts on air (UNDP-APDIP, 2004).

For example, in Ghana the community radio station provides agricultural programmes intended to develop and assist farmers in accessing information about the agricultural practices. Agricultural programmes are prepared by community radio extension officers who visit communities to discuss problems and priorities and record discussions with local experts. They enable smallholder farmers to hear people within their own communities discuss the issues in their local languages. *Arid Lands Information Network-East Africa (ALIN-EA), partnered* with World Space Foundation, ALIN-EA uses digital satellite radio broadcasting to provide Web-based information for smallholder farmers in Ethiopia, Kenya, Tanzania and Uganda. In Kenya, Mali Shambani is a weekly hour-long radio program featuring agricultural news and responding to the business and market access needs of small, rural farmers. The program covers a wide range of topics, including market prices and trends, farming techniques, weather and seasonal issues, financing opportunities, inputs, land use, and quality standards. Each program also offers an interactive call-in component where farmers are given the opportunity to pose agricultural questions to a panel of experts either via phone or SMS (FACET, 2010). Furthermore, Rivera and Sulaiman

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(2009) states that, Farmer Voice Radio (FVR) is a radio extension service currently operating in Kenya, Malawi, Tanzania, Mali, Ghana and Zambia that targets smallholder farmers. FVR's radio extension agents pro-vide regular, on-site extension support to a small group of pre-selected farmers, which are then documented and broadcast via radio.

Television, Videocassette, VCD, and DVD

The UNDP-APDIP (2004) reports that television (TV) is commonly cited as having considerable development potential. It provides programmes with moving pictures and sounds otherwise unavailable to smallholders, using standardized and readily available technologies. Television programmes can be pre-recorded or live and interactive (with smallholders calling in), although the latter may have to be asynchronous over greater distances and different time zones. Television programmes can now be Internet streamed. Videocassettes, VCDs and DVDs can be shared between individuals, families and community groups for self-paced learning. Production and material rights acquisition costs can be high and time consuming to maintain.

There are examples that exist of television usage for agricultural educational purposes. The most notable example of TV used for agricultural development and growth comes from China with its TV University and agricultural TV station. In Viet Nam, two universities in the Mekong Delta Region work with the local TV station to broadcast weekly farmers' workshops that are watched by millions of farmers and rural communities (UNDP-APDIP, 2004). Similarly, the South African Broadcasting Cooperation (SABC) broadcast a multidisciplinary Agricultural TV programme in partnership with the Department of Rural Development and Land Reform. The Agri TV program broadcast information related to agriculture, rural development and land reform. It also aims to inform and keep up to date with the latest developments and trends, while educating by means of practical information on topics ranging form vegetable production, animal health to irrigation technology.

Video and Digital Video Cameras

Video and digital video cameras are emerging as important ICT tools for extension services. Rural smallholders can visually record and communicate problems to subject specialists. Digital photographs and video clips can be distributed and exchanged online through email or instant messaging, or by regular mail, enabling interactive and collaborative problem solving. Use of these applications should grow as costs reduce, and as digital video and operating systems become more standardized and available. Commonwealth of Learning Media Empowerment (COLME), highlighted that in Ghana and the Caribbean, working with in-country agencies, COLME identifies rural community needs and trains extension workers in shooting and editing videos using local content. The tapes and/or broadcasts serve large numbers of farmers, thus offsetting reducing extension services. The programme provides training in literacy for smallholders and women in Ghana, and in agribusiness and environmental sustainability in the Caribbean. For example in India, Digital Green disseminates targeted agricultural information via digital media to small-scale and marginal farmers. The system includes a digital video database that is produced for farmers by farmers. Participating villages are provided with a TV, DVD player and camcorder operated by local NGO staff and managed by farmers, along with DVDs that are shipped to the village. Nightly viewings are set up on a rotating basis around different areas of the village for small groups of 10 to 20 farmers (Rivera & Sulaiman, 2009; FACET, 2010).

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Telephone

In many countries, access to the telephone system is a vital element that government's attempts to implement various policies to offer affordable telephone service but unfortunately some countries lack sufficient telephone lines. In Bangladesh, the Grameen Bank, a village-based micro-finance organization leases Grameen hand phones or cellular mobile phones to successful farmers and community members, this practice has delivered significant benefits to the farmers and rural community dwellers. The phones are mostly used for exchanging price, business and health related information. They have generated information flows that have resulted in better prices for outputs and inputs, easier job searches, reduced mortality rates for livestock and poultry, and better returns on foreign-exchange transactions. Phone owners also earn additional income from providing phone services to others in the community and rural people account for one-fourth of all the phone calls made (Bayes, Von Braun & Akhter, 1999). Bayes et. al (1999) further indicates that for rural communities in general, phones offer additional non-economic benefits such as improved law enforcement, reduced inequality, more rapid and effective communication during disasters and stronger kinship bonding. Furthermore these telephones have perceptible and positive effects on the empowerment and social status of phone-leasing women and their households.

The United Nations Development Programme (Asia-Pacific Development Information Programme, 2004) in collaboration with the Government of India conducted a study on China and found that villages that had telephones as the most basic communications technology, experienced declines in the purchase price of various agricultural commodities and lower future price variability. It also noted that the average prices of agricultural commodities were higher in villages with telephones than in villages without telephones. Vegetable growers said that access to telephones helped them to make more appropriate production decisions, and users of agricultural inputs benefited from a smoother and more reliable supply. Better information also improved some sellers' perception of their bargaining position vis-à-vis traders or intermediaries (UNDP, 2004). Village telephones facilitated job searches, access to emergency medical care and the ability to deal with natural disasters; lowered mortality rates for livestock thanks to more timely advice from extension workers; and improved rates in foreign-exchange transactions (Eggleston, Jensen, & Zeckhauser, 2002). In Nigeria the telephone use in extension delivery even with the recent launch and explosion of the global system of mobile (GSM) as a dividend of democracy is non-existent to very insignificant. The serious limitation of access to reliable telephone lines makes even ordinary intra-and inter-organizational networking for agricultural information exchange a harrowing and frustrating experience (Arokoyo, 2010)

Cell Phones

According to Rivera and Sulaiman (2009) there are currently a wide variety of approaches being tried to use cell phone networks to enhance extension services. Few have managed to scale to millions of farmers and it is not clear yet due to the paucity of research and the relatively short time periods of the implementations which approaches have the most impact. Clearly, a variety of approaches (or combinations of approaches) may prove successful. The approaches are varying in several ways: whether text or voice is used and, for text, if searches or queries are made via SMS or more advanced data queries which require a more capable and expensive phone hand-set or whether farmers use the mobile phone services directly or via a mediator such as a farm extension worker.

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Whether cell phones enable one or two-way communication, whether farmers or intermediaries are "pull" information where farmers initiate the query, or information is "pushed" to the farmer or intermediary via a text message, a voice phone call or voicemail. This capability to enable two-way exchanges (synchronous or a synchronous) is an important enhancement to farm extension service delivery because it allows the service deliverers to receive frequent feedback regarding the most important information for farmers and how well they understand the information being delivered to them (Rivera & Sulaiman, 2009). In the Pacific, mobile phones offer another potential for extension workers, with estimates of up to 50% of Pacific Islanders having access to mobile phones. Mobile phones could help extension workers disseminate information on crop pricing or pests and diseases to farmers. In Tonga, a pilot exercise is underway using mobile phones to link farmers and extension officers. The United Nations Conference on Trade and Development (UNCTAD) is helping develop an efficient market information system and a user-friendly platform to disseminate information via mobile phones. UNCTAD supports the establishment of a regional information hub that would be based at SPC (http://www.spc.int/lrd/index.php).

Public Address Systems

Public address systems (PAS) commonly found in China and Vietnam are used to deliver public information, announcements and daily news. A community in VietNam is planning to augment its PAS, by connecting it to the internet so as to obtain useful information for broadcasting (UNDP, 2004). Public address systems which are localized are more popular than the radio which is technically simpler and less expensive. However, research on less developed communities suggests that the telephone and radio remain the most important to provide direct access to ICT tools for changing the lives of the farmers and rural people (Heeks, 1999).

Computers and the Internet

According to Aboh (2008), the use of computers and Internet as ICT tool will help extension officers to analyze data, write scientific papers, prepare plan of work, draw budgets, produce curricula and handouts and reach out to farmers easily. The Internet has grown to be the world's most important communication medium. It is a reasonably inexpensive, fast, two-way medium and a powerful tool for storage, retrieval, and dissemination of information. It is also good for publishing. The Internet can introduce new information resources and open new communication channels for rural farmers. Extension officers can send the document through which could serve as a subject of demote in an internet discussion group, and they could be placed on a website for viewing .Computer is a group of integrated parts that have the common purpose of performing the given operations and can be defined broadly as any of a class of man-made devices or systems that can modify data in some meaningful way whereas the internet is a loose amalgam of computer networks connecting thousands of sites and millions of users all over the world (FACET, 2010).

Asia-Pacific Development Information Programme (APDIP) conducted by UNDP (2004) in collaboration with the Government of India, APDIP on computers and the internet are commonly made available to rural communities in the form of community-based telecentres. Telecentres provide shared access to computers and the internet and is the only realistic means of doing things for rural communities. Although telecentres come in many guises, with the two key elements being public access and a development orientation. This characteristic distinguishes telecentres from internet or cyber cafes.

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Internet cafe or cyber cafe is a place where people can get connected to the Internet while eating or have a cup of coffee using publicly accessible computer. While the main activity in the cyber cafe is the Internet, such as email, newsgroup and web site surfing, other applications usually available are office suite to type document, spreadsheet, games, such as online games and other utilities such as printing service, scanning and digital photo service. Alao (2010) indicates that cyber cafes can be a useful device in fostering development through ICTs, but the difference is crucial, because development-oriented telecentres embody the principle of providing access for a purpose and that of implementing a development agenda. To achieve this development objective, telecentres perform community outreach services in order to determine the types of information used to foster development activities. Computer literate telecentres staff acts as intermediaries between farmers and rural community members who may not be familiar with ICTs and the information services that they require.

According to UNDP-APDIP (2004) telecentres can provide a range of ICT-based services from which they can earn an income, such as telephone use and faxing, photocopying and printing, email and word processing. This helps with financial self-sustainability, which telecentres are often required to attain, although some argue that rural people should not pay ICT based development services provided as a public service, rather like libraries. The results of experiments with telecentres mixed functions have demonstrated considerable benefits for their target audiences; others are struggling with fragile connectivity and uncertain communities and very few have achieved self-financing sustainability. With Kiosks, telecentres and knowledge centers', rural farmers acquire skills to improve their products better by making them appeal to local and global markets. They have the access to promote their products, handle simple transactions such as orders, and seek opinions to make decisions for their own development.

Telecentres and knowledge centers" have a relative positive impact on rural communities in terms of promoting development, political awareness and social change (UNDP, 2004). For example, the International Rice Research Institute (IRRI) provides a comprehensive resource links with the IRRI Rice Web through the *Rice Knowledge Bank*, which provides information on practices in the field; research findings; technology transfer methods and support skills; training materials; statistics and other data; a discussion area; and access to other agricultural sites. In Kenya, the farmers helpline operated by KenCall, a for-profit call center, is a real-time call center service staffed by agricultural experts that provides agricultural information, advice and support to small holder farmers over the phone, using voice and voice call-back to farmers, not SMS. The service has received funding from GSMA and the Rockefeller Foundation (FACET, 2010).

SIMputers

According to Lie (2006) the Simputer is a low cost portable alternative to PCs, by which the benefits of IT can reach the common man. Simputers are handheld computers similar to personal digital assistants (PDA). However, they are fitted with SIM cards for data transmission and reception. Simputers may be used by an extension worker to provide pricing and market information to farmers received from a central server located in the dzongkhag. The Simputer itself is invented, developed and produced in India. It has a special role in the third world because it ensures that illiteracy is no longer a barrier to handling a computer. The key to bridging the digital divide is to have shared devices that permit truly simple and natural user interfaces based on sight, touch and audio. The Simputer meets these demands through a browser for the Information Markup Language (IML). IML has been created to provide a uniform ex-

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perience to users and to allow rapid development of solutions on any platform. This ICT has been tested successfully in Thailand by the Bank for Agriculture and Agricultural Cooperatives.

By being inexpensive, portable, running on the open source operating system Linux, having network (including internet) facilities, having text-to-speech facilities, being able to run on three AAA batteries, and being robust, the original idea was that it could be capable of playing a role in closing the digital divide. The Simputer was intended to be 'an access device for the masses' and aimed at farmer communities in rural areas. Critiques have been skeptical about these intended target groups. Technical issues as well as economic and socio-cultural issues remain unclear. There were power problems, sales and production costs problems, but also, only a few projects have been recorded that actually use the Simputer in rural change projects.

Bridging the digital divide by using the Simputer that runs on Linux, means introducing ICTs and providing infrastructure (wireless or connected to desktops). From an end-user perspective, open source software is not always an interesting option. Although it is possible to do basic text editing and to work with a spreadsheet on the Simputer, it is not comparable with the major Desktop/notebook applications (Lie, 2006). In July 2003, it was reported that 600 Simputers had been sold and 1,500 to 2,000 Encore Simputer machines were out in the market in September 2003 (Ganapati, 2003). According to Fonseca & Pal "there is limited evidence of end-user consumer purchases in rural India." The only information that seems to be available on existing projects that use the Simputer is the information that is provided by PicoPeta, one of the organizations involved in the manufacture of the Simputer (I4D, 2004). These projects involve fields such as spot billing in electricity metering and micro financing in Karnataka, India. With the coming of the new Amida model of the Simputer in April 2004, the market also seems to have shifted a little bit to the urban rich and urban young who cannot afford to buy an expensive PDA, but can afford to buy a Simputer. For them the Simputer could be an interesting alternative as the price is more interesting. This shift in markets is emphasized by the way the Simputer is advertised (Lie, 2006).

Intranet

These processes link rural radio stations with each other and with the internet. A team of communication experts specifically trained for information gathering and dissemination on the internet, by adapting information to the local context, radio scripting and interviewing techniques, manages the network of stations thus facilitating external as well as location specific information.

Web-Based Information and Learning Resources

Web-based "learning objects"-individual, self-contained and often customizable information or instructional packages with text, images, animations or movie clips-are rapidly growing in number and availability. They allow farmers and rural communities to pursue their own learning routes and interests, but there are issues of cost, computer literacy and Internet access. Smallholders also have to be able to plan and manage their own learning, discriminate between reliable and dubious source material, and draw their own conclusions from the available resources. Program developers must be capable of using advanced authoring tools to customize courses to individual needs, while achieving economies of scale by designing for large learning groups.

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CD-ROM and DVD-ROM

Compact Disc-Read Only Memory (CD-ROM) and Digital Versatile Disc or Digital Video Disc- Read Only Memory (DVD-ROM) are ICT tools with storage medium that, together with a microcomputer, offers rapid access to a very large volume of data, including text, audio, graphics, animation, slides and video in computer-accessible learning and demonstration documents. They are considerably cheaper to mail than print material, but farmers and smallholders must have access to computers and printers and be able to afford the connection, printing and other costs. They are also interactive and provide farmer and extension feedback. Programs can be multimedia, combining text, sound, graphics and video, and can provide simulations, tests and other active learning tasks (Zijp, 1994).

Agricultural development depends on rural communities and farmers having access to information they need and can use effectively. Yet poor communications systems make transmitting timely, accurate information to agricultural extension agents, health workers, and others, a difficult task. Smallholder farmers must be computer literate, or helped in using the technology and computer access is an issue, but mobile computing with laptop and notebook computers is a promising solution for low-income countries (Zijp, 1994). According to Zijp, (1994) CD-ROM is used across all sectors, including agriculture, natural resource management, medicine and social sciences. Most applications involve storage of large amounts of material which can be easily retrieved. CD-ROMs can provide ready access to a vast amount of information on local pests and plant diseases, which can be used to support decision making in cop management and integrated pest management, thereby increasing productivity and reducing the environmental impact of agriculture. They can also delver crop protection information efficiently and effectively to extension agents and other intermediaries, as well as to farmers themselves. For example, CTA- EU selected agricultural information services in Cameroon, Kenya, Mali, Papua New Guinea, Trinidad and Tobago, Western Samoa, Zaire, Zambia and Zimbabwe to participate in a pilot project aimed at improving national self- sufficiency in the dissemination of scientific agricultural information and to introduce computer technology in developing country information services in order to encourage the production of local databases.

Organizations which disseminate scientific agricultural information, such as ministerial libraries, universities and regional development centers, were provided with the necessary CD- ROM equipment and commercially available databases. Up to two weeks of onsite training were given as well. Six to twelve months after installation, evaluation of the project found that the equipment had been used 50 percent of the time for CD-ROM application and the remaining time was put toward word processing, local databases, inputting into international databases and online access to remote databases (Zijp, 1994).

GIS/Decision Support Systems

According to Munyua (2008) Geographical Information System (GIS) is an information technology that links activities in the field and the office, and allows for comparisons between different types of agricultural data. It helps to establish relationships between data sets and is important in the production of maps as well as charts that present results in visual form. In addition, the spatial variability that it captures allows for unique handling of certain locations. It also helps in the analysis of post harvest variation in crop yield measures. This is done by analysing yields of previous years to guide future management decisions. The GIS details include maps and additional information associated with coordinates and time, and these are all linked in a computer database that could be analysed further. In general, a GIS technology provides

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a holistic view of the production system and helps make precision agriculture practical and useful even for small-scale farmers. GIS accounts for its significance in the following initiatives:

In Kenya, the International Livestock Research Institute (ILRI) has used the GIS technology and remote sensing in its Small Dairy Project. It has also employed the technology to map fences in its livestock-wildlife ecosystem initiative; furthermore, the Kenya Agricultural Commodity Exchange (KACE) plans to use a GIS in the near future to develop commodity patterns and seasonal patterns. The information obtained can then be used to produce a map of the country, depicting the seasonality of different crops, the nature of what is being produced and their geographical coverage, among others. In some cases, the data will help in the estimation of supplies and expectations, apart from assisting in the selection of markets before harvesting and in the provision of dispersion distribution and productivity patterns. Finally, the forecasting of supplies and market potential that the technology makes possible is viewed as critical by KACE in its preparation of export plans and local market sales. DrumNet in Kenya plans to apply GIS and has acquired GPS technology to help map out where farmers are located, the collection points, and easy ways of accessing transportation, cell phone accessibility, roads and cell phone connectivity, among others. The International Small Group and Tree Planting Alliance (TIST) is training farmers in Kenya and Uganda in community-based reforestation projects to use PDAs and Global Positioning System (GPS) technology to gather reforestation data, which is then uploaded to an online database (Munyua, 2008).

Munyua (2008) further indicates that in South Africa, the GenARDIS project has used GIS applications in natural resources management in the Roiboos tea lands and in exploring the spatial dynamics of gender in rural areas.

Mobile Mapping

Mobile mapping is a concept and system with the ability to collect field data, including unique geospatial time tags and attributes, for integrating into/updating a GIS. Mobile mapping essentially remembers what has been recorded, when it was recorded and where it was recorded, and allows for addition or expansion of the stored data. Thus, mobile mapping provides the freedom to collect data anytime, anywhere and in any manner (GIS Development 2006).

Factors Influencing Use of ICT by Extension Officers

Agricultural Extension systems in most developing countries are under – funded and have had mixed effects. Much of the extension information has been found to be out of date, irrelevant and not applicable to small farmers needs, leaving such farmers with the very little information or resources to improve their productivity. ICT helps the extension system in re- orientating itself towards the overall agricultural development of small production systems. With the appropriate knowledge small- scale producers can even have a competitive edge over larger operations. When knowledge is harnessed by strong organizations of small producers, strategic planning can be used to provide members with at least- cost inputs, better storage facilities, improved transportation links and collective negotiations with buyers (Amutha, 2010).

Extension services combine educational methodologies such as farmer field schools and demonstration plots as well as advice from extension agents. They include the dual challenges of informing farmers

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as well as keeping extension agents themselves well trained with access to back up experts for tough problems. They are delivered by public and private entities via extension agents. National ministries of agriculture have hundreds and sometimes thousands of extension agents, and large buyers often have their own private agent networks. Still farmers often go years without having direct contact with an extension agent. To increase access to these critical services, both public and private provider shave been using a variety of delivery "channels," such as radio, print media and, increasingly, ICT-enabled channels, some of which are often combined. Mo-bile phone networks are the ICT channel most often used, given the recent dramatic increase in access to such networks, even in rural areas, and affordability even for the poor (Rivera & Sulaiman, 2009).

The information and communication intensity of global agriculture has increased dramatically, as globally – traded commodities and the demand of a growing global middle class for higher value-added, more diversified food products necessitate more time –urgent and contextualized information about crop varieties, supporting technologies, market trends, trading partners and the competition. Poor smallholder farmers face an increased risk of being left et the "bottom of the value chain", seeking to earn income from commodity crops that are increasingly volatile in price while being faced with substantial information disadvantages (impediments and costs imposed in part by physical isolation, weak infrastructure and asymmetric access) that continue to limit their leverage at market and their ability to innovate in response to changing demand.

Some prior studies have demonstrated that demographic and characteristic background such as age, gender, ethnicity, marital status, level of education, prior experiences with computers and the Internet influence the ICT and or e-Learning adoption. Agricultural extension depends to a large extent on information exchange between and among farmers on the one hand, and a broad range of other actors on the other, has been identified as one area in which ICTs can have a particularly significant impact. There is growing recognition that farmers and members of rural communities have needs for information and appropriate learning methods that are not being met. In the midst of this change, extensionists are grappling with the question of how best to harness ICTs to improve rural livelihoods. Meera et al (2004) had noted that as a result of the emerging new paradigm of agricultural development, old ways of delivering important services to citizens are being challenged; traditional societies are also being transformed into knowledge societies all over the world.

Age of Extension Officers

Flor and Hazelman (2004) states that in Indonesia most extension workers based in the local governments are beyond 40 years old and awaiting retirement. They belong to the old school of information and communication. A training course that covers design, development and utilization of information and communication media by agricultural extension workers is required. Although this course would include sessions on digital multimedia production, it should likewise incorporate interfaces with conventional and traditional media as well as alternative last mile linkage strategies. In Indonesia, there are eight thousand researchers compared to 35 thousand extension workers, most of who are now under the payroll of local governments. It is mentioned that innovative agricultural technologies are housed in the AIATs which now carry part of the agricultural extension burden. However, the AIATs are staffed by researchers and not by extension workers.

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Gender Composition of Extension Officers

About 94 percent of agricultural extension agents worldwide are male, multiple studies have reported problems with male extensionists delivering services only to men, or focusing narrowly on traditional roles when delivering programmes to women (FAO, 2006). A holistic approach to agricultural extension today goes beyond technology transfer for major crop and livestock production systems. It also includes goals for human capital development, in terms of enhancing the management and technical skills of farm households relating to production and postharvest handling of high-value crops, livestock and fisheries, sustainable natural resource management, family health and nutrition, and leadership and organizational skills, in addition to social capital development, that is, organizing producer groups (Swanson 2008). As tools embedded within existing social and gender relations, information and communication technologies (ICTs) are perceived, used, and appropriated in ways that are subject to asymmetries in power, privilege, opportunity, and choice.

Several studies including the CTA-sponsored one on rural women's access to public and private extension services have revealed that the village level extension agent is the most effective source of information for farmers but certainly not the most efficient in terms of cost and coverage (Arokoyo, 2010). According to FAO, (2006) the number of female extension officers has increased, although their representation continues to remain extremely low, ranging from 3.1% of the extension staff to 22%. While increased number of women agents does not necessarily guarantee that more women farmers will be reached. Several reports indicate that female extension agents are more inclined to contact female farmers and are more likely to address issues of concern to them, such as subsistence production and household food security. At the same time, women farmers may be more inclined to attend a demonstration when a woman gives it. The situation is still similar in South Africa. The agricultural sector in the Northwest Province is clearly a male dominated sector with more than 80% of the labour force being males. According to the Gender Focal Points, 2003 the total number of extension officers in the department was 939, with the total number of males being 602 (64%) as compared for women 337 (36%)(Mabe, 2005). Modern ICT including internet and web technology is needed to make these systems available regionally and globally. Accessing information communication technologies will bring a wealth of information to all agriculture stakeholders including women farmers in rural and urban areas and will help in overcoming the existing digital divide.

Education Level and Years of Experience of Extension Officers

Adesope et al. (2007) revealed that there was a significant but negative relationship with information technology needed. This implies that the higher the educational qualification the less the information technologies needed and the lower the educational qualification the more the information technologies needed. It is possible that respondents with higher qualifications may have too many responsibilities to grapple with, hence may not have the time to appreciate more need for Information technologies. Agricultural extension has the ability to solve many of the challenges that agriculture is facing, but it needs to be made attractive. Indeed, the nature of agricultural extension itself is challenging since it involves working with the farming community (which is not easy as we need to understand rural life and human behavior), have a good knowledge on agriculture (pest and disease management, market prices and opportunities, other stakeholders in agriculture and their role etc.) and have specific skills (good communication skills, listening skills, be a trainer and learner at the same time etc.).

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Access to Allocated Vehicle for Extension Work

Given the problems that extension agents face in facilitating direct contact with farmer clients and with researchers due to the physical distances involved and the lack of transportation needed for their mobility, the application of ICT offers excellent possibilities. Utilizing ICT for strengthening research-extension-farmer linkages must, however, move from pilot testing phases to integration into research-extension systems and beyond the urban focus. Major factors to also address include the creation of an enabling environment, development of infrastructure, development of software and information content, making ICT sustainable, building capacities, combining its use with traditional media and learning from success stories (APO, 2002).

Average Distance Between Extension Officer and Clients

Given the problems that extension agent's face in facilitating direct contact with farmer clients and with researchers due to the physical distances involved and the lack of transportation needed for their mobility, the application of ICT offers excellent possibilities. Utilizing ICT for strengthening research –extension-farmer linkages must, however, move from pilot testing phases to integration into research- extension systems and beyond the urban focus. Major factors to also address include the creation of an enabling environment, development of infrastructure, development of software and information content, making ICT sustainable, building capacities, combining its use with traditional media and learning form success stories (FAO, 2006). Mmbengeni and Mokoka (2002) indicated that extensionists in Limpopo Province, South Africa experience a serious lack of transport during the execution of their day-to-day duties. This constraint has a direct influence on the ability of extensionists to reach farmers on a regular basis, on the ability of extensionists to facilitate communities and the provision of transport for farmers during farmers-day and training events.

Number of Farmers Covered by Extension Officers

Several studies including the CTA-sponsored one on rural women's access to public and private extension services (Arokoyo, Chikwendu & Ogunbameru, 2002) have revealed that the village level extension agent is the most effective source of information for farmers but certainly not the most efficient in terms of cost and coverage. At the inception of the state-wide ADPs in 1980 the extension agent: Farmer (EA: Farmer), ratio ranged "between" 1:2000 to 1:3000. This was expected to come down to "between" 1:800 to 1:1000 by the project completion date and the withdrawal of World Bank support. This target was never achieved. A recent field survey by NAERLS and PCU (2002) showed that the EA: Farmer ratio was "between" 1:848, in Ogun State in the South- West Ecological Zone to 1:1650 in Katsina State in the North-West Ecological Zone. This is similar to the finding by Arokoyo et al (2002), of ratio of "between" 1:1000 and 1:2000 in the public extension service, and worse for the women-in-agriculture program, which was found to have several extension blocks expected to be filled by female extension agents, vacant. It is clear therefore, that no matter however effective, extension delivery through the village extension agent can neither be efficient nor cost-effective for a developing country like Nigeria, with a population of about 150.00 million, majority of who are involved in agriculture (70 – 80 percent) and illiterate. The Extension Service therefore must be appropriately supported with the use of ICTs (Arokoyo, 2010).

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According to Glendenning et al, (2010) in India, the extension staff of the DoA operates at the district and block levels, which are administrative subdivisions. A block is a subdivision of a district. The numbers and capacity of the staff vary greatly throughout the country, but it is well acknowledged that staff numbers are low. The ratio of staff to farmers varies widely across the country with 1:300 in Kerala and 1:2,000 in Rajasthan. In Ghana the ratio of extension workers to farmers is estimated to be 1 to 2000, but in recent years the number of agricultural extension workers has been going down, while the numbers of farmers is growing. This means the role of the extension workers in the dissemination of knowledge within rural communities is diminishing. The use of ICTs to support the work of the Extension Officers might be beneficial for the development of the agricultural sector (Akkermans, 2010).

In agriculture extension service and the Veterinary services Units play a major role in improving agricultural production. To ensure their effective operation, the district has been delineated into 22 operational areas. Currently there are 13 extension officers in the district giving an extension officer farmers ration of 1: 5000, which is high compared with the acceptable ratio of 1: 400. This indicates that the district has a serious problem as far as the number of extension officers in concerned. A survey of the extension service unit reveals that, the unit faces a number of problems, which have inhibited its ability to reach farmers effectively which include: poor condition of roads leading to some farming communities, inadequate means of transport, delays in the payment of staff allowance, extensive coverage areas for field officers, high extension officer farmer ratio, lack of motivation for field staff.

In Papua New Guinea, the extension officer to farmer disparity points to challenges in delivering information. The extension farmer ratio is one extension officer per 3,600 people, and in some parts of the northern Solomon Islands this ratio is 1 per 14,000. For medium size islands such as Samoa and Tonga, the ratio is closer to 1 per 800 people. Extension work is further hampered by a lack of transport, or lack of fuel for transport.

Contact With Farmers

According to Asian Productivity Organization (2002) given the complex nature of agriculture and the challenges being faced, the use of multidisciplinary approaches involving a mix of specializations is becoming more and more the norm in addressing information delivery today. Technical specialists along with social scientists and communications and information specialists are combining expertise to address farmers' and farming communities' problems and needs. Studies have shown that farmers depend on multiple sources for information and technologies. In most societies, face-to-face contact is still the preferred mode of communication. Given the large populations to be served by extension and the dispersed and distant locations, face-to-face communication is not always possible and thus needs to combine strategies and communication channels to include traditional information sources, such as radio, print, video and television, together with new forms of delivery such as through ICT.

Due to the limited number of extension workers, farmers are using the phone to seek advisory services. Extension information can also be shared through a website. In addition, PDAs could be used to collect and disseminate critical agricultural information that farmers need. The shift to these technologies would cut down face-to-face contacts drastically and reduce telecommunication and transport costs. Farmers would, however, require training and a change of attitude to be able to access the ICT driven information and advisory services. Of importance is the fact that the applications of ICTs in extension services would provide for more content diversification and ensure a wider reach. In India for instance,

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the e-choupal model has made it possible to reach farmers through public access centres that include telecentres, knowledge centres and access points (Munyua, 2008).

Area Covered by Extension Officers

Several research studies conducted on extension organizations have revealed that the delivery of goods is effective when the grass roots extension worker covers a small area of jurisdiction with multiple purposes or broad basing. The existing system of large jurisdiction, each with a narrow range of activities, is less effective. Broad basing agricultural extension activities, developing farming system research and extension, having location specific modules of research and extension, and promoting market extension, sustainable agricultural development, and participatory research are some of the numerous areas where ICT can play an important role. However, broad basing requires grass roots workers to be at the cutting edge of extension and master of many trades, which is not really possible. The emergence of such knowledge workers will result in the realization of the much talked about bottom-up, demand driven technology generation, assessment, refinement and transfer. ICTs can help by enabling extension worker gather, store, retrieve and disseminate a broad range of information needed by farmers, thus transforming them from extension workers into knowledge workers. ICT has many potential applications in agricultural extension. It can bring new information services to rural areas where farmers, as users, will have much greater control than before over current information channel. Access to such new information sources is a crucial requirement for the sustainable developing of farming systems. If extension agents will effectively and efficiently use ICT, it will make their work easier and moreover, facilitates their information delivery and after extension services (Amutha, 2010).

Effect of E-Readiness of Extension Officers

Swatman (2006) clarify that e readiness is defined as being prepared mentally or physically for some experience or action. In terms of e-Learning, Borotis and Poulymenakou (2004) defined e-Learning readiness as the mental or physical readiness of an organization for some e-Learning experience or action. According to Arokoyo (2010) most of the nation's agricultural research and extension system (NARES) members now have computers for information and data management, most of the computers have neither telephone nor internet access. Even ordinary email access becomes a big deal for a whole national Research Institute. The low computer literacy level of the managers and staff makes the ICT-readiness of the system very low. Kauffman and Kumar (2005) introduce three stages of diffusion of ICT at the country level of analysis are the ICT readiness stage, the ICT intensity stage and the ICT impact stage. In the first stage of ICT readiness, they argue that when the technology is new to a country or a region, the readiness of its people to adopt it is a crucial issue. On the other hand, Kaur and Abas (2004) noted that ICT readiness assessment allows one to design comprehensive e-Learning strategies and effectively implement ICT goals. Hence, generally ICT readiness assessments help a country's leaders to measure and plan for ICT integration, focus their efforts and identify areas where further attention is required (Krull, 2003).

FAO (2006) stated that several studies have revealed that lack of access to information hampers the performance of extension activities. In most cases, it was found that extensionists have little or no access to sources of agricultural information. Although most extensionists are aware of the large amount

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of information available on the internet, they do not have access to internet facilities causing constraints not only in terms of access to information, but also in terms of communication (i.e. e-mail).

Constraints Faced by Extension Officers

According to Raabe (2008), information flow within the public sector moves linearly, with content focusing on the transfer of technology for increasing crop production. A wider definition of agricultural extension, beyond improving crop productivity, has not been embraced. Information flow is supply-driven and not needs-based or area-specific so farmers see the quality of the information provided by the public extension staff as a major shortcoming. This is due to the static and inflexible nature of the organization, where a top-down hierarchical approach continues. Sulaiman, (2003) further states that access to extension is also an issue, because of the low level of outreach by public extension services. This is partly due to the public staff being overburdened with implementing state and centralized schemes, which are also not easily modified to suit local needs and conditions.

There are also insufficient funds for operational costs, training, and capacity development, which limits the activities and continual development of the extension staff. Sulaiman, Hall, and Suresh (2005) indicate that of the required 1.3 million to 1.5 million extension personnel, there are only about 100,000 on the job. At the state level, the various line departments have been criticized for working in isolation, with weak linkages and rare partnerships, which limits information flow.

Furthermore, the research–extension link has been criticized for not absorbing or using feedback from farmers and extension staff. Extension personnel and farmers are passive actors, and scientists have limited exposure to field realities. The various components of the public-sector extension system suffer from duplication of programs, without convergence. While Agricultural Technology Management Agency (ATMA) is pushed as the platform through which the multiple agencies can converge, the implementation difficulties are proving too great for effective integration, with shortages of both personnel and funds (Glendenning, Babu & Asenso-Okyere, 2010).

Effects of ICT Use on Information Access by Extension Officers

Information has been identified as one of the resources required for the improvement of agricultural production (Aina, 1995). It is said to be a resource that must be acquired and used in order to make an informed decision. Those who possess appropriate and timely information will make a more rational decision than those without. The various agricultural information users populations can be categorized as policy makers and planners; researchers; extension staff; educators and students; agro-based industries and services staff; and farmers. It was also observed that each of the sectors mentioned above contribute directly to the improvement of agriculture hence relevant information provided to each category of these user populations will contribute positively to the development of agriculture in Africa. Information is the potential ingredient for the advancement of agriculture. Without information the agricultural sector may degenerate into extinction. Information provides the basis for scientific innovations in agriculture. Agricultural information has been defined as all published or unpublished knowledge on all aspects of agriculture.

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Application of ICT in Other Countries

The applications of ICT for agriculture were reviewed in this section with specific examples from countries in Africa, Asia and Europe.

India

The e- Choupal and Satcom were reviewed form India. Swanson and Rajalahati (2010) reported that e-Choupal (which means gathering place in Hindi) and a profitable rural transformation initiative in India, is a web based information and procurement tools for Indian farmers that places computers with internet access in rural farming communities to have access to information and an e-commerce hub. e-Choupal was developed by the private sector in India, and has enabled farmers from selected parts of the country to gain access to up- to- date price and marketing information, as well as to engage in online sales of agricultural products and online purchases of inputs. This privately financed ICT system is owned and managed by ITC Limited and it currently has over 10,000 eChoupal sites where farmers regularly engage in online sales and purchases on a fee – for- service basis. Given the success of this system, the Government of India is now establishing similar common service centers (CSC) whereby rural people and other parts of the country can gain access to similar technical and marketing information, including online transactions. Currently, there are 6,500 functioning CSC's and the plan is to scale this number up to 100,000 CSC's serving the 638,000 rural villages across India. In addition, some block-level extension offices that received World Bank support also have PC's with Internet access: therefore, farmers in these areas cam also gain access eChoupal and other technical and market information.

The e-choupals serves as both a social gathering place for exchange of information which delivers real-time information and customized knowledge to improve farmer's decision-making ability, thereby better aligning farm output to market demands; securing better quality, productivity and improved price discovery. This model helps to aggregate demand in the nature of a virtual producers' co-operative, in this process facilitating access to higher quality farm inputs at lower costs for farmers. The e-choupal initiative also creates a direct marketing channel, eliminating wasteful intermediation and multiple handling, thus reducing transaction costs and making logistics efficient.

This system has also catalyzed the rural transformation that has helped to alleviate rural isolation, create more transparency for farmers, and improve their productivity and income. e-Choupal has helped to empower farmers in India with real time information on weather and prices so that they can insulate themselves from unpredictable climatic conditions and price fluctuations at markets.

Bhatnagar and Schware (2000) also reported that India was amongst the first countries to explore the use of Satellite Communication technology (Satcom) to support development and today its space efforts are recognized the world over for their wide spectrum of application relevant to societal benefit. Satcom offers the unique capability of being able to simultaneously reach out to large numbers spread over large distances even in the remotest corners of the country. It is a very strong tool to support development education. Satcom has been used both in broadcast mode as well as an interactive mode to reach out to rural audiences at large, and to conduct training programmes for extension staff as well as rural population who are participating in the implementation of development actives.

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Sri Lanka

The Department of Agriculture is presently moving towards introducing electronic media for dissemination of information to extension agents as well as farmers. Cyber Extension is one such initiative where farmers could make use of e-mail and the internet facilities to access information and communicate, particularly with the Department of Agriculture (DOA) to get advice and assistance to solve their farming problems. Furthermore the Audio –visual Center of the DOA has initiated a toll-free telephone service for the farmers to directly contact agricultural researchers for obtaining advice to their problems. This service is becoming popular among farmers but publicity has to be given to reap the full of benefit of it (Mudannayake, 2006).

China

According to Ke and Zhang (1999), subsistence farmers do not need to interact significantly with people beyond their own families. Yet in raising output above the subsistence level, communication is important. Despite low levels of ICT in rural China, studies have shown that ICT, including the telephone and internet have positive impacts on farm households in terms of industrial patterns, market expansion, sale and supply channels, education and healthcare. For example, duck farmers in the Hubei province now sell their ducks directly to customers through a telephone order system. With access to telephones, the potential exists to eliminate intermediaries who do not add value to products. Furthermore in Haikou village in the suburbs of the city of Wuhan is well known for producing balsam pears. Although farmers had bumper harvests for years prior to installing telephones, they did not profit from them because local intermediaries had forced prices down. After the installation of telephones in 1998, farmers were able to contact vegetable dealers in their neighboring province and sell their products at much higher prices. This experience led to the installation of 41 telephones in this village within two months. Agricultural universities and research institutes have become pioneers in providing internet- based-education for farmers. The Capital Farmer Network (www.capitalfarmer,net) is a popular web site that specializes in agricultural technology and provides free online seminars to farmers on new agricultural techniques. Lack of internet infrastructure, however, means that few farmers benefit from these services (Ke & Zhang, 1999).

Ireland

According to Acker and Gasperini (2008) the use of ICT has improved safety of animals in Ireland, in 2001, the foot and mouth crisis in Surrey brought back memories of the fears to many Irish farmers, but on this occasion ICT has been able to provide them with some reassurances. The very fact that Northern Ireland can prove that no animals from Surrey have entered it in recent times shows that the benefits of ICT in action. All cattle entering the island of Ireland, on both sides of the border, are tracked and monitored with software used to trace their movement.

A major cattle movement is operated through a monitoring system which is a great help in ensuring safety, as it ensures traceability of cattle from birth to death. ICT is enabling both government and industry to reassure all stakeholders be they consumer of farmer that agricultural products in Ireland are safe to use. The department of Agriculture plans to roll out the monitoring system to cover the movement of ll animals by the end of 2008.

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Israel

According to Gelb et al (2008), the collaborative contribution of extension and research to Israel's agricultural productivity and profitability dates back to the late 19th century. It facilitated technological innovation in agriculture, transfer of information, training of farmers and sector connectivity. These were in effect a dictate of continuous deteriorating agricultural terms of trade, crippling water shortages and severe climate and soil constraints. The Israeli Extension Services (IES) strategic decision to adopt Information and Communication Technologies significantly enhanced Extension's capabilities and scope of activities. ICT empowered extension's ability to develop, introduce and adopt innovative agricultural technologies and collaborate with research and international partners. Adoption of ICT as one instance of technological innovation dramatically improved the transfer and management of information, production chain efficiencies and integration within and with the agricultural sector. These were and are critical Israeli Extension success factors enabling research, services and farmers' ability to sustain a profitable, thriving agriculture sector. The use of ICTs contributed to rural viability and a model for adoption of technological innovation.

Burkina Faso

According to Munyua (2008) the Business Intelligence Trade Points model in Burkina Faso is used in the agro-business sector to address the socio-economic exclusion of small-scale farmers. The project collects and disseminates market information for local producers and facilitates trading through e-commerce which is growing gradually.

Egypt

In 1987, officials at the Egyptian Ministry of Agriculture and land reclamation recognized expert systems as an appropriate technology for speeding development in the agricultural sector. To realize this technology, in 1989, the ministry initiated the Expert Systems for Improved Crop Management Project (ESICM) in conjunction with the Food and Agriculture Organization of the United Nations (FAO) and the UNDP. The project began in mid-1989 and the CLAES joined the Agricultural Research Center (ARC) in 1991. Through the development, implementation and evaluation of knowledge-based decision support systems, CLAES is helping farmers throughout Egypt optimize the use of resources and maximize food production. A dozen expert systems have been developed for horticulture and field crop management (Rafea, 1999).

Jamaica

RU Network in Jamaica is a pilot project of the Caribbean Agricultural Advisory Service (CAIS), which uses "Information Cafés" with internet connection to exchange knowledge and experience between rural communities, researches and extension services. It provides CD-ROM based information and printers, scanners, digital cameras and audio recorders for capturing, storing and distributing local information.

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Mauritius

In Mauritius, there is a mobile service used in Agricultural Extension is the "SMS Disease Alert" by the Agricultural Research and Extension Unit (AREU). This service is about sending SMS to registered planters when there is a disease outbreak on a particular crop. The service is beneficial to the planters as they can take precautions to prevent the disease to affect their crops.

Rwanda

In Rwanda the Sustainable Partnership for Rural Enterprise Agricultural Development (SPREAD) programme is using ICTs to sell coffee internationally and to monitor the international coffee auction through an innovative partnership that links SPREAD, Texas &M University and Michigan State University. This trading model facilitates direct access to new markets and was instrumental in introducing international quality standards on coffee auctions via the Internet (Munyua, 2008).

Senegal

Manobi project uses cell phones with wireless access protocol (WAP) and short messaging service (SMS) technology to provide members of Senegalese fishing communities, and fruit and vegetable grower farming communities, with up to date weather and market price information. The goal of users is to secure higher prices from middlemen and improve the timing of entry to markets when demand is high and supply is low. Users are also able to reduce spoilage by locating buyers while goods are still fresh. The project has also contributed to the expansion of mobile telephone infrastructure in targeted towns. The service integrates a variety of existing technologies, including voice telephone, web and personal data assistants (PDAs) to create a real time data and information processing network (Batchelor, Evangelista, Hearn, Sugden & Webb, 2003).

South Africa

According to Bua news (2010) Limpopo Department of Agriculture, budgeted R6 million in 2010 financial to install technology –based information systems that will enable extension officers to provide relevant and accurate information to farmers' instantly. The Department of Agriculture introduced the e- Agriculture project, which aimed at improving emerging farmers' access to information and markets through the use of information communication technologies such as internet and SMS messages. Since the e-Agriculture project was launched in October 2010, 215 farmers and 16 extension officers have been trained in basic ICT skills using Digital Doorways, which are robust computer stations with multiple screens that provide internet access to rural communities.

Uganda

Information and Communication Technology has a role to play in any country's development. Like other countries' Uganda has recognized the potential and enabling elements of information and communication technologies as a tool for social and economic development. Although there has not been a comprehensive

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survey of human resources in ICT in Uganda, it is fairly obvious that various levels of skills are required and the existing training institutions are meeting some of the training needs. There is a need to assess the national requirement for ICT skills, establish how much is available and then determine the best strategy of meeting the appropriate ICT skills requirement. Communication is one of the basic human rights and access to communication channels should not be left entirely to market forces. This creates a situation of information dualism, with a minority urban information rich and the rural majority being information poor. Conducive environment for investments in communication infrastructure should be prompted to narrow the information gap between the urban and rural areas (Ministry of Works, Housing and Communications, 2003).

Zambia

Agriculture is the economic backbone for many Zambians especially in the rural areas: as such it plays an important role in the social and economic development of the country Kasonde (2009). According to the National Information and Communication (ICT) Policy, the Zambian government has committed itself in making sure that ICTs are integrated in the agricultural sector reform process in order to contribute to the social and economic revival of the country. This will be achieved by working closely with the local community so that they develop human capacity to manage and maintain ICT equipment, create integrated agricultural information systems on agro technologies and techniques, pricing and market information, for all agro products in order to provide strategic information for farmers, governments and other stakeholders at national, provincial and districts level. ICTs should be undertaken to create awareness campaigns for all types of farmers in the use of traditional and new ICT tools at all levels, develop and promote ICT skills development among agricultural extension workers and farmers, develop a monitoring and evaluation system for the conversation and sustainable utilization of natural resources in agricultural production systems.

Zimbabwe

Gudza (2010) notes that podcasting has been adopted as a media to disseminate agricultural information amongst rural farmers. This is an innovative way of using ICTs to disseminate information to those areas that have limited road networks and poor communication infrastructure. Podcasts are being used as an alternative to distribute audio and video content particularly on the internet. Podcasting project has already taken off in Mbire district and it can help to transform the lives of small scale farmers despite of lack of electricity and poor communications. Traditionally the agricultural extension officers who work under Agricultural Research Extension Service (AREX) would provide agricultural information to farmers orally and through brochures, posters and pamphlets even though the local people did not have an input in the development of the content. However with podcasting the local people are able to develop their own content because the concept is dependent upon people, technology and content.

According to Gudza (2010) the podcasts' are in local or indigenous languages and all stakeholders collaborate to develop the podcasts. Theses podcasts will have information covering a variety of themes on crop and livestock production and management. The podcasts are played on MP3 players which are powered by rechargeable batteries. These podcasts are indispensible tools in disseminating knowledge on agriculture to disadvantaged farmers. This project is collaboration between government,

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non-governmental organizations like practical action and local community leaders. The project has made the farmers more knowledgeable and it has helped them to generate and share knowledge that improves productivity through using ICTs.

Sudan

Golder, an international company, has been working with ASBNACO - a Sudan-based company that manages the Agadi Farm and the Arab Authority for Agricultural Investment and Development (AAAID), to introduce commercial mechanised farming. As part of this project, the GPS and the GIS technology have been introduced to help improve farm productivity while conserving the environment. This has been achieved through an acquired auto-steer tractor, fitted with a GPS satellite guidance system that controls tractor steering. PA has helped to cut down planting time on the Agadi farm by 60%, compared with the time taken for a similar task in two previous seasons.

Spatial yield monitoring, using GPS field monitors have also been installed in combine harvesters to monitor yield variations within each field and produce yield maps so that farmers can identify high and low productivity areas on their farms. The maps also guide fertilizer, seed and agro-chemical applications. Controlled traffic farming (CTF) has also been introduced in the project, using GPS-based self-steering tractors that limit movements of tractors to selected rows within a field to reduce soil compaction and erosion. In addition to these changes, a GIS-based farming information and management system is in the process of being developed, while plans are underway to introduce infra-red photography and Variable Rate Application (VRA) technology. These systems and technology would help to identify weed infestations, water stress, and crop pest outbreak areas and make it possible to select appropriate chemical applications, thus reducing the wastage normally associated with conventional blanket spraying. It has been observed that VRA enables the efficient use of fertilizers, chemicals and seed based on the analyses of previous seasons' production and the chemical content of soils. Furthermore, it also prevents unnecessary groundwater contamination (AAAID, 2006).

Key challenges faced by the Agadi Farm include the need to ensure reliable operation and maintenance of highly specialized equipment under harsh and remote conditions; demands associated with providing training in the use of GPS equipment and GIS software for local technicians; intricacies associated with assessing the adoption of precision farming systems or their integration into current practices. It is anticipated that the wide acceptance of PA in Africa will enable the potential of PA to be fully exploited. However, the technology requires adequate funding for high-tech farming applications, which is beyond the financial reach of small scale farmers as individuals (AAAID, 2006).

Factors Influencing Application of Information Communication Technology in Agricultural Extension Services

The theoretical framework explores research on the use of ICT by extension officers in different parts of the world. This is the view of establishing a conjectural link between several variables have been used to determine ICT use, constraints to and effect of e- readiness among extension officers. Ahmadpour, Mirdamadi, Hosseini and Chizari (2010), noted that variables such as age, gender, education level, the number of farmers covered by extension officers, number of years of experience as an extension officer, e readiness, access to allocated vehicle for extension work, and studying for a higher degree have impact

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on the use of ICT's by extension officers.Using descriptive statistics and (Binary) Logistic model, Ndag, Sanusi and Aigbekan (2008) found that the proportion respondents who did not have the requisite knowledge on computer use was slightly higher the North-central (57.14%) than in the South-west (55.71%). Age and ownership of a personal computer (PC) were significant factors ($p< 0.1$) determining the probability of ICT use to search for information by respondents in North-central Nigeria.

Hosseini, Niknam and Chizari (2009) categorized factors influencing ICT use by extension officers into six namely: organizational, technical, financial, social, regulatory and human challenges, ordered by their impact. Based on the findings, organisational challenges are the most important issue. Technical challenges are always potentially troublesome in the application of ICT's. Bheenick et al.., (2003) and Schimtz (2003) stated, for extension organization, in order to fulfill its function, has to overcome technical challenges along with human, regulatory, financial and social challenges as main constraints to apply ICTs. The findings about financial challenges is in accordance with those of Khan (2001); Kushner et. al., (2004) and Stribhadung (2006) which shows that cost of buying and maintaining the system would have effect on the application of ICT. The importance's of technical factors have been pointed out by several authors as Barajars et al. (2000), Surry (2002), Bheenick et al. (2003), Ebadi (2005), and Castels (1996). The findings also reflect an important fact that positive attitude and knowledge and skills of experts directly impacts the application of ICT. This is in corroborating with the findings of Lynch (2001). The results of the study pointed out to this fact that, there was relationship between social factors and application of ICT by the extension service in Iran. The findings are in accordance with studies by Sullivan (2000), Samak (2006), and Tyan (2003). ICTs have tremendous potential in Iran and it is evident now that ICT's will change the way people live, work and learn. In this regard, agricultural extension has the opportunity to harness the effective use of ICTs.

Adesope, Asiabaka and Agumagu (2007), examined the effect of personal characteristics of Extension managers and supervisors on their information technology needs in the Niger delta area of Nigeria. The result showed that there is no significant difference in the Information Technology needs of both categories of respondents. Findings also revealed that number of associations belonged to, educational qualification, training, category of organization were the personal characteristics that significantly influenced information technologies needed by extension managers and supervisors. Lashgarara, Mirdamadi and Hosseini (2010), noted that Information and communications technologies (ICTs) represent an important strategy that can be used in attaining food security in Iran. The results showed that, according to the experts' point of view, the situation of food security in rural Iranian households was medium, but that ICTs could play an important role in improving the situation. The results further showed that increasing food production, transferring of new methods and technologies, improving interactions and communications, providing information about cultivation and harvest, facilitators and content of old technologies account for 71% of the variance of the food availability of rural Iranian households. Moreover, the path analysis technique demonstrated that the improvement of interactions and communications had the greatest influence on determining the casual model of improving the food availability of rural Iranian households.

Aboh (2008) noted and examined the frequency of ICT tools usage by agricultural extension agents in Imo State, Nigeria. Findings of the study revealed that only mobile phone and computer were frequently used by respondents. Though ICT tools were not frequently used for extension services and this has grave implications for agricultural development. Based on the findings of the study, the following recommendations were made: there should be adequate provision of computers for all the extension agents. Adequate provision should be made for the maintenance of the ICT facilities and systems, provi-

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sion should be made in providing training programme for the extension agents in order to update their knowledge on the latest and new information technology, government to establish policy programme as means of bridging the digital divide, creating digital opportunity for various users of extension services in the country. ICT enabled extension service must be able to define its key stakeholders and audience and jointly determine their needs.

Purnomo and Lee (2010) noted that in Indonesia, the perception of agricultural extension officers', readiness and barriers towards implementation of ICT programme, the assessment model of e-LRS to measure the readiness of ICT programme implementation. The first finding reveals that they perceived that three out of the four factors of readiness as positive. The e-LRS assessment revealed that they perceived farmer readiness as lowest and thus considered it as a barrier. Also, the technological and organizational cultures were also seen as the main barriers of ICT programme implementation, and demographic variables such as regency and age, must also be considered when ICT programmes are implemented.

Oladele, (2011) compared the effect of Information Communication Technology on Agricultural Information access among researchers, extension agents, and farmers in South Western Nigeria, and noted that a significant difference in the effect of ICT on agricultural information access among researchers, extension agents, and farmers . The study concluded that access to agricultural information through ICT will continue to improve, since perceptions are overtly positive among researchers, extension agents, and farmers. Agwu, Uche-Mba and Akinnagbe (2008) ascertained that the level of usage as well as constraints to the use of information communication technologies (ICTs) among major stakeholders in the agricultural development process in Abia and Enugu States of Nigeria. The findings indicate that majority of researchers; extension workers and farmers had high, moderate and low knowledge levels of available ICTs, respectively. Out of 24 information communication technologies researchers utilized more ICT than extension officers and farmers. The study revealed major constraints to the use of ICTs to include lack of sufficiently trained computer personnel, lack of confidence in operating modern ICTs, erratic and fluctuating power supply, poor finance, lack of internet access in the rural areas and high cost of ICTs hard and software's, among others. The study concludes with the need to have a National Agricultural Extension Policy on the use of ICTs with major emphasis on access, availability and use.

Akparo, Okon and Inyang, (2007) analysed constraints affecting the utilization of Information and Communication Technologies (ICT) for agricultural extension activities by agricultural extension officers in Nigeria's Niger Delta Region. The findings revealed important specific constraints which include: poor ICT infrastructure development, high cost of broadcast equipment, high charges for radio/ television presentations, high cost of access/interconnectivity and electricity power problems. The use of Factor Analysis aided to crystallize identified constraints into three factors of 'poor enabling environment', 'lack of accesses and 'dissemination of unrelated information'. Adebayo and Adesope (2007) examined awareness, access and utilization of ICT among female researchers and female extensionists in South Eastern Nigeria. Information collected showed that female researchers and female extensionists are aware of ICT; both categories of respondents know how to access Internet on their own, but do not have adequate access to IT. The types of ICT needed by female researchers and female extensionists include; World Wide Web, Electronic Mail, Electronic Spreadsheet, Word Processing, CD-ROM, Use of Projector, Use of computer, Web Design, Chartroom. Salau and Saingbe (2008) indicated that in Nigeria researchers had greater access and utilization to ICT facilities than extension workers. The level of education positively influenced the level of utilization of ICTs while years of working experience had negative influence. The key problems militating against the use of ICTs in the area were poor access to

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ICT facilities, lack of computer knowledge, low income and poor power supply. It was recommended that agricultural organizations should install all necessary ICT facilities in their establishments and provide training opportunities for their staff. Constant power supply to both urban and rural communities should be considered a fundamental human right and treated as such.

REFERENCES

Aboh, C, L. (2008). Assessment of the frequency of ICT tools usage by Agricultural Extension agents in Imo State, Nigeria. *Journal of Agriculture and Social Research*, *8*(2).

Acker, D., & Gasperini, L. (2008). Education for rural people: What have we learned. *Journal of International Agricultural and Extension Education*, *15*(1), 28–30. doi:10.5191/jiaee.2008.15103

Adebayo, E. L., & Adesope, O. M. (2007). Awareness, access and usage of information and communication technologies between female researchers and extensionists. *International Journal of Education and Development using Information and Communication Technology, 3*(1), 85-93.

Adesope, O. M., Asiabaka, C. C., & Agumagu, A. C. (2007). Effect of personal characteristics of extension managers and supervisors on information technology needs in the Niger Delta area of Nigeria. *International Journal of Education and Development Using ICT*, *3*(2).

Agwu, A. E., Uche-Mba, U. C., & Akinnagbe, O. M. (2008). Use of Information Communication Technologies (ICTs) among Researchers, Extension Workers and Farmers in Abia and Enugu States: Implications for a National Agricultural Extension Policy on ICTs. *Journal of Agricultural Extension*, *12*(1), 37–49.

Agwu, E. A., Uche-Mba, U. (2010). *Congruency, agreement and accuracy among researchers, extension workers and farmers on the role of ICTs in Nigeria's agricultural development*. Available at iaald2010.agropolis.fr/proceedings/national-experiences.html

Ahmadpour, A., Mirdamadi, M., & Hossein, J. (2010). Factors influencing the design of electronic system in agricultural extension. *American Journal of Agricultural and Biological Sciences*, *5*(2), 122–127. doi:10.3844/ajabssp.2010.122.127

Aizaki, H., Nakashima, Y., Ujie, K., Takeshita, H., & Tahara, K. (2010). Influence of Information about Agrochemicals provided via Internet –enabled mobile phones on Consumer Valuation of food. *Journal of Agricultural & Food Information*, *11*(3), 209–211. doi:10.1080/10496505.2010.490509

Akkermans, N. (2010). *The Role of ICTs in Knowledge Sharing within Rural Communities in Ghana, Internship MA International Relations*. University of Groningen.

Arokoyo, T. (2010). *ICTs in the transformation of Agricultural Extension: The case of Nigeria.* Available at www.fao.org

Arokoyo, T., Chikwendu, D., & Ogunbameru, K. (2002). *A study of the access of Rural Women to Public and Private Extension Service in Nigeria*. Report of a study commissioned and funded by CTA.

Asian Development Bank. (2004). Building e-community centers for rural development. Report of the Regional Workshop, Bali, Indonesia.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Asian Productivity Organization (APO). (2002). *Report of a study meeting on Integration of Agricultural Research and Extension.* APO.

Ballantyne, P. (2009). Accessing, Sharing and Communicating Agricultural Information for Development: emerging trends and issues. *Sage Journal*, *25*(4), 260-271. Available at http://www.sagepublications.com

Batchelor, S., Evangelista, S., Hearn, S., Sugden, S., & Webb, M. (2003). *ICT for development-Contributing to the Millennium Development Goals: Lessons learned from Seventeen infoDev Projects.* Washington, DC: World Bank. Available on line: www.infodev.org/symp2003/publications/CaseStudies.pdf

Bayes, A., Von Braun, J., & Akhter, R. (1999). *Village Pay Phones and Poverty Reduction: Insights from a Grameen Bank, Initiative in Bangladesh*. ZEF Discussion Papers on Development Policy No. 8. Centre for Development Research. Available on line: http://www.apdip.net/publications/iespprimers/eprimer-pov.pdf

Bertolini, R. (2004). *Strategic thinking: making information and communication technologies work for food security in Africa*. Available online: http://www.ifpri.org/pubs/ib/ib27.pdf

Bhatnagar, S., & Schware, R. (2000). *Information and communication technology in development: Cases from India*. Sage Publications India Pty, Ltd.

Bheenick, K., & Brizmohunr, G. (2003). *The scope of information and communication technology application in agriculture extension in Mauritius*. Available on line: www.Uom.ac.mu/faculty/foa/ais/amas/htm

Boone, K., Meisenbach, T., & Tucker, M. (2000). *Agricultural Communications: Changes and Challenges*. Iowa State University Press.

Boone, K.M., & Paulson, C.E., & Barrick, R.K. (1993). Graduate Education in Agricultural Communication: The need and Role. *Journal of Applied Communications*, *77*(1), 16–26.

BUA News. (2010). *South Africa: Limpopo farmers get ICT boost*. Author.

Chizari, M., Lashgarara, F., Mirdamadi, S. M., & Hosseini, S. J. F. (2009). Role of information and communication technologies in improving food availability of Iranian rural households. *International Journal of Education and Development using Information and Communication Technology, 5*(3), 193-205.

Dodds, T. (1999). *Non-Formal and Adult Basic Education Through Open and Distance Learning in Africa*. Academic Press.

Economic Commission for Africa (ECA). (2005). *Emerging issues in science and technology for Africa's development: science, technology and innovation for meeting key MDGs*. Addis Ababa: ECA Sustainable Development Division.

Eggleston, K., Jensen, R., & Zeckhauser, R. (2002). Information and Communication Technologies, Markets and Economic Development. In *The Global Information Technology Report: Readiness for the Networked World* (pp. 62–63). New York: University Press.

Engelhard, R. (2001). *Wireless: a help line for agricultural development*? Report of the 4th Consultative Expert meeting of CTA"s Observatory on ICTs. CTA Working Document-8024. Available: http://www.agricta.org/observatory

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

FACET. (2010). *ICT to enhance farm extension services in Africa*. Available on line: www.facet.org

FAO. (2000). *The role of information and communication technologies in rural development and food security*. Rome: FAO. Available on line: http://www.fao.org/sd/CDdirect/CDre0055.htm

FAO. (2003). *Virtual extension and research communication network.* Available on line: http://www.fao.org/sd/2003/KN10053_en.html

FAO. (2004). *Institution Building to strengthen Agriculture Extension*. 27th FAO Regional Conference for Asia and the Pacific, Beijing, China. Available on line: www.fao.org

FAO. (2006). *The Internet and Rural and Agricultural Development – An Integrated Approach.* Food and Agriculture Organisation. Available on line: http://www.fao.org/docrep/w6840e/w6840e05.htm

Flor, A. G., & Hazelman, M. (2004). *Regional Prospects and Initiatives for Bridging the Rural Digital Divide*. AFITA/WCCA Joint Congress on IT in Agriculture. Available online www.upou.edu.ph/downloads/2004AFITA.pdf

Gelb, E., Gal, B., & Wolfson, D. (2008). *Information and Communication Technologies(ICT) for Agricultural Extension –An Overtime Israeli Perspective*. Israel: Ministry of Agriculture and Rural Development.

GIS Development. (2006). *GIS application*. Available online: http://www.gisdevelopment.net/application/agriculture/overview/agrio0011dhtm

Glendenning, C. J., Babu, S., & Asenso-Okyere, K. (2010). *Review of Agricultural Extension in India, Are farmers' information needs being met?* IFPRI Discussion Paper 01048. Eastern and Southern Africa Regional Office.

Gudza, L. D. (2010). *Podcasts can inform poor farmers.* Available on line http//www.scidev.net/en/agriculture-and-environment/farming-practices/opinions/podcasts-can-inform poor farmers.html

Gurstein, M. (2000). Community Informatics: Enabling Communities with information and communication technologies. Idea Group Publishing. doi:10.4018/978-1-878289-69-8

Harris, R. (2004). *Information and communication technologies for poverty alleviation.* Asia-Pacific Development Information Programme.

Heeks, R. (1999). *The Tyranny of Participation in Information Systems: Learning from Development Projects.* Institute for Development Policy and Management, University of Manchester. Available on line: http://knownetgrin.honeybee.org/honeybee.html

Hosseini, S. J. F., Niknami, M., & Chizari, M. (2009). To determine the challenges in the application of ICT's by the agricultural extension service in Iran. *Journal of Agricultural Extension and Rural Development, 1*(1), 27-30.

International Fund for Agricultural Development (IFAD). (2002). *Challenges in rural development and poverty alleviation in Eastern and Southern Africa: the role of civil society and development institutions*. Available on line: http://www.ifad.org/ngo/events/pf/reports/session3.pdf

International Institute for Communication and Development (IICD). (2006). *ICTs for agricultural livelihoods: impact and lessons learned from IICD supported activities*. The Hague: IICD.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Jones, G. E. (1986). Investing in Rural Extension: Strategies and Goals. Elsevier Applied Science Publishers.

Kasonde, T. (2009). *Zambia: Promoting Agriculture through the use of ICT's*. Available on line: www.lusaka times.com

Kauffman, R. J., & Kumar, A. (2005). *A Critical Assessment of the Capabilities of Five Measure for ICT Development*. University of Minnesota.

Ke, B., & Zhang, X. (1999). *The development of ICT and its impacts on rural economy in China*. Beijing: RCRE.

Kerrigan, K., Lindsey, G., & Novak, K. (1994). Computer networking in International Agricultural Research Experience of the CGNET. New Information technologies in Agriculture. *Quarterly Bulletin of the International Association of Agricultural Information Specialists, 39*(1-2), 182-193.

Khalil, M., Dongier, P., & Qiang, C. Z. W. (2009). Overview in Information and communications for development (IC4D) Information and communications for development (IC4D). Washington, DC: The World Bank.

Khan, B. H. (2001). *A framework for e-learning*. LTI Magazine.

Krejcie, R. V., & Morgan, D. W. (1970). Determining sample size for research activities. *Educational and Psychological Measurement*, *30*, 607–610.

Kushner, J., & Chong, P. (2004). *Conducive environments for promoting community e-centers*. *Asian Development Bank Regional Workshop*, Bali, Indonesia.

Lashgarara, F., Mirdamadi, S. M., & Hosseini, S. J. F. (2010). Determining the causal model role of ICT in improving food availability of Iranian rural households. *International Journal of Advanced Science and Technology*, *24*, 27–40.

Leeuwis, C. (2004). *Communication for Innovation: Rethinking Agricultural Extension* (3rd ed.). Blackwell Science Ltd.

Lie, R. (2006). *Background paper: ICTs for Agricultural Development. An exercise in Interdisciplinarity, A final report*. Hampton Press.

Lynch, M. M. (2001). *The online educator: a guide to creating the virtual classroom*. London: Routledge.

Mabe, L. K. (2005). *The Role of Women in Agriculture and other non-farm activities in three regions of the North-West Province*. (MSc. Thesis). North-West University, Mafikeng Campus.

Marker, P., McNamara, K., & Wallace, L. (2002). *The Significance of Information and Communication Technologies for Reducing Poverty, The Think! Programme*. Development Policy Department, Department of International Development.

Meera, S. N., Jhamtani, A., & Rao, D. U. M. (2004). Information and communication technology in agricultural development: A comparative analysis of three projects from India. *Agricultural Research and Extension Network, 135.*

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Ministry of Works. (2003). *Housing and communications*. Uganda: National ICT Policy.

Mmbengeni, M. E., & Mokoka, M. S. (2002). *Provincial Report on Education and Training for Agriculture and Rural Development in Limpopo Province*. Limpopo Department of Agriculture.

Mudannayake, I. (2006). *Forging relationships between Libraries and Extension Services for Improved Access to Agriculture Information: A case study in Sri Lanka*. World Library and Information Congress: 72nd IFLA General Conference and Council, Seoul, Korea.

Munyua, H. (2000). Application of ICTs in Africa's Agrcultural Sector: A gender perspective. International Development Research Center (IDRC).

Munyua, H. (2008). *Report on ICTs and small - scale Agriculture in Africa: A scoping study*. IDRC.

Nagarsi, K. (2000). *Assess of creative potential and practice of extension personnel*. New Delhi: IARI Pusa.

Ndag, I., Sanusi, R. A., & Aigbekaen, E. O. (2008). Comparative analysis of Information and Communication Technology (ICT) use by agricultural extension workers in South-west and North-central Nigeria. *Proceedings of the 19th Annual International Information Management Association.*

Obayelu, A., & Ogunlade, I. (2006). Analysis of the uses of Information & Communications Technology for Gender Empowerment & Sustainable Poverty Alleviation in Nigeria. *International Journal of Educational Development*.

Oladele, O. I. (2011). Effect of Information Communication Technology on Agricultural Information Access Among Researchers, Extension Agents, and Farmers in South Western Nigeria. *Journal of Agricultural and Food Information*, *12*(2), 167- 176.

Purnomo, S. H., & Lee, Y. H. (2010). An Assessment of Readiness and Barriers towards ICT Programme Implementation: Perceptions of Agricultural Extension Officers in Indonesia. *International Journal of Education and Development using Information and Communication Technology, 6*(3), 19-36.

Qiang, C. W., Clarke, G. R., & Halewood, N. (2006). The role of ICT in doing business. 2006 information and communications for development: global trends and policies. Washington, DC: World Bank.

Raabe, K. (2008). *Reforming the agricultural extension system in India: What do we know about what works where and why?* IFPRI Discussion Paper 00775. Washington, DC: International Food Policy Research Institute.

Rafea, A. (1999). *Managing agricultural knowledge: role of information and communication technology*. American University in Cairo.

Richardson, D. (1997). *The internet and rural and agricultural development – an integrated approach*. Rome: FAO. Available online: http://www.fao.org/docrep/w6840e/w6840e00.htm

Richardson, D. (2003). *Agricultural extension transforming ICTs? Championing universal access* (Background Paper for CTA's ICT Observatory). Available on line: http://www.cta.int/fr/content/download/2792/20425/version/1/file/backgroundpaper2003.pdf

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Richardson, D. (2005). How can agricultural extension best harness ICTs to improve rural livelihoods in developing countries. In E. Gelb & A. Offer (Eds.), *ICT in Agriculture: Perspectives of Technological Innovation*. Jerusalem: Hebrew University of Jerusalem, Centre for Agricultural Economics Research.

Richardson, D. (2006). *ICTs – Transforming Agricultural Extension.* Report of the 6th Consultative Experts Meeting of CTA's Observatory on ICT's, The ACP-EU Centre for Agrcultural and Rural Co-operation (CTA).

Rivera, W. M., & Sulaiman, R. V. (2009). Extension: Object of reform, engine for innovation. *Outlook on Agriculture*, *38*(3), 267–273. doi:10.5367/000000009789396810

Roy, S. (2005). *Globalisation, ICT and Developing Nations: Challenges in the information age*. New Delhi, India: Sage Publications Ltd.

Said, A., Rafea, A., El-Beltagy, S., & Hassan, H. (2009). Automatic Generation of Explanation for Expert Systems implemented with Different Knowledge Representations. *WSEAS Transactions on Systems, 8.*

Salau, E. S., & Saingbe, N.D. (2008). Access and Utilization of Information and Communication Technologies (ICTs) Among Agricultural Researchers and Extension Workers in Selected Institutions in Nasarawa State of Nigeria. *PAT, 4*(2), 1-11. Available online: www.patnsukjournal.com/currentissue

Satyanarayana, K. V., Reddy, M. N., Balasubramani, N., Sharma, V. P., & Bhaskar, G. (2008). *National Institute of Agricultural Extension Management*. Available at www.manage.com

Schmitz, J. G. (2003). Agricultural Extension on the Web. University of Illinois.

Secretariat of the Pacific Community (SPC). (2011). *Pacific Community*. Retrieved from: http//www.spc.int

Sulaiman, R. (2003). *Agricultural Extension: Involvement of Private Sector*. Mumbai, India: National Bankfor Agricultural and Rural Development.

Swanson, B. E. (2008). Global review of good agricultural extension and advisory service practices. Rome: Food and Agriculture Organization of the United Nations.

Swanson, B. E., & Rajalahti, R. (2010). Strengthening Agricultural Extension and Advisory Systems: Procedures for Assessing, Transforming and Evaluating Extension Systems. The International Bank for Reconstruction and Development/The World Bank.

Tregurtha, N., & Vink, N. (2002). *E-commerce and the South African horticultural export industry: current status and future directions*. Available on line: http://www.gapresearch.org/production/EcommercefinalreportAug2002.pdf

UNDP. (2001). *Information Communications Technology for Development. Essentials ICTD 31. Synthesis of Lessons Learned*. Evaluation Office N0. 5. Retrieved from http://www.undp.org/eo

United Nations Development Programme. (2004). *Asia-Pacific Development Information Programme (UNDP-APDIP).* Available on line: www.apdip.net

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Van Audenhove, L. (2003). *Towards an integrated information society policy in South Africa: an overview of political rhetoric and policy initiatives 1994 – 2000*. Cape Town: HSRC Publishers. Available on line: www.hsrcpress.ac.za

Van Veldhuizen, L., Waters-Bayer, A., & De Zeeuw, H. (1997). *Developing Technology with Farmers: A Trainers Guide for Participatory Learning*. Zed Books Ltd.

Zijp, W. (1994). *Improving the transfer and use of agricultural information: A guide to information technology*. The International Bank for Reconstruction and Development.

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Chapter 10
Strategic Positioning of Turkey Agricultural Products on the Agricultural World Market

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ABSTRACT

Applying a strategic management perspective, particularly the BCG tool, this chapter demonstrates that the agricultural products exported by Turkey are distributed unevenly on the four cells of the global agricultural markets matrix: almost of its products (236 products or 85.20% of its portfolio) are Question Marks, two products are a Star, one product is a Cash cow, and 38 products are Dogs. Such a situation creates important strategic choices for the leaders of the country and for its businesses. None of Turkey top ten exports were among the top ten growers in the world. Turkey is world export leader in ten products, but these products are not the world most growing markets, and the country should increase its relative market share in some of its ten top exports, and also consider developing organic product segments, and eliminate tobacco products in its portfolio.

INTRODUCTION

The Republic of Turkey is one of the fastest growing economies in the world, and has become increasingly intertwined with a global economy. In this global economy, agriculture is very important, as we have witnessed during the global food crisis and the large disputes in the World Trade Organization (WTO) negotiations at the Doha Round and beyond. These resulted in a split between the members of developed and developing countries over the large agricultural subsidies maintained by the richer countries and the industrial subsidies enforced by the developing countries. Despite these disputes, one main agreement made during the WTO negotiations in Doha was the need to eliminate restrictions and distortions in the world agricultural markets.

In Turkey, agriculture is a key sector for jobs and is one of extreme importance in the economy of the country. According to recent data from the FAOSTAT (2014), and the World Bank (2104), agriculture

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utilizes more people than industry in Turkey. Agriculture accounted for 30.40% of the nation's total jobs in 2013. That proportion was even higher for female employment at exactly 52.52% in the same year and indeed is the main source of employment for women there. In response to the opening of and better access to global markets, this chapter addresses the following question: What products should Turkey choose to export to the world markets?

This chapter adopts a strategic management perspective. Application of strategic management and planning is necessary to analyze the current and future position of an enterprise for two fundamental dimensions before developing the strategies of that enterprise or organization; namely: (1) the forces of the external environment that determine the industry trend and the opportunities of the market as well as its threats; and (2) the internal competencies of the enterprise that will determine the potential of the unique competitive leadership which the enterprise can mobilize to establish a commercial superiority against competitors. The strategies chosen must balance the external opportunities and any threats with their own internal strengths, and weaknesses.

The main objective of this study is as follows: Considering the world demand of agricultural products and Turkey's competitive position, what strategies (or what agricultural products) must the country adopt or choose? To answer this question, this chapter adopts the business portfolio analysis approach developed by the Boston Consulting Group (BCG). The growth rate of agricultural products that Turkey exports to the world, the ratio of the total exports of Turkey by agricultural product to the total exports of the world leader of that product, and the share of the exports of each agricultural product of Turkey in terms of the total exports of agricultural products by Turkey are used to measure the three dimensions of the BCG matrix.

The chapter is organized into six main sections: Introduction, Literature Review, Application of the BCG model to the world markets for agricultural products with Turkey as a center for decision-making in terms of that nation's portfolio of world exportable agricultural products, Methodology, Results, Conclusions and the limitations of the study and suggestions for future research. The study duplicates the previous research conducted on West African countries by Sidibe (2011, 2012). The chapter will benefit scholars, scholar-practitioners, business executives, and undergraduate/graduate business and economics students as reference material because it links theory to application.

LITERATURE REVIEW: PORTFOLIO ANALYSIS AND THE BCG MATRIX

This analysis of the BCG matrix follows the presentation of Sidibe (2011) who borrows mainly from Hax & Majluf (1984). Applying the BCG view, an enterprise is a portfolio of business units or firms (SBU for Strategic Business Units), and every unit makes a contribution unique to the growth and profitability of the whole. Still, the units do remain largely independent, and their strategic directions thus need to be approached in a distinctive way. The main objectives of the enterprise are recognized as being both growth and profitability. The BCG developed a growth-market share matrix in which each unit is represented on a grid of four cells (see Figure 1). The horizontal axis corresponds to the relative market share of a business unit (measured by a log of the ratio of the sales of the unit to the sales of its main competitor) to characterize the strength of the enterprise in a specific sector of activity. The vertical axis indicates market growth, representing the attractiveness of the market in which the unit operates (as measured by the growth rate of that market). The area of each circle is proportional to the total sales produced by that particular unit and measures the contributions of every unit to the total sales of the entire enterprise.

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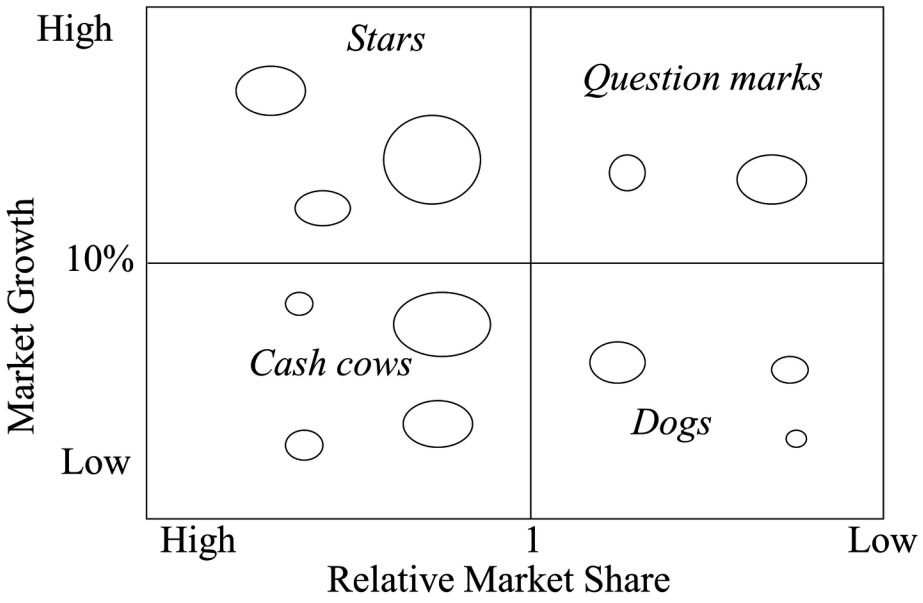
Figure 1. The BCG matrix



Each axis is divided into two parts. In the market growth dimension, the cut-off between strong and weak growth was fixed initially by the BCG at 10%. However, Hax & Majluf (1984) recommended choosing either industry average growth or a measure of general economy growth, such as GNP growth, or a weighted average growth rate of each sector of activity or the growth target of the enterprise as the cut-off. When the business units lie above the cut-off, they are in an embryonic phase of growth; if they are below the cut-off, they are in the maturity or aging phases of business activity. When an industry grows rapidly, one can penetrate the market aggressively and increase market share considerably without necessarily eroding the sales of its competitors. On the other hand, in a mature or aging industry it is not possible to earn market share without decreasing the sales of competitors (Hax & Majluf, 1984: 129; Sidibe, 2011: 33).

To separate the units by their high and low internal strengths, the BCG chose (in its initial proposition) a relative market share of 1.0. The higher the relative market share, the higher will be the competitive advantage of the enterprise, and the more it can exercise considerable dominance in the business. The strategic choices will depend on the location of the units in that matrix. The *Stars* are the units localized in the upper left corner of the matrix. These are very attractive units (high market growth) in which the enterprise has a strong competitive position (high relative market share). They generate a lot of cash and require a considerable influx of cash at the same time if the enterprise wants to sustain its competitive strength quickly in this increasing market. Consequently, the excess final fund contributed to the headquarters or the deficit required from the headquarters is relatively low. The goal of the *Stars* is to increase or maintain their market shares. *Cash Cows* are units that bring an abundant amount of funds to the organization as they have a very high competitive strength in a low market growth situation. Their positive cash flow can be used to sustain the development of other units in the enterprise if the allocation of resources is centralized. Therefore, the strategic choice is to maintain their market shares.

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*Question Mark*s are large, untapped opportunities which are very attractive because of their high growth rate of the market in which they exist. However, the enterprise does not have a significant presence in the corresponding market. Therefore, it is necessary to decide to identify selectively among those products that can be promoted with success to attain a leader position (*Stars*) (Hax & Majluf, 1984: pp. 132-133). The decisions regarding them are to increase the market share of some, harvest (looking to short-term cash flow without too much concern for the long-term), and divest from others. *Dogs* are units that operate in low market growth and are dominated by their competition. Therefore, they are less attractive and are weak. The small amount of cash they generate serves to maintain their operations. If any recovery of the situation is not close at hand, then the logical strategy is to either harvest or divest. In summary, the strategic choices for the units are: Increase market share (for some *Stars,* and some *Question Marks),* maintain market share (for some *Stars,* and for some *Cash Cows*), harvest (for some *Question Marks,* and for some *Dogs*), and divest (for some *Question Marks,* and for some *Dogs*).

STRATEGIC POSITIONING OF TURKISH AGRICULTURAL PRODUCTS ON THE WORLD MARKET

This section of the chapter delineates the research methodology and presents the results analysis and discussion.

1. Methodology

The research methodology for this project is based on the methodology used in an earlier paper as indicated. The data for the present research derived from FAOSTAT, the statistics database of the FAO, which is the most complete, and up-to-date database of all the free online databases for international organizations in the United Nations system used in our research. FAOSTAT3 data for year 2011, the latest available, was collected in October, November, and December of 2014. FAOSTAT3 is the newest and updated database of FAOSTAT.

a. The Data Collection

The data come from the FAOSTAT3 database, and the data collection from the FAOSTAT3 database proceeded very precisely. FAOSTAT has changed the structure of its database, so it is different from the one used by previous research. The new database is FAOSTAT3, so in this research, a period of experimentation was necessary to learn and understand its structure and the precise functionality of the different forms of downloading as well as the compatibility of the downloaded forms with the software the authors used in this chapter. FAOSTAT3 contains many sub-databases, among which are two that were relevant to our study: **Crops and livestock products,** and **Live animals**.

The Crops and livestock products database was accessed first to deliver its results as Exports into the CSV format, as well as the database labeled Live animals first as the total World export for each product and then as each country export for each product. The CSV format files were then transformed into Excel files. Combining the downloaded data from these two databases provided precise data for the full agricultural sector - crops and livestock products (469 aggregated and non-aggregated products),

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and live animals (24 aggregated and non-aggregated products)– for a total of 493 aggregated and non-aggregated products (of which 413 were non-aggregated products) for 203 countries. To avoid a double count, only **the 413 non-aggregated products** were used in the analysis. In summary, Turkey exports for 2011 and then 2010 were sorted so as to measure the growth rate of these exports and also measure the exports of the world competitors of Turkey for 2011 so as to measure the relative market share of each agricultural export from Turkey for that year. After the data collection, this chapter per the authors then calculated the variables for those measurements as discussed below.

b. Measurement of the Variables

Three fundamental variables exist in the model for the BCG (see section PORTFOLIO ANALYSIS: THE BCG MATRIX): Market growth rate of each business unit or product, relative market share of each business unit or product, and the contribution of each business unit or product to the total sales of that enterprise. For market growth rate, we calculated the growth rate of the world export value in US dollars for each agricultural product exported by Turkey from 2010 to 2011 for this chapter per the authors who formulated that variable and did so as follows:

$$\varphi_{it} = (X_{it} - X_{it-1}) * 100 / X_{it-1}$$

φ_{it} = the growth rate of the world export of the agricultural product i exported by Turkey in 2011
X_{it} = the world export of agricultural product i exported by Turkey in 2011
X_{it-1} = the world export of agricultural product i exported by Turkey in 2010
$i = 1 \ldots 250 \ldots 413$

The cut-off between high growth and low growth was fixed at 3.5%, a growth rate of real GDP the International Monetary Fund (IMF) World Economic Outlook (WEO) released on April, 2014 as the projection for Turkey for 2019 (IMF, 2014b: p. 184). The latest data from the IMF Country Report Turkey 2014 Article IV Consultation-Staff Report released on December 5, 2014, prepared by a staff team from the IMF, projected for Turkey a 3.4% average growth rate in real GDP from 2014-2019 (IMF, 2014a: p. 29), while the average growth rate of real GDP for the past 10 years (2003-2013) was 5%.

The cut-off at 10% recommended initially by the BCG seemed coercive because of fluid tensions in the world markets in general, and the agricultural markets in particular as they related to the negotiations within the WTO and in particular due to the tensions between North and South countries, the tensions between the USA and the European Union regarding agriculture, **and the much lower growth of actual, past, and future real GDP for Turkey**. For the actual year 2013, the growth rate for the real GDP for Turkey was 4.1% (IMF, 2014a: p. 29) or 4.3% (IMF, 2014b: p. 184). In the past, the average annual real GDP growth rate from 1996-2005 was 4.3% (IMF, 2014b: p. 184), and from 2003-2013, it was 5.0% (IMF, 2014a: p. 29). From these data, the authors calculated that the average annual real GDP growth over the past 18 years (1996-2013) was 4.65%. All of these figures fall below the rate of 10% recommended initially by the BCG, in less than half.

To obtain the relative market share, the relative market share of each agricultural export value in US dollars for Turkey for year 2011 was measured by calculating the log natural of the ratio for the export

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value in US dollars of each agricultural product exported by Turkey to the export value in US dollars for the world export leader for each product exported by Turkey. If Turkey were the world leader, then the denominator would refer to the exports of the world's second exporter. We formulated this variable as follows:

$$\tau_{i.t=}\ln(x_{i.t} /\max x_{ijt})$$

$\tau_{i.t}$ = relative market share of product *i* exported by Turkey for 2011
$x_{i.t}$= the export in value of product *i* exported by Turkey for 2011
x_{ijt}= the export in value of product *i* by country *j* for 2011

Thus, max $x_{ijt}$is the export in value of world export leader for product *i* exported by Turkey for the year 2011. If Turkey was the world leader, the denominator would refer to the exports of the world's second exporter.

The cut-off between products of high and low relative market share was fixed at 1 as recommended by the BCG. The contribution of each product to the total sales of the enterprise was estimated by the share of the export of each agricultural product as it related to the total agricultural exports of Turkey. In other words, that measure was the percentage of the exports of each agricultural product in terms of the total of agricultural exports of Turkey. That contribution was formulated as follows:

$$\rho_{i.t} = (x_{i.t}/x_{..t})*100$$

$\rho_{i.t}$= share of the export of product *i*to the total agricultural exports of Turkey for 2011
$x_{i.t}$= the export in value of product *i* exported by Turkey for 2011
$x_{..t}$= total agricultural exports of Turkey for 2011

c. The Data Analysis

To analyze the collected data, the three variables above were calculated using EXCEL and then transferred to SPSS where the diagram for the matrix was drawn, using the Graph Interactive Scatterplot function by improving the visualization of the contribution of each product. This contribution is represented by the ranking of the products based on their share to the total agricultural exports of Turkey for 2011, ranging from 1 to 277 where 1 is the top export of Turkey, and 277 the last export. In addition, the product name was abbreviated to have each displayed in the graph. Multiple experiments were necessary to achieve the best result.

RESULTS AND DISCUSSION

In terms of these results, the authors analyze and present successively the range of agricultural products exported by Turkey in 2011, the contribution of each agricultural product to total the country's agricultural exports, the growth of the world's agricultural exports, the competitive position of Turkey on the

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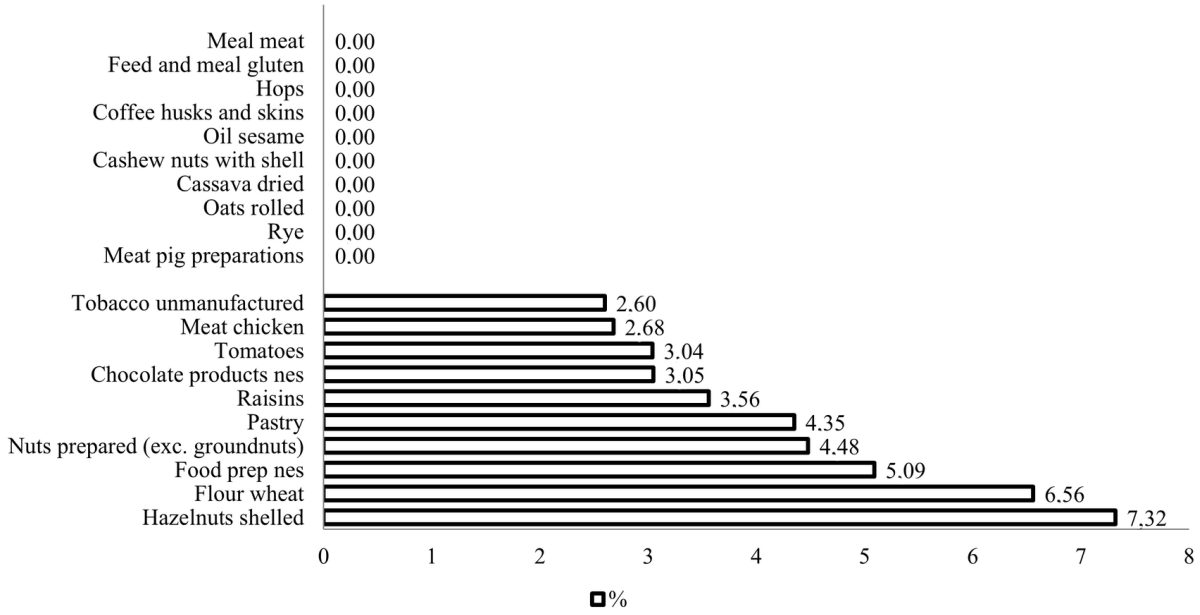
world market for agricultural products (by analyzing the relative market share held by the agricultural exports of Turkey), the positioning of the products exported by Turkey in the strategic matrix, the strategic choices for each product, and then a dynamic discussion of the analysis.

1. Agricultural Exports for Turkey in 2011

The total exports of all agricultural products from Turkey in 2011 totaled US**$14,228, 600,000**, thus accounting for 1.73% of the GDP or 10.55% of Total Merchandise Trade or 103.49% of total agricultural imports. It consisted of 333 agricultural products worldwide (Crops and Livestock products, and Live animals) of which only 56 products (or 16.82%) were marginal exports (below US$1,000 in export value). Those products whose export was less than US$1000 are not listed in the FAOSTAT3 databank and have zero value. Therefore, for Turkey a total of **277 products generated an export of US$1,000 or more** (see Figure 2 and Table 1 for more details) and are analyzed in this chapter.

The total export of these **277 products** accounted for 95.62% of the total exports of the entire agricultural sector (Crop and livestock products, and Live Animals). These products were essentially dominated by Hazelnuts shelled which accounted for 7.32% of the total agricultural exports of the country (see Figure 2). **The five top (main) agricultural exports for Turkey were**, therefore successively, Hazelnuts shelled, Flour wheat, Food prep nes, Nuts prepared (excluding groundnuts), and Pastry. These five top products accounted for 27.77% of the country's total agricultural exports in 2011. **Out of the 277 agricultural products exported, the top 10 represented 42.72% of the total**. Among the top 10 products, Figure 2 shows a relatively equal distribution between the two top products and the three next and the five next others. In comparison to previous research, Turkey is less dependent on small number agricultural exports than are West African countries where Sidibe (2011) found that Cotton lint accounted for 74% of Burkina Faso's total agricultural exports in 2008.

Figure 2. Agricultural exports for Turkey in 2011, share of top ten, and last ten products



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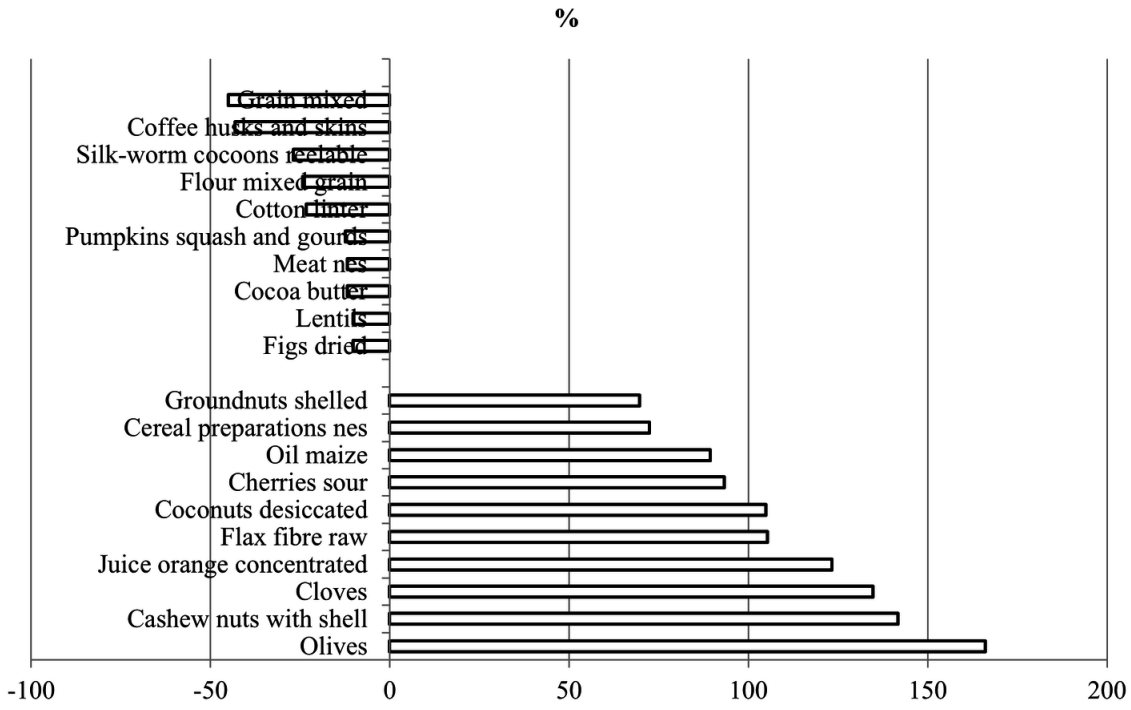
2. Growth of World Agricultural Markets

The World Export of Agricultural Products grew significantly during 2010-2011, indeed at a rate of 21.66%, which is higher than the World Total Merchandise Trade (world exports of all economic sectors for all countries, which totaled just 19.87%). In this general context, the world agricultural markets for Turkey enjoyed excellent growth, even for some its main export products. The world market for the agricultural products exported by Turkey also grew significantly during the 2010-2011 period (see Figure 3 and Table 2 for more details)

The growth rates for the world in 2011 were very high (maximum 166.14%), and almost all products had positive growth rates (251 products out of 277 or 90.61%). The other 26 products out of the catalogued 277 products or 9.39% had a negative growth rate for that same period. A total of 108 products (or 39% of the total) had a growth rate higher than the total world trade growth rate (21.66%), and nearly three-quarters (74%) enjoyed a 2-digit growth rate. Indeed, the growth rate of 78% for the listed products was higher than the growth rate for the entire real GDP for Turkey in 2011 at 8.8% according to the IMF (2014a: p. 29). Further, the growth rate for 85.92% for the products (238 products out of 277) was higher than the target for 2019 (3.5%) as noted in the above section).

The growth in the world agricultural markets for Turkey's Top 10 exports was positive and ranged from 1.39% to 41.65% for that year. Of the Top 10 exports from Turkey, eight products (namely Hazelnuts shelled, Flour wheat, Food prep nes, Nuts prepared (exc. groundnuts), Pastry, Raisins, Chocolate products nes, and Meat chicken) enjoyed a 2-digit growth rate, while Turkey's top two exports (namely Hazelnuts shelled, Flour wheat) had growth rates higher than the world growth rate for that same period

Figure 3. Growth of the world agricultural markets for Turkey, 2011: The top ten, and the last ten



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(respectively -24.92%, and 41.65%). Only two products from Turkey'stop ten exports had growth rates below the target for 2019 (3.5%). The world's top ten growth products were Olives, Cashew nuts with shell, Cloves, Juice orange concentrated, Flax fibre raw, Coconuts desiccated, Cherries sour, Oil maize, Cereal preparations nes, and Groundnuts shelled.

None of the top ten exports from Turkey were among the Top 10 growers in the world. The main 10 exports of Turkey were not from the world's highest growing markets. Among these world growing markets, the best Turkey export position was Olives which is Turkey 235th export. Turkey exports in these Top 10 growers in the world were marginal, accounting for only 0.95% of the total agricultural exports for the country (US$134,734,000 / US$14, 228,600,000 = 0.95%). In general, Turkey's main exports are **not** part of the world's most growing markets.

Generally, one can conclude from a review of these statistics for 2010-2011 that the business opportunities for Turkey are good if one considers the growth rate in the world markets for the products that Turkey exports. It is evident that 78% of the products exported by Turkey are in markets whose growth rates are higher than the growth rate for the GDP of Turkey in 2011 (8.8%), while the growth rate of 85.92% of these export products is higher than the GDP target for 2019 (3.5%). Additionally, nearly half of the products exported by Turkey (39%) are to markets where the growth rates are higher than the growth rate of overall world trade for 2011 (21.66%). Thus, the government of Turkey and the country's business sector should take advantage of or capitalize on these identified opportunities while also taking into account the country's overall world competitive position. However, none of the Top 10 exports from Turkey were among these Top 10 growth products in the world. Thus, the main 10 exports of Turkey were not to the world's greatest growing markets as previously stated.

To capitalize on these world opportunities, Turkey must substantially increase the exports of some of its marginal exported products**;** namely, Olives, Cashew nuts with shell, Cloves, Juice orange concentrated, Flax fibre raw, Coconuts desiccated, Cherries sour, Oil maize, Cereal preparations nes, and Groundnuts shelled - which are the world's greatest growing products. In addition, none of its Top 10 exports had a negative global growth in 2010-2011.

3. Competitive Position of Turkey on the World Market for Agricultural Products: Relative Market Share for Turkey Agricultural Exports

Figure 4 demonstrates that Turkey is the world leader in 10 products: Apricots dry, Hazelnuts shelled, Figs dried, Quinces, Figs, Flour wheat, Cotton waste, Nuts prepared (excluding groundnuts), Raisins, and Poppy seed. For the three first products (Apricots dry, Hazelnuts shelled, and Figs dried), Turkey totally dominated its competitors. Their relative market shares – strengths relative to their main world competitors – are very high and higher than 1. The most competitive product for Turkey (Apricots dry) garnered 3,026.98% of its world main competitor in 2011, Germany. Its second competitive product (Hazelnuts shelled) garnered 843.46% of its world main competitor, Georgia, and the third competitive product (Figs dried) garnered 712% of its world main competitor, the USA. Some of the main exported products for Turkey in terms of value are also products where Turkey holds a better competitive position in the world. They are among the top ten export products that hold a stronger relative market share.

Regarding the Top 10 export products of the country, four (Hazelnuts shelled, Flour wheat, Nuts prepared (excluding groundnuts), and Raisins) are also products for which Turkey also holds a better competitive position in the world. For example, the main export (Hazelnuts shelled) is the country's

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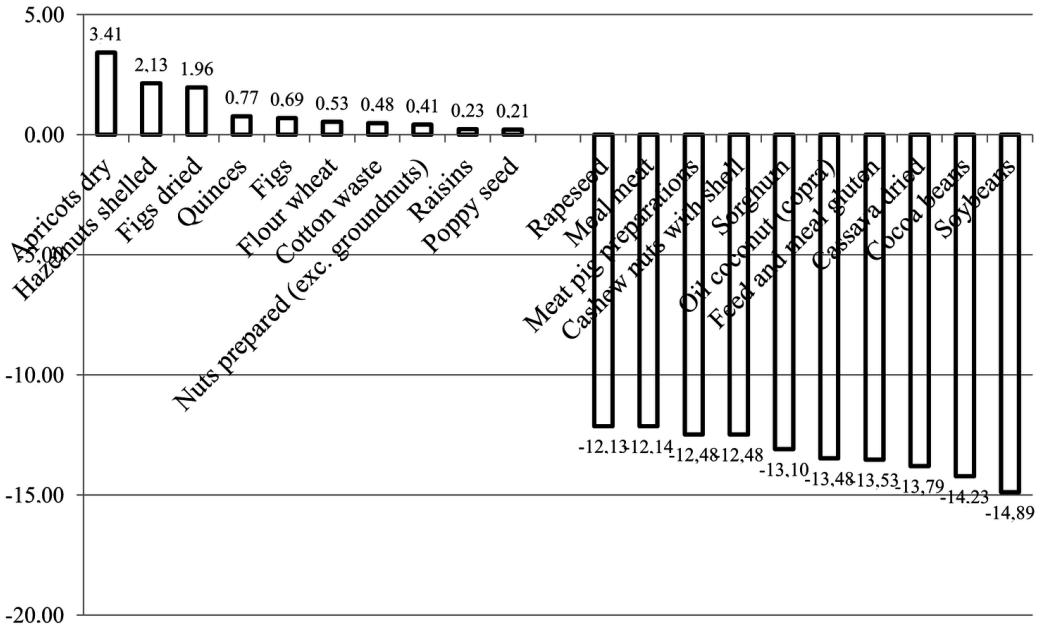
Figure 4. Relative market share for Turkey agricultural exports, 2011



second competitive product (garnering 843.46% of its world main competitor, Georgia). The second main export (Flour wheat) is the country's sixth competitive product (garnering 169.36% of its world main competitor, Kazakhstan), and the fourth export (Nuts prepared (excluding groundnuts)) is the country's eighth competitive product (garnering 150% of its world main competitor, the USA). The sixth main export (Raisins) is the country's 9th competitive product (garnering only 125.76% of its world main competitor, the USA).

The other six of the Top 10 exports are not among the top ten competitive products. For example, the third export product (Food prep nes) is the country's 43d competitive product (garnering only 12.10% of its world main competitor, the United States). The fifth export product (Pastry) is the country's 31st competitive product (garnering only 18.74% of its world main competitor, Germany). The seventh export product (Chocolate products nes) is the country's 48th competitive product (garnering only 11.35% of its world main competitor, Germany). The eighth export product (Tomatoes) is the country's 27th competitive product (garnering only 20.66% of its world main competitor, Mexico). The ninth export product (Meat chicken) is the country's 73rd competitive product (garnering only 5.39% of its world main competitor, Brazil). Finally, the tenth export product (Tobacco unmanufactured) is the country's 42rd competitive product (garnering only 12.83% of its world main competitor, Brazil). Also, we observed that the eleventh main export (Apricots dry) is the country's first competitive product (garnering 3,026.98% of its world main competitor, Germany).

Therefore, Turkey should increase its relative market share (for some of its ten top exports) if it wants to become more competitive and an important player in the world agricultural markets or form useful alliances with other countries. It has a good competitive position in some products, but these products are not the world's highest growing markets.

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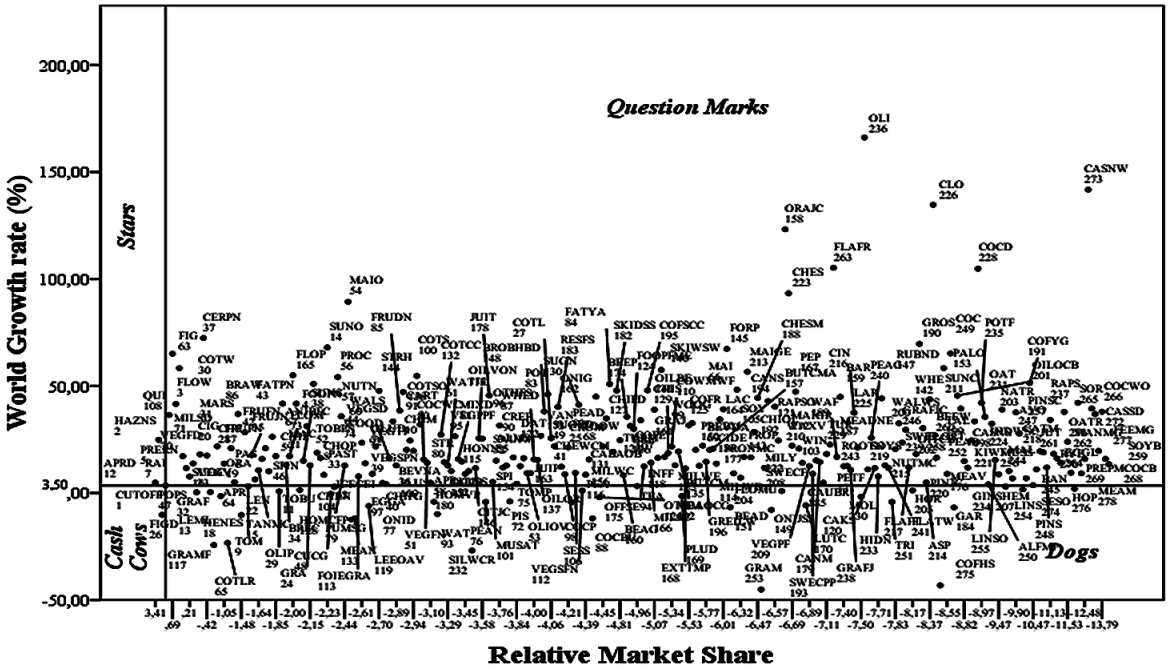
4. Positioning of Agricultural Products Exported by Turkey on the World Growth-Relative Market Share Matrix

Figure 5 shows the positions of the agricultural products exported by Turkey on the matrix framed by two main variables: Growth rates for world exports of agricultural products, and the relative market share for the agricultural products exported by Turkey. The visual reveals that the agricultural products exported by Turkey are unevenly distributed in the four cells of the matrix (the BCG), while almost all of its products are *Question Marks* (236 products or 85.20% of its portfolio). Two products (Hazelnuts shelled «HAZNS», and Apricots dry «APRD») are a *Star,* one product (Figs dried «FIGD») is a *Cash Cow, and* 38 products (or 13.72% of its portfolio) are *Dogs*. This situation creates problems that relate to major strategic choices for the country's leaders and its business sector. This chapter will discuss strategic choices for the Top 10 products in terms of the export receipts for Turkey or, in other words, the country's dominant export products based on the matrix categories.

a. The Stars

Two products (Hazelnuts shelled «HAZNS in Figure 4», and Apricots dry «APRD») are *Stars.* They are the most competitive products for Turkey and thus its strongest products with 2.13 and 3.41 in terms of

Figure 5. Positioning Turkey agricultural products in the world markets, 2011



Note: 277 products are plotted. For the top-ten and least-ten products, each product in the coordinates is represented by a code and a number. The number indicated the product rank in total exports of all agricultural products from Turkey in 2011, i.e. 1 = top export, 2 = the second position, 3 = third position, and so on.

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relative market shares, and world growth rates that reach 24.92%, and 4.84%, respectively. Turkey is the world's leading exporter of these products. Its Hazelnuts shelled exports in 2011 reached US$1,041,430,000, or 8.43 times that of its most important competitor, Georgia. As noted earlier, Hazelnuts shelled is the first export (the top export) of Turkey, and the country is the world leader for this product. Furthermore, Hazelnuts account for 7.32% of the country's total agricultural export value. With this product enjoying an excellent world growth rate of 24.92%, a reasonable strategy would be to increase this export or at least maintain its current position. For Apricot dry, the exports totaled US$360,907,000, or 30.26 times that of its most important competitor, Germany. However, it accounted for 2.54% of the country's total agricultural export value (rank 11), and a slow world growth rate of 4.84%. Even with this slow world growth rate, a reasonable strategy would be to increase this export or at least maintain its current position, in hopes that world growth will increase.

b. The Cash Cows

One product (Figs dried «FIGD») is a *Cash Cow*. It is the third competitive product for Turkey, with 1.96 as relative market share, but with a negative world growth rate (-10.18%). Turkey is the world's leading exporter of this product. It exported US$151,546,000 in 2011, or 7.12 times that of its most important competitor, the USA. Although Turkey is the world leader in this product, it again marginally accounted for only 1.07% of the country's total agricultural export value, ranking 25 out of 277 exported products. If its world growth rate increases substantially, Figs dried can be considered a *Star*. It will not likely become a *Dog* in the near future because Turkey already holds a big market share. Its export of the product is much higher than its most important competitor (7.12 times). Therefore, a logical strategy would be to increase the export of the product or at least maintain its current position for Figs dried.

c. The Dogs

A total of 38 agricultural products (i.e., 13.72% of the products exported) were situated in the *Dogs* cell. These have low market shares in markets that are growing slowly or even decreasing. This weak market share jeopardizes these types of products when facing bigger competitors. The BCG perspective is that these products are big losers; they are less attractive in terms of market growth, and they are weak compared to their world competitors. If there is no legitimate reason to expect any recovery in the near future, the logical strategy is to harvest or divest them. The basic objective for harvesting a dog is to increase short-term cash return without much concern for long-term impact and then sell these products to earn cash needed by the *Question Marks*.

A total of 13 products made up the *Dogs* cell (i.e., 34.21% of that cell) – Tea, Tomatoes, Ginger, Chestnut, Hops, Papayas, Tobacco unmanufactured, Horses, Vegetables fresh nes, Flour mustard, Olives preserved, Grapefruit (including pomelos), and Lemons and limes – are in markets which are growing slowly, but have some positive growth rate. The other 25 products in that cell (i.e., 65.79% of the cell) were in markets that are decreasing (have a negative growth rate). If the overall world growth rate increases substantially, these products may become *Question Marks,* but never *Stars* because their market shares are very small.

The five least competitive products (ascending) among the *Dogs* were Hops, Papayas, Ginger, Garlic, and Coffee husks and skins. Hops were the least competitive. For example, the world leader in Hops, Germany, exported US$173,261,000 in 2011 while Turkey exported only US$1,000; in other words,

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Germany exported 173,261 times that of Turkey. Following the same line of reasoning, Mexico, the world leader in Papayas exported US$46,264,000 in 2011, while Turkey exported only US$2,000; in other words, Mexico exported 23,132 times that of Turkey. For Ginger, the China mainland is the leader and exported US$409,484,000, while Turkey exported only US$29,000, or in other words, the China mainland exported 14,120 times Turkey's exports of Ginger.

Garlic's world leader, the China mainland, exported US$2,068,290,000, while Turkey exported only US$336,000, or in other words, the China mainland exported 6,155 times Turkey's exports of Garlic. For Coffee husks and skins, the United Republic of Tanzania was the leader and exported US$5,031,000, while Turkey exported only US$1,000, or in other words, Tanzania exported 5,031 times Turkey's exports of Coffee husks and skins. Facing such large and strong competitors, the government and the business sector of Turkey has few meaningful choices. A reasonable strategy would be harvesting or divesting or moving toward organic production and export of the named products.

Two products from the Top 10 exports for Turkey were in the *Dogs* group, namely Tomatoes («TOM»), and Tobacco unmanufactured («TOBU»). Regarding world growth and relative market share, Tomatoes are in a better position than Tobacco unmanufactured; we recall that Tomatoes is the eighth export of Turkey, and Tobacco unmanufactured is its tenth export. For example, the world leader in Tomatoes, Mexico, exported US$2,093,140,000 in 2011, while Turkey exported only US$432,461,000; in other words, Mexico exported 21 times that of Turkey, the world growth being 3.04%. Following the same line of reasoning, Brazil, the world leader in Tobacco unmanufactured, exported US$2,878,610,000, while Turkey exported only US$369,464,000, meaning Brazil had 7.8 times Turkey's exports of Tobacco unmanufactured, the world growth being 1.39%.

Divesting Tomatoes would not be acceptable, considering that it is a product that is consumed daily, so there is always a fear of dependence on other countries; further, the product is perishable (and weather is thus a factor). If tomato production is suited well to natural conditions (i.e., soil and climate) of the country, Turkey could move toward a more focused strategy that benefits organic segments tomatoes (with organic being a positive trend). For Tobacco unmanufactured, based on the negative impact of cigarettes on health according to the World Health Organization [WHO](2013, p. 8), these tobacco products should be divested (or abandoned). Divesting (abandoning) these products could free up resources that could then be used to increase the market share of products whose relative market share will increase as discussed and recommended above, and also solve a health issue. The WHO Report on the Global Tobacco Epidemic (2013) stated the following facts and warnings:

The WHO Framework Convention on Tobacco Control (WHO FCTC) recognizes the substantial harm caused by tobacco use and the critical need to prevent it. Tobacco kills approximately 6 million people and causes more than half a trillion dollars of economic damage each year. Tobacco will kill as many as 1 billion people this century if the WHO FCTC is not implemented rapidly (p. 8).

The report continues by stating that "*Complete bans are needed to counteract the effects of tobacco advertising, promotion and sponsorship...*[and]*Bans must completely cover all types of tobacco advertising, promotion and sponsorship*" (p. 26, p. 30) With the documented worldwide will to reduce the demand for tobacco led by the WHO, the practical and logical strategy for Turkey is to divest of or abandon all tobacco and tobacco-related products.

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d. The Question Marks

This is the large portfolio in Turkey as 85.20% of the export portfolio for Turkey, or 236 products out of 277, rest in the *Question Marks* cell. These products enjoy strong world market growth (their growth rate exceeded Turkey's GDP 2019 target growth), but they face much greater world competition. **Seven of the Top 10 Turkish exports are in this category**: Flour wheat, Food prep nes, Nuts prepared (exc. groundnuts), Pastry, Raisins, Chocolate products nes, and Meat chicken. They enjoy a 2-digit world growth. It seems unreasonable to divest them; however, because their importance in terms of the country's exports their world growth rates, and the possibilities to tap new niches. So, a logical strategy for these seven products would be to increase their market share to bring them in a *Star* position, and/or to move toward a more focused strategy that serves organic segments. Thus, it becomes necessary to invest in these seven of the Top 10 exports products from Turkey.

Among the *Question Marks* products, the ten products which have a better competitive position or better strength relative to their global competitors include: Quinces, Figs, Flour wheat, Cotton waste, Nuts prepared (excluding groundnuts), Raisins, Poppy seed, Vegetables in vinegar, Vegetables fresh or dried products nes, and Cereal preparations nes. For these products (particularly for the first seven in which Turkey is the leader), if the country increases its exports, these products would become *Stars*. The logical strategic decision for these products would be to increase their market share and move toward a more focused strategy that serves organic segments. Thus, it is advisable to invest in these ten products as well.

The five least competitive products in descending order which were *Question Marks* include: Oil coconut (copra), Feed and meal gluten, Cassava dried, Cocoa beans, and Soybeans; soybeans were the least competitive. For example, the world leader in soybeans, the USA, exported US$17,563,900,000 in 2011, while Turkey exported only US$6, 000; in other words, the USA exported 2,927,317 times that of Turkey. Following the same line of reasoning, Côte d'Ivoire, the world leader in Cocoa beans, exported US$3,029,180,000, while Turkey exported only US$2,000, meaning Côte d'Ivoire had 1,514,590 times Turkey's exports of Cocoa beans.

For Cassava dried, Thailand is the leader and exported US$978,593,000, while Turkey exported only US$1,000, meaning Thailand exported 978,593 times Turkey's exports of Cassava dried. Feed and meal gluten world leader, the USA, exported US$754,089,000, while Turkey exported only US$1,000; therefore, the USA exported 754,089 times Turkey's exports of Feed and meal gluten. For Oil coconut (copra), the Philippines was the leader and exported US$1,425,450,000, while Turkey exported only US$2,000, or the Philippines exported 712,725 times Turkey's exports of Oil coconut (copra). Facing these large and strong competitors, the government and the business sector of Turkey do not have a meaningful choice. However, the country could try to enter the organic segment for these products, as they were traditionally organic, and animals there are traditionally raised in a natural environment. At the same time, the country could increase the daily protein intake of its own diet by making this choice.

Another *Question Mark* product which could be abandoned is Tobacco products nes (even the world growth rate is only 21.70%, and the relative market share -2.69), because according to the WHO (2013), cigarettes have a negative impact on health, and tobacco products kill nearly 6 million people thus causing hundreds of billions of dollars of economic damage worldwide each year. In the *2013 Report on the Global Tobacco Epidemic,* the WHO introduced stronger measures to help countries worldwide reduce their demand for tobacco (WHO, 2013 p. 8). Therefore, the practical and logical strategy for Turkey

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is to divest all tobacco and tobacco-related products. Divesting these products could free up resources which could be used to increase the market share of products whose relative market share will increase as already recommended.

CONCLUSION

Turkey exports a broad range of agricultural products, 277 products all told in 2011. The growth of all agricultural exports from Turkey (20.58%) was below, but still close to that of, agricultural exports worldwide (21.66%). In other words, Turkey cornered the world market, but not at the same speed as its competitors. However, that world growth was also unevenly distributed among the export portfolio for Turkey: The maximum growth rate was 166.14%, most products (90.61%) did have positive growth rates, and the other 9.39% posted a negative growth rate; nearly three-quarters (74%) enjoyed a 2-digit growth rate, and 78% of the listed products had a growth rate higher than the real GDP for Turkey in 2011 (8.8%).

Furthermore, the growth rate of 85.92% of these export products was higher that the target for 2019 (3.5%). The growth of the world agricultural markets for Turkey's Top 10 exports was positive and ranged from 1.39% to 41.65% for that year. Of the Top 10 exports from Turkey, eight products (Hazelnuts shelled, Flour wheat, Food prep nes, Nuts prepared (excluding groundnuts), Pastry, Raisins, Chocolate products nes, and Meat chicken) enjoyed a 2-digit growth rate, while Turkey's top two exports (Hazelnuts shelled, Flour wheat) had growth rates higher than the world growth rate for that same period (successively -24.92%, and 41.65%).

Only two products from Turkey's Top 10 exports had growth rates below the target for 2019 (3.5%). None of the Top 10 exports from Turkey were among the Top 10 growers in the world. The main ten exports of Turkey are not part of the world most growing markets. Among these world growing markets, the best Turkey export position is Olives which is Turkey's 235th export. Turkey exports in the Top 10 growers in the world are marginal, accounting for only 0.95% of the total agricultural exports from the country. In general, Turkey's main exports are not found to be in the world's greatest growing markets.

However, Turkey is the world leader in ten products: Apricots dry, Hazelnuts shelled, Figs dried, Quinces, Figs, Flour wheat, Cotton waste, Nuts prepared (excluding groundnuts), Raisins, and Poppy seed. For the three first products (Apricots dry, Hazelnuts shelled, Figs dried), Turkey totally dominated its competitors; their relative market shares – their strengths relative to their main world competitors – are higher than 1. The most competitive product for Turkey is Apricots dry, while the second competitive product is Hazelnuts shelled. Regarding the Top 10 export products for the country, four (Hazelnuts shelled, Flour wheat, Nuts prepared (excluding groundnuts), and Raisins)) are also the products where Turkey holds a better competitive position in the world.

For example, the main export (Hazelnuts shelled) is the country's second most competitive product (garnering 843.46% of its world main competitor, Georgia). The second main export (Flour wheat) is the country's sixth competitive product (garnering 169.36% of its world main competitor, Kazakhstan), and the fourth export (Nuts prepared (excluding groundnuts)) is the country's eighth competitive product (garnering 150% of its world main competitor, the USA). The sixth main export (Raisins) is the country's 9th competitive product (garnering only 125.76% of its world main competitor, the USA). Therefore, Turkey should increase its relative market share (in some of its Top 10 exports) if it wants to be more

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competitive and an important player on the world agricultural markets or alternatively, form useful alliances with other countries. Turkey has a good competitive position in some products, but these products are not the world fastest growing markets.

The agricultural products exported by Turkey are distributed unevenly on the four cells of the matrix (of the BCG), and almost all of its products are *Question Marks*: Two products are a *Star,* 1 product is a *Cash cow,* 38 products are *Dogs,* and 236 products (85.20% of its portfolio) are *Question Marks*. This situation creates important strategic choices for the leaders of the country and for businesses. The logical strategic choices for the country now are the following:

• Increase the market shares of the following *Question Marks* products: Flour wheat, Food prep nes, Nuts prepared (excluding groundnuts), Pastry, Raisins, Chocolate products nes, and Meat chicken (seven of the Top 10 exports of Turkey are in this category), Quinces, Figs, Flour wheat, Cotton waste, Nuts prepared (exc. groundnuts), Raisins, Poppy seed, Vegetables in vinegar, Vegetables fresh or dried products nes, Cereal preparations nes (these ten products have a better competitive position in this category), Oil coconut (copra), Feed and meal gluten, Cassava dried, Cocoa beans, Soybeans (these products hold the least competitive position in this category, so increase their share by entering organic segments), and the following *Cash Cows* – Figs dried.

- Maintain the market share of the *Cash Cows* – Figs dried.
- Divest or abandon the following *Dogs* products – Tobacco unmanufactured, *Question Marks* products – Tobacco products nes.

Move toward new organic product segments for the following *Dogs* products – Hops, Papayas, Ginger, Garlic, and Coffee husks and skins, Tomatoes, *Question Marks* products – Oil coconut (copra), Feed and meal gluten, Cassava dried, Cocoa beans, Soybeans. Considering the new passion that the developed or industrialized countries have for organic food, Turkey should choose a focus strategy for their products that will satisfy the growth of this very specific organic food market.

This chapter stresses certain limitations for this research, particularly those related to its static nature. The study examined the internal strength (relative market share) of Turkey for only 2011, and the growth rates of world agricultural markets for only one short period (2010-2011). A more dynamic approach would bring better insight and also further precise strategies to evaluate. This study also did not examine the destinations of the agricultural products exported by Turkey and the consumers (intermediate and ultimate or final consumers) of these exported products. Future research should take account of and examine these specific factors and integrate those results with the results offered here.

REFERENCES

Turkey Country Profile. (2014FAOSTAT. Retrieved from http://faostat.fao.org/CountryProfiles/Country_Profile/Direct.aspx?lang=en&area=223

Hax, A. C., & Majluf, N. S. (1984). *Strategic Management*. Englewood Cliffs, NJ: Prentice-Hall.

Country Report Turkey 2014 Article IV Consultation-Staff Report December 05, 2014 cr14329. (2014a). *International Monetary Fund (IMF)*. Retrieved from http://www.imf.org/external/pubs/cat/longres.aspx?sk=42493.0

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

World Economic Outlook (WEO) April 2014. (2014b). *International Monetary Fund (IMF)*. Retrieved from http://www.imf.org/external/pubs/ft/weo/2014/01/pdf/text.pdf

Sidibe, H. (2011). Strategic Positioning of Burkina Faso Agricultural Products on the Agricultural World Market. *The Business Review, Cambridge*, *19*(1), 32–39.

Sidibé, H. (2012). Strategic Positioning of Senegal Agricultural Products on the Agricultural World Market. *The Business Review, Cambridge*, *19*(2), 330–336.

World Development Indicators. 2014. (2014). *World Bank*. Retrieved from http://data.worldbank.org/country/turkey

WHO report on the global tobacco epidemic, 2013: Enforcing bans on tobacco advertising, promotion and sponsorship. (2013). *World Health Organization*. Retrieved from http://www.who.int/tobacco/global_report/2013/en/

*MINISTERIAL CONFERENCE Sixth Session Hong Kong, 13 - 18 December 200*5. (2005). *World Trade Organization (WTO)*. Retrieved from http://www.wto.org/english/thewto_e/minist_e/min05_e/final_text_e.pdf

ADDITIONAL READING

Barnett, J. H., & Wilsted, W. D. (1988). *Strategic Management*. Boston: PWS-Kent Publishing Company.

Brown, R. (1991). Making the Product Portfolio a Basis for Action. *Long Range Planning*, *24*(1), 102–111. doi:10.1016/0024-6301(91)90030-R

Dessler, G. (2004). *Management*. New York: Pearson/Prentice-Hall.

Henderson, B. (1979). *Henderson on Corporation Strategy*. Cambridge, MA: Abt Books.

Jauch, L. R., & Glueck, W. F. (1988). *Strategic Management and Business Policy*. New York: McGraw-Hill.

Lorange, P. (1977). Divisional Planning: Setting Effective Direction. In P. Lorange & R. F. Vancil (Eds.), *Strategic Planning Systems* (pp. 172–186). Englewood Cliffs, NJ: Prentice-Hall, Inc.

Lorange, P. (1980). *Corporate Planning an Executive Viewpoint*. Englewood Cliffs, NJ: Prentice-Hall, Inc.

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APPENDIX 1

Table 1. Agricultural products exported by Turkey, 2011

Products	Value ($1000)	Share %	Products	Value ($1000)	Share %
Hazelnuts shelled	1 041 430	7,32	Spices nes	63 223	0,44
Flour wheat	933 534	6,56	Poppy seed	60 872	0,43
Food prep nes	723 589	5,09	Cucumbers and gherkins	59 176	0,42
Nuts prepared (exc. groundnuts)	637 659	4,48	Sugar refined	58 171	0,41
Pastry	618 275	4,35	Cocoa powder & cake	53 714	0,38
Raisins	506 499	3,56	Vegetables frozen	53 638	0,38
Chocolate products nes	433 839	3,05	Tobacco products nes	53 484	0,38
Tomatoes	432 461	3,04	Oil olive virgin	49 409	0,35
Meat chicken	380 772	2,68	Oil maize	47 831	0,34
Tobacco unmanufactured	369 464	2,60	Almonds shelled	47 574	0,33
Apricots dry	360 907	2,54	Cheese processed	40 933	0,29
Lemons and limes	354 290	2,49	Nuts nes	39 275	0,28
Oil sunflower	338 753	2,38	Apples	36 605	0,26
Tangerines mandarins clementines satsumas	338 024	2,38	Chick peas	36 508	0,26
Sugar confectionery	328 889	2,31	Walnuts shelled	36 404	0,26
Fruit prepared nes	322 768	2,27	Watersice etc	33 040	0,23
Eggs hen in shell	284 053	2,00	Ice cream and edible ice	31 274	0,22
Oranges	262 902	1,85	Figs	29 291	0,21
Cigarettes	247 712	1,74	Apricots	28 936	0,20
Macaroni	239 876	1,69	Cotton linter	28 076	0,20
Lentils	200 885	1,41	Maize	27 923	0,20
Vegetables in vinegar	176 028	1,24	Anise badian fennel coriander	26 945	0,19
Grapes	175 325	1,23	Food wastes	26 879	0,19
Crude materials	172 789	1,21	Beverages distilled alcoholic	25 863	0,18
Figs dried	151 546	1,07	Vegetables fresh or dried products nes	25 653	0,18
Cotton lint	146 264	1,03	Milk skimmed dried	25 455	0,18
Cherries	131 001	0,92	Pistachios	23 342	0,16
Olives preserved	126 321	0,89	Flour maize	23 006	0,16
Cotton waste	119 270	0,84	Wool degreased	22 199	0,16
Margarine short	113 255	0,80	Tomatoes peeled	21 745	0,15
Grapefruit (inc. pomelos)	109 924	0,77	Peaches and nectarines	21 668	0,15
Tomatoes paste	102 806	0,72	Onions dry	21 414	0,15
Cereals breakfast	101 523	0,71	Glucose and dextrose	21 391	0,15
Juice fruit nes	101 210	0,71	Pumpkins squash and gourds	21 365	0,15

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Table 1. Continued

Products	Value ($1000)	Share %	Products	Value ($1000)	Share %
Beverages non alcoholic	97 994	0,69	Strawberries	20 442	0,14
Cereal preparations nes	85 386	0,60	Mixes and doughs	19 242	0,14
Sunflower seed	81 084	0,57	Meat pig sausages	18 027	0,13
Vegetables preserved nes	77 719	0,55	Potatoes	17 375	0,12
Chillies and peppers green	77 621	0,55	Fatty acids	17 134	0,12
Cheese whole cow milk	73 016	0,51	Fruit dried nes	17 110	0,12
Fruit fresh nes	70 637	0,50	Bran wheat	13 819	0,10
Fat nes prepared	67 974	0,48	Whey dry	13 716	0,10
Vegetables dehydrated	66 704	0,47	Cocoa butter	13 121	0,09
Beer of barley	64 240	0,45	Peas dry	12 332	0,09
Cream fresh	11 995	0,08	Oil cottonseed	2 710	0,02
Carrots and turnips	11 944	0,08	Animals, live, non-food	2 670	0,02
Vegetables temporarily preserved	11 391	0,08	Skins sheep with wool	2 606	0,02
Watermelons	10 502	0,07	Oil boiled etc	2 591	0,02
Tea	10 367	0,07	Wheat	2 580	0,02
Vegetables preserved frozen	10 234	0,07	Potatoes frozen	2 578	0,02
Fructose and syrup other	9 768	0,07	Straw husks	2 573	0,02
Eggplants (aubergines)	9 310	0,07	Forage products	2 425	0,02
Cocoa paste	9 235	0,06	Juice citrus concentrated	2 365	0,02
Wool greasy	9 029	0,06	Rubber natural dry	2 321	0,02
Cottonseed	9 011	0,06	Broad beans horse beans dry	2 176	0,02
Mushrooms and truffles	8 888	0,06	Juice orange single strength	2 128	0,01
Meat chicken canned	8 837	0,06	Meat beef preparations	2 110	0,01
Wine	8 757	0,06	Beans dry	2 038	0,01
Chestnut	8 647	0,06	Juice citrus single strength	2 037	0,01
Oil soybean	8 092	0,06	Oil palm	1 971	0,01
Sesame seed	8 047	0,06	Spinach	1 595	0,01
Coffee extracts	7 928	0,06	Milk whole evaporated	1 446	0,01
Quinces	7 909	0,06	Milk whole condensed	1 373	0,01
Plums and sloes	7 606	0,05	Buttermilk curdled acidified milk	1 132	0,01
Milk whole fresh cow	5 746	0,04	Juice orange concentrated	1 131	0,01
Oil vegetable origin nes	5 726	0,04	Barley	1 047	0,01
Vegetables fresh nes	5 526	0,04	Beans green	1 035	0,01
Fat liver prepared (foie gras)	5 344	0,04	Juice grape	1 030	0,01
Milk whole dried	5 310	0,04	Onions shallots green	1 016	0,01
Honey natural	5 206	0,04	Juice pineapple	974	0,01
Pears	5 101	0,04	Lactose	972	0,01

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Table 1. Continued

Products	Value ($1000)	Share %	Products	Value ($1000)	Share %
Flour mixed grain	5 084	0,04	Flour pulses	947	0,01
Infant food	5 000	0,04	Milk skimmed cow	918	0,01
Leeks other alliaceous vegetables	4 712	0,03	Pepper (piper spp.)	903	0,01
Cake soybeans	4 508	0,03	Tea mate extracts	812	0,01
Oil rapeseed	4 487	0,03	Plums dried (prunes)	749	0,01
Dates	4 334	0,03	Lettuce and chicory	732	0,01
Meat turkey	4 303	0,03	Pet food	728	0,01
Food preparations flour malt extract	4 297	0,03	Hair fine	720	0,01
Coffee roasted	4 226	0,03	Vanilla	709	0,00
Melons other (inc.cantaloupes)	3 659	0,03	Beet pulp	680	0,00
Chillies and peppers dry	3 489	0,02	Offals sheepedible	664	0,00
Fruit cooked homogenized preparations	3 425	0,02	Meat cattle boneless (beef & veal)	580	0,00
Chickens	3 388	0,02	Milk products of natural constituents nes	548	0,00
Sugar nes	3 260	0,02	Juice tomato	528	0,00
Cabbages and other brassicas	3 237	0,02	Mushrooms canned	499	0,00
Cotton carded combed	3 121	0,02	Vegetables homogenized preparations	488	0,00
Meat nes	3 105	0,02	Skins calve wet salted	459	0,00
Cake cottonseed	3 073	0,02	Skins sheep dry salted	390	0,00
Butter cow milk	3 065	0,02	Fatty substance residues	341	0,00
Bread	3 004	0,02	Garlic	336	0,00
Oil olive residues	2 858	0,02	Cauliflowers and broccoli	295	0,00
Cider etc	289	0,00	Ginger	29	0,00
Meat dried nes	252	0,00	Flour potatoes	26	0,00
Cheese sheep milk	248	0,00	Olives	25	0,00
Wafers	247	0,00	Rapeseed	25	0,00
Groundnuts shelled	241	0,00	Juice grapefruit	24	0,00
Coffee green	241	0,00	Sweet potatoes	23	0,00
Offals liver chicken	236	0,00	Peas green	23	0,00
Sweet corn prep or preserved	205	0,00	Flax tow waste	20	0,00
Canary seed	200	0,00	Cocoons unreelable & waste	18	0,00
Coffee substitutes containing coffee	188	0,00	Roots and tubers nes	17	0,00
Grease incl. lanolin wool	165	0,00	Malt	15	0,00
Oilseeds nes	163	0,00	Bananas	15	0,00
Cashew nuts shelled	150	0,00	Juice grapefruit concentrated	14	0,00
Tallow	141	0,00	Avocados	13	0,00
Walnuts with shell	134	0,00	Pineapples	13	0,00
Oil castor beans	134	0,00	Coconuts	12	0,00

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Table 1. Continued

Products	Value ($1000)	Share %	Products	Value ($1000)	Share %
Offals edible cattle	130	0,00	Alfalfa meal and pellets	12	0,00
Rubber natural	127	0,00	Triticale	11	0,00
Flour mustard	123	0,00	Peanut butter	11	0,00
Horses	120	0,00	Grain mixed	10	0,00
Wool hair waste	109	0,00	Linseed	10	0,00
Meat sheep	97	0,00	Oil linseed	10	0,00
Sweet corn frozen	92	0,00	Mustard seed	8	0,00
Feed vegetable products nes	88	0,00	Pineapples canned	7	0,00
Waxes vegetable	86	0,00	Flour roots and tubers nes	6	0,00
Cake sunflower	79	0,00	Soybeans	6	0,00
Maize green	75	0,00	Beeswax	6	0,00
Germ maize	74	0,00	Jute	5	0,00
Asparagus	72	0,00	Mangoes mangosteens guavas	3	0,00
Nutmeg mace and cardamoms	71	0,00	Flax fibre raw	3	0,00
Cinnamon (canella)	69	0,00	Eggs liquid	3	0,00
Flax fibre and tow	59	0,00	Sorghum	2	0,00
Meat cattle	58	0,00	Oil coconut (copra)	2	0,00
Soya sauce	46	0,00	Papayas	2	0,00
Juice pineapple concentrated	43	0,00	Cocoa beans	2	0,00
Kiwi fruit	43	0,00	Meat pig preparations	2	0,00
Millet	42	0,00	Rye	1	0,00
Cherries sour	41	0,00	Oats rolled	1	0,00
Hides cattle wet salted	40	0,00	Cassava dried	1	0,00
Lard	40	0,00	Cashew nuts with shell	1	0,00
Cloves	38	0,00	Oil sesame	1	0,00
Bran maize	37	0,00	Coffee husks and skins	1	0,00
Coconuts desiccated	37	0,00	Hops	1	0,00
Turkeys	37	0,00	Feed and meal gluten	1	0,00
Molasses	34	0,00	Meal meat	1	0,00
Oats	31	0,00			
Silk-worm cocoons reelable	31	0,00			
Hides nes	30	0,00			
Total			13 605 340 $		95,62%
All Agricultural Products			14 228 600 $		

Note. The products whose export is less than $1000 are not listed in the FAOSTAT databank. This is why the Total on the above list is not equal to All Agricultural Products.

Source of Data: http://faostat3.fao.org/download/T/TP/E [Accessed October 28, 2014]

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APPENDIX 2

Table 2. Growth of the world agricultural markets of Turkey, 2010-2011, and relative market share of Turkey

Products	World Growth %	Relative Market Share	Products	World Growth %	Relative Market Share
Alfalfa meal and pellets	4,03	-9,11	Lentils	-10,26	-1,48
Almonds shelled	16,63	-3,79	Lettuce and chicory	-5,80	-6,88
Animals, live, non-food	12,79	-3,76	Linseed	6,90	-10,08
Anise badian fennel coriander	17,24	-1,97	Macaroni	18,84	-2,17
Apples	10,29	-3,30	Maize	48,31	-6,22
Apricots	5,05	-1,30	Maize green	22,13	-6,69
Apricots dry	4,84	3,41	Malt	11,05	-10,54
Asparagus	4,95	-8,31	Mangoes mangosteens guavas	18,28	-11,14
Avocados	34,22	-11,13	Margarine short	36,93	-1,43
Bananas	9,49	-11,92	Meal meat	9,20	-12,14
Barley	44,96	-7,18	Meat beef preparations	22,12	-5,68
Beans dry	-6,63	-6,08	Meat cattle	27,80	-9,98
Beans green	8,32	-4,86	Meat cattle boneless (beef & veal)	11,85	-8,88
Beer of barley	8,97	-3,45	Meat chicken	20,19	-2,92
Beeswax	33,47	-8,94	Meat chicken canned	19,41	-5,45
Beet pulp	35,58	-4,88	Meat dried nes	20,53	-7,83
Beverages distilled alcoholic	20,20	-5,77	Meat nes	-11,85	-2,50
Beverages non alcoholic	14,46	-3,26	Meat pig preparations	15,93	-12,48
Bran maize	18,23	-7,11	Meat pig sausages	15,13	-3,75
Bran wheat	41,77	-1,88	Meat sheep	6,86	-9,90
Bread	16,48	-5,08	Meat turkey	24,63	-4,81
Broad beans horse beans dry	38,07	-4,02	Melons other (inc.cantaloupes)	-1,95	-4,43
Butter cow milk	9,16	-6,12	Milk products of natural constituents nes	11,77	-6,49
Buttermilk curdled acidified milk	20,70	-5,81	Milk skimmed cow	14,12	-5,05
Cabbages and other brassicas	15,68	-4,39	Milk skimmed dried	21,88	-0,83
Cake cottonseed	31,24	-2,13	Milk whole condensed	19,24	-4,62
Cake soybeans	11,63	-7,70	Milk whole dried	7,13	-6,32
Cake sunflower	39,46	-8,80	Milk whole evaporated	12,72	-5,65
Canary seed	42,97	-6,52	Milk whole fresh cow	21,71	-5,34
Carrots and turnips	15,67	-3,07	Millet	20,79	-6,74
Cashew nuts shelled	32,40	-9,19	Mixes and doughs	15,91	-3,30
Cashew nuts with shell	141,71	-12,48	Molasses	-1,72	-7,50

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Table 2. Continued

Products	World Growth %	Relative Market Share	Products	World Growth %	Relative Market Share
Cassava dried	37,96	-13,79	Mushrooms and truffles	5,23	-3,74
Cauliflowers and broccoli	4,82	-7,05	Mushrooms canned	14,48	-7,04
Cereal preparations nes	72,46	-0,21	Mustard seed	8,79	-9,47
Cereals breakfast	13,13	-1,93	Nutmeg mace and cardamoms	18,23	-8,19
Cheese processed	54,16	-2,31	Nuts nes	35,83	-2,40
Cheese sheep milk	44,48	-6,47	Nuts prepared (exc. groundnuts)	17,21	0,41
Cheese whole cow milk	12,27	-4,16	Oats	39,01	-9,54
Cherries	20,97	-1,23	Oats rolled	23,93	-11,53
Cherries sour	93,29	-6,67	Offals edible cattle	16,50	-8,43
Chestnut	2,81	-2,24	Offals liver chicken	24,54	-6,58
Chick peas	17,22	-1,85	Offals sheepedible	12,51	-5,02
Chickens	18,73	-5,26	Oil boiled etc	38,92	-5,07
Chillies and peppers dry	33,94	-4,96	Oil castor beans	45,53	-8,74
Chillies and peppers green	4,69	-2,71	Oil coconut (copra)	36,90	-13,48
Chocolate products nes	16,41	-2,18	Oil cottonseed	47,24	-2,91
Cider etc	16,70	-6,42	Oil linseed	15,47	-9,39
Cigarettes	17,54	-0,42	Oil maize	89,39	-2,49
Cinnamon (canella)	37,50	-7,47	Oil olive residues	15,51	-4,00
Cloves	134,70	-8,42	Oil olive virgin	9,33	-3,95
Cocoa beans	15,93	-14,23	Oil palm	35,59	-9,09
Cocoa butter	-11,81	-4,40	Oil rapeseed	40,36	-6,57
Cocoa paste	8,81	-4,19	Oil sesame	3,64	-10,47
Cocoa powder & cake	31,94	-3,02	Oil soybean	28,59	-6,46
Coconuts	65,28	-8,69	Oil sunflower	67,96	-2,23
Coconuts desiccated	104,89	-8,96	Oil vegetable origin nes	25,63	-3,58
Cocoons unreelable & waste	12,65	-7,44	Oilseeds nes	13,77	-5,95
Coffee extracts	31,33	-4,92	Olives	166,14	-7,55
Coffee green	51,40	-10,41	Olives preserved	0,84	-1,88
Coffee husks and skins	-43,12	-8,52	Onions dry	-4,11	-3,19
Coffee roasted	39,14	-6,01	Onions shallots green	45,03	-4,42
Coffee substitutes containing coffee	47,97	-5,03	Oranges	6,42	-1,62
Cotton carded combed	27,23	-3,26	Papayas	1,77	-10,05
Cotton lint	46,13	-4,05	Pastry	15,88	-1,67
Cotton linter	-23,26	-1,05	Peaches and nectarines	-4,15	-3,60
Cotton waste	58,37	0,48	Peanut butter	14,92	-8,82
Cottonseed	54,72	-2,95	Pears	8,53	-4,39

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Table 2. Continued

Products	World Growth %	Relative Market Share	Products	World Growth %	Relative Market Share
Cream fresh	25,46	-3,58	Peas dry	34,86	-4,49
Crude materials	21,30	-4,21	Peas green	25,80	-7,63
Cucumbers and gherkins	-0,36	-2,23	Pepper (piper spp.)	47,39	-6,70
Dates	16,32	-3,89	Pet food	11,01	-7,61
Eggplants (aubergines)	4,20	-2,79	Pineapples	11,92	-10,92
Eggs hen in shell	-1,42	-0,90	Pineapples canned	37,93	-11,46
Eggs liquid	14,05	-11,27	Pistachios	-3,96	-3,77
Fat liver prepared (foie gras)	7,75	-2,59	Plums and sloes	12,88	-2,89
Fat nes prepared	41,80	-2,05	Plums dried (prunes)	-1,44	-5,45
Fatty acids	50,94	-4,56	Poppy seed	7,66	0,21
Fatty substance residues	40,25	-4,09	Potatoes	25,68	-4,06
Feed and meal gluten	19,66	-13,53	Potatoes frozen	16,83	-6,34
Feed vegetable products nes	12,62	-6,89	Pumpkins squash and gourds	-12,34	-2,49
Figs	65,11	0,69	Quinces	36,42	0,77
Figs dried	-10,18	1,96	Raisins	11,65	0,23
Flax fibre and tow	11,97	-8,17	Rapeseed	42,21	-12,13
Flax fibre raw	105,28	-7,15	Roots and tubers nes	12,56	-7,40
Flax tow waste	11,72	-7,78	Rubber natural	37,69	-9,90
Flour maize	26,27	-1,82	Rubber natural dry	58,40	-8,53
Flour mixed grain	-24,31	-0,49	Rye	16,14	-11,21
Flour mustard	0,98	-6,59	Sesame seed	9,42	-4,25
Flour potatoes	42,12	-8,97	Silk-worm cocoons reelable	-26,85	-3,56
Flour pulses	55,02	-2,00	Skins calve wet salted	16,90	-5,21
Flour roots and tubers nes	30,28	-8,29	Skins sheep dry salted	47,85	-4,67
Flour wheat	41,65	0,53	Skins sheep with wool	57,50	-5,11
Food prep nes	15,09	-2,11	Sorghum	39,43	-13,10
Food preparations flour malt extract	29,94	-4,94	Soya sauce	12,99	-7,77
Food wastes	21,86	-4,45	Soybeans	13,44	-14,89
Forage products	67,38	-6,05	Spices nes	10,21	-1,74
Fructose and syrup other	15,78	-4,00	Spinach	12,58	-3,84
Fruit cooked homogenized preparations	12,88	-2,44	Straw husks	47,76	-2,70
Fruit dried nes	38,53	-2,90	Strawberries	14,70	-3,42
Fruit fresh nes	28,39	-1,51	Sugar confectionery	13,76	-1,05
Fruit prepared nes	20,92	-1,69	Sugar nes	41,24	-4,28
Garlic	-6,71	-8,73	Sugar refined	21,85	-4,07
Germ maize	56,69	-6,39	Sunflower seed	51,00	-2,17

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Table 2. Continued

Products	World Growth %	Relative Market Share	Products	World Growth %	Relative Market Share
Ginger	2,91	-9,56	Sweet corn frozen	14,09	-6,84
Glucose and dextrose	24,50	-2,92	Sweet corn prep or preserved	9,03	-6,96
Grain mixed	-45,04	-6,47	Sweet potatoes	23,62	-8,11
Grapefruit (inc. pomelos)	0,40	-0,48	Tallow	24,50	-8,91
Grapes	12,97	-2,15	Tangerines mandarins clementines satsumas	10,65	-1,64
Grease incl. lanolin wool	14,63	-5,77	Tea	3,25	-4,96
Groundnuts shelled	69,67	-8,26	Tea mate extracts	11,51	-5,52
Hair fine	-4,31	-4,22	Tobacco products nes	21,70	-2,69
Hazelnuts shelled	24,92	2,13	Tobacco unmanufactured	1,39	-2,05
Hides cattle wet salted	19,53	-10,68	Tomatoes	3,04	-1,58
Hides nes	7,74	-7,71	Tomatoes paste	8,51	-2,22
Honey natural	12,00	-3,76	Tomatoes peeled	4,35	-3,84
Hops	2,05	-12,06	Triticale	-4,13	-7,81
Horses	1,26	-8,17	Turkeys	21,23	-7,49
Ice cream and edible ice	8,98	-2,67	Vanilla	26,76	-4,00
Infant food	12,98	-5,42	Vegetables dehydrated	16,28	-2,81
Juice citrus concentrated	11,61	-3,57	Vegetables fresh nes	1,17	-4,32
Juice citrus single strength	10,24	-3,47	Vegetables fresh or dried products nes	18,12	-0,19
Juice fruit nes	17,72	-1,59	Vegetables frozen	14,13	-3,10
Juice grape	31,68	-5,53	Vegetables homogenized preparations	4,73	-3,10
Juice grapefruit	10,80	-7,44	Vegetables in vinegar	13,82	-0,01
Juice grapefruit concentrated	29,56	-8,14	Vegetables preserved frozen	26,49	-3,30
Juice orange concentrated	123,24	-6,67	Vegetables preserved nes	13,87	-2,65
Juice orange single strength	-7,89	-6,55	Vegetables temporarily preserved	19,68	-2,94
Juice pineapple	9,30	-3,99	Wafers	16,85	-7,16
Juice pineapple concentrated	8,96	-8,55	Walnuts shelled	33,47	-2,83
Juice tomato	45,57	-3,64	Walnuts with shell	32,58	-8,11
Jute	19,00	-10,81	Watermelons	-9,81	-3,21
Kiwi fruit	10,29	-9,76	Watersice etc	12,80	-3,29
Lactose	34,46	-5,98	Waxes vegetable	22,66	-7,14
Lard	44,26	-7,77	Wheat	43,78	-8,37
Leeks other alliaceous vegetables	-6,01	-2,67	Whey dry	31,54	-3,76
Lemons and limes	0,34	-0,18	Wine	15,20	-7,03
Wool degreased	23,52	-2,61			
Wool greasy	32,63	-5,59			
Wool hair waste	20,20	-5,64			

Source of Data: http://faostat3.fao.org/download/T/TP/E [Accessed October 28, 2014]

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Chapter 11
Stakeholder Agriculture:
Innovation From Farm to Store

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ABSTRACT

The shift in agricultural production and agribusiness may be a solution in reducing unemployment and particularly that of young people which is dramatically high in several European countries that are experiencing the negative consequences of the recent global financial crisis that led to a dramatic decline in their GDP per capita and has affected all sectors of economic activity, including agriculture. The overall scope of this chapter is to present an Agricultural Entrepreneurship and Social Innovation Framework that can lead to a new business model with social aspects, contribute to the economic growth and sustainability and hence combat the phenomenon of unemployment and poverty in rural areas that have been seriously affected by the recent financial crisis.

INTRODUCTION

According to UN Global Compact (2016), the world's population is expected to grow to nine billion by 2050 and demand on global food systems intensifies every day, while businesses will be critical partners in designing and delivering effective, scalable and practical solutions for food security and sustainable agriculture. Every actor along the agriculture supply chain, including farmers, traders, retailers, investors and consumers have a role to play in advancing food security protecting the environment and ensuring economic opportunity.

Globally recognized organizations like the UN Global Compact have already ranked sustainable agribusiness among their top priority issues. In this context, in 2014, the Food and Agriculture Business (FAB) Principles were launched by UN Global Compact as a voluntary framework to advance the positive impact businesses can have in the food and agriculture space and engage in principle-based collaboration with the UN, governments, civil society and other stakeholders.

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Focusing on European countries, five decades after the founding of the EU and the implementation of a Common Agricultural Policy, the rural structures of each Member State continue to vary considerably. The main reasons for this variation are the different economic and social-political progress achieved in each member state and the different geographical and climatic data. Thus, for each country the agricultural sector represents a different proportion of their overall economy and contributing differently to the national GDP, employment rates and foreign trade as well as the overall cost of living of the population.

Countries experiencing the negative consequences of the recent economic crisis, of the recent years such as Greece, Cyprus, Spain and Portugal show a dramatic decline in GDP per capita, which has affected all sectors of economic activity including agriculture. In parallel, the agricultural sector in these countries has traditionally been of significant importance to their economies, representing a main economic activity and employment opportunity of a large part of their population, and was relatively higher as a percentage of their GDPs compared to the EU average. It is worth to mention that between 2005 and 2008, the employment rate in the EU, at ages 20-64, rose and reached 70.3%. The trend reversed from 2009 and employment returned to 2006 level at 69%. The following five years employment in EU declined further with an average employment level at 66%, making it very difficult to reach the European target of 75% by 2020 (Eurostat, 2015).

The current lack of sufficient employment opportunities in urban areas, as well as several other obstacles together deepened further youth unemployment in the agricultural sector creating continuous instability guiding to social exclusion and finally poverty. Moreover, farmers have nowadays weak cooperatives leading to the development of individual farming culture that does not support at least a minimum standardization level of their products or farming processes. In addition, the majority of them face overexposure to the financial institutions having difficulties to pay back their loans and as a consequence secure further funding for their future production needs. The limited farming knowledge and absence of formal agricultural training creates further barriers for young people entering the farming sector.,

The shift in agricultural production and agribusiness may be a solution in reducing unemployment and particularly that of young people, which according to the ILO's (2016) World Employment, Social Outlook, in the counties mentioned above it increases continuously and remains dramatically high. To enable such a shift, people, especially young, should be encouraged to remain or return to rural areas and supported to enter the field of agricultural production, which seems to be able to ensure a fair income and provide a chance to young people to build their future with dignity.

There is an urgent need to change the existing and problematic reality. This can be done with the participation of as many as possible players of the production. The creation and support of collective economic rural activities in the form of new, highly-equity cooperatives in the context of social enterprises can create economies of scale and enhance the development of commercial agricultural products by the farmers themselves. These social forms of collective representation bodies and the establishment of regional agricultural chambers can further support rural entrepreneurship, for producers to work together as entrepreneurs. The comprehensive training for farmers arises as a basic need and attending a training course on the "Primary production" can help to de-demonize her.

In addition, the development of an effective network of applied agricultural research to serve farmers in cooperation with the academic community, as well as farming in experimental fields using innovative agricultural applications can contribute to the reversal of the age distribution of farmers. At the same time, the provision of financial support through traditional tools and the development of additional tools of social and solidarity economy, the protection of agricultural means of production, the targeted land

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use, and the rational use of water may result in the long-term growth of domestic self-sufficiency rate and the development of a National Rural Policy that would be feasible to implement.

Recognizing the need to change the above situation, this chapter presents and analyses the theoretical concept of an innovative approach that has been successfully implemented by a multinational company,(and is briefly presented later in the case study), with the involvement of different stakeholders, including representatives of the primary sector (farmers / producers), secondary (retail, manufacturing) and tertiary sector (banking, transport etc.), in an effort to: [a] secure farmers' income through contractual farming, [b] provide appropriate training to farmers, [c] help securing financial assistance for them provided by financial institutions that undertake the guarantee on behalf of them, [d] support the upgrading of technical means and utilities in order to obtain a higher yield per hectare of production, and [e] develop the appropriate channels to put into the market "unique" products in response to the continuously changing demands of increasingly socially sensitized consumers.

The overall scope of this chapter would be to develop an Agricultural Entrepreneurship and Social Innovation Framework (AgrESIF) that can lead to a new business model with the social aspects and contribute to the economic growth and sustainability, and hence combat the phenomenon of unemployment and poverty in rural areas that have been seriously affected by the financial crisis over the last years. The conceptual Framework links four different forces which shape the potential of an AgrESI project and determine its success and effectiveness, namely the relative global trends, the needs of the rural community, the consumers' behavioral trends and the support available by the responsible corporations, taking into account parameters such as stakeholder expectations, micro-financing needs, international initiatives and the set of entrepreneurial skills required.

GLOBAL TRENDS

Sustainable Farming

Farming sustainably means growing crops and livestock in ways that meet three objectives simultaneously, those of i) economic stability and profit, ii) social benefits to the small farm holders, their families and the local community, and iii) environmental conservation. According to Food and Agriculture Organization of the United Nations (FAO, 2014f) sustainable agriculture depends on a whole-system approach whose overall goal is the continuing health of the land and people, in respect to the Principles of Sustainable Farming. Therefore, sustainable farming concentrates on long-term solutions to problems instead of short-term treatment of symptoms.

More analytically, sustainable farming requires economic sustainability, meaning that the small farm entrepreneurs and/or enterprises are consistently profitable from year to year, the family savings or net worth is consistently going up, while the family debt, where occurs, is consistently going down. Also purchase cost of off-farm feed and fertilizer is decreasing and in some cases reliance on customer payments is decreasing.

On the other hand, social sustainability means that more money circulates within the local economy as the small farmers support other businesses and families in the community. The number of rural families is holding steady or potentially is going up (ATTRA, 2003). Consequently, low skilled young people take over their parents' farms and continue farming as well as highly skilled college graduates with studies in relative fields to agribusiness return to the community after graduation.

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Also, environmental sustainability, according to the Millennium Ecosystem Assessment (2005) means that agriculture can be treated as ecosystem management of complex interactions among soil, water, air, plants, animals, climate and people, with the ability to integrate all these factors into a production system that is appropriate for the environment, and as described before, the people, and the economic conditions where the farm is located.

A successful transition from traditional to sustainable farming depends on the farmer's careful monitoring both of progress towards the goals set and of the overall health of the system. Planning and monitoring are particularly important in sustainable agriculture, which relies on natural systems to replace some of the work done by input products like fertilizer and pesticides (ATTRA, 2003). Constant support as the ability to evaluate and re-plan farming procedure according to protocols is vital to the farmer who wishes to farm more sustainably. This transition process should be linked with global trends and international initiatives in order to produce concrete improvements to all stakeholders and mostly to future generations.

The 2030 Agenda for Sustainable Development

Our planet faces multiple and complex challenges in the 21st century. The world's population is expected to grow to nine billion by 2050 and demand on global food systems intensifies every day (UN Global Compact, 2016). 2015 was an important year for the future of agriculture and development. A new set of global Sustainable Development Goals, now on known as "SDGs", will shape the next 15 years of policies, programs and funding (Farming First, 2015). More specifically, on 25 September 2015, the 193 Member States of the United Nations adopted the 2030 Agenda with its Sustainable Development Goals (SDGs), a set of 17 aspirational objectives with 169 targets and many more sub-targets expected to guide the actions of governments, international agencies, civil society and other institutions over the next 15 years (2016-2030).

These ambitious 17 Goals of the 2030 Agenda is a global vision for people, for the planet and for long-term prosperity. They integrate the three dimensions of sustainable development – economic, social and environmental, while at the same time no one goal is separate from the others, and all calls for comprehensive and participatory approaches.

The 2030 Agenda for Sustainable Development is as relevant to developed as it is to developing nations and it charts a plan for the future – shifting the world onto a sustainable and resilient course and leading to transformation. Also, the new 2030 Agenda commits the international community to act together to achieve the Goals and transform our world for today's and future generations.

Agriculture and SDGs

Industrialization drove workers from the fields to the factories with the promise of better opportunities and higher living standards. In employment terms, agriculture accounts for approximately 36% of the global workforce and falling, although the figures mask huge disparities between developed and developing countries (ILO, 2013). For example, according to World Bank (2014) data, in 2010, only around 2% of the US working population was engaged in agriculture, while in India the percentage was approximately 50% and over 80% in Sub-Saharan Africa (including related rural enterprises).

Reaching the SDG targets simply will not be possible without a strong and sustainable agricultural sector (Farming First, 2015). More than any other sector, agriculture is the common thread which holds

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the 17 SDGs together. Specifically, Sustainable Development Goal #2 calls to: "end hunger, achieve food security and improved nutrition and promote sustainable agriculture." To fulfill this goal, the United Nations has identified a series of specific targets (see 2.1-2.5), as well as the means of implementation (see 2.a-2.c) for reaching them.

Specific target 2.1 aims by 2030, to end hunger and to ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round. Tackling hunger is not only about boosting food production; it's also about increasing incomes and strengthening markets so that people can access food, even if a crisis prevents them from growing enough themselves (United Nations, 2015).

Specific target 2.2 aims by 2030, to end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women and older persons (United Nations, 2015).

According to the Farming First plan, (a coalition of multi-stakeholder organizations developed as a joint call to action in response to the global challenges posed at the 2009 United Nations Commission on Sustainable Development), agriculture can play an important role to address malnutrition in three ways:

1. Biofortified foods, such as vitamin-A enriched rice or sweet potatoes, are bred to have higher amounts of micronutrients and can help provide essential vitamins and minerals;
2. Micronutrient-enriched fertilizers improve soil fertility, helping to support higher yields of more nutritious food and can combat micronutrient deficiencies in humans;
3. Improved agronomic practices can also help, for instance, crop rotation and conservation tillage by encouraging food diversity and preventing nutrient depletion of soils.

Specific target 2.3 aims by 2030, to double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value added and non-farm employment (United Nations, 2015).

Agricultural development is inextricably linked to economic growth that benefits the poor. In fact, the World Bank (2016) has estimated that agricultural development is about two to four times more effective in raising incomes among poorer than growth from any sector (and up to 11 times more effective in sub-Saharan Africa). Also, increased productivity, when coupled with better access to markets, can help address hunger directly at the farm level or provide sufficient additional income to buy food at the market. Boosting rural incomes and ensuring ample employment means looking at economic opportunities across the entire rural value chain, from farmers and input suppliers to value-added processing and services, such as transporting and marketing of food (Farming First, 2015).

Specific target 2.4 aims by 2030, to ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality (United Nations, 2015).

Agriculture is more vulnerable to climate change than any other sector. A warming climate could reduce crop yields by more than 25%, according to the. Agriculture and land use change are also responsible for between 19–29% of global greenhouse gas emissions (United Nations, 2015). But the sector can also help to substantially mitigate against future greenhouse emissions, especially by increasing

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productivity of land already under cultivation and thus reducing deforestation. A higher price of carbon can help incentivize agriculture's mitigation potential. More productive farms also tend to use less water per unit of crop produced. Innovations such as drip irrigation can also improve agriculture's water use efficiency while still supporting higher productivity.

Reducing food waste is another area which can improve the sustainability and resilience of the agricultural sector. A recent report by WRAP (2015) estimated that one third of all food produced is never consumed, at a total cost as much as $400 billion a year and 3.3 billion metric tons of greenhouse gases being released annually, about 7% of the total emissions. Reducing food waste by 50% globally could save $300 billion a year by 2030 and could feed as many as a billion people. By 2030, this consumer, food waste could cost as much as $600 billion a year, unless we act now to address this problem (Reuters US, 2015).

Specific target 2.5 aims by 2030, to maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed (United Nations, 2015).

Increasing agricultural productivity means that we can produce the food our global population needs while keeping as much other land as natural habitat where biodiversity can flourish (instead of using land more extensively for agricultural and biodiversity simultaneously). Smallholder farmers play a key role, as they hold as much as 75% of the global seed diversity in staple food crops, with the rest being held in gene banks. Urgent action will be needed, since as much as 10% of the biodiversity seen in 2000 may be lost by the year 2030, resulting from land lost to infrastructure as well as from agriculture and climate impacts (EurekAlert, 2015).

More than just its direct impact on hunger and malnutrition, global food system and agriculture are also linked to many global trends and consequently too many of the 17 SDGs.

SDG #1 aims to "end poverty in all its forms everywhere"(UNSDKP, 2015). Growth in agriculture is at least twice more effective in reducing poverty than from any other sector, taking into account that rural people represent the largest segment of the world's extreme poor by far contain more than 70% of the total (Farming First, 2015).

SDG #4 aims to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all"(UNSDKP, 2015). Agriculture extensions enable farmers to access to the skills, tools, inputs and knowledge they need to thrive. Investment in agricultural extension services yields 80% annual rates of return and can help farmers to double their crop yields(Farming First, 2015).

SDG #5 aims to "achieve gender equality and empower all women and girls" (UNSDKP, 2015). Women produce over half the food globally, so bridging this gap could reduce global hunger by as much as 17% according to Farming First plan. Given equal access to recourses as men, women would achieve the same yield levels, boosting total agricultural output in developing countries by 2½ - 4%. This additional yield could reduce the total number of undernourished people in the world by 100-150m or 12-17%(Farming First, 2015).

SDG #6 aims to "ensure the availability and sustainable management of water and sanitation for all" (UNSDKP, 2015). By 2030, global water demand will increase more than 50%, with agriculture alone requiring more than what can be sustained to feed the world even before domestic and industrial needs are met(Farming First, 2015).

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SDG #7 aims to "ensure access to affordable, reliable, sustainable and modern energy for all" (UNSDKP, 2015). By 2030, energy demand is expected to increase as much as 50%, driven mostly by developing world demand. Crops are more likely to be diverted for use as biofuels, doubling or even tripling as a proportion of total use(Farming First, 2015).

SDG #8 aims to "promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all" (UNSDKP, 2015). Agriculture is an engine of pro-poor economic growth in rural areas. Entrepreneurship across the rural and food sectors can generate employment and growth. More specifically, according to the data from Farming First plan, 85% of farmers are small holders, who have less than two hectares of land. Also, 43% of the agricultural laborforce in developing countries are women. Moreover, 70% of the youth aged 15-24 in sub-Saharan Africa and south Asia live in rural areas, and they are twice as likely as adults to be unemployed(Farming First, 2015).

SDG #12 aims to "ensure sustainable consumption and production patterns" (UNSDKP, 2015). Nowadays around one third of the food produced is wasted. At the same time average per capita consumption is expected to grow through 2030, despite population increases (Farming First, 2015).

SDG #13 aims to "take urgent action to combat climate change and its impacts" (UNSDKP, 2015). By 2030 agriculture's carbon mitigation potential could reach as much as 7,5% of total global emissions, depending on the price of carbon and adoption of agricultural productivity measures (Farming First, 2015).

SDG #15 aims to "protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss" (UNSDKP, 2015). Improving the efficiency of farmland can help meet world's growing consumption demand while minimizing the loss of natural habitats and forests for additional cultivation (Farming First, 2015).

As derived from the above, there are significant interactions between SDGs.Staying with the food SDG example, a commonly discussed set of interactions lies in the "nexus" between food, water and energy (Weitz et al. 2014). More specifically, vital for agriculture, water is also required for energy production in cooling thermal power plants and generating hydropower.In addition, energy is required for water pumping and irrigation systems and at the same time water is needed for irrigating agriculture. Finally, according to the ICSU (2016), there are also competing resource requirements, forexample; food production may compete with bioenergy production for the same land or water. All these factors create an active debate in the coming years upon solution space in terms of governance measures or technological options that could transform negative interactions into more positive ones.

LOCAL RURAL COMMUNITY NEEDS

It is widely agreed that in order to avert future food crises, agricultural productivity must be increased in ways that are sustainable, resilient and conducive to rural development and poverty reduction. While the world's cultivated land areas have grown by 12 per cent over the past 50 years, agricultural production has roughly tripled owing to significant increases in the yields of major crops (FAO, 2009).

At the same time, much of the agricultural expansion has been at the expense of forests: between 2000 and 2010, 13 million hectares of forests were lost each year through conversion to other land uses (FAO, 2010). However, forests are crucial for sustainable agriculture as they protect soils, regulate water flows, serve as gene pools and maintain a healthy climate. As a result, agriculture productivity growth is slowing down in many parts of the world.

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Family farmers produce at least 56 per cent of all agricultural production worldwide (FAO, 2014a). With supportive, stable policies and greater participation in policy processes, smallholder farmers can respond positively to policy and market opportunities. To realize the full potential of smallholder agriculture, there is a need to remove the constraints that limit its investment capacity. Responsible investments in agriculture are a top priority from the perspective of both donors and recipients (FAO, 2014b).

The first objective is to support investments by smallholders themselves, but their capacity to do so depends on other related investments in collective action, in public goods and supportive rural infrastructure (UNSG, 2014). Secondly, investment in agricultural knowledge, science and technology can contribute to substantial increases in agricultural production over time. Increases in productivity can also contribute to a net increase in global food availability per person and general food security (FAO, 2011).

Also, according to FAO's (Food and Agriculture Organisation of the United Nations) publication under the title "Deep Roots" on the occasion of the appointment of 2014 as International Year of Family Farming (FAO, 2014c), with the expertise of companies and brands that often are the main customers of smallholder farmers and resources of several indirect partners, such as creditors or distributors of their products, smallholder farmers can be supported to achieve better yields, reduce their losses after the harvest, and improve the quality of their staple crops (FAO, 2014d).

Moreover, efforts to gather and share lessons on effective approaches to connect smallholder farmers with markets in a sustainable way and share them widely with stakeholders, as well as investment in smallholder farmers capacity-building are considered necessary for agricultural development in local rural areas (WFP, 2015).

Furthermore, post-harvest handling, storage and transportation of the products, should be reexamined in order to obtain yield sustainable results and boosting local and even national food security over the long term (FAO, 2013).

Generally, investments in infrastructure work better if they support the models of production and markets that are appropriate to smallholder farmers and, furthermore, these investments would need to be bolstered by measures to secure tenure rights (USAID, 2014).

CONSUMERS' BEHAVIORAL TRENDS

During the last decades, a new model of consumption can be seen mostly in wealthy capitalist nations around the world (Lewis & Potter, 2011). Ethical consumption has become an umbrella term covering a wide range of concerns from animal welfare, labor standards and human rights to questions of health and wellbeing and environmental and community sustainability (NRI, 2001).

One of the first polls for the issue by Global Market Insite across 17 countries, including the USA, Australia, Japan, China, India and various European countries, found that 54 per cent of online consumers would be prepared to pay more for organic, environmentally friendly, or Fair Trade products (Horne et all, 2016).

On the one hand, negative modes of campaigning such as boycotts emerged in the nineteenth century continued as global brand-based activism into the twentieth, and on the other hand the shift in the consumer behavior with the development of the general idea of combining ethics and shopping that become

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a mainstream concept especially in developed countries, guide to the conclusion that if consumers cared about moral issues, then companies and brands that did the right thing would have a larger market share.

Especially for agricultural products ethical consumers purchase those products that minimises social and/or environmental damage, while avoiding products deemed to have a negative impact on society or the environment. But most importantly consumers across the globe are growing increasingly concerned about the origins of the food they eat. Interest in the food safety, local food economy, environmental impacts, and the complexity of the entire food supply chain, has led to the creation of new categories and labels to differentiate food products, such as "bio", "ethical" or "green" (AAFC, 2013)

These developments in consumer behavior can be seen as opportunities for companies, but also farmers as ethical products are expected to see increased demand in the near future as environmental awareness amongst consumers continues to grow. This trend is expected to be seen in nearly all product categories and will have a significant impact on the food sector, as already organic items seeing particularly increased demand (AAFC, 2013).

Within the ethical foods market, manufacturers need to earn customer trust through transparency and wider recognized labels that will promote on a larger scale the overall potential benefits of these products.

Organic foods that were once reserved for niche markets are now becoming more mainstream and with increased exposure and competition. Due to increasing demand and growing availability, unit prices for organic food are expected to decline over the next couple of years, giving the consumer more buying power and subsequently boosting sales(AAFC, 2013).

Fair trade is an alternative approach to conventional trade and is based on a partnership between producers and consumers. Fair trade can make a difference helping producers build sustainable livelihoods, diversify their businesses, and even reinvigorate entire sectors of production (Fairtrade, 2014).

Products that are marked as 'fair-trade' are gaining popularity among today's consumers, although not as quickly as some other ethical food categories, although consumer demand for low prices is seen as a persistent obstacle to market growth by fair trade producers(AAFC, 2013).

At the same time there is a strong need for consumer education regarding ethical products. The lack of international standards, limited product availability in most cases and falsified or inconsistently defined claims happen in the past have created an overall mistrust of ethical labels, so companies and brands will have to invest in earning again consumers' trust by bringing transparency and traceability characteristics of their products. Consistent, clear, and commonly adopted definitions for claims such as "sustainable", "ethical", "fair trade", "carbon neutral" or "social product" would reduce consumer skepticism and increase market potential. According to OECD (2008) study on best Practices in developed countries members of the organization, consumer education as to what these labels represent would also empower consumers to choose products that address the issues of most importance to them.

Last but not least consumer education should also focus on reduction of food losses and waste. Given that many smallholder farmers in developing countries live on the verge of food insecurity, a reduction in food losses in those countries could have an immediate and significant impact on their livelihoods. According to FAO (2014e), if food losses and waste could be halved, the required increase of food available to feed the world population by 2050 would only need to be 25 per cent, and not 60 per cent as currently projected. Considering its nature and causes, halving food losses and waste could be a feasible target based on technical, economic, environmental and social considerations.

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RESPONSIBLE CORPORATIONS' INITIATIVES AND SUPPORT

The last few decades of globalisation have generated unprecedented growth but also unprecedented levels of inequality. According to Oxfam's (2014) estimates, one percent (1%) of the world's population will soon own more wealth than the other 99% and the richest 85 people on the planet as much as the poorest half of humanity.

With citizens nowadays demanding responsible business behavior from all kinds of organizations corporations and their leaders (Antonaras et al, 2011) are accountable not only for their specific responsibilities in terms of consultation, impact assessments, benefits and grievance mechanisms but also in relation to wider approach on sustainable development. Galinski argued that having a moral compass leads to more effective business practices — whether in building sales, retaining employees, or reducing litigation and regulation costs (as sited in Antonaras& Memtsa, 2009). It is clear that there is some sort of a relationship between business ethics and business success, or better sustainable excellence (Antonaras& Memtsa, 2009).

In this direction, the 2030 Agenda for SDGs expect both direct and indirect contribution from the business. Direct, through financing and partnering on SDG related projects (e.g. infrastructure) where business will be called upon to invest more in developing countries, or in poor rural areas in developed countries. Indirectly, through an increase of business activity emphasizing on equitable economic growth as a driver for development implies a significant global expansion in the private sector itself. Developing countries as well as rural areas of developed countries need businesses to create more jobs, move people out of poverty and contribute to local problems and needs.

The SDGs clearly prioritize both employment and development. For the agriculture sector this is a long-term balance endeavor with the use of the benefits of agricultural technology and mechanization for greater efficiency on the one hand, while on the other make efforts to avoid potential losses in employment that will affect smallholder farmers and their families.

AGRICULTURAL ENTREPRENEURSHIP AND SOCIAL INNOVATION FRAMEWORK

Taking into consideration all the above forces, a theoretical framework on developing Agricultural Entrepreneurship and Social Innovation (AgrESI) projects (or even businesses) is presented in an effort to provide a simplified model approach and positively influence interested parties in getting involved in such projects. The conceptual framework links the four different forces which shape the potential of an AgrESI project and determine its success and effectiveness, namely the global trends, the needs of the rural community, the consumers' behavioral trends and the support available by the responsible corporations.

It seems that these forces contribute significant input in designing an AgrESI project that will assist people in rural areas to participate in entrepreneurial initiatives, enable organizations to align their CSR related activities to the needs of this vulnerable group taking into account the changing trends in consumer behavior and attempting to respond to the global trends for sustainability as they are expressed, among others, through the 2030 SDGs.

The framework also takes into consideration several other factors such as: the stakeholders expectations and the willingness of responsible corporations to support an AgrESI project, the entrepreneurial

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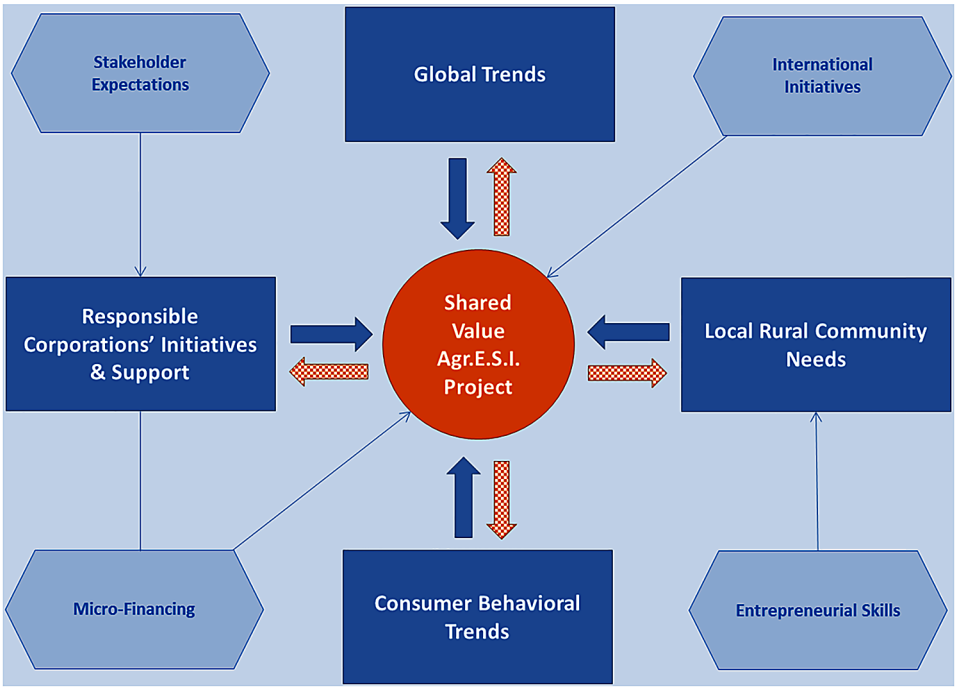
skills needed by the people in rural communities in order to ultimately manage the new agri-business, the experiences from similar international initiatives, and the need for micro-financing in order for the new agribusiness to grow and emerge into a sustainable businesses.

Figure 1 below graphically depicts the theoretical framework for agricultural entrepreneurship and social innovation.

The checkerboard arrows indicate that once an AgrESI project is effectively designed and implemented it will soon return value back to the four forces of the framework, in other words it creates shared value. The organizations involved may receive back part of their investment as dividends from their participation in the new agribusiness and benefit from the increased social value that their participation in the AgrESI project will create. Consumers will receive better and high quality products as a result of their preference and demand for products that comply with strict social and environmental criteria. The local rural community will receive the direct value resulting from the new workplaces that will be developed for the local people as a result of the AgrESI projects. Finally, the implementation of AgrESI projects will gradually shape the national trends for sustainable development which in their turn will influence the relative European and international trends.

As explained, the successful initiation of an AgrESI project needs to ensure that stakeholders' expectations are managed, appropriate support, both financial and in kind, is available, and people involved acquiring the necessary entrepreneurial skills and utilize the experiences from similar international initiatives. The significance and importance of these parameters for an AgrESI project are explained below.

Figure 1. Agricultural Entrepreneurship and Social Innovation Framework (AgrESIF)



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Stakeholder Expectations

The adoption of CSR by enterprises is an ongoing process of learning and change. The key issue is to realize their role in the modern socioeconomic environment and to mobilize in adopting CSR initiatives which will assist them in taking a preventative approach to new developments and the new market requirements.

In order to do business sustainably, companies musthave good knowledge and strengthen their reflexes towards all the actors around their sphere of activity. Identifying their stakeholdersis the first step, followed by a second which is to prioritize them, so as to identify therelevancy of their modes of interaction and the relative risks. This practical approach is a core part of CSRpolicies.

Stakeholders whether they act as individuals or groups of individuals they have an impact on the one hand or they are affected on the other by the activities,products or services of a company.Stakeholders cover a wide variety of actors, such as employees and their representatives; customers and consumers; public authorities; national and local communities; Governments, professional organizations, public and international organizations; civil society and NGOs; suppliers and the wider supply chain; media and press; investors and rating agencies; the wider financial community and others.

According to CSR Europe's (2008) Toolbox for Proactive Stakeholder engagement, community involvement and development, promote communication and positive relations between a company and local stakeholders. It facilitates acceptance of corporate activities by the local population. It creates the base and opportunities for synergieswith local decision-makers, who become more positive to support the company in case of difficulty, thus facilitating the long-term sustainability of its activities within the country. In certain delicate contexts, it also tends to reduce incidents and tension, thus preventing provocation and security risks.

A main stakeholder group of a food and agriculture corporation are the small farm holders that act at the same time both as suppliers offering their products, but also at the same time as members of the local community that offers to the corporation the "social license to operate".

When farmers act as a group of individuals and part of the local rural community face sometimes problem to communicate or express their wishes exposingdemands as a shopping list where they ask everything and anything. Businesses have a duty therefore not only to listen, but several times to train local communities in the dialogue process. Also, small farm holders and family farmers, both women and men are the main investors in their own rural community and play a vital role in the sustainability of the community itself but also in the sustainability ofthe food value chain and systems.

Moreover, organizationsrepresenting farmers and their families should strengthen the capacity of those they represent to invest responsibly through provision of assistance in order for farmers to gain improved access to inputs, extension, advisory, specialized financial services, specific education, dedicated training, and access to final consumersthrough retailers including supermarkets.

Equally, according to the CFS's (2014) Principles for Responsible Investment in Agriculture and Food Systems, corporations involved in agriculture and food systems are encouraged to inform and communicate with other stakeholders, conduct due diligence before engaging in new arrangements, conduct equitable and transparent transactions, and support efforts to track the supply chain.

Furthermore, according to the above mentioned Principles processors, retailers, distributors, input suppliers, and marketers are encouraged to inform and educate consumers about the sustainability of products and services and respect national safety and consumer protection regulations. Enterprises in-

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volved in the marketing of food products are encouraged to promote the consumption of food which is balanced, safe, nutritious, diverse, and culturally acceptable, which in the context of this document is understood as food that corresponds to individual and collective consumer demand and preferences, in line with national and international law, as applicable.

Last but not least the role of workers in agriculture and food systems is vital.Workers and their organizations play a key role in promoting and implementing decent work, thereby contributing to efforts towards sustainable and inclusive economic development.

Finally, consumer organizations can contribute to the implementation of a new sustainable oriented agreement in the agriculture and food systems by informing and educating consumers about products, farmers, companies and other players about the followed methods with them towards a safer food system that will be able to feed also future generations with dignity.

Entrepreneurial Skills

As mentioned above, the successful implementation of an AgrESI project requires the involved people in rural communities to acquire the appropriate entrepreneurial skills in order to ultimately manage the new agribusiness. People in many rural areas, especially young people, are not only lacking farming and agricultural knowledge and experience, but also lack entrepreneurial and business skills. Potential agribusiness entrepreneurs need to develop a set of skills that will enable them to identify a problem, develop a solution and provide evidence of value for that solution. Therefore, they need to possess appropriate entrepreneurial skills including observation and experimentation skills, creativity and critical thinking skills, communication skills, integration and problem solving skills. In addition, they need to demonstrate commitment against the initiative itself and the other stakeholders involved in the AgrESI project initiative.

According to the Entrepreneurial Learning Initiative (2016)an entrepreneurial mindset can empower ordinary people to accomplish extraordinary things. It can empower people from all walks of life, from every background, culture and discipline. And the implications of entrepreneurial mindset, education reach far beyond enterprise creation.

Entrepreneurship is a mindset that can empower ordinary people to accomplish the extraordinary. Entrepreneurial success does not require revolutionary new ideas (Taulbert& Schoeniger, 2010) but the appropriate skills. After all, entrepreneurs come in all shapes and sizes and their impact extends far beyond the creation of new ventures. Policy makers from the White House to the World Economic Forum have begun to recognize the power of entrepreneurial thinking in all aspects of our increasingly interconnected, globalized societies, including the public, private, academic, and non-profit sectors.

So the challenge for any AGrESI project is to ensure that people to be involved in the new agribusiness initiative should acquire this entrepreneurial mindset. This can be done in cooperation with universities and business incubators that possess the knowledge and the resources to transfer it to the people in the rural areas.

Micro-Financing or In-Kind Support

The majority of the world's population is poor, subsisting on $2-3 per day. Although, according to the UNDP (2009), over 500 million of the world's poor are economically active earning their livelihoods

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by being self-employed or by working in farms and microenterprises. Poor people constitute the vast majority of the population in most developing countries. Moreover, an overwhelming number of the poor around the world continue to lack access to basic financial services. In the contrary, developed countries despite the global economic crises that increase dramatically financial inequalities and the amount of poor, continues to seemicrofinance as a marginal financial product with high risk. In order to achieve its full potential of reaching a large number of the poor, microfinance should become an integral part of the financial sector. According to the Key Principles of Microfinancing launched by CGAP (the Consultative Group to Assist the Poor) (2004) financial sustainability is necessary to reach significant numbers of poor people, while sustainablemicrofinancing is about building permanent local financial institutions.

A study of IFAD (2010) describes ways that lack of formal credit affects rural poverty and encourages indigenous financial arrangements to take the place of missing formal finance. Limited access to credit is linked to low technology, agricultural production systems and to people working as an unpaid family labor rather than in self- or wage employment (Meyer, 2011).

Microfinance could be seen as a sustainable mean of poverty alleviation leading to lasting, sustainable development.This development should also be a holistic one covering all aspects of livelihood of small entrepreneurs including small farm holders. From the economic aspect a small amount of financial support in a form of loan helps reduce desperation and anxiety while at the same time allows farmers to make more effective investment choices. Having a limited, butstable income, they can then begin savings with cultivating costs and looking forward to expand their business and eventually becoming more financially secure. From the social aspect microfinancing could help the entire local rural community if the support is given as a program that brings farmers together in groups, enabling them to support each other. Cooperation and trust within the groups strengthens over time and can lead to improved decision making in the wider community. At the same time, for each farmer as an individualto receive a small financial support through a small loan is not just an economic or financial transaction. It is a significant personal moment where each farmer is trusted again and feel valued for his/her family and for the wider community. Also, microfinancing can produce a multiplier effect as in several cases, receivers of small loans become more eager to provide small loans to others especially within their local community.

Given the limited availability of agricultural credit, marketing arrangements that integrate financial services help smallholder farmers participate in markets. Supermarkets, input supply companies and traders often offer inputs on credit as a way to develop preferred supplier relationships with small farmers (Meyer, 2011).Other innovative approaches for supporting individual farmers shouldnot be limited only to financial microloans but also extend to other kinds of support taking into account and assessingeach farmer's needs, character, standard of living, educational level, financial status, repayment capacity, and personal values and vision.

In more detail, individual support could be provided to farmers by other players in the wider value chain by linking them to suppliers with high-quality seeds and fertilizers and negotiating prices on their behalf. Another kind of support could be the provision of formal and informal education in good farming practicesand crop-specific training,provided by experienced and expert agriculturists and relative scientists. Also, providing smallholder farmers with necessary funds to pay the required tuition fees for their children in order to acquire the necessary agricultural education and return back home, could also be seen as an overall investment with high level of long-term return.

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Additionally, a way of support could be to link farmers with buyers,assisting them through packaging, labeling and traceabilitytechnology in orderto obtain better market prices. Technology is also a vital success factor. Supportingsmallholder farmers with technological equipment may result to increased efficiency and cost reduction through field-based data collection and proactive management of meteorological changes. Furthermore, empowering women to participate in the farm work through support and on the job training to strengthen their ability to participate in income generation and to better protect their families against loss from unforeseen events as small harvests or bad weather conditions.

Finally, assistance either financial through micro loans either in kind through support can be the solution for smallholder farmers in order to improve their lives of themselves and their families, under the provision that farmers are not bound by unilateral contracts.

International Initiatives

Small scale farmers need support to ensure they are not perpetuating the kinds of practices the SDGs seek to eliminate: as child labor, exploitation of girls and women, or use of forced labour, issues covered by the 10 Principles of the UN Global Compact that is followed in a voluntary basis by thousands of companies lots of them involved with the agriculture sector.

UN Global Compact is the world's largest voluntary corporate sustainability initiative. It was launched in 2000, as a call to companies around the world to align their strategies and operations with universal principles on human rights, labor, environment and anti-corruption, and take actions that advance societal goals. On May 13th, 2014 the UN Global Compact launched the Food and Agriculture Business (FAB) Principles (2014), following a two-year consultation process with over 1,000 businesses, UN agencies and civil society organizations engaged in agriculture, food and nutrition systems. The six FAB Principles aim to help realize sustainable development and empower businesses to contribute to the post-2015 development agenda. The principles were introduced in Rome, Italy, on 13 May 2014.

The Principles respond to calls from the UN Conference on Sustainable Development (UNCSD, or Rio+20) for sustainable development of food production through increasing local investments in a responsible way, reducing waste and the use of water in supply chains and ensuring access to local and global markets. The FAB Principles are the first set of global voluntary business principles ofthe food and agriculture sector, and are designed to serve as umbrella principles that complement existing initiatives on agriculture and food sustainability.

UN Global Compact (2014) business participants in the food and agriculture sector are invited to take an additional, voluntary step to embrace a set of Food and Agriculture Business Principles (see Table 1) and report annually on their progress.

The Principles are aimed at companies in food and agriculture sector wanting to act responsibly and could be followed by all farmers and agribusinesses – regardless of size, crop or location – as a principle-based commitment and as a framework to show their overall orientation toward corporate sustainability.

Also in 2011, the OECD Declaration on International Investment and Multinational Enterprises, known as OECD Guidelines, that provide an open and transparent international investment environment to encourage the positive contribution of multinational enterprises (MNEs) towards economic and social progress, were revised.The OECD Guidelines are the most comprehensive set of government-backed recommendations on what constitutes responsible business conduct (RBC). They cover nine major areas

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Table 1. Food and agriculture business principles

Principle	Requirement
Aim for Food Security, Health and Nutrition	Businesses should support food and agriculture systems that optimize production and minimize waste, to provide nutrition and promote health for all people.
Be Environmentally Responsible	Businesses should support sustainable intensification of food systems to meet global needs by managing agriculture, livestock, fisheries and forestry responsibly. They should protect and enhance the environment.
Ensure Economic Viability and Share Value	Businesses should create, deliver and share value across the entire food and agriculture chain from farmers to consumers.
Respect Human Rights, Create Decent Work and Help Communities to Thrive	Businesses should respect the rights of farmers, workers and consumers. They should improve livelihoods, promote and provide equal opportunities.
Encourage Good Governance and Accountability	Businesses should behave legally and responsibly by respecting land and natural resource rights, avoiding corruption, being transparent about activities and recognizing their impacts.
Promote Access and Transfer of Knowledge, Skills and Technology	Businesses should promote access to information, knowledge and skills for more sustainable food and agricultural systems.

of RBC: information disclosure, human rights, employment and industrial relations, environment, bribery and corruption, consumer interests, science and technology, competition, and taxation. (OECD, 2015). Large corporations in the area of food and agriculture should take into account these principles when cooperate in the global environment, especially through their supply chains in rural areas of developing countries.

In addition, the Committee on World Food Security (CFS) endorsed on 15 October 2014 at its 41st session the Principles for Responsible Investment in Agriculture and Food Systems, known as CFS-RAI Principles (2014). The principles contain ten core principles related to: food security and nutrition; sustainable and inclusive economic development and poverty eradication; gender equality and women's empowerment; youth; tenure of land, fisheries, and forests and access to water; sustainable management of natural resources; cultural heritage, traditional knowledge, diversity and innovation; safe and healthy agriculture; inclusive and transparent governance structures, processes, and grievance mechanisms; impacts and accountability. An additional section describes the roles and responsibilities of stakeholders.

The objective of the Principles is to promote responsible investment in agriculture and food systems that contribute to food security and nutrition, thus supporting the progressive realization of the right to adequate food in the context of national food security (CFS, 2014).

All the above mentioned volunteer frameworks and principles are addressed to corporations that accept the concept and principles of CSR and recognize the vital role of sustainable development. CSR has a twofold importance. It relates both to their stand-alone / autonomous operation and contribution to the social and natural environment in which they operate, and to their relationship with larger businesses whose suppliers, subcontractors or associates they are. As a result of this twofold importance is that in most cases businesses as part of wider value chains are invited by major clients to operate under specific frameworks and to adopt CSR initiatives to ensure their existing cooperation.

The main aim of businesses operate in the food and agriculture sector is being able to evaluate their priorities and risks and incorporate CSR principles into their own policies, strategies and everyday way of work and thus capitalize on the advantages this approach could bring both in terms of improved competitiveness and maintain sustainable in the future.

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THE McCAIN CASE

The Company

Founded by farmers, McCain became a global business, operating under three core values: authenticity, commitment and trust that guide its behavior and business interactions. McCain builds close, long-term relationships with local farmers – some of them are suppliers for three generations – in several markets that operates. McCain focus on Good Food, Good People and Good Business, setting standards for all its operations. Company's involvement is mostly driven, locally and managed by the individual regions, so the support can take many forms such as transfer of knowledge and expertise to growers, donation of products and services, sponsorships that inspire broad participation towards worthwhile goals and, sometimes, direct financial support.

The company supports social business and in 2013 McCain signed an alliance with Nobel Peace Prize Laureate, Muhammad Yunus, to kick-start the 'Campo Vivo' project. This was the first South American joint venture between a multinational company and the Yunus Social Business and the project's aim is to improve the quality of life of Colombian farmers. Campo Vivo benefits underprivileged farming families in Colombia who face many challenges. Some lack the necessary land or resources to produce crops and many farmers have been displaced by the armed conflict in the country. By providing education and support services via the Campo Vivo Cultivation Center of Excellence, the project helps them to successfully develop commercially viable potato, carrot and pea farming businesses in a fair and sustainable way (McCain, 2016).

In addition to local community support, the company funds The McCain Foundation – a philanthropic organization, largely supporting initiatives in the Atlantic provinces of Canada where McCain Foods was founded. The McCain Foundation has five areas of support; arts & culture, community projects, health & wellness, education and environment.

"Karpos Frontidas": An Initiative for Social Product Creation

In 2013, McCain decided to enrich its Corporate Social Responsibility strategy with new innovative approaches and initiated a consultation process with key stakeholders in three European countries (Germany, Greece and Poland) in order to choose the country from which it would start its efforts based on the conclusions of the open dialogue with its stakeholders.

The result of the stakeholder dialogue conducted in the three countries led to the launch of an ambitious intervention in Greece in order to assist local rural farmers to overcome the difficult economic situation in the country, due to the global financial crisis, and in an effort to help them remain at their places, and continue to support their families, local society and country at large.

As a result of that stakeholder engagement process (see: AgrESI - Stakeholder expectations), in 2015, McCain in collaboration with CSR HELLAS –a Greek non-for-profit business driven network for the development of business responsibility and sustainability – created a unique product in the category of fresh vegetables, and especially potatoes. Through this initiative, McCain aims to support Greek small farmers and unemployed young people who returned back to their birthplaces as a result of the high-level of unemployment rates in the cities, in order to get involved with the cultivation of fresh potatoes. "Karpos Frontidas" project is the first pilot step essential for the multiplication of the approach in other

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products, regions and countries. It also acts as a consumers' awareness approach in order to buy responsibly, yet sustainably.

The project initiates a new relationship between the company and poor farmers living under the poverty line. McCain safeguards the income of farmers through contractual agreements while at the same time is trying to equip them with entrepreneurial skills (see: AgrESI -Entrepreneurial skills)in order to develop the appropriate entrepreneurial mindset.It also provides training, technical means and farming know-how(see: AgrESI - Micro-financing or in-kind support) so as small farmers cultivate potatoes of high quality, as well as gain access to the market under the label of a new social product that has been grown according to the principles of sustainable agriculture (see: AgrESI -International initiatives).

Also, taking into consideration that the new product is grown with special care for the environment and the consumer needs and demands (see: AgrESI -Consumers' behavioral trends), and that it secures a better income for the farmers, this product aims to become the first Social Product in the market of fresh vegetables originated by Greek small poor and underprivileged farmers.

Several other businesses operating within the context of CSR and in order to safeguard their sustainability (see: AgrESI -Responsible corporations' initiatives and support),were invited to cooperate with McCain for the successful implementation of the project. Primarily, as mentioned before McCain (2016b) has the project coordination, while CSR HELLAS acts as consultant on socioeconomic issues. Program integration obtains partially the support of a global ethical investment fund, well known for its support of Greek people and organizations of wider civil society during last years' financial crisis. The provided support from the foundation aimed at strengthening organizations that exhibit strong leadership and sound project management and that can bring considerable, enduring and positive social influences and changes at large.

Furthermore, one of the largest financial institutions in Greece provides financial support (see: AgrESI -Support through Micro-financing or in Kind) to farmers through a new product (credit card) specially designed for small farm holders. With this credit card farmers have the ability to buy their products such as crops, fertilizers, etc. necessary for their farming while McCain safeguards for those micro credits to the bank.

Moreover, McCain through its long-term cooperation with academic institutions offering agriculture education provides training and expertise to farmers, developing special cultivating protocols dedicated to the specific land and farmer's needs. The cooperation with the academic community is continuous through elaboration of research with national or regional scope to determine the investment criteria by region, such as farmer's income, social factors, unemployment rates and analysis of soil ingredients. Also, McCain's business partners offer to small farmers persistence audits of active substances and special discounted rates to the supply of their products, while agronomists and consultants oversee and support farmers (see: Local rural community needs).Furthermore, McCain invests towards renovation and modernization of existing infrastructure for the selection process and packaging, in collaboration with farmers themselves. Last but not least one of the most important services McCain offer to farmers is access to market through its traditional channels of distribution, in order the final product reach consumers. The final product which is a bag of 3 kg of potatoes provides traceability data available to consumers through the use of new technology applications.

In conclusion, the program aimed to tackle poverty and social exclusion through partnership and constructive engagement between businesses and smallholder farmers in disadvantaged rural communities. The programme was designed to meet the four goals below.

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Goal 1: Promote awareness, knowledge and uptake of the notion of "Sustainable agriculture", "Farming Sustainability" and "Social Product".
Goal 2: Increase access to formal and informal educational, recreational and business cultural development activities and resources.
Goal 3: Increase smallholder farmers' work readiness, employment prospects and income increase.
Goal 4: Promote active engagement with policy, practice and decision making processes on matters affecting agricultural but also commercial issues.

The main aim of the proposed approach is the gradual withdrawal of McCain as the main supporter of the initiative and the emergence of a self-managed model in which farmers/producers will themselves be involved in the process as the main stakeholders and shareholders of a new agribusiness.

Finally, McCain's initiative is directly aligned with the Sustainable Development Goals (see: Global Trends) and more specifically with Goal#2 that among others "promotes sustainable agriculture"; Goal#8 that "promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all"; Goal#12 that "ensures sustainable consumption and production patterns" and Goal#17 that "strengthen the means of implementation and revitalize the global partnership for sustainable development".

FUTURE RESEARCH DIRECTIONS

Although the above case study shows that such projects can be successfully designed and implemented, further work is required in order to analyze the various parameters from the different stakeholders' perspective. In addition, the possibility to design more similar initiatives can be explored by investigating the intentions of corporations that are actively involved in CSR activities and try to identify if these organizations are more likely to support such projects. Socially responsible companies can be identified through CSR Networks operating in many European countries and a quantitative / qualitative survey may be conducted in order to investigate the interest as well as the ability of such organizations to adopt or join respective social innovation programs, which can lead to clear benefits for both the companies themselves and the society at large. At the same time the survey can capture the groups of potential beneficiaries and stakeholders based on the sector of activity of each company concerned.

CONCLUSION

This chapter presented a conceptual framework to enable the development and implementation of Agricultural Entrepreneurship and Social Innovation projects or even enterprises. This new business model which contains various social aspects, can contribute to the economic growth and sustainability and hence combat the phenomenon of unemployment and poverty in rural areas that have been seriously affected by the recent financial crisis in many European countries. An actual case study of such a project was presented describing how a private initiative involving different stakeholders can produce mutual benefits and create social value, and therefore justifying the proposed framework.

Several factors were explained in this chapter, some of which can be seen as innovative approaches to traditional practices, while the development of a clear framework of collaboration among various

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stakeholders may result in overall improvements in the farming sector. Briefly summarized, farmer's continuous training on modern farming techniques and available technologies should be integrated in their every-day work in order to improve received knowledge and further enrich their skills, keeping focus as well on the development of entrepreneurial perspective. At the same time, communication becomes a high priority for farmers in order to maintain exposure of their products. So, the development of a common communication strategy among farmers from a specific area that cultivate the same product could be seen as an innovative approach for reaching final consumers through appropriate messages that underline the unique characteristics of the product, inform about the adoption of internationally accepted Principles and farming guidelines, and increase overall transparency and traceability.

Moreover, reinforcement of agriculture sector through appropriate financial support could contribute to better promotion and acquaintance of the consumer with the end product, its background and the goals it represents, such as solidarity, fighting youth unemployment, etc. The adoption of regular and systematic communication between all identified stakeholders through effective channels, so that everyone is informed about recent developments, current difficulties and possible opportunities, can be perceived as a prerequisite for the success of the process and as an enhancement of transparency among partners. Social media is a new era for the farming sector that require enrichment regarding farming processes and new technologies that can keep stakeholders, mostly consumers, inform about all dimensions and innovations covered by the agribusiness program, including soil analyses, weather forecasts, safe transportation and storage, etc. In other words, there is a necessity for raising awareness among the consumers regarding branded agricultural products from small farmers, that respect at all stages of the value chain the principles of responsible entrepreneurship and contribute justifiably and transparently to the selling price. Finally, through the appropriate stakeholder engagement and by linking the product to its origin, history, and way of grow, farmers could create the story of the product that accompanies it from farm to store!

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REFERENCES

AAFC. (2013). *Agriculture and Agri-Food Canada, Global Analysis Division, Ethical Food Trends in Japan*. Retrieved August 17, 2016, fromhttp://www5.agr.gc.ca/resources/prod/Internet-Internet/MISB-DGSIM/ATS-SEA/PDF/6473-eng.pdf

Antonaras, A., Iacovidou, M., & Memtsa, C. (2011). Measuring social return on investment using the EBEN GR Business Ethics Excellence Model. *Current Issues of Business and Law*, *6*(1), 69–89. doi:10.5200/1822-9530.2011.04

Antonaras, A., & Memtsa, C. (2009). *Business Ethics and Sustainable Excellence*. Presented and published in the proceedings of the 3rd Annual Quality Congress of the Middle East, organised by e-University in partnership with MEQA, Berkley University of California and the International Academy for Quality, Dubai, UAE.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

ATTRA. (2003). *Applying the Principles of Sustainable Farming - Fundamentals of Sustainable Agriculture*. Retrieved August 22, 2016, fromhttp://ipm.ifas.ufl.edu/pdfs/Applying_the_Principles_of_Sustainable_Farming.pdf?pub=295%5D

CFS. (2014). *Principles for Responsible Investment in Agriculture and Food Systems, World Food Security (CFS).* Retrieved August 19, 2016, fromhttp://www.fao.org/fileadmin/templates/cfs/Docs1314/rai/CFS_Principles_Oct_2014_EN.pdf

CGAP. (2004). *Key Principles of Microfinance - Building financial systems for the poor*. Retrieved August 19, 2016, fromhttps://www.cgap.org/sites/default/files/CGAP-Consensus-Guidelines-Key-Principles-of-Microfinance-Jan-2004.pdf

CSR Europe. (2008). *ProactiveStakeholderEngagement, Practical Guide for companies and stakeholders, CSR Europe Toolbox*. Retrieved August 19, 2016, from http://www.csreurope.org/csr-europes-toolbox-user-manual#.V8VoVyiLSUm

Entrepreneurial Learning Initiative. (2016). *Entrepreneurial Mindset Education and Training Programs*. Retrieved September 1, 2016 from https://elimindset.com/about/

EurekAlert. (2015). *The Global Source for Science News, World crop diversity survives in small farms from peri-urban to remote rural locations, Article by Penn State*. Retrieved August 26, 2016, from http://www.eurekalert.org/pub_releases/2015-02/ps-wcd021115.php

Eurostat. (2015). *Eurostat News Release 81/2015*. Retrieved May 7, 2015, from http://ec.europa.eu/eurostat/documents/2995521/6823708/3-07052015-AP-EN.pdf/7e507ea0-43c7-452f-8e6a-b479c89d2bd6

Fairtrade. (2014). *FairtradeInternational - Sustainable Development Goals and Fairtrade: The case for partnership*. Retrieved August 17, 2016, from http://www.fairtrade.net/fileadmin/user_upload/content/2009/resources/15-10_Sustainable_Development_Report.pdf

FAO. (2009). *How to Feed the World by 2050, High-Level Expert Forum*. Retrieved August 27, 2016, from http://www.fao.org/fileadmin/templates/wsfs/docs/Issues_papers/HLEF2050_Global_Agriculture.pdf

FAO. (2010). *World deforestation decreases, but remains alarming in many countries*. Retrieved August 27, 2016, from http://www.fao.org/news/story/en/item/40893/icode/

FAO. (2011). *The State of Food Insecurity in the World, How does international price volatility affect domestic economies and food security?* Retrieved August 27, 2016, from http://www.fao.org/docrep/014/i2330e/i2330e.pdf

FAO. (2013). *Post-harvest food losses estimation - Development of consistent methodology*. Retrieved August 27, 2016, from http://www.fao.org/fileadmin/templates/ess/documents/meetings_and_workshops/GS_SAC_2013/Improving_methods_for_estimating_post_harvest_losses/Final_PHLs_Estimation_6-13-13.pdf

FAO. (2014a). *Family Farmers: Feeding the world, caring for the earth*. Retrieved August 27, 2016, from http://www.fao.org/docrep/019/mj760e/mj760e.pdf

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

FAO. (2014b). *CFS-Committee on World Food Security, CFS Chair's Statement for the FAO Regional Conferences 2014*. Retrieved August 27, 2016, from http://www.fao.org/fileadmin/templates/cfs/Docs1314/RC/CFS_Chairs_RC_Statement_EN.pdf

FAO. (2014c). *DEEP ROOTS*. Retrieved August 27, 2016, from http://www.fao.org/3/a-i3976e.pdf

FAO. (2014d). *State of Food and Agriculture in the Africa Region and Comprehensive Africa Agriculture Development Programme Implementation with a Specific Focus on Smallholder Farmers and Family Farming*. Africa Regional Conference, March 2014. ARC/14/3. Retrieved August 27, 2016, from http://www.fao.org/docrep/meeting/030/mj566e.pdf

FAO. (2014e). *Food Losses and Waste in Europe and Central Asia*. Document ERC/14/3. Retrieved August 17, 2016, fromhttp://www.fao.org/docrep/meeting/030/mj621e.pdf)

FAO. (2014f). *Building a common vision for sustainable food and agriculture - Principles and Approaches.* Retrieved August 22, 2016, fromhttp://www.fao.org/3/a-i3940e.pdf

Farming First. (2015). *The story of Agriculture and the Sustainable Development Goals*. Retrieved August 29, 2016, from http://www.farmingfirst.org/sdg-toolkit#home

Horne, Fien, Beza, & Nelson. (Eds.). (2016). *Sustainability, citizenship and cities: theory and practice*. New York: Routledge.

ICSU. (2016). *International Council for Science, A draft framework for understanding SDG interactions by Måns Nilsson, Dave Griggs, Martin Visbeck and Claudia Ringler*. Retrieved August 29, 2016, from http://www.icsu.org/publications/reports-and-reviews/working-paper-framework-for-understanding-sdg-interactions-2016/SDG-interactions-working-paper.pdf

IFAD. (2010). *International Fund for Agricultural Development - Rural Poverty Report 2011: New realities, new challenges: new opportunities for tomorrow's generation, IFAD, Rome*. Retrieved August 20, 2016, from https://www.ifad.org/documents/10180/c47f2607-3fb9-4736-8e6a-a7ccf3dc7c5b

ILO. (2013). *International Labour Organisation. Global Employment Trends 2013*. Retrieved August 29, 2016, from http://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_202326.pdf

ILO. (2016). *World Employment Social Outlook - Trends 2016*. Retrieved August 29, 2016, from http://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_443480.pdf

McCain. (2016). *KarposFrontidas*. Retrieved September 1, 2016 from http://www.karposfrontidas.gr/

McCain. (2016a). *Responsible Business*. Retrieved September 1, 2016 from http://www.mccain.com/good-business/responsible-business

Meyer, L. R. (2011). *Microcredit and Agriculture: Challenges, Successes, and Prospects*. Retrieved August 20, 2016, from https://www.incofin.com/sites/default/files/attachments/publications/Microfinance%20and%20agriculture.pdf

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Millennium Ecosystem Assessment. (2005). *Ecosystems and Human Well-being: Synthesis*. Retrieved August 20, 2016, from http://www.millenniumassessment.org/documents/document.356.aspx.pdf

NRI. (2001). *Natural Resources Institute - University of Greenwich, Ethical Consumers & Ethical Trade: A Review Of Current Literature*. Retrieved August 17, 2016, from http://www.nri.org/projects/publications/policyseries/PolicySeriesNo12.pdf

OECD. (2008). *Promoting Sustainable Consumption, Good Practices In OECD Countries.* Retrieved August 17, 2016, from http://www.oecd.org/greengrowth/40317373.pdf

OECD. (2015). *International Standards Considered In The Oecd-FAO Guidance For Responsible Agricultural Supply Chains*. Retrieved August 19, 2016, from https://mneguidelines.oecd.org/OECD-FAO-Guidance_International-Standards.pdf

Oxfam. (2014). *Even it Up: Time to End Extreme Inequality*. Retrieved August 19, 2016, from https://www.oxfam.org/sites/www.oxfam.org/files/file_attachments/cr-even-it-upextreme-inequality-291014-en.pdf

Reuters, U. S. (2015). *Build better roads in developing world to bolster food supplies: study, Article by Alister Doyle*. Retrieved August 25, 2016, from http://www.reuters.com/article/us-environment-food-idUSKBN0L200520150129

Taulbert, C., & Schoeniger, G. (2010). *Who own the ice house? Eight life lessons from an unlikely entrepreneur*. ELI Press.

UN Global Compact. (2014). *Food and Agriculture Business Principles*. Retrieved August 19, 2016, fromhttps://www.unglobalcompact.org/take-action/action/food

UN Global Compact. (2016). *Food and Agriculture*. Retrieved August 29, 2016, from https://www.unglobalcompact.org/what-is-gc/our-work/environment/food-agriculture

UNDP. (2009). Impact of UNDP microfinance programme on poverty alleviation among farmers in selected local government areas of Kaduna State, Nigeria. *International Journal of Sociology and Anthropology, 1*(6), 99-103. Retrieved August 20, 2016, from http://www.academicjournals.org/article/article1379409974_Kudi%20et%20al.pdf

United Nations. (2015). *Transforming our world: the 2030 Agenda for Sustainable Development*. Retrieved August 29, 2016 from https://sustainabledevelopment.un.org/post2015/transformingourworld

UNSG. (2014). *Agriculture development, food security and nutrition*. Report of the UN Secretary-General, A/69/279, 7 August 2014.

USAID. (2014). *Land tenure in urban environments*. Retrieved August 27, 2016, from http://www.usaidlandtenure.net/sites/default/files/USAID_Land_Tenure_Urban_Brief_061214.pdf

Weitz, N., Nilsson, M., & Davis, M. (2014). A Nexus Approach to the Post-2015 Agenda: Formulating Integrated Water, Energy, and Food SDGs. *SAIS Review of International Affairs*, *34*(2), 37–50.

WFP. (2015). *World Food Programme, P4P Purchase for Progress - The Story: Connecting farmers to markets*. Retrieved August 27, 2016, from https://www.wfp.org/sites/default/files/the%20P4P%20Story%20-%20Connecting%20Farmers%20to%20Markets,%20Feb%202015.pdf

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

World Bank. (2014). *Employment in agriculture*. Retrieved August 28, 2016, from http://data.worldbank.org/indicator/SL.AGR.EMPL.ZS?page=2159Donor

World Bank. (2016). *Agriculture*. Retrieved August 28, 2016, from http://www.worldbank.org/en/topic/agriculture/overview

WRAP. (2015). *Waste and Resources Action Programme. Strategies to achieve economic and environmental gains by reducing food waste – Final Report*. Retrieved August 25, 2016, from http://static.newclimateeconomy.report/wp-content/uploads/2015/02/WRAP-NCE_Economic-environmental-gains-food-waste.pdf

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Chapter 12
Striking a Perfect Fit in Leadership Style for Effective Farmer Training in Botswana

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ABSTRACT

Botswana since pre-independence days prides itself with decades of experience in development planning supported by structural frameworks comprising networks of institutions at central government and village levels responsible for leadership and coordination of affairs. Unfortunately when problems arise, development planners focus on the structural frameworks alone disregarding the leadership powering development planning at different structural levels and diverse stakeholder dynamics at play. Therefore, re-structuring is always the common solution even though not necessarily the best intervention. The trend is noted with farmer training whose program organization has for 79 years undergone cycles of re-structuring. The chapter argues for a holistic evaluation approach to always check the fit between the leadership style and whether the power processes at the different structural levels are in synch. The chapter advocates for well aligned leadership style with structural frameworks and recommends a leadership style that can be a perfect fit for effective farmer training.

CASE BACKGROUND

The general view of leadership is that of a process through which employees are influenced to work willingly towards achieving organisational goals. Leaders at all levels in the organisation use the influencing process to communicate ideas and gain acceptance of them, inspire followers to support and implement the ideas through change. Once supportive interpersonal relationships develop between leaders and followers, organisations are sure to succeed in realizing their missions (Du Toit et al., 2011).

Leadership style actually anchors on the influencing process and therefore affects communication, employee morale and their input to improving work processes, setting of goals, productivity, and the

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whole organisation's effectiveness. Leadership style is a critical facilitator in the achievement of organizational goals, at the same time enabling personal growth and development. Characteristics such as trust, reputation to deliver on promises, having satisfied customers, ability to attract and keep talented employees, being result-oriented, having output exceeding that of competitors, adaptability to change, and informative performance management systems describe effective organizations (Root lll, 2014; Singh et al. 2008).

In the case of farmer training, the organization of concern is historically that of agricultural extension whose services are a common feature of administrative structures of change in rural areas. Leadership is an essential process in the organization of agricultural extension. In fact, the mandate of extension is educational leadership and change (Khalil et al. 2008; Morse et al. 2006).Agricultural extension services in partnership with farmers are responsible for directing development programs and change in rural areas. The purpose of the services is mainly to develop farmer training programs that will not only increase local food, but also increase farmer income and the sustainability of agricultural practices. This is to ensure that farmers have the most current information on how to grow food efficiently and economically; they must have knowledge of new techniques and technologies above all to increase their level of productivity (Rosegrant & Cline, 2003).

An extension approach that succeeds in providing the right training and therefore, increased food production exists when the right fit of leadership style is maintained throughout program planning and implementation. This is the leadership style that accommodates change and promotes collaborative action by multiple and diverse groups such as farmers who are key to successful operation of an extension system (Morse et al. 2006). Other forces that need factoring into the leadership process are globalization, its challenges, and impact on the role of agricultural extension (Karbasioun et al. 2007; Toness, 2001). The leadership style therefore, should cultivate an environment enabling extension systems to operate like learning organizations in response to inevitable changes in their work environments (Ladwig & Rohs, 2000). Learning organizations respond timely to work changes and they are quick to learn, adapt, and change accordingly (Noe, 2010).

Botswana since pre-independence days prides itself with decades of experience in development planning guided by structural frameworks comprising networks of institutions at central government, district, and village (grass-root) levels. However, when problems arise development planners tend to focus on the institutions and structural frameworks alone and not the prevailing leadership processes as well. Re-structuring alone without focus on whether the leadership is congruent with structures in place is always seen as the solution even though not necessarily the best. This chapter therefore, discusses the institutions, emergent structural frameworks and leadership processes which have over time supported farmer training in Botswana. This is to review the structures and the leadership in order to determine the leadership style that can best align with the institutional frameworks in place for effective farmer training and successful implementation of development programs at the grass-root level. Firstly, the chapter discusses the concept of leadership in relation to farmer training. The chapter then provides an overview on farmer training, the institutions offering training, organizational and leadership structures. Secondly, the chapter reviews the institutional networks and leadership processes that have governed and supported farmer training overtime and constraints. In conclusion, the chapter recommends a leadership style that can be a perfect fit for more improved farmer training in Botswana.

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CONCEPT OF LEADERSHIP

The concept of leadership is big and its complexity is compounded by the diverse contexts in which it is practiced and the many interpretations. When exploring leadership, it is also important to separate the term from that of leader because often what a leader does is not necessarily what leadership is (Scouller, 2011). According to Scouller (2011, para. 6), a leader is a person who "leads a particular group at a particular time". His or her purpose is to ensure that there is leadership in the group or organization. Leadership is a process and this means that it comprises several tasks, activities, and a series of choices different leaders make when defining and achieving a goal. Leadership is performed by leaders acting at different times in different situations. The leader's responsibility is to ensure therefore, that there is appropriate leadership at all times and it is not necessarily performed by the one designated as leader (Scouller, 2011; Adair, 1983). As revealed in the literature, we can find leadership in every purposeful endeavour of any scale that requires organized effort towards achievement of goals: work, play, adventure, program, project, and personal life. The managerial view of leadership defines it in the context of work as the process during which an individual with supervisory responsibility influences employees to work willingly towards the achievement of organizational goals (Du Toit et al. 2010). Scouller (2011) provides a definition of leadership that is more encompassing to contexts that are not work-specific when he said it is a three-stage process that involves (1) setting a purpose and direction which inspires people to combine and work towards willingly; (2), paying attention to the means, pace, and quality of progress towards the aim; and (3), upholding group unity and individual effectiveness throughout.

Leadership models, philosophies, and styles provide a theoretical framework that simplifies the concept of leadership. They show that the thinking behind leadership even though offering different perspectives is overlapping and compatible. For instance, while a leadership model gives ideas on how to lead effectively or become a leader, a leadership philosophy comprises value-based ideas and prescribes the sources of the leader's power and how he or she must act. A leadership style is a description of the behaviour of a real-life leader (Leadership Theories). In this chapter leadership style is seen as broad-based and an integral part of a model: it refers to a process that can be used to learn, teach, apply and adapt leadership: a set of behaviours that enable people to lead effectively and at the same time, grow as leaders. This concept of leadership style borrows from Scouller's (2011) three-stage process of leadership: setting a purpose, direction, and inspiring people to combine and work towards it willingly; paying attention to the means, pace, and quality of progress towards the purpose; and upholding group unity and individual effectiveness throughout: coordination.

Historically, three groups of leadership models define effective leadership and are the foundation to many such as John Adair's (1983) Action-Centered Leadership model and the Scouller's (2011) Three Levels of Leadership (3P-public, private, and personal) model. The models are the Trait-Based, Behavioural Ideals, and Situational-Contingency models. The theory behind the trait-based model is that leaders are born and cannot be made and that certain traits make effective leaders. The behavioural ideals models focus on what researchers identified and believe are behaviours of effective leaders; while, the situational-contingency models their theory is on the idea that leaders' behaviour must vary according to the circumstances they are facing and that leaders can change their behaviour at will to meet differing circumstances (Scouller, 2011).

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Five critical elements constitute the leadership process. These are ((a), authority, being the right to give commands and demand action from followers; (b), power, comprising the ability of a leader to influence the behaviour of followers; (c), responsibility, is the obligation the leader has to perform the required activities to achieve organizational goals;(d), delegation, the leader assigning responsibility and authority to followers, giving them new tasks to perform; and (e), accountability, is about the leader taking stock and evaluating how well followers meet their responsibilities. According to Du Toit et al. (2011), strong leaders influence followers because they have power that allows them to exercise their authority fully. Therefore, power gives the leader leverage to influence others towards achieving organizational goals.

Leadership style describes the behaviour of real life leaders. Leadership style is an observed classification of behaviour of people in leadership. Unlike leadership philosophy, a leadership style does not prescribe behaviour type for leaders but merely reflects what exists as observable behaviour of leaders in action: that is, how best leaders exercise their authority, use position or personal power to influence others, and how individuals perform (Leadership Theories). Three leadership styles, authoritarian, participative, and 'delegative' popularized by Lewin (1939) present distinct modes of behaviour by leaders and followers. Authoritarian leadership style has leaders behaving like autocrats or dictators and more likely to use position and coercive power in their dealings with followers. Authoritarian leaders make decisions without much consultation with others; they hand out pre-determined goals, methods, and deadlines. Participative leadership style in which leaders consult, participate in group work, accept advice from colleagues, and then make final decisions is also referred to as democratic leadership style. 'Delegative' or Laissez-Faire leadership style, often seen as a no-leadership-process has the leader delegating responsibility for results to followers with groups setting goals, deciding on work methods, roles, and setting own pace of work. This leadership works better when followers share the same vision for the organization and its strategic direction as the leader and if he or she trusts the followers (Leadership Theories).

According to the literature, leadership can be found in every purposeful action of any scale that requires organized effort towards achievement of goals. No one single ideal approach to leading exists because organizational cultures and circumstances vary. Leadership styles provide a framework or guide and should not be taken as straight-jacketed behaviour expected of leaders. The leader's personality, personal goals, and relationship with followers strongly influence his or her leadership style (Singh et al. 2008). As the situational-contingency theory advises, the leaders' behaviour must be flexible and therefore, vary according to the circumstances they are facing (Scouller, 2011). This is to create and maintain a goal-achievement supportive organizational culture (Schein, 1985).

LEADERSHIP AND FARMER TRAINING

A better and practical approach to understanding leadership is to focus on a particular framework or an organization (Gupta, 2009). In the case of farmer training, agricultural extension systems provide such frameworks. Agricultural extension is a transformational system based on education, communication, and rural development. Its major purpose is to provide educational leadership and change among rural communities or farmers. Agricultural extension operates within a knowledge system that includes agricultural research in a process integrating farmers, agricultural educators, scientists, and extension agents. As revealed in the literature, the process and the many actors imply several levels of power and diverse leadership behaviour. The farmers' position in the knowledge system as the main target and beneficiary

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places them between research and extension. Extension agents become a critical communication link between the system, research and farmers. This makes the agents critical role players in the effectiveness of farmer training and the knowledge system as a whole (Khalil et al. 2008; Morse et al. 2006). Extension agents, actually have two main work roles with differing areas of responsibility that require leadership competencies. These are the work roles of (1), knowledge, communication, innovation and, (2), educator, facilitator, and catalyst (FAO, 2001).

Extension Agent's Role of Knowledge, Communication, and Innovation

In the role of knowledge, communication and innovation, the agent's responsibility is to train farmers: arm them with knowledge and information for decision making about particular innovations. The extension agents are conveyors of technical knowledge; they are trainers, teachers, and instructors of the farmers in the use of the very knowledge. Depending on the approach used by the local extension system, the agents will also have technical knowledge, information or technology packages to promote among the farmers.

To communicate extension messages successfully to farmers and engage them in learning and discovery, agents have to break through barriers of rural isolation and understand the values, customs, indigenous knowledge systems and the meanings that affirm the identity of farmers as members of a community whose culture will influence their decision to adopt new practices. In this approach, extension work is highly structured and follows rigidly existing government policies and programs of rural development (Daskon & Binns, 2009; Schwieder, 1993 in Morse et al. 2006).

Extension Agent's Role of Education, Facilitator, and Catalyst

The work role of educator, facilitator and catalyst, deviates a little from that of technology transfer. Technology transfer model is a linear model and often criticized for being a top-down extension approach and in Botswana, the reason for many problems of technology adoption and low farm yields (Acquah, 2003). Extension agents assume the role of educator, facilitator, trainer and catalyst in the transformation of farmers' lives. The agents follow a more participatory extension approach that recognizes multiple sources of innovation, interdependence of technology development and the farmer as an equal partner in the process (Sulaiman et al. 2006). In this role extension agents concern themselves more with the farmer's personal development and less with pushing programs and specific targets. The agents' task is to support and encourage farmers' initiative, helping them to gain confidence, organize themselves, participate more in extension activities and solve their own problems.

FARMER TRAINING IN BOTSWANA

Agricultural extension has been the main provider of farmer training in Botswana for over 79 years. The extension system originated in 1926 with dairy farming specific messages until 1935 when its mandate became all agriculture inclusive with programs targeting small scale traditional agricultural production systems (Hobb, 1985). Farmer education and training programs were implemented through methods such as individual farm visits, process and result demonstrations, farm walks, and media such as radio, posters, pamphlets. Extension agents organized short courses at rural training centres. The first rural training centre, the Denman Rural Training Centre (DRTC) located in Sebele, 10 km north of Gaborone,

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the capital city began operating in 1967. Currently, there are five rural training centres in Botswana. The Rural Training Centres operate under the direction and leadership of Centre Principals and subject-matter specialists (Sebadieta, 2006).

Several extension approaches over the years, changed one after the other always as an attempt to find appropriate methods for improving national farmer training programs; for example, the Cooperative Demonstration Plot Scheme (CDPS) in 1947, marked the first farmer education activities of a formerly established agricultural extension system in the country. The CDPS emphasized on-farm demonstrations as the major training method. Extension agents set up demonstration plots on farmers' fields to ensure a wider training coverage and improved transfer of technologies among farmers (Lever, 1970). In 1962, the Pupil Farmer Scheme (PFS), an approach based on a concept borrowed from Zimbabwe replaced the CDPS (Lever, 1970). In the PFS extension approach, one agent worked with and focused extension education programs on 15 to 25 farmers. Individual farmers or a household had to own a plough, draught oxen, a de-bushed and de-stumped field To qualify as a pupil farmer and register with the training program. Once in the program, as the pupil farmer's skills acquisition progressed and production methods improved, he or she was promoted and graduated to progressive, improved, and then master farmer level (Baker, 1988).

Similar to the CDPS, the PFS was selective with limited coverage: farmers who were not registered with the scheme were not getting any extension advice; while, the expectation was for all farmers to access the training programs by a public extension system. Other problems faced by the PFS extension methods were lack of coordination, inadequate supervision of staff, lack of equipment, poor transportation, poor housing (Willet, 1981).

Extension service reviews by consultancy agencies such as the Ford Foundation (1972/73), Chambers and Feldmann (1973), and Chambers (1977) were commissioned by the Botswana Government still in a quest for better extension methods that reached all farmers, increasing coverage, improved training effectiveness, and agricultural production (Odell 1978). As a result, many strategies were used to improve extension program implementation. The Integrated Rural Development Program (IRDP) replaced the PFS and then the Accelerated Rural Development Program (ARDP), followed in 1973 to 1976 (Mrema, 1995). In 1980s, Farming Systems Research Extension (FSR/E) Approach, promoted by FAO then was introduced together with inputs programs supporting farmers such as Arable Land Development Project (ALDEP), Accelerated Rainfed Arable Project (ARAP) and Agricultural Technology Improvement Project (ATIP).

Farming Systems Research Extension approach (FSR/E) was implemented through four projects: Farming Systems in the Southern Region (FSSR), Agricultural Development Ngamiland Project (ADNP), Molapo Development Project (MDP), and the Agricultural Technology Improvement Project (ATIP) as the fourth in 1983. The projects tested technologies recommended by research on farmers' fields and found them inappropriate, unworkable, and requiring modification. The FSR/E did not have significant impact on agricultural production; it did however, succeed in (a), testing and developing relevant technologies for small farmers with limited resources, (b) improving linkages with research, extension, and other institutions, (c) improving farmer confidence in research and extension, (d) skills development among subject specialists and extension workers in the Ministry of Agriculture (MoA), and (e), developing research infrastructure in the countrywide.

The FSR/E faced several challenges such as (a), the severe drought conditions in 1982 to 1987, (b) impact by the approach in the target was limited compared to the amount of resources used, (c) the size of expatriate staff, the level of their training and access to resources as compared to that of the local

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research staff of the MoA caused disparities and competition between the two groups, (d) lack of access to trained personnel who were willing to work in remote areas where most FSR/E projects were located, (e) difficult coordination of project activities administered by different departments of MoA and other government ministries, (f) lack of funds to support the FSR/E and other development programs, and (g), timing of the FSR/E, institutionalization of the approach into the MoA too early (Frankenberger & Mitawa, 1988). The added constraints became the spending of lots of money on subsidies; a major part of agricultural extension service occupied with taking the subsidies to farmers, and therefore a diversion by extension from its mission as extension workers spent most of their time distributing inputs, preparing payment of subsidies, and assessing farmer applications and not much on education and training (Mrema, 1995).

Following a major review of the agricultural sector in 1989-90, a new agricultural policy focusing on training for household food security as opposed to national food self-sufficiency was adopted in 1991. The policy emphasized relevant agricultural extension programs targeting farmers' needs. At the same time as the new policy on agriculture was formulated, The Ministry of Agriculture (MoA) underwent a major reorganization through the Organizational and Methods (O&M) study of the Government Departments. This led to the split of the former Department of Field Services and the establishment of two parallel agricultural extension systems in the Ministry and regions: one system provided livestock production and health training, and the other crop production and forestry.

In 2006 Cabinet approved yet another restructuring of the MoA that was carried out by O&M. The restructuring took into consideration a number of recommendations from the First National Conference on Agricultural Extension (1995) including (a) the separation of the Department of Animal Health and Production and (b) renaming one the Department of Veterinary Services and the other, the department of Animal Production. The two departments are presently under the Deputy Permanent Secretary, Technical Services. Farmer education and training combined into one unified service under six Regional Agricultural Coordinators at regions and coordinators reporting to the Deputy Permanent Secretary (Support Services). Other departments which were renamed were the Division of Agricultural and Statistics as the Division of Research and Statistics; the Department of Crop Production and Forestry became the Department of Crop Production. Another new department was that of Agricultural Business Promotions; while, the Department of Agricultural Research was retained without change. Another major re-structuring activity was the establishment of a coordinating unit of agricultural extension under the Deputy Permanent Secretary's Office (Support Services). This meant that functions under Crops and Horticulture, Animal Production, Farmer Education, Animal Health, Agribusiness Promotion and Conservation of Agricultural Resources were to be coordinated by one department: Extension Service Coordination Department assuming the role of unifying force among all stakeholders in farmer training.

ORGANIZATIONAL AND LEADERSHIP STRUCTURES

Several institutions coordinate, monitor, and evaluate activities of agricultural and non-agricultural (rural extension) extension at the Central government (Ministry), region, district and village or grass-root levels. The Rural Extension Coordinating Council (RECC), whose main mandate is to promote team work, ensure efficient use of resources, improvement of standards by Government Ministries involved in planning for development at the village level is a structure at the Ministry level. The Council (RECC) was established in 1982 and consists of a team of Heads of Extension Departments at ministry level.

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Principals of Rural Training Centres, Agricultural College, and other institutions such as Cooperatives, Public Health, and Wild Life and Tourism involved in development-related training are members of the RECC. The Council is chaired by the Coordinator of Rural Development and meets every four months to ensure continued exchange of information on extension programs, monitoring and evaluation of all rural development plans. The RECC has a sub-committee on training that advises the Council on matters of training for extension agents and the relevance of the programs. The Sub-RECC for training promotes research, evaluation and coordinates training programs.

At the district level, the District Extension Teams (DET), a sub-committee of the District Development Committee (DDC), has a membership of Heads of Extension Departments. The DET includes the District Officer Extension, District Adult Education Officer, and District Agricultural Officer. The DDC guides and supports policy implementation at the district level by the DET; while the DETs interpret policy for the Village Extension Teams (VETs), guides, and monitors VETs activities at the village level. The DETs, VETs, the Farmers Committee (FC) and Village Development Committee (VDC) coordinate implementation of extension programs at the district and village levels. The DETs strengthen planning and monitoring systems by VETs: they monitor the implementation of VET activities, promote communication among extension staff for coordinated and integrated programs and efficient use of resources.

The VETs comprise extension workers from different extension departments at the village level and help villagers to prepare and implement the village plan. The VETs are communication links between the village and district; while the mandate of the VDCs set by a Presidential Directive in 1968 is to mobilize community members and other institutions for development action. The VDC serves as a link between village leaders, politicians, and district authorities to increase the flow of development information, identify needs and develop plans for their villages. They are the main institution responsible for coordinating development programs in the village. Other coordinating institutions include Parents and Teachers Association (PTA), Village Health Committee (VHC), Social Welfare Committee (SFC), and Community Based Organizations (CBOs) (District Planning Handbook Draft, 2008).

At the village level the other link in farmer training are extension agents, technical staff popularly referred to as agricultural demonstrators (ADs) who work directly with farmers to implement extension education programs. Farmers need continued learning to acquire new skills, knowledge and information in order to improve their farming and other productive activities. The work roles of AD's as extension agents put the officers in leadership positions and their leadership styles therefore affect the farmers they train, others with whom they work, especially those at the village level, and attainment of extension goals (Khalil, et al. 2008). Hence as revealed by the needs assessment study (2009) of the University of Botswana Centre for Continuing Education, Public Education Section ADs need training in leadership to improve their skills.

Two groups of institutions provide the framework that guide extension program implementation and farmer training as conducted by the AD's at the grass-root or village level. The traditional institutions comprise of chieftaincy, chiefs, headmen or headwomen, and their deputies. This group is referred to as traditional because of its pre-colonial origin. The other groups of institutions referred to as modern institutions were created after Botswana's independence (in 1966). The institutions include the VDC, the Village Extension VET, FC, and PTA (District Planning Handbook Draft, 2008). The institutions at the village level represent different levels of power and leadership processes that the AD's must understand; they need to appreciate the importance of the leaders and their support in making farmer education and training more effective. The extension management must therefore determine the strengths of the structural frameworks in relation to the diverse leadership styles presented by the two types of institutions,

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and the power types at play as brought about by chiefs, headmen/headwomen, religious leaders, and political leaders. Extension management must also recognize the amount of influence the leadership dynamics have within the rural communities at the same time, positioning of AD's in supportive and enabling leadership environments by the Ministry of Agriculture (MoA) is essential to enable them to play their role well in effective farmer education (Hart, 2006: Morse et al. 2006).

BEST FIT LEADERSHIP STYLE FOR MORE EFFECTIVE FARMER TRAINING

According to Hart (2006), great lessons and benefits for extension can be gained from tribal leadership styles and practice; especially when extension leaders need to make tough decisions about currently facing extension systems. These are essential decisions about best approaches and strategies for implementing educational programs, relevance of the programs to the needs of farmers, prevailing economic and market forces, globalization and climate change. He describes tribal leadership as a process during which the leader "mentors, shares leadership, develops leadership for others, builds consensus, leads by example, allows other people to take the lead, gives other people the opportunity to be in their position, and is the last one to eat at a meal" (para. 6). This sounds more like servant leadership described by Greenleaf (1977) as a self-sacrificing leadership where the leader serves followers, always striving to make a positive difference to their benefit. The servant leaders are strong in listening, motivation, empathy, self-awareness, healing, persuasion, conceptualization, foresight, stewardship, and commitment to other people's development and community spirit (Leadership Theories).

Morse et al. (2006), on the other hand, suggest a catalytic or public leadership for adoption by extension systems that are re-organizing to address a new role change and power shift dictated by globalization. Luke (1998, p. 33) defined catalytic leadership as a "trans-organizational leadership process" that focuses attention on mobilizing diverse group of individuals and agencies to address a particular public problem. The leadership "evokes collaboration and concerted action among diverse and often competing groups toward a shared outcome". Public or catalytic leadership style is participatory and congruent with the educational mission of extension; extension agents act as catalysts in the communities. As implied by the definition of 'catalyst', extension agents will act more like a chemical reaction where "a substance usually used in small amounts relative to the reactants modifies and increases the rate of a reaction without being consumed in the process". In this type of scenario, what is needed is "a different mind-set", a different way of thinking about leadership or what it means to be an extension agency, rather than simply providing content, the extension system must also facilitate process or group development: processes where community members work together, create a vision, and make a difference. Clearly, this shows that successful farmer education and training programs require leadership styles that fit well into the structural frameworks already created, recognize the leadership at the different institution levels of extension organization, keeps the processes in synch and allows power sharing (Crosby & Bryson, 2005).

Catalytic/Public leaders have four primary tasks to achieve: firstly, raising awareness in the community, inviting stakeholders to encourage appreciation of problems and issues. Secondly, public leadership task is to form working groups to address common problems. The leader convenes meetings and uses knowledge, personal contacts, networks, and knowledge of stakeholder interests to motivate everyone in the work groups to participate. Thirdly, the task of the catalytic leader is to create strategies: the leader opens up guided discussion and gets interested parties talking around a particular issue to stimulate creation of strategies. Fourthly, the catalytic leader's task is that of 'sustaining action': the leader tries to

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maintain momentum among work groups, identifying talent, re-enforcing cooperative behaviour among groups, motivating them to stay focused on goal achievement. Catalytic leadership skill requirements are similar to those of extension work. For instance, some of the skills that training of extension agents should provide include group dynamics and formation, analysis and diagnosis, initiative, and communication which use the same principles as the public leadership skill of strategic thinking, group facilitation, and networking (Morse et al. 2006; FAO, Guide to Extension Training).

Other leadership styles that are recommended presently are those able to facilitate a transition of extension to a learning organization such as transformational leadership (Ladewig & Rohs, 2000). Transformational leaders value personal growth and individual development. They appeal to higher needs and values of followers, inspire them with new possibilities in order to raise their level of confidence, conviction and desire to achieve a common, moral purpose. Transformational leadership occurs when one or more people engage with others in such a way that leaders and followers raise one another to higher levels of motivation and morality (Burns, 1978). This leadership fits well with extension systems currently as the systems attempt to respond to the many changes impacting extension operations. In coping with changes in extension work, the systems must encourage a learning culture among stakeholders at all levels to acquire the leadership competence necessary to transform (Petterson, 1998 in Ladewig & Rohs, 2000).

Singh et al. (2008) in their study of effects of motivational training program on the development of leadership styles in agricultural scientists and extension agents revealed a high preference for participatory, motivating, and empowering leadership styles. The results revealed the need for a leadership process of a complimentary nature, combining more than one group of leadership behaviours and competencies. This confirms Scouller's (2011, para. 7) statement when he said that "leadership is a process, with which there may be different leaders acting at different times in different situations"; the formal leader's purpose therefore, would be to ensure that there is leadership at all times. This is the situation in Botswana: the case of formal, traditional, and informal leadership institutions that drive extension programs especially at the village level.

Another leadership style that can improve relevance of extension presently is one that borrows aspects of the Scouller's 3P model. The leadership model combines the strengths of traditional leadership theories to offer a more integrated approach described in the catalytic (Morse et al. 2006), tribal (Hart, 2006) transformational, and learning organization (Ladewig & Rohs, 2000) models. The 3P model comprises of three levels of leadership: central to the process is the personal and third level of leadership; public (first) and private (second) levels of leadership which deal with outer behaviours. Public leadership is about the actions or behaviours involved when a leader needs to influence two or more or more people simultaneously; while the private leadership level is about behaviour required to influence individuals, one by one. Scouller (2011) outlined four dimensions of leadership which he says represent public and private leadership and what leaders should be doing to influence people in groups or individually. The dimensions are:

- Shared group motivating purpose or vision;
- Action, progress and results;
- Collective unity or team spirit; and,
- Individual selection and motivation.

The personal leadership emphasizes a person's leadership presence built around one's knowledge, skills, beliefs, emotions, and unconscious habits. As observed by Scouller (2011), central to leadership

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is the leader's "self-awareness", his /her progress toward self-mastery and technical competence, and sense of connection with those around him/her. The inner core is the source and represents a leader's outer leadership effectiveness. There are three performance areas for the personal leadership level:

- Leader developing his/her technical knowledge and skills;
- Growing the right attitude toward other people; and,
- Leader working on his/her psychological self-mastery.

The main argument in Scouller's leadership model is that: (1), self-mastery by the leader is key to growing his/her leadership presence; that is, building trusting relationships with followers and being flexible to accommodate change, while remaining authentic; (2), personal leadership is the most powerful of the three levels of leadership and can be instrumental in making extension agents more effective in executing their duties. The main criticism of the 3P model of leadership is that it may be difficult to use as a guide to self-development without a professional coach or psychologist as self-mastery is a deeply-psychological concept. Extension can take care of the issue by offering regular in-service training and engage psychologists in adult education to train the agents and the supervisors; after training, the agents and supervisors will coach farmers and other agents.

CONCLUSION AND RECOMMENDATIONS

The chapter discussed extension in Botswana, constraints and strengths as the system promoted its mandate to provide farmer education and training; the institutions and structural frameworks which supported farmer training over 79 years were reviewed. The chapter questions the many re-structuring exercises used to intervene whenever extension program implementation problems arose without due regard for the leadership processes which are part of the structural frameworks created to promote farmer education. A holistic evaluation approach is recommended for more targeted and inclusive interventions that can help determine the perfect leadership style fit for more effective farmer training in Botswana.

Literature on leadership and extension revealed several leadership styles with potential for promoting effective farmer training. These include:

- Tribal leadership style recommended by Hart, (2006) especially when extension leaders need to make tough decisions about current global issues facing extension systems. Actually, sustainable community development is successfully achieved when such local leadership is formally recognized through formal tools measures such as government extension policy (Ozor & Nwankwo, 2008).
- Catalytic or public leadership, because the skill required to successfully practice the leadership are similar to those of extension work. These are skills such as group dynamics and formation, analysis and diagnosis, initiative, communication, and strategic thinking (Morse et al. 2006).
- Transformational leadership (Ladewig & Rohs, 2000), will facilitate a transition of extension to becoming a learning organization because transformational leaders value personal growth and individual development. Transformational leadership fits well with extension systems currently

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to enable well targeted response to the many changes impacting on their operations. Extension systems must cultivate a learning culture among all stakeholders to acquire transformational leadership competencies (Patterson, 1998).

- The 3P Leadership model by Scouller (2011) is another leadership style for improving extension relevance; it borrows aspects of the 3P model. The third level of leadership in the 3P model, the personal leadership is the most central to leadership styles recommended for extension: it emphasizes a person's leadership presence built around one's knowledge, skills, beliefs, emotions, and unconscious habits. The personal level represents the inner core which is the source of a leader's outer leadership effectiveness. The leadership model actually combines strengths of the traditional leadership theories and uses them to offer a more integrated approach described in the catalytic, transformational leadership, and learning organization (Ladewig & Rohs, 2000) models.
- In conclusion, the leadership model that provides the perfect fitting leadership style for effective farmer education and training in Botswana is one that adopts and combines principles of leadership as presented by the 3P model in the three levels of leadership. This is because the leadership model combines strengths of the leadership styles recommended in the literature as the best for re-aligning extension missions worldwide.

REFERENCES

Acquah, B. K. (2003). Making Technology Work for Resource-Poor Farmers in Botswana. Pula: *Otswana*. *Journal of African Studies*, *17*(2).

Adair, J. (2006). *Leadership and Motivation*. London: Kogan Page.

Baker, D. (1988). *Agricultural Development in Botswana, Agricultural Technology Improvement Project ATIP*. Gaborone, Botswana: Department of Agricultural Research, Ministry of Agriculture.

Burns, J. M. (1978). *Leadership*. New York: Harper & Row.

Crosby, B. C., & Bryson, J. M. (2005). *Leadership for the Common Good: Tackling public problems in shared-power world* (2nd ed.). San Francisco: Jossey-Bass.

Dart, J. J. (2000). in Allahyari, M.S. (2009) Agricultural Sustainability: Implications for extension systems. African. *Journal of Agricultural Research*, *4*(9), 781–786.

Daskon, C., & Binn, T. (2009). Culture, tradition and sustainable rural livelihoods: Exploring the culture- development interface in Kandy, Sri Lanka. *Community Development Journal*. *Oxford Journals*, *45*(4), 494–517.

Du Toit, G. S., Erasmus, B. G., & Strydom, J. W. (2011). *Introduction to Business Management*. Oxford University Press.

Chambers, R. (1977). *Botswana's Accelerated Rural Development Program, 1973-1976, Experience and Lessons*. Gaborone, Botswana: Government Printer.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Chambers, R., & Feldmann, D. (1973). *Report on Rural Development Program*. Gaborone, Botswana: Ministry of Finance and Development Planning.

Government of Botswana. (2008). *District Planning Handbook Draft*. Gaborone, Botswana: Ministry of Finance and Development Planning.

Lever, B. G. (1970). *Agricultural Extension in Botswana*. Reading University.

FAO. (2001). *Agricultural and Rural Extension Worldwide: Options for Institutional Reform in the Developing Countries*. Rome: FAO.

Frankenberger, T.R. & Mitawa, G. (1988). Farming Systems Research and Extension Activities in Botswana: Results Inventory. USAID/Botswana.

Greenleaf, R. K. (1977). *Servant Leadership*. Mahwah, NJ: Paulist Press.

Gupta, A. (2009). *Role of an Organizational Leader. Practical Management: Designing a better workplace*. Retrieved from: http://www.practical-management.com/Leadership- Development/Role-of-an-Organizational-Leader.html

Hart, J. G. (2006). *Exploring Tribal Leadership: Understanding and Working With tribal People*. Available at http://www.joe.org/joe/2006august/a3.php

Hasler, M. G. (2005). *Leadership Development and Organizational Culture: Which Comes First?* Available at http://www.ehow.com/about_6639830_organizational-development-leadership.html

Hobb, J. A. (1985). *Agricultural Development in Botswana. Agricultural Technology Improvement Project (ATIP)*. Gaborone, Botswana: Department of Agricultural Research, Ministry of Agriculture.

Karbasioun, M., Mulder, M., & Biemans, H. (2007). Towards a Job Competency Profile for Agricultural Extension Instructors: A Survey of Views of Experts. *Human Resource Development International*, *10*(2), 137–151. doi:10.1080/13678860701347115

Khalil, A. H. O., Ismael, M., Suandi, T., & Silong, A. D. (2008). Extension Workers as a Leader to Farmers: Influence of Extension Leadership Competencies and Organisational Commitment on Extension Workers' Performance in Yemen. *The Journal of International Social Research*, *1*(4).

Ladewig, H., & Rohs, F. R. (2000). Southern Extension Leadership Development: Leadership Development for a Learning Organization. *Journal of Extension*, *38*(3), 1–6.

Lewin, K., Lippit, R., & White, R. K. (1939). Pattern of Aggressive Behaviour in Experimentally Created Social Climates. *The Journal of Social Psychology*, *10*(2), 271–279. doi:10.1080/00224545.1939.9713366

Luke, J. S. (1998). *Catalytic Leadership: Strategies for an interconnected world*. San Francisco: Jossey-Bass.

Morse, R. S., Brown, P. W., & Warning, J. E. (2006). Catalytic Leadership: Reconsidering the Nature of Extension's Leadership Role. *Journal of Extension, 44*(2), 1-6. Available at http;//www.fao.org/sd/EXdirect/EXre0029.htm

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Mrema, G. C. (1995) *Agricultural Development and Extension in Botswana: a Review Focusing on the Future With an Eye to the Past.* Paper presented at the *National Conference on Agricultural Extension*, Gaborone, Botswana.

Noe, R. (2010). Employee Training and Development (5thed.). Singapore: McGraw-Hill.

Odell, M. (1978). *Village Area Development: a Review and Evaluation of an Experiment in Integrated Rural Development*. Gaborone, Botswana: Government of Botswana.

Ozor, N., & Nwankwo, N. (2008). The Role of Local Leaders in Community Development Programmes in Ideato Local Government Area of Imo State: Implication for Extension Policy. *Journal of Agricultural Extension*, *12*(2), 63–75.

Patterson, T. J. (1998). *Commenter ll: a new paradigm for extension administration*. Available at http://www.joe.org/joe/1998february/comm1.html

Rosegrant & Cline. (2003). *Farmer Education & Agricultural Extension Mission 2014: Feeding the World*. Available at http://12.000.scripts.mit.edu/mission2014/solutions/farmer-education-agricultural-ext

Schein, E. H. (1985). *Organizational Culture and Leadership: A dynamic view*. San Francisco: Jossey- Bass.

Schwieder, D. (1993). *75 Years of Service: Cooperative Extension in Iowa with a forward by Wayne D. Rasmussen*. Ames, IA: Iowa State University Press.

Scouller, J. (2011). *The Three Levels of Leadership: How to develop your leadership presence, knowhow and skill.* Management Book 2000 Ltd.

Sebadieta, B. G. (2006). *Factors Affecting the Implementation of Acquired Skills and knowledge Presented to Farmers at the Denman Rural Training Centre in Gaborone Agricultural Region, of Botswana*. (Unpublished Masters Dissertation). University of Pretoria, South Africa.

Singh, N., Sinha, B. P., & Vijayaragavan, K. (2008). Motivational Training Program: Effects on the Development of Leadership Styles in Agricultural Scientists. *Indian Research Journal of Extension Education*, *8*(1), 25–27.

Sulaiman, V. R., Hall, A., & Raina, R. (2006). *From Disseminating Technologies to Promoting Innovation: implications for agricultural extension*. Paper prepared for the SAIC Regional Workshop on Research Extension Linkages for Effective Delivery of Agricultural Technologies in SAARC Countries.

Toness, A. S. (2001). The Potential of Participatory Rural Appraisal (PRA) Approaches and Methods for Agricultural Extension and Development in 21st century. *Journal of International Agricultural Extension Education*, *8*(1), 25–37. doi:10.5191/jiaee.2001.08103

Willet, T. (1981). Agricultural Development Setting in Botswana. In *Agricultural Development in Botswana, Agricultural Technology Improvement Project (ATIP)*. Gaborone: Department of Agricultural Research, Ministry of Agriculture.

Zhou, Y. (2009). *Reinventing Agricultural Extension to Small Holders*. Syngenta Foundation for SustainableAgriculture.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

ADDITIONAL READING

Connaughton, S. L., Lawrence, F. L., & Ruben, B. D. (2003). Leadership Development as a Systematic and Multidisciplinary Enterprise. *Journal of Education for Business*, *79*(1), 46–51. doi:10.1080/08832320309599087

Kelloway, E., Barling, J., & Helleur, J. (2000). Enhancing transformational leadership: The roles of training and feedback. *Leadership and Organization Development Journal*, *21*(3), 145–149. doi:10.1108/01437730010325022

Nikolaou, I. (2003). Fitting the person to the organization: Examining the personality-job performance relationship from a new perspective. *Journal of Managerial Psychology*, *18*(7), 739–648. doi:10.1108/02683940310502368

Northhouse, P. G. (2004). *Leadership:Theory and Practice* (3rd ed.). Thousand Oaks, CA: Sage.

Patton, M. Q. (1986). Extension's partnership with the future. *Journal of Extension* [on-line], 24(3). Available at: http://www.joe.org/joe/1986fall/sfut1.html

Patton, M. Q., & Blaine, T. W. (2001). Public issues education: Exploring Extension's role. *Journal of Extension* [on-line], 39(4). Available at: http://www.joe.org/joe/2001august/a2.html

Prewitt, V. (2002). Leadership development for learning organizations. *Leadership and Organization Development Journal*, *24*(2), 58–61. doi:10.1108/01437730310463242

Rivera, W. M., & Kalim Qamar, M. (2003). *Agricultural Extension, Rural Development and the Food Security*. Rome: FAO.

Rolling, N., & Prtty, J. (2000). Extension Role in Sustainable Agricultural Development. In Improving Agricultural Extension. A Reference Manual. FAO, Rome.

Schein, E. H. (1985). *Organizational Culture and Leadership: A dynamic view*. San Francisco: Jossey- Bass.

Schwieder, D. (1993). *75 Years of Service: Cooperative Extension in Iowa with a forward by Wayne D. Rasmussen*. Ames, IA: Iowa State University Press.

Scouller, J. (2011). *The Three Levels of Leadership: How to develop your leadership presence, knowhow and skill.* Management Book 2000 Ltd.

Seevers, B., Graham, D., Gamon, J., & Conklin, N. (1997). *Education Through Cooperative Extension*. New York: Delmar Publishers.

KEY TERMS AND DEFINITIONS

Agricultural Extension: Extension and agricultural extension used inter-changeably; extension used to mostly when referring to agricultural extension. Extension purpose is to develop farmer training programs; support local food production, increase farmer income. Extension services, with farmers direct development programs and change in rural areas.

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Extension Agents: Formally educated and trained professionals; they serve as a critical link in all extension activities. They link government with the people at the rural community level to bring about change. Their job places them in multiple roles of conveyors of technical knowledge, teacher, educator, facilitator, motivator, consultant, administrator, organizer, arbitrator, advocate, friend, as well as catalyst, motivator, activist, and leader.

Extension Approach: An organizational structure, providing the style of action for the system: leadership, allocation of resources, equipment, facilities; framework for program planning and implementation; and framework of linkages to guide interactions with other organizations.

Farmer Education and Training: Providing knowledge and skills through educational and training programs and at the same time, communicating to the farmers; providing information particular technologies and innovations from agricultural research.

Formal Leaders: Hold recognized positions of authority; appointed by someone in higher authority; others inherit the leadership position.

Informal Leaders: Do not hold any particular position of authority; often not easy to identify; people respected by others because they have an attractive personality or personal presence; there are knowledgeable and make good decisions; team leaders.

Leadership Style: A set of behaviours used by leaders as they perform activities to achieve pre-set goals.

Traditional Leadership: Shared leadership; organized by the clan system, guided and sustained by elders of a clan through teaching of tradition, values, culture, and language of a particular tribe.

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Chapter 13
Rebirth of a Program via Community, Industry, and Philanthropic Support

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ABSTRACT

In 2002, Lake Region State College closed their "Agricultural Farm Business Management" program, due to low enrollment and lack of interest. However considering that agriculture is one of the leading economic developers in North Dakota, Lake Region State College (LRSC) leaders and the community felt this might have been a premature closing, and decided to look at other agriculture workforce initiatives, considering ways to revitalize the agriculture workforce and its needs. This was an ambitious goal considering how rural LRSC is, with roughly 2000 in student matriculation in a given year. Before looking at reinventing, or "rebirthing" the ag program, challenges and steps needed to be addressed and employed. The following chapter will provide a case study on how LRSC leaders, its community, and the alignment of philanthropic support was able to revitalize or "rebirth" the agriculture program to the new cutting edge of Precision Agriculture.

INTRODUCTION

The fiscal relationship between higher education and its respective state has been eroding for a number of years. In fact, according to Mortenson (2004) there have been huge cuts with state appropriated funding for higher education in the last two and a half decades. In FY 2004, states appropriated $60.3 billion for operations, and this was down from FY2003 at $61.5 billion, and down from FY 2002 at $62.8 billion (p. 3). In fact, since 1978, state appropriated funding has declined by 40%. There are many factors that contribute to this nationwide decline for state funding, the biggest factor has been contributed to the economic recessions noted in the last 25 years, and two-year institutions are not immune to this decline in funding (Weerts & Ronca, 2006, p. 936).

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The first and oldest community college was Joliet Junior College, founded in 1901 in Illinois. Community colleges then flourished nationally in the 1960's with 457 active campuses. Community colleges historically focused on liberal arts, however, during the depression took a more pragmatic turn, offering job-training programs in order to offset widespread unemployment (Community Colleges Past and Present, 2015). Two-year institutions are known to be 'open enrollment' and serve a range of students (Thelin, 2004). Local funds primarily funded and supported two-year institutions at 94 percent, however was soon to be insufficient, and other revenue streams were mainstreamed- state revenue, tuition and fees, federal funds, and gifts and grants. In the 70's came the awareness that public funding was not going to be sufficient for community colleges to meet their missions (Strauss, 2001).

Today, community colleges enroll nearly half the nation's undergraduate students (Worth & Smith, 1993) and funded primarily from state, local government, and student fees (p. 347). When it comes to fundraising, rarely see the "megagifts" at the two-year institution that four-year institutions have come to know and count on for philanthropic giving. However, reported by the "$70 Million Gift to Help California Students" (cited in Ramano, Gallagher, & Shugart, 2010) in 2008 a $70 million donation was presented to a community college system, to assist scholarships for California's 109 two-year colleges. However the gift was focused on scholarships, and as reported by Gose (cited in Ramano, Gallagher, & Shugart, 2010), "most community college donations are earmarked for scholarships" (p. 59). Additionally, in the 2014 CASE Survey of Community College Foundations (Paradise, 2015) reported that when it comes to a comprehensive or capital campaign, 80 percent of surveyed participants cited scholarships as the top destination (p. 27).

Two-year institutions are divided and recognized by three different types of demographics, categorized by the Carnegie Classifications of Institutions of Higher Education™. Carnegie defines community colleges by *service areas*; rural, suburban, and urban. This type of classification was set in place to demonstrate that nearly all public community colleges are place-based institutions, with geographic service delivery areas defined by state statute, regulation, or custom (Hardy & Katsinas, 2007, p.6). The Carnegie Foundation for the Advancement of Teaching (as cited from Hardy & Katsinas, 2007) defined that *serving*, whether the student is from an urban, suburban, or rural areas, depends on the physical location of that campus.

When it comes to fundraising, two-year institutions are not viewed the same, despite what service area they serve, and rural community colleges face the greatest budgetary strain. In fact, according to one study provided by Katsinas, Tollefson, & Reamey (2007), reported "rural community colleges lacked access to a good stream of local support" (p.4). For example when it comes to alumni and future support, students who attend two-year and matriculate to a four-year institution transfer their alumni loyalties, and later become donors to that four-year institution (Worth & Smith, 1993). Additionally, Worth and Smith (1993) further reported that since two-year institutions are program based and not research focused have constraints on where and what kinds of foundations and donors to solicit. In fact, a survey provided by The Marts & Lundy reported to *The Chronical for Philanthropy* (Daniels, 2015) that fifty-one percent of the large gifts to higher education went to university hospital centers and health programs, up from 41 percent in 2013. John Cash, Marts & Lundy's chairman said that "Instead of being driven by a sense of loyalty to their alma mater, Mr. Cash said, many of his clients prefer to give to institutions that are on the cusp of big breakthroughs."…"Donors are giving their big gifts to support research," he says. "They're much more opportunistic. They're not building buildings and creating monuments to themselves" (Daniels, 2015; https://philanthropy.com/article/Mega-Gifts-on-the-Rise-at/227955). Comparing prestigious and well-known four year agricultural institutions, such as Purdue where gifts are provided by the Bill

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and Melinda Gates Foundation (Austin, 2011), two-year institutions cannot compete, and therefor need to look at other avenues. Therefor to assist with philanthropy and fundraising, two-year institutions align themselves with the workforce, as is their mission, and solicit gifts supporting their unique programs and industry. To assist in this process, community college foundations have learned to align themselves to philanthropic opportunities via their foundation boards. In fact, Paradise (2015) reported in a CASE whitepaper that community college boards are composed of 98 percent of business and industry.

Reinventing a program in higher education, especially one that needs to be tied to a rural community presents a myriad of programs and challenges. However, such efforts have become necessary. A case study of a recent program reconstructed at a rural community college is presented. It will highlight the needed outreach nature of a close alignment of philanthropy, community, and higher education. By way of example will be a case study of the reinvented traditional agriculture program to the new cutting edge of Precision Agriculture.

Precision Agriculture (Precision Ag) is the combination of agriculture and technology. In the agriculture arena, the demand on farmers to continuously produce more food, fiber, and fuel for this world has made it imperative to become more efficient. In turn this need for efficiency has prompted the adoption of various forms of precision agriculture technologies. The use of precision agriculture technologies is the tool to allow farmers to manage small areas, and treat these areas uniquely in regards to their individual characteristics. Technology allows for the collection of immense amounts of data that assists in making necessary management decisions. The demand does support a workforce with these new skills.

The precision ag industry was very new and cutting edge. Initial research provided by key leaders at Lake Region State College (LRSC) indicated that there was not another institution regionally or nationally undertaking this type of workforce and developing a viable accredited program. However, the question was how to get industry to support this program, when there was no other model regionally, nationally or internationally? How much industry and community interest was there to support this type of program? Without proof that there was going to be a return on investment, and the fact that Lake Region State College (institution that housed the program) had initially closed their "Agricultural Farm Business Management" program, local industry was not interested in committing funding. Where was the revenue going to be generated from in order to implement and sustain this program? Other revenue would have to be considered and applied for, such as statewide grants that supported equipment and program funding.

The following chapter will discuss the following: 1) data collected in order to support a new and cutting edge workforce program, 2) local community funding committed in order to support the program, 3) overview of the Trade Adjustment Assistance Community College and Career Training federal grant, which required local support, that launched the program 4) other statewide grant funding that was used to support the program, such as the Workforce Enhancement Grant (North Dakota Department of Commerce), and 5) what the current efforts in place from the community in order to continue to provide support.

BACKGROUND: TRENDS IN REGARDS TO HIGHER EDUCATION AND THE WORKFORCE

Two-year institutions are recognized as a vital backbone in economic and workforce development (Bailey & Kienzal, 1999, p. 1), especially in rural locations. Push for two-year institutions to work with specific industries and offer content-specific courses or programs continues (Zinser, 2003, p. 1). Business leaders

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continue to voice their disapproval regarding higher education not producing the necessary workforce. With this kind of censure, two-year institutions eliminate programs that are not closely related to workforce. Fain (2014) reported that the two-year system, Louisiana Community and Technical College, made large programmatic cuts in recent years as state appropriated funding went from 70 percent to 30 percent. The system eliminated close to 700 programs, which were not closely tied to workforce needs. For example, the system cut its cosmetology program, since it no longer supported a workforce need (p. 2).

These funding cuts not only took place in Louisiana, but nationally. In the article, *Signs of hope for state funding* (2014, November 20), it was reported that during the last recession, 11 states had higher education funding cuts of more than 30 percent. Other states had decreases between 20 and 30 percent.

The trend of cutting higher ed programs not closely tied to workforce is not just a response to the last recession, but has been taking place many years. State appropriated funding has dwindled, and institutions of higher education, especially the two-year institutions, have had to align themselves closer to the workforce. Lake Region State College (LRSC) had to make the same type of cut in the early 2000's, and closed their "Agricultural Farm Business Management" program since it was not seeing student enrollment or retention. Like many institutions (two or four-year) looking to cut and save state appropriated funding, the closing of the program seemed like a logical strategy. However, in a state where agriculture is one of its prime economic developments, the community and agriculture industry of Devils Lake questioned the decision of discontinuing the program. Leaders and stakeholders revisited the closed program, and considered a bold move of reinventing the closed program, constructing and launching a new program, which would be tightly coupled with the community and local workforce industry.

REBIRTH OF A PROGRAM

In 2005, LRSC leaders and stakeholders revisited the agricultural program, to consider if there was a way to reinvent the ag program, providing a new prospective in the industry. After researching the agricultural needs statewide and nationally, it was concluded that agriculture was seeing considerable workforce needs within *Precision Agriculture*. In fact, precision agricultural careers continue to expand in occupational diversity and are numerically increasing as reported by the US Bureau of Labor Statistics in the Ag Leader Insights Magazine (2014, Spring), "employment opportunities will increase by more than 29 percent and create more than 100,000 new jobs by 2020" (p. 8).

Precision ag technology has been evolving since 1995 (Greene, 2011). Producers within the central regions of the U.S. recently reported in communication that 92 percent use one or more precision agriculture technologies, and have had such technology on their farm for an average of 5 years. Sixty percent plan to increase use of such technology within the next two years, and the majority of producers turn to their local agricultural implement dealer for information assistance when acquiring, installing, servicing such technology (P. Gunderson, personal communication, 2011).

Regionally and locally, precision agricultural was also considered a workforce need since approximately 32,000 farms/ranches are located in North Dakota however, of that number 3,000 are "limited resources", 5,000 are "retirement farms/ranches", and 8,100 are "residential lifestyle farms/ranches." These farms/ranches generated at least $250,000 or more in sales annually, and the children of these agricultural enterprises would be targeted as potential students for the program (U.S. Censes of Agriculture, 2007, Table 64). This in turn concluded that this new agricultural program could potentially

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impact a constituent of 29,000. This was a significant finding for a small regional institution, averaging an enrollment of 2,000 comprised of traditional and non-traditional students.

ISSUES, CONTROVERSIES, PROBLEMS: THE CLOSING OF ONE PROGRAM AND THE REBIRTH OF ANOTHER…CAN IT BE DONE AND RECEIVE LOCAL PHILANTHROPIC SUPPORT?

The Dakota Precision Ag Center (DPAC), Center of Excellence, was first created under the auspices of the ND Governor's Center of Excellence grant initiative in 2006. It was one of the first Centers to initiate research and job creation activity.

It was a long road before DPAC became to fruition. After the writing, and funded Center of Excellence (COE) grant, the program was underway. Answer Farms, an agricultural research facility, was recruited to assist DPAC in assessing current precision agriculture technology on local farms. The plan involved recruiting local farmers and producers from the cohort of adult farm management trainees directly involved in LRSC's Adult Farm Management program. With this selection, leaders of the DPAC program would be able to do research on farms, discovering which 'precision technology' was effective in order to base the reinvented agriculture degree program, Applied Associates of Science in Precision Agriculture. However resistance form the local agricultural community was encountered since LRSC had previously closed its agriculture training program- Agriculture Farm Business Management. Workforce and the local community was apprehensive in providing resources or assistance to an institution that closed a program that was providing much needed education and training in a field that was one of leading economic drivers of the state- agriculture.

Meetings and renewing relationships led by DPAC and LRSC leaders of local agricultural producers, establishing that once the newly reinvented ag program was in place, and successful, it would not be closed. However, only 3 (three) ag producers was willing for DPAC to use plots of their land for research, finding out what 'precision technology' was going to be the most needed and used as training and educational platforms for future precision ag students.

While three producers vested into the research and program was a good start, it was hardly the indication needed to ensure that the local community and workforce was vested into the DPAC program. An endeavor of this magnitude was going to need a vested community and workforce in order to build and sustain the program, which was going to need vast amount of equipment and other expenditures to get the program reinvented and launched. More research would have to be deployed, demonstrating need and sustainability before the ag workforce and local community would once again support an ag program at a small rural two-year institution.

Data Collected in Order to Support a New and Cutting Edge Workforce Program

According to the site, Bureau of Labor Statistics (North Dakota) North Dakota is the most rural of all the states, with farms covering more than 90 percent of the land with a strong economy and a low unemployment rate which stands at 2.8 percent, the lowest in the country (Bureau of Labor Statistics-North Dakota, 2015). During the country's most recent economic downturn where many states had few jobs,

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North Dakota was creating jobs and hiring. In fact, the state added 21,300 new jobs since 2005 earning a top position in the nation for growth (Murphy, 2010, p.116).

Considering North Dakota has such a high farm population, it could be concluded that the economic impact of a reinvented cutting edge agriculture program was within scope. However, intense research was deployed since the institution already had low enrollment numbers in past agriculture training programs which led to the closing of the program. This, in turn, produced a cautious local agriculture workforce and an institution needing a 'sound investment' before commitments would be forthcoming. Additionally, when it came to sustaining this type of program, other implications needed to be addressed; 1) any educational program in this arena will not be successful unless the target audience, agriculture producers, are directly involved in its design and 2) agricultural industries must possess economic clout, both locally and regionally in order to provide support.

In response, DPAC and LRSC leaders provided research in support for a new agriculture program in precision ag and the following key points were addressed; 1) what type of precision ag training was needed; 2) earnings for future employment; and 3) what were current industry economic profits in order to support future employees. In 2010, the following data was collected via surveys provided by the North Dakota Implement Dealers Association (NDIDA). They surveyed and compiled the following data:

- There are 126 retail farm equipment dealerships in North Dakota
- Annual total retail sales of new and used farm machinery and repair parts in North Dakota is over $495 million
- Over 3,120 people statewide are employed by retail farm equipment dealership.
- The average dealership employee earns over $43,000 per year
- The average annual payroll per dealership is over $1.1 million
- Dealership payroll statewide is over $132 million annually
- Dealer payroll comprises 12% of ND's total retail payroll
- Dealers statewide pay over $17.5 million in payroll takes and employee benefits annually (NDIDA, 2010)

Based on preliminary research, the need and support for a new agriculture workforce seemed promising, however, more in-depth research needed to be deployed. LRSC and DPAC leaders with specific questions created a survey in order to understand what the needs are from farmers, producers, and other ag workforce to build a successful program. Seventy-eight producers and dealerships responded to a survey conducted through the North Dakota Agriculture Association, which included the following inquiries:

1. Estimate the number of employees you will be hiring in the next 5 years who will specialize in precision farming technology.
2. How many new employees will you be hiring in the next 5 years that need basic precision ag knowledge but won't necessarily specialize in it?
3. Where would you expect future employees to receive training in technical areas of precision ag?
4. Where would you expect future employees to receive training in consultation of precision ag?
5. Where would you expect future employees to receive training in agronomics, businesses management, and soft skills?

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Results from the survey included in Table 1 indicated that precision ag skills and knowledge would be a necessary and required skillset of 187 new employees across the next 5 years in North Dakota. Table 2 indicated that an additional 272 job openings in agribusinesses will require basic precision agriculture skillset. Table 1 and 2 combined indicated 459 jobs would be added where individuals could benefit from precision ag training. Additionally, results concluded that ag industries were looking towards and expecting state colleges to step up and provide the necessary training.

For survey question 3, "Where would you expect future employees to receive training in technical areas of Precision ag?" Table 3 indicated that 58 percent said college courses, however 92 percent responded with *industry sponsored* – which was not a surprising result considering the lack of a program locally or regionally that could support this type of program.

Survey question 4, "Where would you expect future employees to receive training in consultation of precision ag?" Results from Table 4 indicated 73.3 percent in favor of *industry sponsored* however the second strongest response was *formal training (college courses)* with 64.5 percent.

Survey question 5, "Where would you expect future employees to receive training in agronomics, businesses management, and soft skills?" The results from Table 5 indicated employees would be get-

Table 1. Estimate the number of employees you will be hiring in the next 5 years who will specialize in precision farming technology. (Data source: DCTOA (c). N.D. Agricultural Implement Dealer Survey. Devils Lake, ND. Lake Region State College – Dakota Center for Technology-Optimized Agriculture. November, 2011. 8 pages.)

Answer	Number of responses	Number of people that will be hired
None	16	0
1-3	44	88
4-6	12	60
6-8	1	7
8+	5	32
	Total	187

Table 2. How many new employees will you be hiring in the next 5 years that need basic precision ag knowledge but won't necessarily specialize in it. (Data source: DCTOA (c). N.D. Agricultural Implement Dealer Survey. Devils Lake, ND. Lake Region State College – Dakota Center for Technology-Optimized Agriculture. November, 2011. 8 pages.)

Answer	Number of Responses	Number of people that will be hired
None	6	0
1-3	42	84
3-6	15	75
6-8	7	49
8+	7	64
	Total	272

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Table 3. Where would you expect future employees to receive training in technical areas of precision ag? (Data source: DCTOA (c). N.D. Agricultural Implement Dealer Survey. Devils Lake, ND. Lake Region State College – Dakota Center for Technology-Optimized Agriculture. November, 2011. 8 pages.)

Answer	Number of Responses	Response Percent
Industry Sponsored	69	92%
Self-Training	35	46.7%
Mentor/Coworker	45	60%
Formal Training (College Courses)	43	57.3%
Training is not applicable to my future employees	2	2.7%
(Skipped Question)	3	

Table 4. Where would you expect future employees to receive training in consultation of precision ag? (Data source: DCTOA (c). N.D. Agricultural Implement Dealer Survey. Devils Lake, ND. Lake Region State College – Dakota Center for Technology-Optimized Agriculture. November, 2011. 8 pages.)

Answer	Number of Responses	Response Percent
Industry Sponsored	56	73.7%
Self-Training	28	36.8%
Mentor/Coworker	38	50%
Formal Training (College Courses)	49	64.5%
Training is not applicable to my future employees	4	5.3%
(Skipped Question)	2	

Table 5. Where would you expect future employees to receive training in agronomics, businesses management, and soft skills? (Data source: DCTOA (c). N.D. Agricultural Implement Dealer Survey. Devils Lake, ND. Lake Region State College – Dakota Center for Technology-Optimized Agriculture. November, 2011. 8 pages.)

Answer	Number of Responses	Response Percent
Industry Sponsored	31	40.8%
Self-Training	30	39.5%
Mentor/Coworker	35	46.1%
Formal Training (College Courses)	66	86.8%
Training is not applicable to my future employees	2	2.6%
(Skipped Question)	2	

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ting their training from the *formal training (college courses)* at 86.8 percent, and *industry sponsored* was second, with 40.8 percent.

Quantitative responses were also captured from equipment dealers, which said that, "The guys on staff right now in the state (N.D.) are not up to date on knowledge of precision agriculture." Some dealerships indicated that, "No employee is currently trained in precision agriculture technology" (P. Gunderson, personal communication, 2011).

Another industry leader indicated the following in an interview:

INTERVIEW WITH INDUSTRY LEADER

We need you (the Techs and Universities) to be bringing the next

…generation of precision worker to the workforce. There are not enough hours in the day to try to train people on the go, it usually takes a year to get them up to speed. To have them come in the door with the basic skills and knowledge, priceless. Additionally, the following statement was captured during an interview with a local N.D. agricultural cooperative, I don't know what I'm going to do; my guys aren't training, none of the other guys are out other (n=5) locations are training to use this stuff either. (Company name) doesn't provide the training, a local precision ag firm doesn't provide the training, but they want a special pricing agreement in exchange for providing the training, and we don't have any other source for training. You guys at Lake Region know how to do this stuff…why aren't you involved in training statewide for us? Every ag co-op in the state is in the same shape we are (P. Gunderson, personal communication, 2011).

DPAC and LRSC leaders disseminated qualitative and quantitative data and concluded that a precision ag program needed to be started and implemented at LRSC. However, 'wanting' and 'needing' this type of program was not going to get the program off the ground without local philanthropic support.

Local Community Funding Committed in Order to Support the Program

Devils Lake resides beside the largest natural body of water in North Dakota. The lake covers more than 160,000 acres, and has earned the reputation of being the "Perch Capital of the World." The city consists of 8,000 people, with 500 businesses (Devils Lake North Dakota, 2015, p. 20), which includes the necessary businesses to support the program. At least six ag businesses located in or around the city proper, including CASE-IH, John Deere, and Butler-Cat®. The state of ND houses the largest CASE-IH agricultural dealer network in the world, and the largest John Deere agricultural dealer network in the U.S. Hence, its agricultural implement dealer networks were not only poised to recruit and place large numbers of precision agriculture technicians, those networks also were capable of providing paid internships and other training opportunities in partnership with LRSC and DPAC.

With the need established within the workforce, the next step was to find and solicit local community support and funding. Considering the program was not up and implemented, and the institution could not prove the program would be viable with producing the workforce needed, funding from the community was going to be a challenge. As noted by Milliron & Browning (2003) that compared to four-year institutions, community colleges are relatively new to 'high stakes' fundraising (p. 90), and LRSC is no

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exception. LRSC was not known as an institution to solicit and receive large donations, or 'megagifts'; and with little validity that the program would work, soliciting donations needed to provide sustainability was going to be a challenge. Philanthropy for the program was going to have to come in the way of 'gifts in kind' via local industry; and few local industries were interested in supplying 'gift-in-kind' to assist in the development of the program. High Plains Equipment (HPE) of Devils Lake, N.D. had 27 employees and is the CaseIH Agricultural/AFS-Advanced Farming Systems™ / Borgaults ®/ Unverferth ® farm machinery dealer in the Devils Lake area. HPE had recently moved to a new location and constructed an ultra-modern facility. DPAC leaders developed a relationship convincing HPE that DPAC was poised to train the next generation of precision ag employees, however needed a viable building to implement the program. LRSC could not house the program on its campus since it did not have the necessary space needed. With the newly formed relationship in place, HPE provided complete access and use of their 4,480 square foot building 1 mile north of the LRSC campus for instructional and staff purposes and part of the 6,160 square foot shop space for student hands on training. Additional facility space would also provide for faculty and staff.

Farming is a risky business, considering a good yield (how much money a crop produces) could produce a huge return on investment or a below par yield could potentially bankrupt a farmer, its family, and future family for life. With such high risks involved, producers and farmers rely on accurate input from the land and the equipment they invest. Understanding and correctly interpreting the technologies used in precision ag, (this goes beyond the use and mechanical upkeep of a tractor or combine), was critical. DPAC leaders built and reinvented a program not only around the basic upkeep and maintenance of ag equipment, but the advanced technologies used in order to farm efficiently- and thus developing an Associate of Applied Science in Precision Ag. DPAC leaders looked outside of the scope of the 'basic equipment needs' of the program, and started talking and achieving buy-in from other industries where technologies would be utilized to achieve the precision in agriculture. Two local industries where cultivated to provide 'gift-in-kind' with access to software critical to the development and implementation of the precision ag program.

A local industry was approached to provide satellite remote sensing, which provides inferred mapping. Inferred mapping is a valuable tool when providing insight to a farmer's yield. When inferred pictures are captured, developed and stitched together to form a complete picture of a field, it can indicate the best and most profitable yield while assessing problems within the field itself, such as lack of nutrients and water. Again, in the high risk life of farming, every square inch of a field needs to be scrutinized and evaluated for yield production consistencies and inconsistencies.

Additional support was solicited from a company that built and sold Unmanned Aerial Vehicles (UAV). Gift-in-kind was provided in the purchase of UAVs in order to provide training for DPAC students in the flying and accessing inferred pictures (inside the Center). Like satellite remote sensing, UAVs can provide inferred photos that can assist producers and farmers with the necessary understanding of what their yield is or is not producing in the way of food. Without understanding and having training on these types of technologies, graduates of the program would be handicapped to assist farmers and producers when assessing fields and overall profit of their yield.

Additional support came from local industries from Butler-Cat®, John Deere®, FarmWorks Software®, and other high tech industries - each one providing gift-in-kind, from the use of high-tech precision ag equipment, to accessing needed software. All support provided an imperative need and support to implementing the program and providing necessary job training to future DPAC students.

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Overview of the Trade Adjustment Assistance Community College and Career Training Federal Grant, Which Required Local Support

What ultimately launched the Dakota Precision Ag Center (DPAC) was seed funding from the Trade Adjustment Assistance Community College and Career Training (TAACCCT) grant. According to the Department of Labor- TAACCCT website, in 2010, President Barack Obama signed the Health Care and Education Reconciliation Act, which included $2 billion over four years to fund the TAACCCT grant program (DOL, 2010). The TAACCCT grant program, funded through the Department of Labor and partnered with the Department of Education, was implemented to "assist community colleges and other institutions of higher education with funds to expand and improve their ability to deliver education and career training programs. Training programs are geared for individuals to complete their education in two years or less, and focused on workers who are eligible for training under the TAA for Workers program" (DOL, 2010).

The TAACCCT grant was written and submitted by DPAC leaders in the spring of 2012, and awarded the following fall. The grant project was entitled Training Precision Agriculture Technicians (TPAT) and was geared to create career pathways through coursework and training through technology in precision agriculture. The project's major purpose was to deliver training and assistance to TAA-impacted workers, unemployed Veterans, unemployed and underemployed persons seeking to increase their skills for new and higher-paying jobs in the state of North Dakota. Lake Region State College would support and provide online learning and personalized instruction. Through competency based skill assessments, use of cognitive tutors, and developmental educational services, students would have the ability to accelerate progress for certifications and degrees.

The grant was developed to fiscally launch the precision ag program, which also solidified more community and local workforce support. In order to submit the grant, DPAC leaders had to ensure that the support from the institution and the community was in place. While data supported the need to re-invent the closed agriculture program, the federal government was not going to fund LRSC and DPAC $2.9million dollars in funding unless the local community and workforce were supporting the effort. With diligence, and the building of the foundation for the program over the last few years, the community and institution was ready to move forward behind the grant. A partnership was created with Job Service North Dakota (JSND), the State agency that administers the TAA for Workers program. DPAC had solicited and sustained a network of agriculture industry employers and businesses and created The Council of Consultants. In 2012-2013 The Council of Consultants consisted of 5 (five) individuals from implement dealerships, agronomy firms, and precision agricultural consulting firms, providing recommendations for curriculum development and technical, job skill-set banking, post-training assessment, on the job training opportunity, and resources such as precision technology test equipment and job opportunities. Today, with a membership of 15 (fifteen), the Council has expanded to a Board of Directors, composed of agricultural implement dealership management-level staff, precision agriculture software vendors, agronomists, crop consultants, producers, and agricultural cooperative representatives who provide overall training and research program advice and linkage to employees.

After a year of funding from the TAACCCT grant, the TPAT program at the Dakota Precision Agriculture Center (DPAC) had met and surpassed its expectations and was seeing success as a statewide, regional, and international program, providing services to students from Montana, Iowa, South Dakota, Michigan and Canada. In its first year of launching the program (2013), the program had enrolled 29 (twenty-nine) students and 27 (twenty-seven) completed their first year.

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These key ingredients were needed in order to land the funding and launch the Precision Ag program. However, initial seed money can only reinvent and launch the program, more work needed to be deployed in order for the program to survive the next phase and reach sustainability.

Other Statewide Grant Funding That Was Used to Support the Program, Such as the Workforce Enhancement Grant (North Dakota Department of Commerce)

Seed money from the TAACCCT grant assisted in the launching of the precision ag program, however other local and statewide funding needed to be solicited considering program's needs were expensive, and $2.9 million in federal funding was not going to be able to cover all the initial costs.

DPAC leaders looked at the state for the next round of funding, which included the Workforce Enhancement Grant (WEG), administered through the North Dakota Department of Commerce. The Workforce Enhancement Grant Program provides funding for a demand driven response to workforce training needs for the five (Bismarck State College, Bottineau College, Lake Region State College, North Dakota State College of Science, and Williston State College) two-year institutions in North Dakota.

DPAC leaders knew that this program needed to be more than just a training program for those wishing to achieve an associates degree. The WEG was constructed not only to help supplement the program fiscally, but also provide another vital need; DPAC needed to provide outreach and training to those already in the precision ag business by providing workshops and training opportunities for local constituents. This, in turn, would start to bridge the gap towards producers and local ag workforce who were skeptical in providing necessary verbal or financial support for the program, and creating long term partnerships.

Again, through survey efforts provided by LRSC and DPAC leaders, identified necessary workforce skills that ag producers, farmers, and other ag businesses were lacking. In fact, identified that some agricultural equipment dealers, grain merchandising services, and independent agronomists/precision agriculture consultants needed necessary basic skills to manage farms in this high tech age of precision ag. Through Workforce Enhancement Grant funding, DPAC leaders constructed training needs in basic computer skills, basic precision agriculture, enhanced electronics skills, and customer relation skills. Grant funded efforts was able to provide DPAC leaders extended outreach and educational outreach to 55 (fifty-five) farmers in need of assistance and refresher classes in precision ag. This also continued to rebuild the torn relationships among the local workforce within farmers and producers.

What Are the Current Efforts in Place From the Community in Order to Continue to Provide Support?

The collaboration among institutions that is facilitated by consortia is a vital lever for transformational change—the type of change that will enable colleges and universities to not just survive but to prosper. (Forcier, 2011, p. 1)

CHANGE, COLLABORATION, AND CONSORTIA

Change, collaboration, and consortia – 3 C's - have become the watchwords of contemporary higher education. The one element that state and federal policymakers, major foundations (Lumina, Kresge,

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Gates, and others), and government agencies all share is the firm belief that higher education must change in order to remain effective. One increasingly common strategy to promote such transformation is an intense focus on collaboration between and among institutions, including the creation of consortia arrangements. Indeed, in many cases, collaboration and/or the formation of consortia are now requisite for the receipt of external funding. (Krotseng & Ruch, 2013, p.18)

Identifying and connecting with natural partners is the first step in developing long-lasting collaborations. (Krotseng & Ruch, 2013, p. 19)

DPAC was successful with the Workforce Enhancement Grant, providing educational outreach to farmers in need of assistance and refresher classes in precision ag. However, this was local, and DPAC wanted to move beyond the regional borders and provide this type of educational outreach statewide with a mobile training lab. This type of large-scale training was beyond the limits of the current program, and was time to employ the next phase to build support for the DPAC program. DPAC leaders knew that in order to provide change the next obvious step was collaboration building towards consortia. DPAC leaders looked towards their natural partner to collaborate with which was TrainND Northeast. TrainND is part of the North Dakota Workforce Training System, which provides and delivers training where the business needs it.

In collaboration with TrainND, DPAC leaders assisted in writing the Career Technical Education (CTE) grant in order to support workforce training in precision ag with a mobile training lab. With this collaboration, DPAC and TrainND would be able to offer non-credit workforce training developed specifically for the agricultural industry statewide. Small Business Computer Skills, GIS Systems, Basic Precision Agriculture, Enhanced Electronic Skills, Introduction to Welding, and Service to Customer Communication Skills will be available to producers, implement technicians, equipment operators, and other agriculture employees. Grant efforts would enable collaborative partners to purchase and equip a mobile high-tech training laboratory that will enable the delivery of precision agriculture technology training to the rural areas in the state of North Dakota.

SOLUTIONS AND RECOMMENDATIONS

The birth or rebirth of a program takes time, research, investment of a community, solicitation and commitment of the industry who will support it, extramural funding, and then collaboration of partnerships. The rebirth of the ag program took 8 years, troubleshooting and learning 'best practices.' The following take-away(s) could provide rural higher education institutions through philanthropy and other promising strategies ways to birth or rebirth a program tied to the community and workforce.

1. Research. Know the program you are trying to birth or rebirth. Talk with those in the industry. Ensure there is a need, and support for the program. You do not want to be a program that gets funded and implemented, only to have to close the program down in two-years, and to become another statistic like the ones stated at the start of the chapter. Some other items to consider:
    a. Is this a program your local constituents want? Talk with those who are involved and not involved in the industry and get their perspectives.

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   b. Do not stay local when it comes to researching the proposed program. Go outside the area to ensure this is a program needed locally, regionally and statewide. Once support has been provided locally, efforts will be needed outside the area for continued support and build sustainability.
   c. Enlist the support of your local legislature. Securing funding and support in the state, whether through political actions or statewide grants, is another vital way to build sustainability.
2. Start looking at external support. Federal grants are a good place, especially in the Department of Labor (DOL) or the US Department of Education. The current US federal administration is geared towards workforce development, and now is the time to capitalize on it. Current research and articles provided via the DOL indicates that this is a focus that will not be going away anytime in the near future.

   Also, look at statewide grants that support career and workforce developments, such as your CTE (Career Tech and Education) grants. Most states have these types of grants in place, or pools of money institutions can apply and compete for.
3. Continue to work with local workforce as programmatic activities are solidified. Develop a steering committee comprised of those who are vested either financially (workforce), legislatively (state), and who can provide guidance and extramural support.
4. And according to Krotseng & Ruch (2013), if you have not already considered or initiated collaborations with key partners or other like-minded institutions – start now. This is not a trend that will fade; it is becoming the norm to qualify for grants and extramural funding from federal, corporate, and private foundation sources. Begin today to identify potential partners and solidify productive alignments in preparation for the next major grant opportunity (Krotseng & Ruch, 2013, p. 19).

FUTURE DIRECTIONS AND RESEARCH TO BE CONSIDERED

Tight coupling between workforce and higher education is not a fad, and is becoming more of an emerging trend. As institutions continue to look for ways to develop or rebirth a program, whether in small rural locations or in an urban setting, this chapter speaks to all types of institutions and leaders, i.e. administration, faculty, legislatively, community and local workforce. Philanthropy and higher education is now an 'all hands on deck' practice, were everyone from the President down the chain of an institution is a fundraiser of some sort. No one is immune or not included in the process. All are involved with cultivating relationships. According to Ashford (2015, January, 5), "Rural colleges face plenty of challenges, such as a smaller pool of donors and fewer large corporations and wealthy donors nearby, but they actually have some advantages" reported Rich Gross, a consultant hired by the Danville Community College foundation. Such as being a "critical component in the community's workforce development, economic development, healthcare and quality of life," Gross reported (Ashford, 2015). LRSC DPAC leaders considered the 'community's workforce development' when rebirthing the program, Precision Ag. Furthermore, these are the areas a rural community college should focus on when it comes to cultivating relationships and building philanthropic donations- whether developing or rebirthing a program, building endowments, etc.

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CONCLUSION

Rural institutions and community philanthropy support, while difficult to obtain, is the future of institutions of higher education to gain financial stability. However, key stakeholders and leaders should not dive into the process serendipitously. As this chapter demonstrated, steps and other issues need to be considered before moving forward. Again, data collection is vital; and most institutions rely heavily on data collection in order to make changes or decipher directions or missions. In the process of collecting data via quantum methods, do not forget qualitative; discussing and talking with local constituents, obtaining their ideas, thoughts and opinions is also important to knowing what is going to be sustainable in the way of programs. The development and sustainability of the Dakota Precision Ag Center was not developed, built and implemented overnight, or with little understanding of the workforce, community needs and philanthropic opportunities. Building workforce relationships, which provided the necessary foundation for the program, in order to achieve 'gifts-in-kind' in the way of expensive agriculture equipment, and internship and employment opportunities for graduating students.

However, when building or 'rebirthing' a program, rural or urban, leaders and key stakeholders need to look 'outside' there borders, and think of other ways to bring in funding for support; such as federal and statewide grants which align with efforts. Also, working with local legislative representatives, aligning with their efforts is another necessary process.

And last, for future sustainability, collaboration and consortium with natural partners with similar visions and missions is key- especially for rural institutions. The sharing and collaboration of resources demonstrates the commitment needed to ensure future sustainability.

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REFERENCES

Ag Leader Insights. (2014, Spring). *Mapping New Classroom Opportunities; Rewarding careers in precision agriculture.* Author.

American Association of Community Colleges. (2000). *Community Colleges Past to Present (Based on material from National Profile of Community Colleges: Trends & Statistics, Phillippe & Patton, 2000).* Retrieved from http://www.aacc.nche.edu/AboutCC/history/Pages/pasttopresent.aspx

Ashford, E. (2015, January 5). *Fundraising is all about cultivating relationships*. Retrieved from http://www.ccdaily.com/Pages/Funding/Fundraising-is-all-about-cultivating-relationships.aspx

Austin, J. B. (2011, July 12). *Purdue fundraising shows growth*. Purdue University News Service. Retrieved from http://www.purdue.edu/newsroom/general/2011/110712CalvertYearend.html

Bailey, T., & Kienzal, G. (1999). *What Can We Learn About Postsecondary Vocational Education From Existing Data?*. Retrieved from http://ccrc.tc.columbia.edu/media/k2/attachments/vocational-education-existing-data.pdf

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Bureau of Labor Statistics. (2015). *North Dakota*. Retrieved from http://www.bls.gov/regions/midwest/north_dakota.htm)

2007 . Census of Agriculture, United States Summary and State Data. (2007). *Summary of Farm by Typology: 2007*. Retrieved from http://www.agcensus.usda.gov/Publications/2007/Full_Report/usv1.pdf

Community College Daily- American Association of Community Colleges. (2014, November 20). *Signs of hope for state funding*. Retrieved http://www.ccdaily.com/Pages/Campus-Issues/Signs-of-hope-for-state-funding.aspx

Daniels, A. (2015, February 19). Mega-Gifts on the Rise at Colleges, Study Says. *The Chronical of Philanthropy.* Retrieved from https://philanthropy.com/article/Mega-Gifts-on-the-Rise-at/227955

Devils Lake North Dakota. (2015). *Visitor Guide,* 1-20.

Fain, P. (2014, August 7). Linking Business and Budgets. *Inside HigherEd.* Retrieved from https://www.insidehighered.com/news/2014/08/07/new-workforce-fund-louisiana-ties-money-jobs-and-private-donations

Forcier, F. M. (2011, September/October). Innovation Through Collaboration: New Pathways to Success. *Association of Governing Boards of Universities & Colleges, 5*(19). Retrieved from http://agb.org/trusteeship/2011/9/innovation-through-collaboration-new-pathways-success

Greene, R. (2011). *LightSquared Wireless Broadband – A Detriment to rural America?* Retrieved from http://precisionpays.com

Hardy, D. E., & Katsinas, S. G. (2007). Classifying Community Colleges: How Rural Community Colleges Fit. *New Directions for Community Colleges*, *13*(137), 5–17. doi:10.1002/cc.265

Katsinas, S. G., Tollefson, T. A., & Reamey, B. A. (2008). *Funding Issues in U.S. Community Colleges: Findings from a 2007 Survey of the National State Directors of Community Colleges.* Retrieved from http://www.aacc.nche.edu/Publications/Reports/Documents/fundingissues.pdf

Krotseng, M. V. & Ruch, C. (2013). *Promoting and Sustaining Change Through Collaboration and Consortia.* American Association of State Colleges and Universities.

Milliron, M. D., De los Santos, G. E., & Browning, B. (2003). Feels like the third wave: The rise of fundraising in the community college. *New Directions for Community Colleges*, *2003*(124), 81–93. doi:10.1002/cc.137

Mortenson, T. (2004, January). State Tax Fund Appropriations for Higher Education FY1961 to FY2004). *Postsecondary Education Opportunity* (no. 139). Oskalossa, IA: Mortenson Research Seminar on Public Policy Analysis of Opportunity for Post-Secondary Education. Retrieved from http://www.postsecondary.org/last12/139TAXFY04.pdf

Murphy, M. (2010). *An Energized Future*. Delta Sky Magazine.

North Dakota Implement Dealers Association. (2010) *Economic Impact of North Dakota's Retail Farm Equipment Dealers*. Paper presented at the North Dakota Implemented Dealers Association, Bismarck, ND.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Paradise, A. (2015). *Results from the 2014 CASE Survey of Community College Foundations* [White paper]. Retrieved May 19, 2015, Council for Advancement and Support of Education: http://www.case.org/Documents/WhitePapers/CCF_Survey2014.pdf

Romano, J. C., Gallagher, G., & Shugart, S. C. (2010). More than an Open Door: Deploying Philanthropy to Student Access and Success in American Community Colleges. *New Directions for Student Services*, *2010*(130), 55–70. doi:10.1002s.360

Signs of Hope for State Funding. (2014, November 20). *Community College Daily-American Association of Community College*. Retrieved from http://www.ccdaily.com/Pages/Campus-Issues/Signs-of-hope-for-state-funding.aspx

Strauss, L. (2001, December). *Trends in Community College Financing: Challenges of the Past, Present, and Future.* Retrieved from ERIC database. (ED467983)

Thelin, J. R. (2004). *A History of American Higher Education*. Baltimore, MD: The Johns Hopkins University Press.

United States Department of Labor. (2010). *Trade Adjustment Assistance Community College Career Training Program Summary*. Retrieved from http://www.doleta.gov/taaccct/

Weerts, D. J., & Ronca, J. M. (2006, November/December). Examining Differences in State Support for Higher Education: A Comparative Study of State Appropriations for Research I Universities. *The Journal of Higher Education*, *77*(6), 935–967. doi:10.1353/jhe.2006.0054

Worth, M. J., & Smith, N. J. (1993). Raising Funds for Community Colleges. In M. J. Worth (Ed.), *Educational Fund Raising: Principles and Practice* (pp. 347–356). Phoenix, AZ: American Council on Education and the Oryx Press.

Zinser, R. (2003, Winter). Evaluation of a Community College Technical Program by Local Industry. *Journal of Industrial Teacher Education*, *40*, 1–8. Retrieved from http://scholar.lib.vt.edu/ejournals/JITE/v40n2/zinser.html

KEY TERMS AND DEFINITIONS

Agricultural Producers or Producers: Another word for farmer.

Answer Farms: An agricultural research facility located near Fort Dodge, Iowa.

Career Tech Education Grant: North Dakota grant administered via the Career Technical Education department for the development and support of workforce enhancement.

Dakota Precision Ag Center: One of Lake Region State College's programs, which houses the Associates of Applied Science in Precision Ag.

Lake Region State College: Two-year higher education institution located in Devils Lake, North Dakota.

Precision Agriculture: This is the combination of agriculture and technology.

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Trade Adjustment Assistance Community College Career Training Grant: Federal grant that was signed by President Barack Obama, and administered by the Department of Labor and Department of Education, in order to assist two-year and other higher education institutions in the development and expansion of education and career training programs.

Unmanned Aerial Vehicles (UAV): This is also known as a Drone, which is an unpiloted aerial vehicle.

Workforce Enhancement Grant: Grant administered via the North Dakota Department of Commerce in the development and support of workforce enhancement.

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Chapter 14
Impact on Agricultural Sustainability of Maghreb Countries:
An Empirical Analysis by 3SLS

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ABSTRACT

This paper is aimed at making the diffusion of the technological innovation and their role in affecting the agricultural sector in the three-sided (social, economic and environmental), a hand, it can participate to resolve problems of the agricultural sector: the effects of the climatic changes, the farming exodus and the migration and the problems of poverty. The theoretically and empirically studies analyze the mechanical innovation role in improving agricultural sustainability through the impact of mechanization on agricultural productivity, CO2 emission and demographic growth for a panel of three Maghreb countries (Algeria, Morocco and Tunisia) during the period 1999-2012. By using simultaneous equations, the authors' finding that mechanical innovation cannot achieve the purpose of sustainable development in the agriculture sector in the Maghreb countries through the negative impact of mechanization and research and development on agricultural productivity.

INTRODUCTION

The agriculture is a sector which plays a crucial role in the enhancement of territories, since this sector contributes to the increased growth of the country, nourishes all living things, but meeting a sustainability problem especially in developing countries. Agriculture is introduced into the sustainable development plan to improve and modernize this sector for agriculture called 'environmentally responsible' (Ambroise et al, 1998).

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At the beginning of the seventy years, agriculture has found its place in political debate through the exposure of these issues such as: the mode of production productivist, environmental degradation, political and institutional structures etc.

This is a great debate that is open to the world in all commissions and United Nations organizations that is related to sustainable agriculture to set new targets for renewable and sustainable development.

This debate based on the work of UN member states, seeks to combine a consensus around vital of a new human world politics, fair and concerned with protecting the environment.

The birth of this new concept "political ecology" began to spread in the world where some developed countries were changing their mode of production by the substitution of industrial processes of physical or chemical to biological processes. For example, with the use of nitrates substituting nitrogen fixation by bacteria as herbicides and pesticides will have been replaced with natural antagonists of weeds and insect pests (Estevez et al, 1999).

The Sustainable increase in agricultural yields each time was not achieved without the destructive effects of the environment. The transition from conventional mode to sustainable ways of agriculture has formed a long journey that has supported both socioeconomic and environmental terms.

On this basis, in the early ninety, the concept of sustainable agriculture began to appear officially. This new agriculture aims to protect resources in agriculture (soil, water, energy ...) and stimulating the biological process that is the basis of stability by the mastery of pests and weeds (Estevez et al, 1999) and find a quick way to balance the three aspects already mentioned in the economic, social and environmental occurrence and in the agricultural sector.

Although the word sustainability was popularized by the spread of the concept of sustainable development (Delchet, 2004), the term sustainable agriculture and sustainable society have been discussed in the North American continent (The limits to growth, Meadows and al, 1972). On this basis, the author has initiated a debate on the production-growth and its environmental and social consequences in a period characterized by an energy crisis. Since then, the concept of sustainable agriculture has been distributed increasingly in all environmental debates.

While the question of whether technological innovation, particularly the mechanization improves or prevents the agricultural sustainability opens the door to the birth of several economic and political debates, there are little theoretical and empirical studies on the factors of development and economic durability of irrigation system in Maghreb countries.

The objective of this paper is to make up the void in the literature and make an in-depth analysis the sustainability agriculture sector of the Maghreb countries in order to identify their socioeconomic and environmental factors.

To better understand what leads the mechanization effect on the Maghreb agriculture sustainability, we browse in these paper three types of factors, social, economic and environmental. The scope of our study covered 3 Maghreb countries during the 1999-2012 periods. We utilized an econometric methodology based on the 3SLS.

Our results show that the mechanical innovation, research and development cannot achieve the sustainable development purpose in the agricultural sector of the Maghreb country in particular economic efficiency.

The rest of the paper is organized as follows. Section 2 furnishes a brief literature review of the impact of technological innovation in the agricultural sustainability. Section 3 presents the trend of agriculture and mechanization in the Maghreb countries. Section 4 shows the data and the adopted econometric

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methodology. The empirical results are obtained and interpreted in section 5. The rest of the paper is devoted to the presentation of some solutions, policy implications, suggestions and conclusion.

Technological Innovation and Sustainable Development: A Brief Literature Review

Major prior studies related to the present paper include Alani (2012), Blazy and al (2011), Esposti (2002), Van Rijn and al (2012), Feder and al (1993), Ruttan (1974), Khaled and al (2014, 2016). These studies focus on the effects of technological innovation such as mechanization, on the development of agricultural sustainability in developed and developing countries.

The concept of "innovation" is developed by the neoclassical approach as Adam Smith, David Ricardo, Marx etc. and improved by the Austrian school as Joseph Schumpeter. Technological innovation is defined as the set of innovations that induce transformation or a disruption of resources and methods of production, organization of work, products and markets, economic structures.

Schumpeter distinguished five types of innovation such as product innovation (production of a new product, process innovation (new method of production), discovered a new source of raw materials or energy, commercial innovation and new types of organizations (Dubouloz, 2006).

The neoclassical school indicates that the technological innovation and technological progress are factor that enhances the production quantities of capital and labor unchanged. This is an unexplained residue like manna falling from heaven. While Schumpeter explains that technological innovation is the engine of economic development.

Several authors analyze the impact of mechanical innovation and their role in the development of agricultural sustainability. For example, Alani (2012) shows that the improving agricultural productivity is linked with technical progress, he argues their work by a theoretical model derived from a production function type Cobb–Douglas to measure the impact of technological innovation and the productivity on economic growth in Uganda. He found that as technological innovation enhances economic growth. While the labor and capital productivity has reduced economic growth. He explains this result by the low productivity of the workforce who prefers leisure than work.

Fadavi et al (2010) analyzed the impact of mechanization on production through a survey of a diverse swatch contains 80 apple growers in Iran. They have obtained results as mechanization could not vary significantly because of the increased labor and energy cost during the harvesting operation. According to these authors, the agricultural mechanization is a destruction source of the land and natural resources.

Blazy et al (2011) indicate that, the improvement in agricultural production based on the reduction of pesticide use and renovation of soil fertility in the fight against weed, provide the nitrogen to the soil without insecticides increases in numbers, each of this way has led to technological innovation. According to the authors the innovations also have different effects on the net operating income and the productivity. The implementation of some innovating method in the agricultural sectors based on environmental, social and economic conditions.

Blazy et al (2011) conducted a survey on conventional farmers and organic banana farmers to have the most efficient technology adopted in the French Antilles (Guadeloupe and Martinique). They are found as a result that mechanization will be a source of sustainability in the production of organic banana due to its negative impacts on the environment.

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Recent research shows that agricultural development is improving by the technological innovation, but whereas the durability can affect positively or negatively by the mechanization as it explains Khaled and al (2016) in his empirical analysis that is founded on the OLS modeling.

The innovation in agriculture and rural enterprise comes from whatever source (formal or informal) of new modes in the production and organization of agricultural activity.

The rural populations have a human capital integrating essential sources of knowledge and new procedures through their knowledge and modes of organization.

Good solutions found by small farmers themselves are a necessary source for enhancing agricultural productivity of developing countries.

Poole (2006) explains that, the mechanism and the level of research and innovation in the formal agricultural system have increased in the eighteenth and nineteenth century later has the use of scientific methods in relatively advanced economies (quoted by Khaled et al, 2016).

The R&D preferences in agriculture were encouraged during the last century by the government, which led to the birth of the formal national research systems in advanced and developing countries and the creation of organism's international research.

The green revolution is represented as a result of public research or as a classic example of a method giving land ownership to the farmer.

At this point, we can say that innovation is constituted by various researches and it can be spread through different distribution procedures by economic historical, political, institutional and climate contexts. In recent years, the increasing advances in technology led to the creation of technology platforms such as information and communication technology (ICT) and biotechnology (Khaled et al, 2016).

EVALUATION OF SOCIOECONOMIC AND ENVIRONMENTAL FACTORS

Energy

The farming surroundings and the agricultural sectors endure mediocrity of the infrastructure and the lack of information. These two difficulties cause the reduction of the outputs of the agricultural production and the decrease of the level of employment in this sector, what conducted to the apparition of poverty in these surroundings (Khaled et al, 2016).

For solving these problems, it is necessary to encourage the investment in the energy since he/it is considered like means of enhancing the life quality for rural populations, while being based on the technologies, in particular of information and the communication.

The lack of infrastructure and high costs are often explained by the lack of rural energy associated with various social, economic and political difficulties.

The energy is necessary to reinforce the nonagricultural farming economy directly and the agricultural farming economy indirectly.

The current price of oil and its derivatives can release hazardous effects that affect various areas such as air pollution, sea pollution that led to the decline the marine resources and soil pollution and thus to reduce the fertility of agricultural land and subsequently to lower yields and lower employment in this sector, Which encourages migration from rural to industrial or other services.

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Energy supply associated with conventional technologies in rural areas can be more expensive. The social and environmental benefits of the development of services based on energy sources other than oil are viable.

We must invest in the energy sectors other than oil for environmental and economic reasons, such as wind and solar energy, which are technically feasible for local markets in rural areas.

Poverty Reduction

The project " objectives of the millennium for the development " (OMD) defined real strategies to avoid poverty while improving the investments in the infrastructure and the human capital in the farming surroundings, what permits to improve the agricultural sector by a qualified manpower, as well as the increase of production following the increase of the transportation means and thereafter a growth of the outputs and a reduction of poverty in the background farming, while motivating the equality between the sexes and the protection of the environment (Khaled et al, 2016).

The project of the OMD includes the science, the technology and the innovation and permits to apply the knowledge to the development.

The difficulties faced by developing countries in innovation are not related to the creation of new knowledge, but the effective use of existing techniques.

The System of Supermarkets

The impact of the international proliferation of large series on food retail sectors was generally analyzed for developing countries and also in several other regions such as Latin America, Central and Eastern Europe, sub-Saharan Africa and Asia (Khaled et al, 2016).

In developing countries, to reason at a time of demand bound to the tendency of the local life forms and to the big international business entry, the food systems are quickly going to be complex. In Tunisia the international supermarket entry is increasing with the time the sample Carrefour Market that has developed in most regions of Tunisia.

However, the international supermarket is a novelty that ensures the sale of food products, such as fresh produce, namely fruits, vegetables, meat and fish, which promotes the growth of production in the two sectors agriculture and fisheries.

So the international supermarket is an innovation that improves several areas such as fisheries and agriculture, and for industry.

Khaled et al (2016) indicates that, the international supermarket system offers the advantages that are the development of the employment in these stores and in their specific supply chains, an overall increase in the quality of food coming from the technology transfer and commercial uses of farmers.

National supermarkets are represented as major suppliers and demanders of local products, in the less advanced countries. These companies run into relationship marketing and ensure the root of supply series. This new business model is distinguished by low margins and high quality, creating new opportunities and new challenges for providers, such as self-service sales, healthy environments, indicating prices, the aggressive marketing and the promotions are henceforth the strategic norm (Cadilhom et al, 2006).

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The development of monopsony system and economies of scale associated with the production, the basis of the standards and the organization rule and multiplication of knowledge to make, transmission of the markets that explains the situation of the small agriculturists of the difficult zones that is outside of these markets.

Agricultural Evolution in the Maghreb Country

The Maghreb region includes richest country in oil and gas (Libya, Algeria) and countries whose resources are very limited compared to their populations (Tunisia, Morocco and especially Mauritania) throughout the region of Africa north (Khaled et al, 2016).

To solve this problem of limited natural resources, many economic and political leaders put agriculture in question. For all the Maghreb countries, the agricultural sector remains of major importance in the economic, social and political level.

The sector must continue to achieve two strategic objectives: the protection of the development of basic agricultural products so-called strategic (cereals, milk, potatoes and sugar) and compensation for producers in the event of agricultural disasters.

Globally, on the basis of the green revolution goal, the success of these R&D should result increased the production volume of basic agricultural products, by increasing yields and agricultural productivity and lower the level of agricultural imports expensive and rarely by the degree of respect and apply the principles of sustainable development (Khaled et al, 2016).

So the use of new technologies such as cultural diversity or animal genetic material shows very contradictory results, with rising environmental costs (protection of forest areas and backgrounds, the use of mechanization on fragile soils with increased erosion, ...) and the social costs (loss of a genetic heritage applied to the arid conditions, deterioration of the collective actions with the individual production motivations).

In some difficult areas, these new technologies do not find their place because of the lack of infrastructure for production and transport, and low participation in services such credits to finance the costly inputs.

Also applied research, partly in experimental research institutions overlooked the local expertise of the actors and the spread of this research was done at the expense of local knowledge which ensured a balance between the medium and the community.

In the arid media, the options distribution difficulties are in intensive systems, which have been frequently reduced for social reasons, such as non-rationality of producers or low level of education in marginal and disadvantaged areas, etc.

The basic consequence is the reduction of the actions to the destructive technical applications of the nature to restrict the environmental risks, in particular the risks of drought.

However, facing the demographic increase of the Maghreb countries, and in light of the urbanization and unemployment increases rates attached to the emigration from the marginal surroundings, of the pastoral zones deterioration, the increasing desertification problem, and the weak technological transfer of research in the difficult zones that correspond to more of 85% of the territory, the agricultural research was interested again controlled in the small and medium agricultural farmers of the arid and semi-arid zones, but this new orientation made itself it in a setting of liberalization, from the years 80, named pre – adjustment period.

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Table 1. Summarize the tendency of socioeconomic and environmental factors such as the agriculture productivity, energy production, number of mechanization and the net income per capita in the three Maghreb countries in 2005 and 2010

Country	Agriculture Productivity		Energy Production		Number of Mechanization For 100 Square km		Net Income Per Capita	
	2005	**2010**	**2005**	**2010**	**2005**	**2010**	**2005**	**2010**
Algeria	8.221	9.0	166662.44	150524.713	128	141	10270	12630
Morocco	14.677	14.4	610.282	879.445	490	490	4710	6200
Tunisia	10.127	8.2	6681.4	8120.509	127	120	7360	9800

(WDI, 2014).

The above table measures the evolution of socioeconomic factors (agricultural productivity, number of mechanization and net revenue per capita) and the environmental factor (energy production) in the two years 2005 and 2010.

The table showed that, in Algeria, the all socioeconomic factors increase by against the environmental factor such as energy production is dropped. In Morocco, the number of mechanization remains constant during the years 2005-2010. While the net income per capita increases despite declining agricultural productivity and increases of energy production. In Tunisia, the number of mechanization has decreased, as well the agricultural productivity. While net revenues per capita and energy production have increased.

This table indicates that mechanization has evolved with the same sense of agricultural productivity and inversely to the energy production. This trend explains that mechanization is the motor of productivity (Feder et al, 1993) and production in Maghreb countries.

The Maghreb countries are characterized, in recent years, by the introduction of green and not productivist technologies, for this reason the number of mechanization is reduced as the case of Tunisia (Boughanmi 1995).

However, the adoption and dissemination of this model seem to be moving very slowly because mainly of its uniformity and lack of adaptation to regional diversity and heterogeneity of production systems in Maghreb countries. The biological and chemical technologies (improved seeds, chemical fertilizers) are basically neutral about the size of the operation and can be adopted by both large and small farmers, provided that an effective extension system, closely related research and near the farmer (Ruttan, 1985; Boughanmi 1995). The Tunisian experience related to extension remains too rigid administrative and involving little agricultural profession, despite some reforms in the direction of decentralization and coordination of extension programs.

Econometric Methodology and Data

The approach selected in this paper was to model the mechanical innovation impact on the agriculture sustainability in the Maghreb countries. Our initial intention was to cover all countries in the Maghreb, but given that some countries have not yet data of agricultural productivity (for example, Libya, Mauritania), the samples are included only 3 Maghreb countries: over the period of 1999-2012.

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Data

Data were extracted from two sources, the data will be used for the measurement of variables are taken from the database of the World Development Indicators (WDI 2014) and food agriculture organization (FAO 2014).

Information related the expenses in research and development "R&D" (ERD), the expenses in information and communication technology "ICT" (EICT), the CO2 emission (CO2_E) and the demographic growth (DG) are collected from Worlds Development Indicators (World Bank, 2014). Other information related to agricultural productivity (AP), the mechanization, the Labor (L), the farming population (FP) is collected from food agriculture organization (FAO, 2014).

The dependent variables of interest are agriculture productivity, energy production and net income per capita.

The Variables

Our analysis founded on macroeconomic factors:

- **Agricultural Productivity (AP):** Agriculture in value added by the worker (% of GDP) (WDI, 2014). V. Ruttan (1974) indicates that the agricultural growth, improvement begins with the apparition of one sustained increase period in the total productivity via the use of new factors and new technologies; our technology is the system of irrigation (Khaled and al, 2014).
- **The Expenses in Research and Development (ERD):** Clark and Youngblood (1992) showed that the variable " technology ", as the expenses of the R&D changes the supple utilitarian shape with time is included in the specification of the function of profit, this variable permits to solve the problem of tendency of time (Thirtle and al, 1995). The R&D is the key of development and modernization of the agricultural sector (quoted by Khaled and al, 2016).

Even in the developed country, the agricultural systems of research meaningful are dedicated to testing and refined the innovations of the agriculturists and to test the adaptation of exotic exploitation varieties and the species of the animal (Ruttan, 1974).

- **The Expenses in Information and Communication Technology (EICT):** Permits to improve the sector by the diffusion of innovation to the world level and the diffusion of the R&D toward the producers and the consumers.

The ICT decreases the uncertainty of the producers concerning the bought input and of the consumers concerning the consumed product (Feder et al, 1993).

- **The Mechanization (M):** It is a very important technology to improve the outputs of producers. (Clay, 1982).
- **The labor (L):** Alani (2012) proved that the labor is considered as a technology that permits of replaced the machinery in some cases to keep the durability of the sector.

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- **The Farming Population (FP):** Himself the producers, the consumers and the manpower. The farming sociologist research has contributed to the diffusion efficiency of technology (Ruttan, 1974).
- **The CO2 Emission (CO2_E)**: Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid and gaseous fuels and flaring (WDI, 2014). This variable is defined by Soni and al (2013) as environmental determinant.
- **Demographic Growth (DG):** The population growth (annual %) corresponds to the exponential growth rate of the population in the middle of the year n-1 to n, expressed as a percentage. (WDI, 2014). SemihAkc-omak et al (2009) and Van Rijn and al (2012) indicates that, the demographic growth is a factor of social aspect.

Econometric Methodology

From a methodological viewpoint, we chose to value the involvement of the innovations technological to the durability and the growth of the agricultural sector based on the standard production function of Cobb - Douglas type (1928) improves by Dowricks and Rogers (2002) respecting the properties traditional neoclassical (Khaled and al, 2016).

$$Y = AK^{\alpha k}H^{\alpha h}L^{\beta} \text{ or } \beta = 1 - (\alpha_k + \alpha_h) \quad (1)$$

Where, Y is a dependent variable which is defined by agricultural productivity, CO2 emission and demographic growth. K, H, L and A are, respectively, the physical capital, the human capital, the labor that grows to the rate exogenous and constant " n ", the technical progress is neutral in the sense of Hicks (1932) and αk, α_h, β are the production elasticity's (Khaled et al, 2016).

However to evaluate the participation of mechanical innovation, we decomposed the stock of physical capital in two parts: the material, physical capital is the mechanization (M) and the immaterial physical capital is the expenses in the information and communication technology ICT (EICT).

The ERD is the investment in human capital, according to the theory of human capital (Nafiou, 2009).

The expenses in R&D (ERD) and the expenses in the technology of information and communication, ICT (EICT) are considered like an investment in the innovation (OECD, 1999).

The stock of the labor is decomposed into two parts: the labor in the agricultural sector (L) and the farming population (FP).

The goal of this paper is to examine the relationship between mechanical innovation and agricultural sustainability through the impact of mechanization on agricultural productivity, CO2 emission and demographic growth.

This relationship is measured by a simultaneous equations model (3SLS) extended as follows:

$$AP_{it} = \alpha + \beta_1(EICT)_{i,t} + \beta_2(M)_{i,t} + \beta_3(ERD)_{i,t} + \beta_4(L)_{i,t} + \beta_5(FP)_{i,t} + \beta_6(CO2_E)_{i,t} + \beta_7(DG)_{i,t} + \xi_{i,t} \quad (2)$$

$$CO2_E_{it} = \alpha + \beta_1(EICT)_{i,t} + \beta_2(M)_{i,t} + \beta_3(ERD)_{i,t} + \beta_4(L)_{i,t} + \beta_5(FP)_{i,t} + \beta_6(AP)_{i,t} + \beta_7(DG)_{i,t} + \xi_{i,t} \quad (3)$$

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$$DG_{it} = \alpha + \beta_1(EICT)_{i,t} + \beta_2(M)_{i,t} + \beta_3(ERD)_{i,t} + \beta_4(L)_{i,t} + \beta_5(FP)_{i,t} + \beta_6(AP)_{i,t} + \beta_7(CO2_E)_{i,t} + \xi_{i,t} \quad (4)$$

$i = 1, 2,\ldots N, t = 1,2,\ldots Ti$

Where AP, CO2_E and DG are the dependent variables, are defined respectively as agricultural productivity, CO2 emission and demographic growth. The Independent variables are the expenses in research and development (ERD), the expenses in information and communication technology (EICT), the mechanization (M), the labor (L), and the farming population (FP).

Equation (2), allows measure the impact of mechanical innovation on economic sustainability through the effect of the mechanization (M) on the agriculture productivity (AP), as well as the spending of research and development (ERD) and spending of information and communication technology (EICT) impact.

Equation (3), allows examine the impact of mechanical innovation on environmental sustainability through the effect of the mechanization (M) on CO2 emission (CO2_E), as well as the spending of research and development (ERD) and spending of information and communication technology (EICT) impact.

Equation (4), examines the impact of mechanical innovation on social sustainability through the effect of the mechanization (M) on the demographic growth (DG), as well as the spending of research and development (ERD) and spending of information and communication technology (EICT) impact.

Our methodology is based on an estimate of the simultaneous equations model (3SLS), a sample of 3 Maghreb countries (Algeria, Morocco, Tunisia) and a measurement of the variables from the data for the countries will of 1999 until to 2012.

This simultaneous equations model is estimated by the generalized method of moments (GMM). Since generally, the results of GMM are robust.

RESULTS AND INTERPRETATION

Table 2 provides summary statistics on the variables.

Table 2. Descriptive statistics

Variable	Mean	Std. Dev	Min	Max
AP	12.04083	3.502358	6.68	20.223
ERD	.5452381	.331392	.07	1.5
EICT	4.497619	3.163703	1.5	14.5
L	6.506214	2.970074	2.3	10.9
FP	39.64065	4.713145	33.902	47.6508
M	5.632143	2.200882	2.45	8.1
CO2_E	2.215405	.717636	1.132	3.529
DG	1.201214	.2298503	.928	1.776

N 42
n 14
T 3
Note. — N, total number of observation; n, number of observation for only one country; T, number of country.

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Table 2 shows that the average agricultural productivity, the entire sample is 2.437398%. The inter-individual variance (between) 0.0908%, while the intra individual variance (time) is equal to 0.0172%, in our case the inter-individual dimension (3 countries) is very important that the intra-individual dimension (17 years country) (0.0908%> 0.0172%). The same for the regression (3) and (4).

Table 3 summarized the results of three least squares (3SLS) models for the sample of the 3 Maghreb countries from 1999 to 2012.

The first column presents the effect of mechanization on economic sustainability through their impact on agricultural productivity. The second column indicates the effect of the mechanization on environmental sustainability through her effect in CO2 emission. The third column shows the impact of mechanization on social sustainability through her effect on demographic growth.

According to the regression (2), we show that, the variables: population growth (DE) and expenditure of R&D (ERD) are positive and significant at the 5% and 10% level. The variables: labor (L) and mechanization (M) are negative and significant at the 1% level. While the variables: expenditure of ICT (ECIT), farming population (FP) and a CO2 emission (CO2_E) are positive and not significant.

The above table (regression 2) shows that, where agricultural productivity (AP) increases by 1 percentage points, mechanization (M) decreases by 1.747371 percentage points and labor (L) decreases by 0.4338862 percentage points. By against, demographic growth (DG) rise by 3.887044 percentage points and R&D expenditure (ERD) increase by 2.011479 percentage. This result is similar to the study of Fadavi and al (2010) and Khaled et al (2016).

Table 3. The model estimation by the 3SLS method

Models	**(2)**	**(3)**	**(4)**
Variables	**AP**	**CO2_E**	**DG**
AP	---	.0213774 (0.386)	.0679745 (0.000)***
CO2_E	.8139869 (0.386)	---	.3073321 (0.010)***
DG	3.887044 (0.000)***	.4615501 (0.01)***	---
M	**-1.747371 (0.000)*** **	**.0752307 (0.000)*** **	**-.0032265 (0.962)**
ERD	2.011479 (0.023)**	-.3136046 (0.021)**	-.2275172 (0.043)**
EICT	.0069395 (0.936)	.0263234 (0.049)**	-.0141828 (0.206)
L	-.4338862 (0.000)***	.076319 (0.000)***	.0193965 (0.202)
FP	.1810303 (0.107)	.0436239 (0.013)**	-.028774 (0.057)*
Constant	9.928643 (0.106)	-3.26619 (0.000)	.9223143 (0.264)
Observations	42	42	42
R^2	0.9220	0.9524	0.6737

Note. — Panel estimations of the 3 Maghreb countries. The dependant variable is the agriculture productivity (AP), CO2 emission (CO2_E) and the demographic growth (DG). Variables in parentheses are at the significance level of 1% *, 5%** and 10%***.

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This negative impact of mechanization on the economic sustainability explains that the mechanization cannot achieve economic efficiency in the Maghreb countries due to the intensive use of mechanization in the sector, allowing deteriorate soil fertility over time and eventually lowers productivity and performance in the agricultural sector (Fadavi and al, 20101).

The variables: expenditure of ICT (ECIT), farming population (FP) and a CO2 emission (CO2_E) are not significant because the relationship is indirect with agricultural productivity. This relation is created through other factors such as labor, energy production, etc.

In the regression (3), we mark that, the variable expenditure on R&D (ERD) is negative and significant at the 5% level and the: expenditure on ICT (EICT), labor (L), farming population (FP), mechanization (M) and population growth (DG) are negative and significant at the 1% and 5% level. While the variable: agricultural productivity is positive, but not significant.

The above table indicates that, when CO2 emission (CO2_E) rises by 1 percentage points, mechanization (M) increases by 0.0752307 percentage points, labor (L) increases by 0.0752307 percentage points, demographic growth (DG) rise by .4615501 percentage points, communication and information technology expenditure (EICT) increase by 0.0263234 percentage points and farming population (FP) raises by 0.0436239 percentage points. However, R&D expenditure (ERD) drops by 0.3136046 percentage points.

According to the study of Kallivroussis et al (2002); Soni et al (2013), the use of mechanization in the agricultural exploitation causes diffusion of pollution in the soil and in the air as CO2 which leads eventually to the reduction of soil fertility, development of diseases in rural areas, etc.

The variable agricultural productivity is not significant because of its indirect relation with the issuance of CO2.

Regression (4), indicates that, Variables: expenditure of R&D (ERD) and rural population (FP) are negative and significant at the 5% and 10% and the variables: agricultural productivity (AP) and a CO2 emission (CO2_E) are positive and significant at 1%. While the variables: mechanization (M) and expenditure on ICT (EICT) are negative and not significant and variable labor (L) is positive but not insignificant.

The above table suggests that, demographic growth (DG) increases by 1 percentage points, the CO2 emission (CO2_E) rises by 0.3073321 percentage points and the agriculture productivity (AP) increases by 0.0679745 percentage points. Whereas, R&D expenditure (ERD) and farming population (FP) decreases respectively by 0.2275172 percentage points and 0.028774 percentage points.

The variables mechanization (M), expenditure of ICT (EICT) and labor (L) are not significant. These results explain the indirect relation between this factor and demographic growth.

According to the regression 2 and 3 analysis, mechanization (M) can affect negatively the demographic growth by diffusion of CO2 in the soil and air (regression 3) which subsequently leads to disease development and subsequently the reduction of population growth. The CO2 diffusion induces to soil degradation and subsequently the decline in productivity and production (regression 2) agricultural which causes the increasing undernourishment and decreased demographic growth.

Mechanization improves the purchasing power of Employers in the industrial sector such as an equipment manufacturing society, for against the rural population suffers from very high level of poverty. As he explains Timmer (1992), the agricultural sector is like a black box, it provides power to all the other sectors against it is not growing.

In the Maghreb countries, the mechanization affects negatively the environmental, economic and social sustainability's.

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According to the results of the simultaneous equations model (3SLS) estimation, we noticed that the workforce has a negative role in the functioning of agricultural machines (Ruttan, 1974). The regressions (2) show that the relationship between agricultural productivity and labor is negative (0.4338862).

Labor recruited in the agricultural sector of the Maghreb countries is unqualified. It is malfunctioning agricultural machinery and deteriorates the production by ecological footprint (Fersino et al, 2002).

The impact of mechanization on economic, social and environmental aspects is explained by the effect of labor on the three durability's. The workforce in agriculture of the Maghreb countries is unqualified. The lack of learning by doing in the agricultural sector prevents increasing performance and productivity through ecological footprint, poor use of fertilizers, spreading pollution and over-exploitation of water resources (Feder et al, 1993).

The result of the estimated regression 2 and 3 shows that the level of research and development have a negative impact on the environmental and social aspects through their impact on CO2 emission and demographic growth, this result can be interpreted by the novelty of the sustainable agriculture in the Maghreb countries, such as organic farming. These results are similar to studies of Esposti (2002), and Khaled et al (2016).

Biological research and development remains until today in the laboratories and has not yet applied to a field.

The information and communication technology (ICT) has a positive effect on environmental aspect, this result is explained by the introduction of new technology (mobile, internet, etc.) in rural areas and their participation in the agricultural sector through improved marketing of an agricultural product line, development and definition of sustainable agriculture concept and organic products in the Maghreb countries (Khaled et al, 2016).

The result of the estimated regression 3 indicates the farming population affects negatively the environmental aspect through their impact on CO2 emission.

The population increase in rural areas increases the pollution in the zone and increases the use of water resources, leading to over-exploitation of natural resources.

Mechanization used by Maghreb countries is not sustainable since it cannot achieve the sustainable development aims in the agricultural sector of the Maghreb countries.

RECOMMENDATION POLICY

The results of the model estimation 3SLS include policies of very important implications for producers and consumers of sustainable agriculture in the Maghreb countries are listed as follows:

1. The government support for funding and Development: The Maghreb Farmers need for state subsidies to buy sustainable agricultural machines with good quality. They also need the development of their rural areas by building infrastructure to attract investors to invest in the agriculture sector.
2. Improve training in the rural middle, especially how to operate farm machinery: the workforce in the agricultural sector of the Maghreb countries is not qualified because of their limited education level. The majority of labor worked in agriculture is the farming population.
3. The development of environmental protection strategy and implementation in the rural middle, for example, the payment of fees for people that generate negative externalities in the rural areas.

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SUGGESTION

In order to enhance the estimation model, this section suggests some recommendations for future studies. There are a few studies that examine the mechanical innovation and their role in determining the agricultural sustainability. Research on the innovation of sustainable agriculture, in recent years, begins to develop, but many questions remain unanswered or their answers are ambiguous. This section provides suggestions for future study. The empirical studies that are performed on innovation for sustainable agriculture focus on the Maghreb countries. Future studies on the mechanization factors and their impact on the agriculture sustainability could focus on a large sample of developing countries that exceeds 3 countries. This is to analyze the trend of impact method of sustainable and innovative culture on socioeconomic (the cost of production and transportation, the qualification of manpower, funding for agricultural sector), institutional, policies (agricultural sustainability policy) and biophysical (protection of natural resources) factors in these countries. The future studies should compare the level of development of sustainable agriculture in developed countries and developing countries.

CONCLUSION

The concept of sustainable development has spread during the 90s in scientific research both locally and planetary. All this research agrees that the achievement of sustainable development depends on the respect of three essential principles: equity between nations and generations, the equilibrium of the economic situation and the protection of the environment (Khaled et al, 2016).

On this basis, several economists and scientists believe that the diffusion of technological innovation is a basic means to ensure sustainable development in the agricultural sector.

To verify this effectiveness, we tested the effects of mechanical innovation on the agricultural sector in the three Maghreb countries (Tunisia, Morocco and Algeria) for a period from 1999 to 2012 by a model of simultaneous equations, as well as their ability or non to achieving the objectives of sustainable development in agriculture sector.

The estimation results show that mechanization used by Maghreb farmers is unsustainable. For this it's unable to achieve the sustainable development objectives in the agricultural sector of Maghreb countries. The mechanized agricultural land use may lead to reduced fertility and increased pollution. This result is similar to the study of Khaled and al (2016).

A recent study done by CEMA (2014) indicates that there are 12 types of agricultural mechanization in the world. The weak type is used by developing countries, particularly Africa. It can be concluded that the poor quality of mechanization used by Maghreb countries negatively affects the agricultural sector sustainability.

REFERENCES

Akçomak, İ. S., & ter Weel, B. (2009). Social capital, innovation and growth: Evidence from Europe. *European Economic Review*, *53*(5), 544–567. doi:10.1016/j.euroecorev.2008.10.001

Alani. J. (2012). Effects of Technological Progress and Productivity on Economic Growth In Uganda. *Revue Procedia Economics and Finance*, (1), 14 – 23.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Ambroise, A., Barnaud, M., Manchon, O., & Vedel, G. (1998). Bilan de l'expérience des plans de développement durable du point de vue de la relation agriculture-environnement. *Courrier de l'environnement de l'INRA, 34*.

Blazy, J.-M., Carpentier, A., & Thomas, A. (2011). The willingness to adopt agro-ecological innovations: Application of choice modelling to Caribbean banana planters. *Revue Ecological Economics*, *72*, 140–150. doi:10.1016/j.ecolecon.2011.09.021

Boughanmi. H. (1995). *Les principaux volets des politiques agricoles en Tunisie: évolution, analyse et performances agricoles*. CIHEAM-options méditerranéennes, ser.B/n 14, les agricultures maghrébines à l'aube de l'an 2000.

Cadilhon, J.-J., Fearne, A. P., Giac Tam, P. T., Moustier, P., & Poole, N. D. (2006). Quality incentives and dependence in vegetable supply chains to Ho Chi Minh City. *Acta Horticulturae*, (699), 111–117. doi:10.17660/ActaHortic.2006.699.11

CEMA. (2014). *Promouvoir le développement rural et agricole en Afrique grâce à la mécanisation agricole (MA) avancée*. Comité Européen des groupements de constructeurs du machinisme agrico.

Clark, J. S., & Youngblood, C. E. (1992). Estimating Duality Models with Biased Technical Change: A Time Series Approach. *American Journal of Agricultural Economics*, *74*(2), 353–360. doi:10.2307/1242489

Clay, E.J. (1982). Technical innovation and public polic: agricultural development in the Kosi Region, Bihar, India. *Agricultural Administration, 9*, 189-210.

Delchet, K. (2004). *Qu'est-ce que le développement durable?*. Academic Press.

Dubouloz, J. (2006). Acception et défense des loca publica dans les Variae de Cassiodore, Un point de vue juridique sur la cité. dans M. Ghilardi, Ch. J. Goddard et P. Porena dir., Les cités de l'Italie tardo-antique (IVe –VIe siècle), Institutions, économie, société, culture et religion. *Actes du colloque de l'Ecole française de Rome, 369*, 53-74.

Esposti, R. (2002). Public agricultural R&D design and technological spill-ins a dynamic model. *Revue Research Policy, 31*, 693–717.

Estevez, B., & Domon, G. (1999). Les enjeux sociaux de l'agriculture durable un débat de société nécessaire? Une perspective nord-américaine. *Courrière de l'environnement, 36*.

Fadavi, R., Keyhani, A., & Mohtasebi, S. S. (2010, December). Estimation of a Mechanization Index in Apple Orchard in Iran. *The Journal of Agricultural Science*, *2*(4).

Feder. G & Umali. D. L. (1993). The Adoption of Agricultural Innovations. *Technological Forecasting and Social Change, 43*, 215-239.

Fersino, V., & Petruzzella, D. (2002). Organic agriculture in the Mediterranean area: state of the art. Options Méditerranéennes: Série B. Etudes et Recherches, 40, 9- 51.

Kallivroussis. L, A. Natsis. N & Papadakis. G. (2002). The Energy Balance of Sunflower Production for Biodiesel in Greece. *Biosystems Engineering Revue, 81*(3), 347–354.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Khaled, R., & Hammas, L. (2014). Macroeconomic and institutional determinants of the irrigation system and their impact on development and economic sustainability of the agricultural sector in MSEC: A new result by using panel data. *International Journal of Sustainable Economies Management*, *3*(3), 54–66. doi:10.4018/ijsem.2014070104

Khaled, R., & Hammas, L. (2016). Technological innovation and the agricultural sustainability: What compatibility for the mechanization? *International Journal of Innovation in the Digital Economy*, *7*(4).

Meadows. D, Randers. J & William. W. (1972). *The limits to growth. A report for the club of Rome's project on the predicament of mankind*. Academic Press.

Nafiou. M.M. (2009). Impact de l'aide publique au développement sur la croissance économique du Niger. *Revue africaine de l'Intégration, 3*(2).

OCDE. (1999). *Développement durable les grands questions?.* Author.

Poole. N. (2006). *L'innovation: enjeux, contraintes et opportunités pour les ruraux pauvres*. Document de synthèse, Janvier.

Ruttan, V.-W. (1974). Induced innovation and agricultural development. *RE:view*, *64*(May), I-14.

Ruttan, V.-W. (1989). Institutional-Innovation and Agricultural Development. *Review World Development*, *17*(9), 1375–138. doi:10.1016/0305-750X(89)90079-X

Soni, P., Taewichit, C., & Salokhe, V. M. (2013). Energy consumption and CO2 emissions in rainfed agricultural production systems of Northeast Thailand. *Agricultural Systems*, *116*, 25–36. doi:10.1016/j.agsy.2012.12.006

Thirtle, C., Townsend, R., & Van Zyl, J. (1998). Testing the Induced Innovation Hypothesis in South African Agriculture (An Error Correction Approach). *Agricultural Economics*, (19), 145–157. doi:10.1016/S0169-5150(98)00030-9

Timmer, C.P. (1992). agricultural and economic development revisited. *Agricultural Systems, 40*, 21-58.

Van Rijn, F., Bulte, E., & Adekunle, A. (2012). Social capital and agricultural innovation in Sub-Saharan Africa. *Revue Agricultural Systems, 108*, 112–122.

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Chapter 15
Deployment of Wireless Sensor Networks for Soil Macronutrients Measurements in Farms

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ABSTRACT

Farmers need accurate information about soil nutrient content if they are to apply the correct amount of fertilizer. Farmers who do not practice regular soil tests are facing numerous difficulties such a lack of accurate statistical information for soil and crop management, increased costs for fertilizers, and environmental degradation. However, traditional laboratory testing is costly and laborious, taking up to three weeks to complete. This study presents a technology which integrated various elements into a portable in-field device that measures soil macronutrients of nitrogen (N), phosphorus (P) and potassium (K) and soil pH. Then it transmits the measured data wirelessly to remote base station for analysis, presentation and storage in real-time. Farmers can access the information from the base station server through their mobile phones. Firstly, the grower can use the test data to provide important indicators into the levels of nutrients in the soil which can be interpreted to stem over-use or under-use and efficiently manage their fertilizer application. Secondly, the system can decrease response time for the grower to implement alterations in the soil nutrient composition. And lastly, it can increase the awareness of precision agriculture, its benefits and usage amongst the average farmer. The results from this test provide important indicators into the levels of nutrients in the soil which can be interpreted to stem overuse or under-use. The grower can use the data compiled to efficiently manage their fertilizer application.

1. INTRODUCTION

All essential elements are by definition required for plant growth and completion of the plant life cycle from seed to seed. Some essential elements are needed in large quantities and others in much smaller quantities. However, from a practical standpoint, three of the six essential macronutrients are most often "managed" by the addition of fertilizers to soils, while the others are most often found in sufficient

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quantities in most soils and no soil amendments are required to supply adequate quantities. From a management perspective only, the primary nutrients are Nitrogen (N), Phosphorus (P), and Potassium (K), because they are most often limiting from a crop production standpoint. All of the other essential macronutrient elements are secondary nutrients because they are rarely limiting, and more rarely added to soils as fertilizers (Amundson, Guo, & Gong, 2003; Brady & Weil, 2002).

Nitrogen is a part of all living cells and is a necessary part of all proteins, enzymes and metabolic processes involved in the synthesis and transfer of energy. It is a part of chlorophyll, the green pigment of the plant that is responsible for photosynthesis. It helps plants with rapid growth, increasing seed and fruit production and improving the quality of leaf and forage crops. Nitrogen often comes from fertilizer application and from the air (legumes get their N from the atmosphere, water or rainfall contributes very little nitrogen) (Schaetzl & Anderson, 2005).

Like nitrogen, phosphorus (P) is an essential part of the process of photosynthesis. It is involved in the formation of all oils, sugars, starches, etc. It helps with the transformation of solar energy into chemical energy, proper plant maturation, and withstanding stress. Phosphorus effects rapid growth, encourages blooming and root growth. Phosphorus often comes from fertilizer, bone meal, and superphosphate (Schaetzl & Anderson, 2005).

Potassium is absorbed by plants in larger amounts than any other mineral element except nitrogen and in some cases, calcium. It helps in the building of protein, photosynthesis, fruit quality and reduction of diseases. Potassium is supplied to plants by soil minerals, organic materials, and fertilizer (Schaetzl & Anderson, 2005; Silva & Uchida, 2000).

Deficiencies of nutrients in plants have various visual symptoms that are usually similar regardless of the species. The most common deficiency symptom is reduced growth, which is difficult to detect and diagnose at a glance. Other visual symptoms usually involve changes in coloration following a specific pattern, such as from the leaf tip down the midrib towards the base of the leaf or from the leaf margin toward the midrib, or between the veins of the leaf. Such symptoms may appear in new leaves or old leaves, indicating the phloem-mobility of the deficient nutrient and the ability of the plant to translocate existing stocks of the deficient nutrient (Havlin, Beaton, Tisdale, & Nelson, 2005; Hillel, 2004; Lutgen & Tarbuck, 2004).

With nitrogen deficiency, plants often have stunted growth; leaves develop a yellow color, which is a condition known as chlorosis. Since nitrogen is a mobile nutrient within the plant, nitrogen moves from older growth to new growth when deficient. As a result, nitrogen deficiencies first appear in older leaves. Since deficiency symptoms are sometimes difficult to diagnose, the location of the symptom (new or old growth) helps us determine which nutrient, if any, is deficient. When nitrogen is severely deficient, chlorotic leaves may die and fall off the plant (Silva & Uchida, 2000; Soil Survery Staff, 2007).

Plants often have overall stunting, particularly during the early stages of growth during phosphorus deficiency. Phosphorus is a mobile nutrient; and so, symptoms first appear in older growth. When deficient, older leaves develop a dark green to blue green color. In certain corn and grass species, older leaves may develop a purple coloration. Phosphorus deficiencies can cause poor fruit and seed development as well as delay crop maturity (Silva & Uchida, 2000; Soil Survery Staff, 2007).

Likewise, plants often experience stunted growth with potassium deficiency. Like nitrogen and phosphorus, potassium is a mobile nutrient. Older leaves may develop chlorosis along the margin, or edge, of leaves. Certain crops may have weaken stalks, which causes lodging (toppling over) (Silva & Uchida, 2000; Soil Survery Staff, 2007).

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Soil pH is one of the most important soil properties that affect the availability of nutrients. Macronutrients tend to be less available in soils with low pH and more available in soils with high pH. Lime can be added to the soil to make it less sour (acid) and also supplies calcium and magnesium for plants to use. Lime also raises the pH to the desired range of 6.0 to 6.5. In this pH range, nutrients are more readily available to plants, and microbial populations in the soil increase. Microbes convert nitrogen and sulfur to forms that plants can use. Lime also enhances the physical properties of the soil that promote water and air movement (Silva & Uchida, 2000).

Growing concerns about environmental pollution by excessive use of fertilizers have led to increasing needs to monitor soil nutrients required for crop growth. Traditionally, such measurements have been carried out in a central laboratory, involving time-consuming sampling, transportation and storage steps. On-site monitoring of Nitrogen (N), Phosphorus (P) and Potassium (K) nutrients is preferable due to the potential for a higher density of measurements at a relatively low cost, allowing more efficient mapping of soil nutrient variability for variable–rate nutrient management. We need better soil information to solve pressing problems such as how to monitor the effects of climate change on soil, how to use precision agriculture for improving the sustainability and efficiency of food production and how to assess and remediate contaminated land (Kim, Sudduth, & Hummel, 2009).

The macronutrients (nitrogen, phosphorus and potassium) are managed and replaced as fertilizer on a crop-by-crop basis. They represent a significant input cost of food production both financially and environmentally. Excessive nitrogen fertilizer can subsequently leach soil nitrates into waterways and have direct consequences on human and environmental health and water quality (Rossel, Adamchuk, Sudduth, McKenzie, & Lobsey, 2011). Since no proven economical methods has been yet devised to effectively and efficiently allocate chemicals to meet crop needs, significant energy waste occurs in application of agriculture chemicals. Consequently chemicals and fertilizers are applied in uniform amount irrespective of local changes in soil chemical conditions (Mishra, Mapara, & Vyas, 2015). The solution to this problem can be the use of sensors capable of determining several analytes, such as soil macronutrients and pH, simultaneously. It would further reduce sample processing time, sample volume and reagent consumption. Integration of the multiple data streams available from such sensors might provide improved estimates of the individual analytes through its ability to quantify and factor out any cross-channel responses (Kim et al., 2009).

However, traditional variable rate methods used in soil sampling are time consuming, costly and not accurate. Thus, they fail in providing a true estimate of the nutrients soil needs. To obtain better crop response to inputs, a rapid, non-destructive, timely and cost-effective soil analysis are needed to enable site-specific fertilizer applications (Jimenez-Donaire, 2015). Inorganic fertilizers, in particular nitrogen-based fertilizers, have revolutionized agriculture. However, effective management of the amount of fertilizer used on land is becoming ever more important for many reasons including economic efficiency and for sustainable agricultural practices to preserve and enhance crop yields and avoid damage to the environment and to human health. In order to accurately supply the right amount of nutrient for crop growth it is important to know what nutrient reserves exist within the soil. Nitrogen is highly mobile and therefore needs to be monitored more regularly than phosphorus and potassium as these are more stable and changes in levels are slower. They also hope that the real-time information detected by the sensor and used to prescribe the application rate would optimize the overall economic or agronomic effect of the production input. The values obtained may not be as accurate as a laboratory test, but the high sampling density may increase the overall accuracy of the resulting soil nutrient or pH maps. Conventional soil testing methods, however, which combine soil sampling in the field and chemical analysis in the

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laboratory, are costly and time consuming, thereby limiting the number of samples analyzed in the field and making it difficult to characterize spatial variability in soil nutrient concentrations in an agricultural field (Schepers & Schlemmer, 1998; Artigas et al., 2001; Kim, Hummel, Sudduth, & Motavalli, 2007).

When soil test results are combined with information about the nutrients that are available to the various crops, a reliable basis for planning the fertility program can be established (Hoeft, Peck, & Boone, 1996). Soil nutrient monitoring can be used to reduce fertilizer and application costs, diagnose soil problems and evaluate crop performance and economic returns based on nutrient utilization. These applications have prompted the development of sensors to measure soil properties and complement the more conventional laboratory techniques used for their analyses (Rossel et al., 2011).

Wireless sensor network (WSN) devices are now widely used for real-time environmental monitoring as well as in agriculture, on ground that, they allow conditions to be monitored continuously and on a remote basis. They have proven to be powerful tools for monitoring short-term variations in these parameters particularly in agriculture. Wireless sensor network (WSN) monitoring schemes have the advantage of easy installation, convenient maintenance and cost effective. Moreover they are update, flexible as to information and inspection as compared to traditional wire monitoring system (Yoshikawa, Murata, Furuya, & Eguchi, 2007).

In this work, ZigBee wireless communication technology (IEEE 802.15.4) is preferred over other technologies for the development of wireless sensor network due to its low cost and low power consumption property (Simbeye, Zhao, & Yang, 2014; Simbeye & Yang, 2014). This paper proposes a real-time wireless sensor network system that enables sensor data to be delivered within time constraints so that appropriate observations can be made or actions taken. Obtaining these accurate real-time results in-situ allows growers to determine how much fertilizer their land actually needs, therefore saving of money through efficient application of fertilizer, ensuring that crops are not malnourished (disease management), which would result in wasted resources and capital and safeguarding the surrounding environment from harmful pollution. This research will provide farmers with constant monitoring of fields, tailored crop analysis and disease management, making information on the nutrient status of arable land easily accessible and available to the farmer anytime anywhere.

2. RELATED WORKS

Although traditional lab analyses provide accurate results, they neglect local spatial variation in macronutrient concentrations within a soil area. They usually involve either random, adaptive, or grid sampling techniques. In random sampling, soil cores are obtained randomly within the field. In adaptive sampling, prior information is used to select locations for soil core samples. In grid sampling, soil cores are collected from predetermined points in the field. None of these soil sampling practices has been recognized as the most effective (Adamchuk, Hummel, Morgan, & Upadhyaya, 2004). The chemical analyses required to create a precision fertilization scheme that accounts for such variation involves extremely intensive and complex laboratory testing that demand a lot of time and cost. In the past, many have viewed this technique as physically impractical and cost prohibitive over a large area of farmland. Furthermore, colorimetric methods hinder real-time information supply. Modern agriculture demands continuous information of chemical and physical soil parameters, which is not available with traditional techniques (Lemos et al., 2004; Mouazen, Maleki, De Baerdemaeker, & Ramon, 2007).

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Sensors provide quantitative results and can be more time and cost effective than conventional laboratory analyses. They are becoming smaller, faster, wireless and more accurate, energy efficient and intelligent (Rossel et al., 2011). A multi-parametric analytical system for measuring primary nutrients contents in cultivated soil was developed for on field analysis using the techniques as UV Spectroscopy. The authors analyzed soil propertie for accurately mapping various primary nutrients in the soil. Various soil samples were taken from cultivated farms at the agriculture college, Pune. The results were as the concentration of the primary nutrients (N, P and K) varies the maximum absorbance of soil sample also varies. However, some drawbacks include atmospheric and soil interference and the high cost of instruments. Soil fertility research has established measure of macronutrient concentrations in the soil that are enough for field crop production without further additions. For example, Magdoff, Ross, and Amadon (1984) suggested that soil with a residual nitrate level below 10 mg/kg would require a full-rate nitrogen application rate to achieve 100% corn yield goal. Residual nitrate levels above 30 mg/kg would require no additional fertilizer. Similarly, for corn production, soils having plant available phosphorus and exchangeable potassium levels of 27.5 mg/kg and 150 mg/kg, respectively, would be considered adequate to support crop production if the amounts removed by the crop each year were replaced.

Soil sensing techniques to assess this variability on-the-go has been developed by Sethuramasamyraja et al. (2008) as an alternative to tedious manual soil sampling and laboratory testing. The goal of this study was to evaluate an Agitated soil measurement (ASM) method for integrated on-the-go mapping of soil pH, soluble potassium and residual nitrate contents using ion-selective electrodes. To implement ASM, an integrated agitation chamber module (IACM) was developed and attached to a commercial soil pH mapping implement. In a field simulation test, neither precision nor accuracy errors obtained with ASM were lower than for a previously investigated direct soil measurement (DSM) method. Laboratory evaluation of the ASM method revealed substantially lower measurement errors and increased regression analysis r2 values when compared to the field simulation, indicating that the proposed ASM method retains the potential for improving on-the-go field mapping. However, for reduced electrode abuse and the ability to use less expensive half-cell ion-selective electrodes, physical implementation of ASM through the IACM did not bring substantial improvement over conventionally available DSM. This could be attributed to the design of the IACM and use of half-cell electrodes. The authors proposed further research to improve the design of the solution-based measuring equipment and to develop an algorithm integrating on-the-go measurements with other sources of spatial data for an improved decision-making process. However, difficulties encountered with current systems included a slower-than-desired and not completely reliable extraction process, electrodes of limited durability, and the need for frequent recalibration due to signal drift. The disadvantage of on-the-go sensors based on ion selective technology is that soil sampling and nutrient extraction are required, increasing the complexity of the system and the time required for a measurement.

Kim et al. (2013) presented an automated sensing of hydroponic macronutrients using a computer-controlled system with an array of iron-selective electrodes (ISEs). The study reported on development and evaluation of ISEs for direct measurement of macronutrients in recirculating hydroponic solutions. An ISEs array incorporating the selected membranes in combination with a computer-controlled measurement system was evaluated for the direct measurement of nitrate, potassium and calcium concentration in paprika hydroponic solutions. However, the tested calcium electrodes did not provide satisfactory results due to reduced sensitivity in the hydroponic solution. Moreover, signal drift and reduced accuracy over time are major concerns with an in-line management system based on continuous immersion of ISEs in a solution.

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Recently published research (Kapis & Ombeni, 2015), proposed a framework for deployment of easy to use wireless sensor networks for farm soil monitoring and control: a case study of horticulture farms in Pwani region Tanzania. The communication within the network (intra communication) was done through ZigBee module in the coordinator while analysis, interpretation, and transfer of information to farmers and remote server were done in the base station connected to the coordinator. In this framework data collected from the soil was analyzed in the local server in the field and sent to the remote farmer directly to their mobile phones cellular network in real time. Internet service was used to send information to the remote server in which farmers can still receive information even if the internet connection is not available. Much research has been done on deployment of WSN for different applications like precision agriculture and so forth. Some frameworks guidelines have been proposed. However, many of these frameworks are not complete and practical as they just mention only few technologies like routing protocols. For those few developed frameworks they do not lead to systems which can be easily used by users who are ICT illiterate and with little knowledge on horticulture sector (Kapis & Ombeni, 2015).

The scientific objectives of this study was first to create a technology which integrated various elements into a portable in-field permanent device that measures soil macronutrients of N, P and K and soil pH. Then it transmits the measured data wirelessly to remote base station for analysis, presentation and storage in real-time. Farmers can access the information from the base station server through their mobile phones. The grower can use the test data to provide important indicators into the levels of nutrients in the soil which can be interpreted to stem over-use or under-use and efficiently manage their fertilizer application. Secondly, to decrease response time for the grower to implement alterations in the soil nutrient composition. The waiting period for results of current methods of soil analysis is too long and does not allow the grower to identify problems arising from actual depletion or saturation of nutrients within the soil in time. This can result in crop diseases, yield loss, soil erosion and the loss of beneficial organisms contained in the soil. Lastly, to increase the awareness of precision agriculture, its benefits and usage amongst the average farmer. At present there is a science barrier in the agricultural community, where technological products in the market only cater for high-end users and are not feasible for the average farmer to purchase.

3. MATERIALS AND METHODS

A. Data Acquisition System

The data acquisition system was designed using the Nutri-Stat sensors based on innovative probes that are part porous ceramic and part PVC. The PVC encloses the electrochemical sensor, measuring approx. 4 x 3 cm, which contains four channels for each Ion-Selective Electrode (ISE). Water/Liquid that flows from the soil into the porous ceramic cup via a micro pump creates a vacuum in the cup. Once in the cup, the water is in contact with the sensor, enabling an ISE to take a nutrient reading; measuring NO3- (Nitrate), K+ (Potassium), PO4 3- (Phosphorus) and pH respectively. The four ISEs are housed in a novel lab-on-chip platform, using low temperature co-fired ceramics (LTCC) technology. These processes, performed inside the porous ceramic enclosure, allow it to be buried in the soil for an indefinite time without enduring damages. It is managed through a small LCD controller that also displays results. The sensors have the following range and accuracy: Nitrate range from 0 to 650mg/L ±5% F.S,

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phosphate range from 0 to 200mg/L ±10% F.S, potassium range from 0 to 800 mg/L ±5% F.S and pH range from 0.0 - 14.0 ±0.05% F.S.

Although the probe will be submerged in the soil, a controller above the soil monitors the whole testing process. The controller contains a battery operated LCD. When enough water is acquired in the probe from the soil, the controller starts a sequence, pumping the sample into the LTCC Lab-on-Chip, takes the readings and discards the sample into a waste collection cup. If a wash is required after the measurement, the controller starts the washing procedure and resets the equipment for another test. The hardware design mainly includes an AVR ATmega64 microcontroller (MCU) as a core control system and peripheral circuit design. The ATmega64 MCU has enhanced low-power AVR RISC architecture, data throughput up to 1MIPS/MHz, which can alleviate the contradiction between system power consumption and processing speed. The input analog signals from nitrate, potassium, phosphorus and pH sensors are digitized using analog to digital converter AD7705 chip and fed to the MCU. On one hand, the microcontroller performs computations and transmits the information to the personal computer (PC) in real-time through Zigbee wireless communication module for data analysis, processing and display. The coordinator node's responsibility is to receive data acquired from different sensors such as samples of dissolved oxygen, pH, temperature and water level, and send command in order to achieve human-computer visualization interface. The smart nodes need to communicate with the coordinator node to transmit measured data. The coordinator was interfaced with the monitoring base station through RS232 cable.

B. Monitoring Software

With the results from the data acquisition system in hand, the grower and/or crop consultant need to implement a number of decisions based on the final statistics. The measurement and control software for the base station was realized by LabWindows/CVI software development platform whereas the data acquisition control software was realized by ICCV.7 of AVR for better nutrient management. The user-interface provides features for the complete real time measurement, control, data processing, display result output, report printing and other functions. The main features include real-time measurement and display of nitrate, potassium, and phosphorus as well as soil pH. It realizes real-time acquisition and control of the precise timing and high speed sampling. The implementation of the test results should be real-time displayed in a variety of experimental curve display and can always switch observation and zoom, and save operation curve very conveniently. In addition, farmers can request measured information from the system at any time by querying a mobile code. Furthermore, the system can automatically calculate and generate test report of soil macronutrients and soil pH according to user needs. The implementation of the automatic calibration and easy to operate improves greatly the reliability of the system.

The LabWindows/CVI software delivers the versatile array of test definition, analysis and reporting capabilities required to address the evolving needs of advanced researchers, as well as the intuitive operator interface needed to establish and sustain standard, industry-compliant manufacturing quality testing. To ensure the function of the majority of the test sample material for testing, the system detects in real time the data sample to be uploaded to a computer. The computer system software supports a large number of test data processing to ensure that the detection system can detect a large number of data in real-time, secure transmission to the computer, communications interface between the computer system and USB communication ports (Simbeye & Yang, 2014). Based on virtual instrument technology, the system combined with computer technology and instrument technology, sampling the multi

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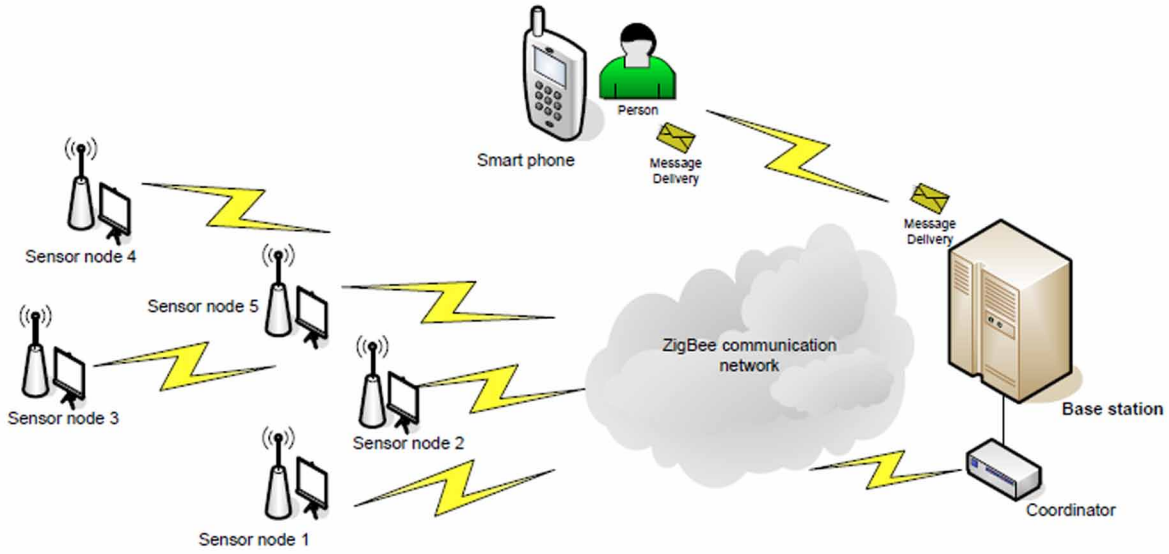
input parameter signals and exporting the detailed control signal in the coordination with the hardware. Also, this software monitors and controls the applications process, hardware circuit, real-time sampling, data analysis and signal processing. According to measurement and control requirement, it generates the control signals on the basis of feedback control algorithm, expressing and exporting data, thus achieving a wide range of automatic test requirements and specific function.

The virtual instruments, that is, on to the general-purpose computer as the core hardware platform design is defined by the user. The test function is achieved by the test software with a computer system virtual instrument panel. Users can operate this computer via user-friendly graphical interface, as in the operation of their own customized as a traditional instrument. It takes full advantage of the unique computing, storage, playback, call display and intelligent features such as document management, while the traditional instruments of the specialized features and software of the control panel combine to make it blend with the computer. So they constitute a fully functional of computer resources from the exterior to the same traditional instruments, while use fully a new intelligent instrumentation system. LabWindows/CVI software features robust capabilities for interacting numerically and graphically with post-test data. With this operation one can get the most from test results with intuitive displays and flexible, interactive data plots and have full freedom to explore different scenarios by adding variables, calculations, tables or charts. Integrated analysis tools include movable markers, text and construction lines, and the ability to define the region of interest and easily zoom in for closer inspection. Multiple graphs of the same post-test data can even be contrasted simultaneously for deeper insight into parameter properties. The captured and analyzed information from the base station monitoring software was transferred to the server and user mobile phones using GPRS technology. The overall system architecture is shown in Figure 1.

Figure 1. Overall system architecture



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4. RESULTS AND DISCUSSION

The system was validated by taking soil samples and extracted samples using soil macronutrients and pH sensors in several places and then running the system and analyzing the soil samples using real-time analysis and comparing the results. The results were very promising and can be used as a diagnostic tool or to identify trends through time. After analyzing the data obtained from the experiments, it could be observed that the levels of macronutrients nitrogen, phosphorus and potassium and soil pH were changing consistently not varying greatly from year to year. The values obtained for nitrogen in different soil samples were differing significantly among themselves, as depicted in Figure 2. As for the average contents of phosphorus and potassium, it was found that values were fluctuating in the range of ±50.0 and 107.0 mg/kg respectively (Figure 3 and 4).

Determining the nutrient concentrations for nitrogen, phosphorus, and potassium can reveal how a soil is functioning in regards to its intended use and how nutrients are cycling through the soil. A nutrient measurement provides an analysis of average nutrient concentration (mg/L) for all nutrients tested. In an agricultural setting, knowing the concentration of nutrients can help food producers know when to add fertilizer, how much to add, and which nutrients need supplemented and in what amount. Consistently high nitrogen soils, for instance, would be good for growing nitrogen-demanding crops such as soy and corn. High nitrogen levels are also particularly useful for non-flowering plants because nitrogen is required for any green part of plants. High nitrogen levels can suppress flowering however, if they remain higher than phosphorus levels. Phosphorus controls flowering in plants and is important to any plant production involving flowering or fruiting plants and phosphorus is often added to soils or directly to plants before and during flowering and fruiting life-cycle stages to increase agricultural yields in larger

Figure 2. Monitored macronutrient of nitrogen

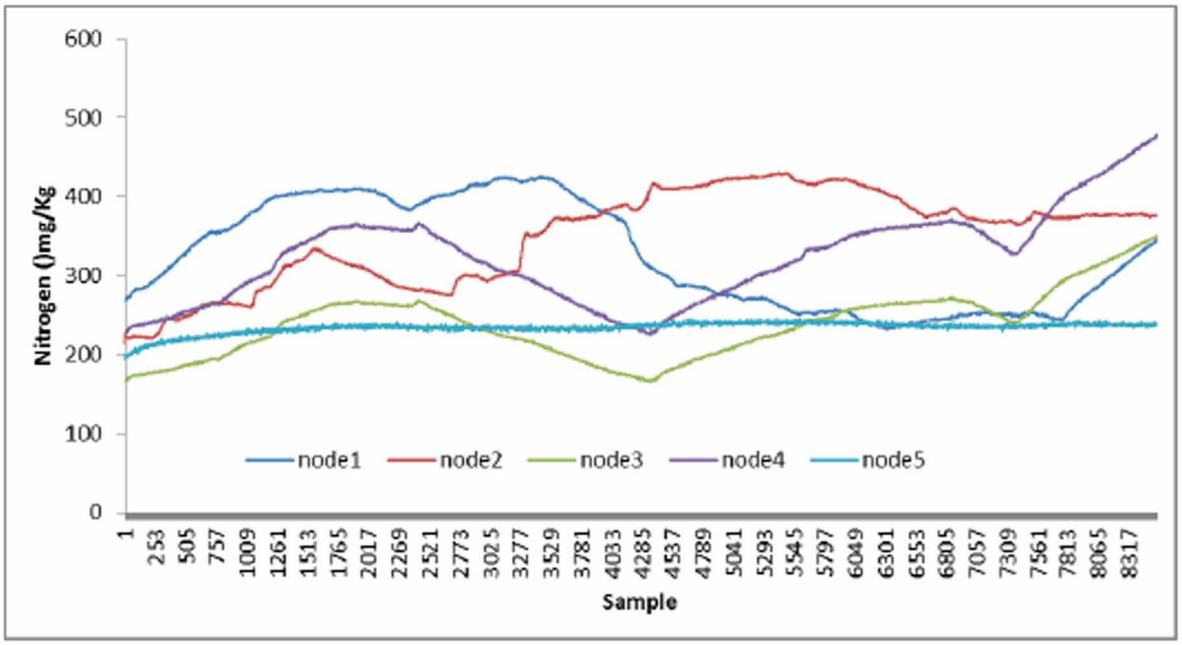

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Figure 3. Monitored macronutrient of phosphorus

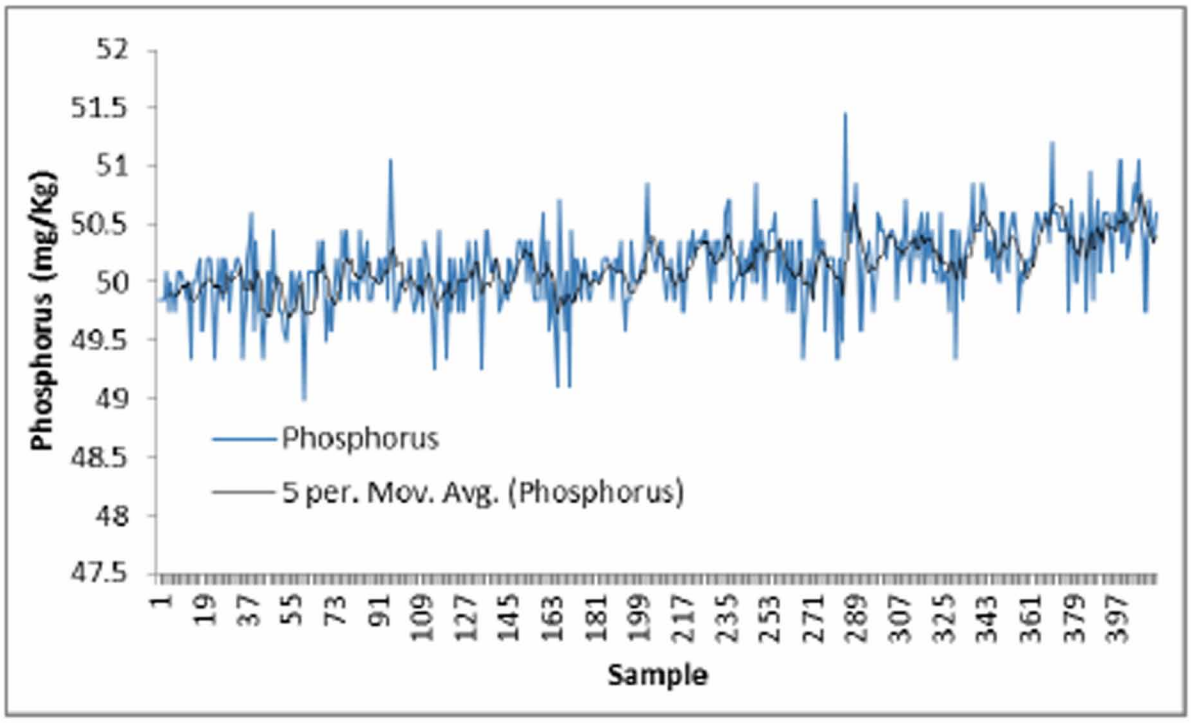
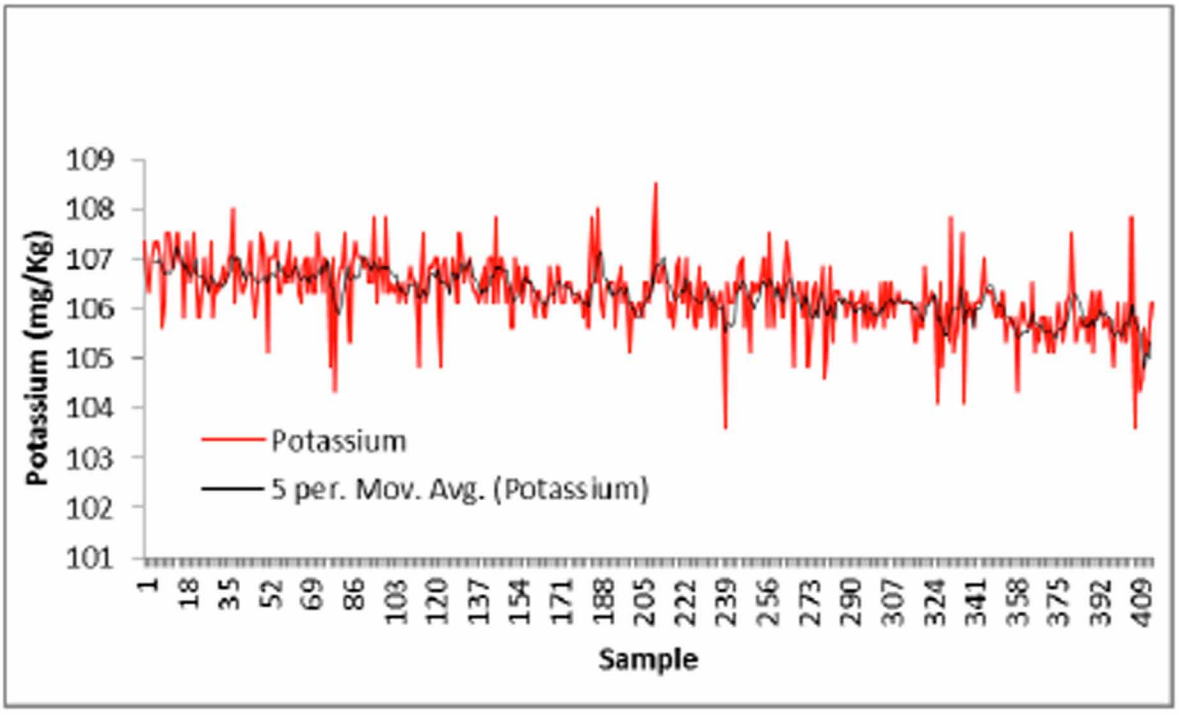


Figure 4. Monitored macronutrient of potassium



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crop size and increased amounts of fruit production per plant. Potassium is involved in catalyzing many chemical reactions required to support plant life including drought tolerance and moisture regulation. Low potassium soils will likely need to be irrigated if soil amendment is not possible. Nutrient concentration can also inform of nutrient deficiencies or surpluses that can be detrimental to plant growth. If a nutrient is too high, amendments can be performed to reduce a surplus, such as adding mulch or tilling the soil. If nutrients are too low to support plant production, fertilization can be used to add nutrients in an amount needed for a specific crop. Low nutrient soil may also have more applicable uses to land managers for recreational or developed (paved surfaces or building construction) spaces.

Table 1 shows the statistical performance of our system for soil macronutrients and pH measurement. The data analyzed I n computer at the field were sent to the farmer mobile phones through cellular network and to the remote server through internet. The ISE module was evaluated with respect to the pH response and the long-term stability. It could be shown, that the pH response of the system using the novel miniature reference electrode is equivalent to the response of a system using a more traditional reference electrode (Figure 5). The measured soil samples of farm are slightly alkaline ranging from 7.4-8. All the sites were carefully selected so as to include different soil types and different conditions. Soils tend to acidify over time, particularly when large applications of ammonium based fertilizers are used or there is a high proportion of legumes in the rotation. With this project, Farmers now have a tool that makes it easier for them to provide fertilizer in the field whilst adhering to the soil macronutrients levels. This tool also provides the farmer information about the uptake of nutrients by the crop itself hence giving the farmer information about the status of the plant. The results from this test provide important indicators into the levels of nutrients in the soil which can be interpreted to stem overuse or under-use. The grower can use the data compiled to efficiently manage their fertilizer application.

Figure 5. Monitored value of pH

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Table 1. Summary of statistical data on soil macronutrients of nitrogen, phosphorus and potassium and soil pH

	Node1				Node2				Node3				Node4				Node5			
	Min	**Max**	**Mean**	**Stdev**	**Min**	**Max**	**Mean**	**Stdev**	**Min**	**Max**	**Mean**	**Stdev**	**Min**	**Max**	**Mean**	**Stdev**	**Min**	**Max**	**Mean**	**Stdev**
Nitrogen (mg/Kg)	231.5	452.2	324.5	1.23	212.6	430.2	349.6	2.3	165.2	350.3	236.8	1.8	225.3	477.7	322.9	1.4	192.9	245.9	233.9	1.3
Phosphorus (mg/Kg)	49	51.45	50.15	0.28	49.45	54.63	52.91	0.23	47.5	56.8	53.12	0.68	51.4	62.2	20.17	0.71	41.7	52.3	21.16	0.8
Potassium (mg/Kg)	103.6	108.5	106.2	0.34	96.0	107.2	99.6	1.5	97.5	108.6	105.23	2.3	101.6	111.4	107.56	1.8	97.3	109.8	104.66	1.7
pH	7.2	7.65	7.32	0.48	7.8	8.1	7.85	0.18	7.7	8.2	7.95	0.18	7.6	7.9	7.65	0.16	7.5	7.9	7.82	0.15

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CONCLUSION

At a rate of growth of 2.7 percent per annum, the national average population growth rate ranks as one of the fastest in the world and translates to a net total of about 1.2 million people being added to the population annually. At this rate Tanzania's population is projected to reach 70.1 million in 2025 (Agwanda & Amani, 2014). There is an urgent need for sustainable agriculture to be reinforced as to meet the inadvertently increasing demands for produce. The Tanzanian government has already taken action in this regard, issuing a number of policies, directives and legislations related to sustainable agriculture. This study will contribute to these efforts by facilitating accurate and frequent soil testing and fertilization management. Such nutrient concentration homogeneity across the field will optimize the yield and the quality of the produce for the benefit of consumers, creating a positive impact on healthy foods and healthy eating in society. Optimal application of fertilizers will deliver benefits for the environment by reducing pollution.

Improved soil macronutrient sensing leading to potentially commercial products will require additional research and development efforts. Further efforts are needed to improve the durability of sensing systems under harsh conditions found in the field. We need a more robust database management system that would provide the backbone to the graphic user interface, able to handle networks of more than 100 nodes (500-1000 sensors). This database must be able to manage rapid computations and statistical analysis. These systems also need to be web-enabled, so that farmers can access sensor data with handheld devices in the field, using the same wireless networks that transmit the data to the office computer (server). The information can be processed onboard or relayed in its raw form over a short-range wireless network to a central access point which could comprise of a laptop or a personal digital assistant (PDA). The system can be employed to raise an alarm condition when a subject's vital signs exhibit unusual behavior. Any adverse change in a subject's status can then be signaled to the relevant parties'.

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REFERENCES

Adamchuk, V. I., Hummel, J. W., Morgan, M. T., & Upadhyaya, S. K. (2004). On-the-go soil sensors for precision agriculture. *Computers and Electronics in Agriculture*, *44*(1), 71–91. doi:10.1016/j.compag.2004.03.002

Amundson, R., Guo, Y., & Gong, P. (2003). Soil Diversity and Land Use in the United States. *Ecosystems (New York, N.Y.)*, *6*(5), 470–482. doi:10.100710021-002-0160-2

Artigas, J., Beltran, A., Jimenez, C., Baldi, A., Mas, R., Dominguez, C., & Alonso, J. (2001). Application of ion selective field effect transistor based sensors to soil analysis. *Computers and Electronics in Agriculture*, *31*(3), 281–293. doi:10.1016/S0168-1699(00)00187-3

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Brady, N. C., & Weil, R. R. (2002). *Elements of the Nature and Properties of Soils*. Prentice Hall.

Havlin, J. L., Beaton, J. D., Tisdale, S. L., & Nelson, W. L. (2005). *Soil Fertility and Fertilizers*. Prentice Hall.

Hillel, D. (2004). *An Introduction to Environmental Soil Physics*. San Diego, CA: Elsevier Science.

Hoeft, R. G., Peck, T. R., & Boone, L. V. (1996). Soil testing and fertility. In *Illinois Agronomy Handbook 1995–1996, Circular 1333* (pp. 70–101). Cooperative Extension Service, College of Agriculture, University of Illinois at Urbana-Champaign.

Jimenez-Donaire, V. (2015). *On-line measurement of selected soil properties towards the refinement of Nitrogen fertilization management in vegetable crops*. Academic Press.

Kapis, K., & Ombeni, M. (2015). A Framework for Deployment of Easy to Use Wireless Sensor Networks for Farm Soil Monitoring and Control: A case Study of Horticulture Farms in Pwani Region Tanzania. *IJNCAA*, 107.

Kim, H. J., Hummel, J. W., Sudduth, K. A., & Motavalli, P. P. (2007). Simultaneous analysis of soil macronutrients using ion-selective electrodes. *Soil Science Society of America Journal*, *71*(6), 1867–1877. doi:10.2136ssaj2007.0002

Kim, H. J., Kim, W. K., Roh, M. Y., Kang, C. I., Park, J. M., & Sudduth, K. A. (2013). Automated sensing of hydroponic macronutrients using a computer-controlled system with an array of ion-selective electrodes. *Computers and Electronics in Agriculture*, *93*, 46–54. doi:10.1016/j.compag.2013.01.011

Kim, H. J., Sudduth, K. A., & Hummel, J. W. (2009). Soil macronutrient sensing for precision agriculture. *Journal of Environmental Monitoring*, *11*(10), 1810–1824. doi:10.1039/b906634a PMID:19809703

Lemos, S. G., Menezes, E. A., Chavez, F. S., Nogueira, A. R. A., Torre-Neto, A., Parra, A., & Alonso, J. (2009). 2004. In situ soil phosphorus monitoring probe compared with conventional extraction procedures. *Communications in Soil Science and Plant Analysis*, *40*(7-8), 1282–1294. doi:10.1080/00103620902761155

Lutgen, F. K., & Tarbuck, E. J. (2004). *Essential Geology*. Prentice Hall.

Magdoff, F. R., Ross, D., & Amadon, J. (1984). A soil test for nitrogen availability to corn. *Soil Science Society of America Journal*, *48*(6), 1301–1304. doi:10.2136ssaj1984.03615995004800060020x

Mishra, P., Mapara, S., & Vyas, P. (2015). Testing/Monitoring of Soil Chemical Level Using Wireless Sensor Network Technology. *International Journal of Application or Innovation in Engineering & Management*, *4*(11), 114–117.

Mouazen, A. M., Maleki, M. R., De Baerdemaeker, H., & Ramon, H. (2007). On-line measurement of some selected soil properties using a VIS-NIR sensor. *Soil & Tillage Research*, *93*(1), 13–27. doi:10.1016/j.still.2006.03.009

Rossel, R. V., Adamchuk, V. I., Sudduth, K. A., McKenzie, N. J., & Lobsey, C. (2011). Proximal soil sensing: An effective approach for soil measurements in space and time. *Advances in Agronomy*, *113*, 237–282.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Schaetzl, R. J., & Anderson, S. (2005). *Soils: Genesis and Morphology*. Cambridge, UK: Cambridge University Press. doi:10.1017/CBO9780511815560

Schepers, J. S., & Schlemmer, M. R. (1998). Influence of grid sampling points on fertilizer recommendations. In *Proc. Int. Conf. on Geospatial Information in Agriculture and Forestry*. ERIM Int. Inc.

Sethuramasamyraja, B., Adamchuk, V. I., Dobermann, A., Marx, D. B., Jones, D. D., & Meyer, G. E. (2008). Agitated soil measurement method for integrated on-the-go mapping of soil pH, potassium and nitrate contents. *Computers and Electronics in Agriculture*, *60*(2), 212–225. doi:10.1016/j.compag.2007.08.003

Silva, J., & Uchida, R. S. (Eds.). (2000). *Plant Nutrient Management in Hawaii's Soils: Approaches for Tropical and Subtropical Agriculture*. Honolulu, HI: College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa.

Simbeye, D. S., & Yang, S. F. (2014). Water quality monitoring and control for aquaculture based on wireless sensor networks. *Journal of Networks, 9*(4), 840-849.

Simbeye, D. S., Zhao, J., & Yang, S. (2014). Design and deployment of wireless sensor networks for aquaculture monitoring and control based on virtual instruments. *Computers and Electronics in Agriculture*, *102*, 31–42. doi:10.1016/j.compag.2014.01.004

Soil Survey Staff. 2007. National Soil Survey Characterization Data. Soil Survey Laboratory. National Soil Survey Center.

Yoshikawa, T., Murata, O., Furuya, K., & Eguchi, M. (2007). Short-term covariation of dissolved oxygen and phytoplankton photosynthesis in a coastal fish aquaculture site. *Estuarine, Coastal and Shelf Science*, *74*(3), 515–527. doi:10.1016/j.ecss.2007.05.004

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Chapter 16
Industrial Wastewater Management in the Context of Climate Change Adaptation in Selected Cities of India:
A Business Approach

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ABSTRACT

Climate change and wastewater control are one of the foremost demanding situations for Indian cities. Urbanization and unparalleled growth of cities across India continue to create immense pressure on land and water resources. This uncontrolled growth continues to produce growing volumes of wastewater. Climate change, impacts inclusive of, intense storm events in summer time or extended moist periods in wintry weather are quite visible in India. In urban and peri-urban areas, wastewater use for agriculture is an emerging precedence. Due to susceptible enforcement of regulatory, most of the wastewater generated is permitted off untreated/ partially treated. While many previous studies have checked out the global modifications and associated impacts of climatic variations on water resources, few have targeted at the evaluation of the particular effects and adaptation priorities for water systems in towns. Proper reuse of wastewater for irrigation will significantly lessen the shortage, offer a sustainable water source, improving farming productiveness, lessen pollution, generate livelihood potential for low earnings city households along with contributing to their each day food needs. There are tradeoffs which need to understand which includes problems to individual's health, and surroundings. Through suitable treatment methods, water users' cooperatives, policy shift and the introduction of market based approaches, treated wastewater use in agriculture can be enhanced and all associated risks can also be curtailed. This chapter focuses on use of treated urban wastewater and its management for agriculture in selected Indian cities.

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INTRODUCTION

Urban wastewater management is a challenge for many developing countries including India. Rapid urbanization and unparalleled growth of cities across India continue to create immense pressure on land and water resources. This uncontrolled growth continues to produce growing volumes of wastewater. Due to weak enforcement of regulatory measures, most of the wastewater generated let off untreated/ partially treated. While many preceding research have checked out the global modifications and climate related variability on water sources, few have targeted at the assessment of the specific consequences and version priorities for water systems in cities. Proper reuse of wastewater in irrigation can significantly lessen water shortage, offer a sustainable source of water, improving agricultural productivity, lessen pollution, create livelihood potential for low earnings city households, put in to their each day food needs. Hence a needed focus to understand and review the wastewater supply and treatment for Indian cities is required. The variety of challenges associated with climate, water and cities are very pressing, which depends on its demography, economics and administrative potential. The urban wastewater use for irrigation is a growing global phenomenon. Such irrigation method can build livelihood opportunities and strengthen food security. But the major hurdle is to come up with the sensible, low-cost safeguards that do not hamper farmer's livelihoods and thus providing a useful resource in meeting food needs and supplying cheap produce to expanding towns. Through suitable treatment methods, water users' cooperatives, policy shift and the introduction of market based approaches, treated wastewater use in agriculture can be enhanced and all associated risks can also be curtailed. This chapter focuses on use of treated urban wastewater and its management for agriculture in selected Indian cities.

CHANGE IN CLIMATE AND ITS EFFECT ON WATER RESOURCES AND AGRICULTURE

Climate change as per the United Nations Framework Convention on Climate Change (UNFCCC) has been defined as, "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods". Increased emission from industrial sectors along with changed agricultural pattern combined with widespread deforestation has effected a change in the gaseous composition of earth's atmosphere (Table 1).

Table 1. Greenhouse gases in surroundings

Elements	CO_2	CFCs	CH_4	N_2O
Avg. concentration 100 years ago (ppbV)	290×10^3	0	900	270
Present concentration (ppbV) (2007)	380×10^3	3 to 5	1774	319
Proposed concentration in the year 2030 (ppbV)	400×10^3 500×10^3	3 to 6	2,800 to 3000	400 to 500
Atmospheric life (years)	5 to 200	75	9 to 15	114
Global warming ability years relative to CO_2	1	4750 to 10900	25	298

Source: IPCC (2007)

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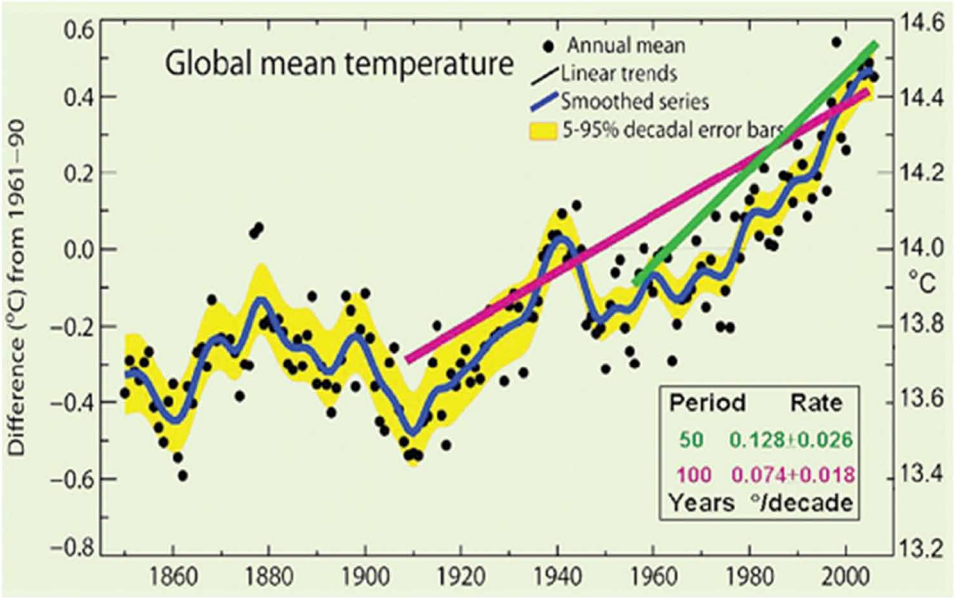
The global yearly mean temperature toward the end of the twentieth century, as an after effect of GHG aggregation in the climate, has expanded by 0.4–0.7 ºC over that recorded toward the end of the nineteenth century. The previous 50 years have demonstrated an expanding pattern in temperature @ 0.13 °C/decade, while the ascent in temperature amid the previous one and half decades has been much higher (Figure 1). The Inter-Governmental Panel on Climate Change (IPCC) has anticipated the temperature increment to be between 1.1 °C and 6.4 °C before the end of the 21st Century (IPCC, 2007). The worldwide temperature alteration is relied upon to prompt other local and worldwide changes in the atmosphere related parameters, for example, precipitation, soil dampness, and ocean level. Snow spread is additionally answered to be bit by bit diminishing.

Along these lines, coordinated endeavors are required for moderation and adjustment to decrease the helplessness of farming to the unfavorable effects of environmental change and making it stronger. With more than sixty percent of its populace subject to atmosphere touchy exercises, for example, farming, the effects of environmental change on horticulture accept huge significance for India. Environmental change projections made up to 2100 for India, demonstrate a general increment in temperature by 2-4°C combined with expansion in precipitation, particularly amid the rainstorm time frame. Mall et al. (2006) give a great audit of environmental change sway examines on Indian farming for the most part from physical effects point of view. The accessible proof shows critical drop in yields of essential grain crops like rice and wheat under environmental change conditions. Biomass and yield tend to decay with expanding temperature, as higher temperatures abbreviate crop length, upgrade breath and diminish time for radiation interference (Rawson, Gifford, & Condon, 1995). As yields in probably the most profitable areas of the world are drawing nearer a level or notwithstanding declining (Pathak et al., 2003), the possible impact of environmental change on harvest generation adds to the officially complex issue. It is a noteworthy test to assess the effect of rising temperature on product yield. Indian farming is profoundly

Figure 1. Trends in global temperature over the years
(IPCC, 2007)



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reliant on the onset, retreat and extent of rainstorm precipitation, especially in the downpour sustained territories of east, north-east and south India. Atmosphere modelers and IPCC records have anticipated conceivable outcomes of expanding variability in Asian Monsoon flow in a hotter world. Regardless of extension of range under watering system, dry spells, created by insufficient and uneven dispersion of precipitation, keep on being the most imperative climatic distortions, which impact the horticultural generation in India. The seriousness of a dry spell will be heightened in a hotter world. Extreme and incessant flooding because of environmental change would be a noteworthy issue in the Indian subcontinent. Soil temperature influences the rates of natural matter disintegration and arrival of supplements. At high temperatures, however supplement accessibility will increment in the short-term, over the long haul natural matter substance will reduce, bringing about a decrease in soil ripeness.

INDUSTRIAL AND MUNICIPAL WASTEWATER IN MAJOR CITIES

There is an extensive literature in context to industrial and municipal (sewage) wastewaters, its sources, volumes generated, wastewater characterization, impacts on life forms, legal norms and diverse treatment methods/strategies; however, most studies have not considered explicitly the implications of climate change for the delivery of water management objectives (Arnell et al., 2015; Gebrezgabher et al., 2015; Grit et al., 2015; McCarl et. al., 2015; Neumann et. al., 2015; Peirson et al., 2015; Zouboulis & Tolkou, 2015; Lewis, 2016; Valta et al., 2016). In the recent times, there have been research papers that are tackling the issues of industrial wastewaters treatment and management by novel methods, technology adoption, etc. taking climate change aspects into account (Itankar & Patil, 2015; Patil & Rao, 2015; Rao & Patil, 2015). For betterment of the class of life and improvement of productive competency of the people city water supply and sanitation are important basic needs. Also in many arid and semi-arid countries water is becoming an increasingly limited resource and planners are forced to consider any sources of water which might be used economically and effectively to promote further development. In urban areas, water is tapped for domestic use (78% of population has access to safe drinking water and 38% to sanitation as per CPCB 2009) and industrial uses from streams, rivers, lakes and wells. Municipal sewage is defined as "waste originating from a community; may be composed of domestic wastewaters and/or discharge from industry" and is major source of water pollution in India, particularly in and around large urban centers (Central Pollution Control Board, 2009). Almost 80% of the water supplied for domestic purposes, comes out as wastewater. In most of the cases wastewater is let out in the same form and it either gets soaked into the ground as a possible contaminant of ground water or is discharged into the natural sewage system ensuing in the contamination in downstream areas. According to the Central Pollution Control Board (CPCB, 2001) the Infrastructure Development Finance Corporation estimated that 73% of urban wastewater in India is untreated; with the increase in the drinking water supply to urban areas, the wastewater increases. Tables 2 shows the quantity of water requirement in future for various sectors whereas the Table 3 gives the sewage water generation from class I cities and Class II towns which also includes the upcoming smart cities as recently announced by the Government of India

If wastewater is not treated or disposed, it will create problem (Misra, 2014). It also poses great threat to the hydrology as well as water quality of natural water bodies. It is linked with a number of hazards, counting community's physical condition, agronomic, and ecological. Microbial health hazards are harsh in low and middle-income nations, which frequently involve the straight or indirect use of raw wastewater and/or impure waters from rivers to water edible-crops.

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Table 2. Sector wise water demand

Sector	Water Demand in km^3 (BCM)					
	2010		2025		2050	
	A*	B#	A*	B#	A*	B#
Drinking water	43	56	62	73	111	102
Irrigation	557	688	611	910	807	1072
Energy	19	5	33	15	70	130
Industry	37	12	67	23	81	63
Others	54	52	70	72	111	80
Total	**710**	**813**	**843**	**1093**	**1180**	**1447**

Source: A* National Council for Integrated Water Resource and Development (NCIWRD), B#Website of Ministry of Water Resources, Govt. of India, National.

The wastewater treatment requires an investment of US$65 billion which is ten times bigger than what is proposed by government (Kumar, 2003). India ranked as the 3rd largest user of untreated wastewater for agriculture in the world (Scott et al. 2010). In the year 2012, Israel and India used wastewater for agriculture to the tune of 64% and 24%, respectively (Grover, 2012). India will soon cross the 50:50 urban-rural population threshold and reach 750 million urban Indians by 2050 (Scott et al. 2010). A total of 38,254 million liters per day (MLD) of wastewater discharge in the year 2009 is projected to increase 120,000 MLD in 2051 (Planning Commission, 2012). There are various issues like treatment technology, different sizes of urban settlements and the land availability for setting-up treatment facilities. Mara (2009) suggests that the waste stabilization ponds (oxidation ponds, maturation ponds and duckweed ponds) can be appropriate for small towns having land availability. Afifi (2011) points for large urban settlements with land scarcity for the establishment of sewage treatment plants (STPs) and less demand for treated sewage for farm application, mechanical treatment systems viz. activated sludge process, trickling filter, up-flow anaerobic sludge blanket (UASB) and aerated pond are suitable to create good results.

OPPORTUNITIES AND CHALLENGES OF WASTEWATER RECLAMATION AND REUSE

Total municipal wastewater generated by Indian industries is 13,468 MLD out of which 60% is treated and the small and medium industries being major contributor to untreated wastewater. As it is known, that the industrial waste effluent is typically more poisonous thus the efforts for its use in agricultural needs to be focused mainly on municipal sewage for the predictable prospect. This difference is also seen in the research writing, which is filled with the studies on sewage-fed agriculture but barely the reuse of industrial wastewater for agriculture (although much investigation is being undertaken on water use competency in industries and on-site use by recycling).

The exception is industries producing comparatively less unhealthful effluent such as those within the food/beverage sector, for example breweries, sugar mills and fruit processing units. Data on brewery manufacturers shows that two million KL (Kilo Liters) of beer was consumed in India in 2012. According to the CPCB, about ten KL of effluent is generated per KL of beer created in India on an average which

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Table 3. Class I Cities and Class II Towns Sewage Generation

Name of the City	Sewage Generation (in MLD*) *Million Liters Per Day
Hyderabad	426.1
Vishakhapatnam	135
Vijayawada	128.4
Patna	279.1
Delhi	3799.9
Ahmadabad	472.02
Surat	432.1
Rajkot	109
Vadodara	1179.85
Bangalore	772
Indore	204.02
Bhopal	334.8
Jabalpur	143
Mumbai	2671.02
Pune	474.01
Nagpur	379
Solapur	149.5
Nasik	227.8
Ludhiana	235
Amritsar	191.5
Jaipur	451.7
Chennai	158.01
Kanpur	417.4
Lucknow	364
Agra	260.4
Kolkata	705.86
Jamshedpur	199
Faridabad	164.01
Asansol	147.1
Meerut	177.1
Madurai	98
Coimbatore	120.01
Varanasi	230.2
Kochi	188
Allahabad	176
Dhanbad	192
Total	15794

Source: *Status of sewage in India(CUPS/61/2005-06)- Central Pollution Control Board* (http://www.sulabhenvis.nic.in/Database/STST_wastewater_2090.aspx)

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results in 20 million KL of effluent per year or about 55 MLD. It may seem that this is a small number but as per statistics the beer industry in India is experiencing growth in the coming future which invites a large amount of waste generation. In dry season or in the water scarce regions a small amount of reuse of wastewater can make difference. Thus these industries are more interested in wastewater reuse which has been seen in EU sponsored W4C project.

Most of the industries are practicing the reuse of wastewater in agriculture. Treated wastewater is being distributed by the SABMiller brewery in Andhra Pradesh for free of charge to local farmers. The treated effluent from the sugar mill is being sold by the Ugar Sugar Works in Karnataka at a cost of Rs. 3,000/ha to farmers. These are also generating the media coverage in positive way but the actual situation is more complicated. The main problematic issues are that there is no monitoring and of these practices. Most of the industries are situated in non urban areas.

State Pollution Control Boards (SPCBs) in India do not have the assets to check them continuously. Due to lack of any monitoring, there is no way to assure a certain quality of treated wastewater to farmers. Without technical studies it is not possible to state whether such wastewater reuse methods are having a negative effect on soils, crops or farmers' physical condition. In addition, farmers' needs frequently differ by season; for example, they would desire wastewater in the dry season stopping wastewater supply to farmers and putting more stress on reuse on-site and in-process. This may sometimes result into the evaporation of waste matter which can be energy serious and creates solid waste that needs removal.

An appropriate monitoring method can solve this crisis and help in agricultural reuse of wastewater from these industries. If an self-governing body can be set up containing of local agricultural extension officers, scientists from local universities, representatives from local farmers' and involvement of cooperative and industries, this committee can draw up official preparations and be able to check class and amount of wastewater delivered. Ideally, financial support for this should be shared justifiably among the various stakeholders; while the involved industry should cover a comparatively big share of financial support; if it is only industry sponsored there may be perceptions of disagreement of interest. Some primary steps are being taken in this way through the W4C project: ICRISAT is researching on SABMiller's wastewater reuse in Andhra Pradesh and the University of Agricultural Sciences, Dharwad is investigating on Ugar Sugar Works' wastewater reuse in Karnataka. The results of this beginning research will optimistically guide to testing with establishing a feasible model for checking agricultural reuse of water from the industries.

Use of wastewater in agriculture is a budding priority in India under water shortage. The influential issues are accountable for this are - growing water stress in a lot of areas of tier-I cities as well as tier-II cities; rising urbanization increasing wastewater flows connected with the growing water delivery and sewage; also more city households engaged in agricultural events, chiefly as foodstuff prices carry on to enlarge. The unforeseen consumption of raw wastewater helps to increasing risks to society, flora, and the surroundings. In these conditions, state administration is more and more worried to make wastewater reuse for agriculture an optimistic power for growth as component of their water resources management schemes, is about to be an major key region for development. The succeeding foremost messages look for to direct governments, practitioners, and stakeholders, water professionals, willing to construct and/or make stronger national as well as local capacities for protected wastewater irrigation.

A study of main issues concerned to wastewater irrigation can be stated by segregating cities into four heads by state of financial development, characterizes the variation of issues across cities in diverse steps of growth, depicts probable ways and prospect importance for developing wastewater handling. Correctly designed, managed and implemented, wastewater irrigation policies can give numerous paybacks that

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accumulate in the agricultural, as well as environmental sectors. Facing such problems and benefits, cities looking better wastewater use for agriculture should follow the under mentioned objectives:

I. reduce danger for community health;
II. reduce surroundings risk;
III. advance livelihoods for city agriculturists; and
IV. put together wastewater as part of water resources management context

One or more combinations of these objectives can be followed by the city depending upon the economic growth (Table 4). As an example the cities with low income can put more concern on reducing microbial hazards to physical condition while developing the livelihoods of urban farmers, whereas on the other hand cities with medium and high income can give importance to reduce chemical and environmental hazards, mostly when they are stressed out with water, a complete collaboration of wastewater and the water resources management schemes.

Checking of Microbial Risk and Establishing Pathogen Decreasing Targets

The World Health Organization's "Guidelines on Wastewater Use in Agriculture" of 2006 focuses on a risk evaluation and organization approach which follows the Stockholm Framework. Following are the advancements:

1. Definition of bearable highest extra load of sickness;
2. To get bearable risks of infection;
3. To lay down health-based goals to reduce pathogen;
4. To decide how the necessary pathogen reductions can be achieved; and
5. To put in a scheme for confirmation monitoring.

The 2006 strategy provide nations at all level of growth with the way to sensibly take embattled steps to decrease health risks. Even when complete wastewater treatment is the solution, it presents a multi-barrier move toward shielding the health of farmers and consumers.

Table 4. Wastewater irrigation objectives in Indian Cities

Economic Development	Minimize Public Health Risk		Objective 2: Minimize Environmental Risk	Urban Agriculture and Improvement in Livelihood	Integration of Water Use in Wastewater Irrigation
	Microbial	Chemical			
Cities with low income	Vital	Short	Short	Vital	Short
Lower-middle income cites	Elevated	Emerging	Emerging	Elevated	Incipient
Upper-middle income cities	Elevated	Vital	vital	Elevated	Evolving
High-income non-OECD cities	Elevated	Elevated	Elevated	Short	Advanced
High-income OECD cities	Short	Elevated	Elevated anthropogenic compounds is focused	Nil	Advanced

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Gradually Apply Industrial Pre-Treatment and Control

To reduce the chemical risk and the desired function of the treatment set and wastewater irrigation policies the effluent generated from the industries discharging considerable amount of wastewater needs to be controlled. To confirm that the heavy metals, salts, organic toxins and other pollutant produced by industrial processes do not attain levels which may destroy pipes, slow down biological treatment processes, contain in the wastewater in large amount than the allowable for irrigation use or discharge in the surroundings or get collected in the sludge, thus limiting its reuse for this standards and discharging restrictions must be stated for the industries. The rising industrialization of city regions requires that chemical hazards of wastewater for irrigation be accounted, mainly through the preface, gradual execution, enforcement of industrial wastewater pre-treatment and manage programs.

Approach for Wastewater Use in Agriculture

Summers of 2016 in India, have brought the water scarcity issue at the forefront, thus making treated wastewater as the best commodity for trade for meeting industrial and irrigation needs of the cities. To make wastewater a viable resource governments investment and policies would inspire and encourage private sector to get involved through pedicle business models, (like the 2006 WHO tips). An approach to move from unstructured to structured wastewater use for irrigation and recognizing that dreams can't be met in a day or in single phase, the strategic plan have to be multi-phased and within an agreed and practical time-frame.

Resourceful Wastewater

The wastewater reuse system, establishment of equivalent authoritarian framework, and the execution of structured wastewater irrigation requires embedded use of agricultural wastewater inside the broader water property manage background. A quantity of integrated water property control thoughts should be accomplished, in particular: accept a multi- sectored method to water management in affiliation with river basin manage; inspire stakeholder participation and devolution of duty; promote non-public region involvement; and rent financial gadgets.

Wastewater Reuse Case Studies

Beneficial use of wastewater has been practiced in California since 1890s, when raw sewage was implemented on 'sewer farms'. Over a period of time there was a steady increase in the sewage utilization and by the year 1987, roughly 900 m3/d of municipal wastewater (7-8% of the production) was getting used for the various applications (California State Water Resources Control Board, 1990). Historically, agricultural use has dominated, and maintains to do so, but during the last decade reclaimed wastewater has been more and more used for landscape irrigation in urban regions and for groundwater recharge. Maximum of the reclaimed water (78%) is used inside the principal Valley and South Coastal regions of California. This has saved around 0.759 Mm3/d of clean water. In the period 1981 to 1987, the Ministry of Agriculture and Public Health, with assistance from the United Nations Development Program (UNDP), carried out studies designed to assess the effects of using treated wastewater and dried, digested sewage sludge on crop productivity and on the hygienic quality of crops and soil. Treated wastewaters

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and dried, digested sludge from the La Cherguia (Tunis) and Nabeul (SE4) activated sludge plants were used in the studies and irrigation with groundwater was used as a control. At La Soukra, tests were conducted on sorghum (*Sorghum vulgare*) and pepper (*Capsicum annuum*) using flood irrigation and furrow irrigation, respectively. Clementine and orange trees were irrigated at OuedSouhil (Nabeul). Use of treated wastewater and sewage sludge at the L. A. Soukra and Oued Souhil experimental stations, wherein the soils are alluvial and sandy-clayey to sandy, had no longer adversely affected the physical or bacterial best of the soils. The use of wastewater led to annual and perennial crop yields higher than yields produced via groundwater irrigation. Sewage sludge application increased the production of sorghum and pepper and resulted in the plants containing better concentrations of N, P and K and some minor factors (Fe, Zn and Cu). Untreated sewage has been used for decades to irrigate forestry tasks a long way from the inhabited areas of Kuwait. Effluent from the Giwan secondary sewage treatment plant became used to irrigate plantations on an experimental farm from 1956 (Agriculture Affairs and Fish Aassets Authority, Kuwait 1988). Use of raw sewage for irrigation within the Mezquital Valley of the Tula River Basin began in 1886 (Sanchez Duron 1988). But, it become now not until 1945 that the Ministry of Agriculture and Water assets installed the number 03 Mezquital Irrigation District to manage the distribution of wastewater from Mexico town for irrigation functions. Irrigation is important in this Irrigation District due to the fact rainfall is constrained and poorly allotted over the year, most falling between July and September. Sewage from Mexico town blended with variable proportions of surface water gathered in reservoirs in the basin has enabled farmers within the Mezquital Valley to provide agricultural produce for the capital city. The East Calcutta sewage fisheries are the biggest unmarried wastewater use machine regarding aqua-way of life inside the global. An historical account of the development of this gadget has been given by using Edwards (1985 and 1990). Ghosh (1984) offered the facts on the range of size and numbers of sewage fisheries in Calcutta as shown in desk 45. In 1945, the location of sewage-fed fish ponds become approximately 4628 ha, in a wetlands region of about 8000 ha, however the fish pond location have been reduced to about 3000 ha through 1987 because of city reclamation and conversion of fish ponds to rice paddies. Possession of the ponds is in the control of around 160 urban dwellers, who appoint almost 4000 households as fishermen, and there are several fishermens' cooperatives (Strauss & Blumenthal, 1989).

Consequences of Use of Wastewater

There are many winning wastewater use policies throughout the globe where nutrient reuse is a main benefit to the project (Pescod & Arar, 1988; FAO, 1992). Rarely, however, is a system laid out or intended on the base of nutrient recycling the main restraint to any wastewater use project is community health.

Depending on its composition, the treatment it has undergone, the extent to which it is irrigated and the regulations and principle guidelines under which it is being utilized, wastewater use in agriculture can be viewed as both a benefit, providing water and nutrients for the cultivation of crops and ensuring food supply to the cities, as well as a source of pollution, a threat affecting the health of users, consumers and the environment (Javier et al., 2013). Wastewater, especially domestic wastewater, contains pathogens which can cause disease spread when not managed properly. The survival of pathogens and how they infect a new host needs to be understood in developing a program to eliminate or minimize health risks. The primary objective of any wastewater use project must therefore be to minimize or eliminate potential health risks. As stated earlier, wastewater contains pathogenic microorganisms inclusive of bacteria, viruses, and parasites, which have the ability to reason disorder mainly, human parasites such

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as protozoa and helminth eggs are of unique importance on this regard as they show to be most hard to eliminate by using treatment procedures and had been implicated in some of infectious gastrointestinal illnesses in both developed and growing nations (Hussain, Raschid, Hanjra, Marikar, & Hoek. 2002). However, in evaluating health impacts it must be remembered that it is the actual risk that make people fall ill that must be quantified and not the presence of pathogens in water. Whilst the potential risk may be quite high, the actual risk depends on many other factors. The use of untreated wastewater for irrigation, no doubt, poses a high risk to human health in all age groups. However, the degree of risk may vary among the various age groups. Untreated wastewater irrigation leads to relatively higher prevalence of Ascariasis infections with children (Cifuentes et al. 2000; Habbari et al., 2000), hookworm (Feenstra, Hussain, & Hoek, 2000). A lot of cities are facing key challenges in organizing the hazards linked with unrestrained wastewater irrigation, mainly water-shortage cities and low-income cities. Many have also begun to concentrate on those problems and progressed toward some degree of intended wastewater use in agriculture some with budding ways and others with definite plans. Each nation is sole, and experiences of other countries and cities can give some instruction as to how to get better wastewater irrigation practices. Cities can become accustomed to the techniques and schemes developed somewhere else to go with their own situation.

Development Partners

The support from the different organizations was sought by the cities for implementing their own ideas, skill development institutions, NGO's, etc. Many of the organizations have generated awareness among the people to avoid the usage of untreated wastewater. Most of them helped to maintain the cities with the secured wastewater irrigation and also selling of the same. Many volunteers are being motivated to offer more attention on this kind of initiative and add an asset to his/her nation. The different organizations that helped in the above context are - World Health Organization, The United Nations Development Program, International Development and Research Centre, International Water Management Institute, Resource Centre for Urban Agriculture and Forestry (RUAF), Water Partnership Program (WPP) to name a few.

BUSINESS MODEL FOR WASTEWATER REUSE IN AGRICULTURE

Fifty percent of the world's inhabitant's lives in urban areas and this is likely to reach two thirds by 2050. In many developing countries, urban populations are fraught with inefficient waste and used water management systems and these spill over into the environment, often with dire consequences. A walk through any Indian city would reveal open sewages and trash-filled drains. Moreover, rivers in many cities like Pune have turned in to veritable sewers. These cities have an immediate and urgent need for improved waste management and sanitation; however, the local authorities are neither financially nor managerially ready to meet the burgeoning challenge. Untreated wastewater inadvertently enters agricultural fields in India and is a prime reason for the spread of pathogens. However, for the entrepreneur urban waste presents a business opportunity and for municipal bodies this could be a potential market approach to solve an everyday urban problem. Due to India's monsoon based climate and consequent seasonality of its rivers, most parts receive their natural supply of fresh water only about four months in the year. In such a condition urban wastewater generated daily, turns out to be a resource which can bridge the supply gap. Wastewater, can be, in many cases a source of rich materials which can be re-

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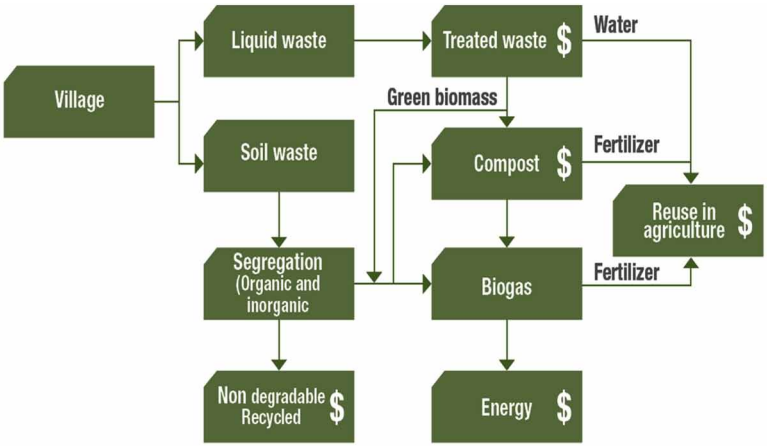
covered after some treatment. The nutrient value of domestic wastewater in agriculture is well studied but carries significant health risks. Involving the private sector in wastewater treatment and developing a business model can potentially turn this activity operationally efficient and distributionally effective.

The two major applications of urban wastewater, or used water, are in agriculture and in industry. Significant developments are seen in both cases, especially in arid regions of the world like Australia, Middle East and United States. Industry can safely use treated wastewater in a variety of applications like cooling system make-up water, boiler feed water, process water, wash down water and uses like site irrigation, fire protection, road cleaning. A successful example is seen in the mining industry, where an increasing number of mining companies are using reused water from residential or industrial areas (Workshop on industrial water reuse in the mining sector, 2013). In India, an example of urban wastewater use is seen in the city of Bangalore where it is used to recharge ground water sources. Urban wastewater is used for refilling exhausted irrigation tanks in rural neighborhoods and this in turn replenishes ground water levels. Such a depleted tank situated in Hoskotte in rural Bangalore receives excess water from an urban tank and serves as a storm water and wastewater reservoir throughout the year (Drechsel, Qadir, & Wichelns, 2015). Another ongoing project of the International Water Management Institute is being run with the objective of analyzing risk and opportunities of fecal sludge reuse in Indian agriculture. The project will examine options for optimizing private sector engagement in the valorization of fecal sludge and urine as agricultural inputs. The project focuses on the areas around the cities of Bangalore and Hubli-Dharwad in the State of Karnataka, but will also explore the scale of fecal sludge reuse across at least five other states within India. Of particular interest is private sector participation and search for scalable business models.

Similarly, for rural waste management, which is perhaps a problem of lesser proportion but similar consequences, the Decentralized Waste Management Systems model recommended by ICRISAT (ICRISAT, 2015) can be implemented through the green business model (Figure.2).

In African countries small-scale entrepreneurs are using human waste to make a profit. In Ghana, for instance, urban and peri-urban farmers use nutrient-rich sludge and wastewater to grow crops (International Water Management Institute, 2015). While this requires careful attention to health concerns,

Figure 2. Decentralized Waste Management Systems model recommended by ICRISAT
Source ICRISAT



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they can be overcome by regulation and third party audits. Planners must ascertain that there are enough end-users for a waste product.

For assessing the viability of any urban or rural wastewater use projects, planners must evaluate two aspects of the proposed project. Economic justification – are the total benefits arising out of the project higher than the total costs? There is a high probability of economic justification for most Indian urban wastewater projects for a reason – the untreated wastewater finds its way to farms and ground water sources and poses a massive health hazard. This cost, while difficult to quantify, is nevertheless a real cost and one which must be factored in this evaluation.

Financial viability – who pays and how? This is not an easy challenge. The urban wastewater requires energy intensive technology for treatment while the output is valuable to agriculture and industry. Does the municipal authority pay for the treatment with the urban tax payer's money or must the beneficiaries of the treated water pay for it. Successful examples from several places in the world can be looked to find an effective and equitable way to manage the costs.

Arguments Favoring Private Sector Participation in Used Water Treatment

Studies and examples from other countries provide these compelling arguments, which are summarized below. Profit motive can lead to efficient operations, which is not possible when operations are undertaken by the local governing body. The introduction of a profit motive can lead to increasing the efficiency as compared to public management of the water system.

Private enterprises can get in managerial skills and capabilities which may not be available with local governing bodies. The private sector has improved managerial capabilities and sources of financing leading to better planning and control systems. Moreover, efficient operating and accounting procedures and effective distribution must be incorporated for securing profits.

Assurance of customer satisfaction is a strong influencer to efficient operations. This is a key objective of any business. Businesses run on customer satisfaction, while public authorities woefully lack this objective.

Lessons From Other Countries

Various countries have successfully used private partnerships to create sustainable business models in urban wastewater management. United Nations has worked with several African countries and developed economies in the European Union and has implemented models which seek business profits and social good. In these cases local bodies provide the services using a mixture of financing sources which suit local conditions. The public-private liasons (PPP) models with contractors can include management contracts, service contracts, leases, divestures concessions (build-operate-transfer), and public-private organizations (Hutton & Wood, 2013). In many nations, wastewater management service are not supported, low valued and rules (where they exist) may not be meticulously applied, thus cost revival may be difficult. Cost upturn options include creating business opportunities and economic instruments. Murray et al. (2011) have recommended that public-private liasons based on cost-recovery from the recycle of human waste could help to co-finance the sanitation/wastewater sector and to incentivize also, at the same time, promoting small and medium scale entrepreneurs. They put ahead four waste- based business models (involving aquaculture, biogas recovery, compost production and the use of fecal waste as an

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industrial fuel) and they projected a number of competence indicators in order to permit a comparison between different reuse options and hence allow a monetary assessment to be made of different reuse business concepts.

Critical Success Factors for Successful Public-Private-Partnerships in Wastewater Treatment

A good number of works by experts and several winning examples demonstrate the usefulness of partnering with the private sector. But, these tie-ups are complex to design, to practice and function. Therefore, PPPs must be carefully checked in the background of the project, the social benefit and the concerned gains to be attended under various ways. Some of the critical factors for a successful PPP are discussed below.

1. **Availability of Market:** Private participation cannot be attractive where there is no prevailing demand. While it may seem that treated wastewater may be readily in demand, there have been cases where farmers have declined to use such water. This could be due to low awareness and may require government campaigns to promote its use.
2. **Multiple Stakeholder Benefit Objectives:** Profit is certainly the motive for private participation, however, it must be met with social benefits, which may not always be quantifiable. The stakeholder analysis often requires data and strong managerial capabilities to lay out the multiple benefits that the PPP must address.
3. **Competitive Procurement Process:** While this is a fundamental requirement of social projects, there have been instances where private companies, on the basis of technological uniqueness, have driven specifications to make the bidding process favorable to them.
4. **Thorough Risk Assessment:** Many studies have shown the local governing bodies to be ineffective to quantify project risks. On the other hand, some successful projects have employed the services of third party risk assessors. This could be an option when the local body lacks the required skills.
5. **Shared Authority and Responsibility:** Holding the private partner responsible for the outcome is effective when they have the required authorities in place. Where such authority has been lacking, the projects have encountered undue delays in the bureaucratic decision making processes.
6. **Social Support:** This is an essential condition to any public-private project. The society which stands to benefit from the project must have a buy-in of the project. In urban wastewater treatment projects, this includes the polluters and the beneficiaries of the treated water.

Lower-average-income nations (like Iran and Jordan), higher-center-profit nations (like Chile, Argentina, Mexico), and high-earnings nations (like Kuwait and Qatar) give best examples of the successful use of wastewater. It can be the examples that a major role in treatment of wastewater can be played by the private sector by providing private investments, design, build and operate the treatment plants so as to attain the standards for irrigation. Many water scarce nations practice the involvement of private sector for the same and use in irrigation has been practice in many water scarce countries.

A study by Ernst & Young indicates that the Indian water sector can require venture of around $130 billion between 2011 and 2030. Wastewater management, in particular, is emerging as a key thrust area. Currently, only 60% of industrial and 26% of domestic wastewater is treated in India. Metros and large cities are treating only about 30% while smaller cities treat a minuscule 3.7% of their wastewater. Wastewater treatment has been a largely neglected area because municipal bodies cannot charge water

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users for the service. Thus, while municipal bodies often do get funding for wastewater treatment projects, operating and maintaining treatment plants is still a challenge. Recycling and reuse of wastewater has been encouraged by the Water Policy 2012. Industries in coming years may have to rely mostly on reuse of water for which recycled water can fetch a good price. A Chennai based company has bagged a project in Tuticorin from the Tamil Nadu government to set up a sewage treatment and solid waste treatment plant. The contract includes building the plant free, taking ownership and operating it. The treated water will be sold to industries which will bring in the revenues.

CONCLUSION

Climate change and wastewater control are one of the foremost demanding situations for Indian cities. Urbanization and unparalleled growth of cities across India continue to create immense pressure on land and water resources. This uncontrolled growth continues to produce growing volumes of wastewater. Climate change impacts inclusive of, intense storm events in summer time or extended moist periods in wintry weather are quite visible in India. In urban and peri-urban areas, wastewater use for agriculture is an emerging precedence. Due to susceptible enforcement of regulatory, most of the wastewater generated is permitted off untreated/ partially treated. While many previous studies have checked out the global modifications and associated impacts of climatic variations on water resources, few have targeted at the evaluation of the particular effects and adaptation priorities for water systems in towns. Proper reuse of wastewater for irrigation could significantly lessen water shortage and offer a sustainable source of water, improving agricultural productiveness, reduce pollution, and create livelihood possibilities for low earnings city households and contribute to their each day food needs. However, there are tradeoffs that need to be understood which includes risks to human health, and environment

The success stories from Israel and Chile indicates that for achieving secure and successful wastewater irrigation requires slow, steady and determined efforts on all fronts for several years. Learning from these examples Indian wastewater projects can create big opportunities for countering urbanization and helping economic development.

Possible solution to achieve this is to help municipal authorities to transport large volumes of water from long distances (150 km) which are a part of the rural agricultural system. During this process couple of hurdles gets created like over excessive fees of lifting water, river pollution and groundwater contamination. In every panorama, water augmentation must be considered at the side of special wastewater remedy strategies for multiple makes use of, and ought to be backed up with public policy and social incentives. This will surely guard the downstream customers and also offer financial benefits and help the surroundings offerings that constitute an imperative part of all varieties of lifestyles. A state and city wise approach for wastewater use in agriculture ought to seize the variety seen within the Indian context; this bottom up approach will identify nodal agencies for systematic data series and collection. Data collected can be effectively used for wastewater control plans thus preserving and reducing continued dispute between states for freshwater use .The reuse of wastewater generated will conserve groundwater, ecosystems, and reduce downstream affects thus helping in restoring livelihoods. However, wastewater treatment is crucial stages and hence should be designed to meet the requirements of end users, but these needs to be elaborated based on the wastewater supply at that location. Such sector based study can become a part of municipal improvement plan, making best use of wastewater generated in the towns. If wastewater is taken into consideration and included as a vital factor into national water plans

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and water cycles catchments, doubtlessly this will protect the downstream users and provide economic opportunities through alternative use of wastewater within towns.

The crude approach for India estimated that over 1.1 Mha of land can be irrigated using the available wastewater resource from different cities. Water can be collected through dedicated channels and infrastructure. Wastewater needs to be diluted with fresh water for its better usability,

Because dilution changes the water class, and estimations may require a exceptional modeling approach, technology driven systems like Remote Sensing and Geographical Information Systems (GIS) and unique mapping of drainage networks can offer better basic consequences which could help to investigate the nutrient loads leaving the metropolis. GIS-based mapping make land-use as part of their utility, to increase baselines, upon which future research may be modeled. Wastewater irrigation may be a dynamic system in the urban areas, and land-use patterns can exchange with development and socioeconomic exchange; consequently, to study techniques to capture this dynamism, spatially and temporally. Case studies confirmed that because of wastewater use farmers spent plenty less on inputs, and wherein the nutrient resources can be balanced the final results modified into more excessive exceptional (Delhi, Kanpur and Kolkata) in phrases of price monetary financial savings and economic returns. This become most effective primarily based on agricultural production, and a further holistic economic analysis desires to be completed to seize the personal advantages to the households and social benefits to the organizations. Wastewater agriculture is but no longer without horrible externalities, and fitness affects on farmers and clients are of huge state of affairs as mentioned above. From an Indian context more research are required in the regions of wastewater irrigated agriculture, health and food protection, and health economics, particularly at the farm and purchaser stages, to capture the diverse settings wherein the problems exist. Threat evaluation device like Quantitative Microbial chance evaluation (QMRA) and Quantitative Chemical chance evaluation (QCRA) may be used to evaluate the capability risk, which want to then be addressed via a couple of barrier approaches with fitness-based totally dreams for risk discount (WHO, 2006). In evaluation in India, greater emphasis wishes to be located on wastewater treatment processes that take away heavy metals, which seem to have a great deal better tiers than in maximum components of Africa (Raschid-Sally & Jayakody, 2008). Wastewater management and remedy cannot be planned in isolation. They should be a center a part of the strategic plans for water deliver and sanitation, irrigation and drainage, strength, and environmental offerings (World Bank, 2004). Moreover, it will become very essential to recall the ones additives in light of water availability for cities, and to highlight the need for continuous inter-sectoral communicate and action plans to address the ever-developing water demands (Global Economic Organization, 2010). Integration of water assets improvement with water services can provide greater help for agricultural water control. India being in recent times greater urban and peri-city than rural, it's time for safe wastewater.

REFERENCES

Afifi, A. A., Abd El-Rheem, & Youssef. (2011). Influence of Sewage Water Reuse Application on Soil and the Distribution of Heavy Metals. *Nature and Science*, *9*(4), 82–88.

Arnell, N. W., Halliday, S. J., Battarbee, R. W., Skeffington, R. A., & Wade, A. J. (2015). The implications of climate change for the water environment in England. *Progress in Physical Geography*, *39*(1), 93–120. doi:10.1177/0309133314560369

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

California State Water Resources Control Board. (1990). *California Municipal Wastewater Reclamation in 1987*. Office of Water Recycling.

Central Pollution Control Board, (2005). *A report on Status of Water Supply, Wastewater Generation and Treatment in Class-I Cities & Class-Ii Towns of India*. Author.

Cifuentes, E., Gomez, M., Blumenthal, U., Tellez-Rojo, M. M., Romieu, I., Ruiz-Palacios, G., & Ruiz-Velazco, S. (2000). Risk factors for Giardia intestinalis infection in agricultural villages practicing wastewater irrigation in Mexico. *The American Journal of Tropical Medicine and Hygiene*, *62*(3), 388–392. PMID:11037783

Drechsel, P., Qadir, M., & Wichelns, D. (2015). *Wastewater: Economic Asset in an Urbanizing World*. Springer. doi:10.1007/978-94-017-9545-6

Environmental Information System (ENVIS) Centre on Hygiene, Sanitation, Sewage Treatment Systems and Technology. (n.d.). Retrieved from http://www.sulabhenvis.nic.in/Database/STST_wastewater_2090.aspx

Feenstra, S., Hussain, R., & van der Hoek, W. (2000). Prevalence of intestinal parasites in the Southern Punjab, Pakistan. IWMI Pakistan Report 101.

Gebrezgabher, S., Rao, K., Hanjra, M. A., & Hernández-Sancho, F. (2015). Business Models and Economic Approaches for Recovering Energy from Wastewater and Fecal Sludge. In Wastewater (pp. 217-245). Springer Netherlands. doi:10.1007/978-94-017-9545-6_12

Grit, R., Jörg, L., Steffen, D., & Gerel, O. (2015). Integrated urban water management: Development of an adapted management approach. *Environmental Earth Sciences*, *73*(2), 709–718. doi:10.100712665-014-3701-z

Grover, M. (2012). *Degremont Water Treatment Technologies and A Case study of 635 MLD WTP at Sonia Vihar–Delhi*. Presented to working group of Planning Commission on Working Group on Urban and Industrial Water for Twelfth Plan of Government of India.

Habbari, K., Tifnouti, A., Bitton, B., & Mandil, A. (2000). Geohelminthic infections associated with raw wastewater reuse for agricultural purposes in Beni-Mellal, Morocco. *Parasitology International*, *48*(3), 249–254. doi:10.1016/S1383-5769(99)00026-4 PMID:11227765

Hussain, I., Raschid, L., Hanjra, M. A., Marikar, F., & van der Hoek, W. (2002). *Wastewater use in agriculture: Review of impacts and methodological issues in valuing impacts. (With an extended list of bibliographical references)*. Working Paper 37. Colombo, Sri Lanka: International Water Management Institute.

Hutton, G., & Wood, A. (2013). *Development financing for tangible results: A paradigm shift to impact investing and outcome*. Academic Press.

International Crops Research Institute for the Semi-Arid Tropics. (2015). *Waste management recycling and reuse.* Retrieved from ICRISAT: https://www.google.co.in/url?sa=t&rct=j&q=&esrc=s&source=web&cd=4&cad=rja&uact=8&ved=0ahUKEwi4v5-9uL3LAhWUUI4KHbdFCw4QFggzMAM&url=http%3A%2F%2Fwww.icrisat.org%2Fidc-flyers%2F3_Waste%2520management_CSR%2520Flyers.pdf&usg=AFQjCNFBTLfK7Mu_ng0uljn_TzJO0eAyMQ&

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

International Water Management Institute. (2015, March 10). *Wastewater Business models.* Retrieved from: http://www.iwmi.cgiar.org/issues/wastewater/business-models/

Itankar, N., & Patil, Y. (2015). Biosorptive Removal of Hexavalent Chromium from Aqueous Industrial Solutions by A Novel Wood Apple Shell Powder Biomass. *Advanced Materials Research*, *1130*, 689–692. doi:10.4028/www.scientific.net/AMR.1130.689

Lewis, N. D. (2016). Sustainable development through a gendered lens: Climate change adaptation and disaster risk reduction. *Reviews on Environmental Health*, *31*(1), 97–102. doi:10.1515/reveh-2015-0077 PMID:26943600

Mara, D. (2009). *Design Manual for Waste Stabilization Ponds in India*. University of Leeds. Available at http://www.leeds.ac.uk/civil/ceri/water/tphe/publicat/wspwarm/wspwarm.html

McCarl, B. A., Musumba, M., Smith, J. B., Kirshen, P., Jones, R., El-Ganzori, A., ... Bayoumi, M. (2015). Climate change vulnerability and adaptation strategies in Egypts agricultural sector. *Mitigation and Adaptation Strategies for Global Change*, *20*(7), 1097–1109. doi:10.100711027-013-9520-9

Mekala, G. D., Davidson, B., Samad, M., & Boland, A. M. (2008). *Wastewater reuse and recycling systems: a perspective into India and Australia*. Colombo, Sri Lanka: International Water Management Institute (IWMI). Retrieved from www.iwmi.cgiar.org/Publications/Working_Papers/working/WOR128.pdf

Misra, A. K. (2014). Climate change and challenges of water and food security. *International Journal of Sustainable Built Environment*, *3*(1), 153–165. doi:10.1016/j.ijsbe.2014.04.006

Mohan Kumar, R. (2003) Financing of Wastewater Treatment Projects. Infrastructure Development Finance Corporation and Confederation of Indian Industries, Water Summit 2003, Hyderabad, India.

Murray, A., Cofie, O., & Dreschsel, P. (2011). Efficiency indicators for waste-based business models: Fostering private-sector participation in wastewater and faecal-sludge management. *Water International*, *36*(4), 505–521. doi:10.1080/02508060.2011.594983

Neumann, M. B., Rieckermann, J., Hug, T., & Gujer, W. (2015). Adaptation in hindsight: Dynamics and drivers shaping urban wastewater systems. *Journal of Environmental Management*, *151*, 404–415. doi:10.1016/j.jenvman.2014.12.047 PMID:25594746

Pathak, H., Ladha, J. K., Aggarwal, P. K., Peng, S., Das, S., Singh, Y., ... Gupta, R. K. (2003). Climatic potential and on-farm yield trends of rice and wheat in the Indo-Gangetic Plains. *Field Crops Research*, *80*(3), 223–234. doi:10.1016/S0378-4290(02)00194-6

Patil, Y., & Rao, P. (2015). Industrial waste management in the era of climate change - A smart sustainable model based on utilization of active and passive biomass. In W. L. Filho (Ed.), *Handbook on Climate Change Adaptation* (pp. 2079–2092). Springer-Verlag Berlin Heidelberg. doi:10.1007/978-3-642-38670-1_49

Peirson, W., Davey, E., Jones, A., Hadwen, W., Bishop, K., Beger, M., ... Gray, L. (2015). Opportunistic management of estuaries under climate change: A new adaptive decision-making framework and its practical application. *Journal of Environmental Management*, *163*, 214–223. doi:10.1016/j.jenvman.2015.08.021 PMID:26321531

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

M. B. Pescod, & A. Arar (Eds.). 1988. Treatment and use of sewage effluent for irrigation. *Proceedings of the FAO Regional Seminar on the Treatment and Use of Sewage Effluent for Irrigation*.

Rao, P., & Patil, Y. (2015). Climate Resilience in Natural Ecosystems in India: Technology Adoption and the Use of Local Knowledge Processes and Systems. In Handbook of Climate Change Adaptation. Springer Berlin Heidelberg.

Raschid-Sally, L., & Jayakody, P. (2008). *Drivers and characteristics of wastewater agriculture in developing countries: Results from a global assessment. IWMI Research Report 127*. Colombo, Sri Lanka: IWMI.

Rawson, H. M., Gifford, R. M., & Condon, B. N. (1995). Temperature Gradient Chambers for Research on Global Environment Change. I. Portable Chambers for Research on Short-Stature Vegetation. *Plant, Cell & Environment*, *18*(9), 1048–1054. doi:10.1111/j.1365-3040.1995.tb00616.x

Sanchez Duron, N. (1988). *Mexican experience in using sewage effluent for large scale irrigation. Treatment and Use of Sewage Effluent for Irrigation* (M. B. Pescod & A. Arar, Eds.). Sevenoaks, UK: Butterworths.

Scott, C., Drechsel, P., Raschid-Sally, L., Bahri, A., Mara, D., Redwood, M., & Jiménez, B. (2010). Wastewater irrigation and health: challenges and outlook for mitigating risks inlow-income countries. In P. Drechsel, C. Scott, L. Rashid-Sally, M. Redwood, & A. Bahri (Eds.), *Wastewater Irrigation and Health: Assessing and Mitigating Risk in Low-Income Countries* (pp. 381–394). London: Earthscan.

Strauss, M., & Blumenthal, U. J. (1989). *Human waste use in agriculture and aquaculture: utilization practices and health perspectives*. IRCWD Report No. 08/89. International Reference Centre for Waste Disposal.

Valta, K., Moustakas, K., Sotiropoulos, A., Malamis, D., & Haralambous, K. J. (2016). Adaptation measures for the food and beverage industry to the impact of climate change on water availability. *Desalination and Water Treatment*, *57*(5), 2336–2343. doi:10.1080/19443994.2015.1049407

Workshop on industrial water reuse in the mining sector. (2013). *Report on Workshop on industrial water reuse in the mining sector.* Windhoek: Water Research Commission. Retrieved from www.wbcsd.org/web/water/2013Report-IWA-WBCSD-WRC-Mining-Water-Reuse-Workshop.pdf

World Bank. (2010). *Improving Wastewater Use in Agriculture: An Emerging Priority, Energy Transport and Water Department Water Anchor*. ETWWA.

Zouboulis, A., & Tolkou, A. (2015). Effect of climate change in wastewater treatment plants: Reviewing the problems and solutions. In *Managing Water Resources under Climate Uncertainty* (pp. 197–220). Springer International Publishing. doi:10.1007/978-3-319-10467-6_10

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Chapter 17
Sericulture Industry: A Bonanza to Strengthen Rural Population in India

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ABSTRACT

India has a huge potential for sericulture development unlike other agro industries since sericulture is a unique agro-based industry comprising of several components such as mulberry cultivation, silkworm rearing, silk reeling and other connected activities. Each of these components appear to be independent but closely linked with one another having intricacies of their own. The major activities of these components comprises of mulberry food-plant cultivation to feed the silkworms which spin silk cocoons and reeling the cocoons for unwinding the silk filament for manufacturing silk goods, subjecting them to the process of degumming, bleaching, dyeing, weaving and printing. Thus sericulture industry provides employment to approximately 7.85 million in rural and semi urban areas in India. Of these, a sizeable number belongs to the economically weaker sections of the society, including women. In addition to this, India has the unique credibility of producing all the five known commercial silk viz., mulberry, tropical tasar, oak tasar, eri and muga of which muga with its golden yellow glitter is unique and prerogative of India. Though silk is a luxury item, it is produced by the rural populace and purchased by urban rich, causing money to flow from urban to rural. It also prevents rural people to migrate to urban areas. The United Nation's recent endeavor "Millennium Development Goals" has an eight point programme to make our earth more healthy wealthy and free from inequalities by 2015. Sericulture being a rural and women friendly business aligns well with many of these ideas which are explained in detail in the chapter.

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INTRODUCTION

Father of the Nation, Mahatma Gandhi said that the "Real progress / development in India can be achieved only through village development programs". Rural development can be assured only by creating sustainable entrepreneurship with employment and income generation to the rural needy poor people. But most of the people are illiterate and the available resources are scarce and are not reaching the actual needy. Good number of schemes were planned and executed by different agencies in rural areas especially for the development of agriculture dependents. Eradication of poverty and unemployment are often attributed to the lack of "sustainable livelihood". A livelihood comprises the capabilities, assets (stores, resources, claims and accesses) and activities required for a means of living. A livelihood is sustainable which can cope with and recovers from stress and shocks, maintain and enhance its capabilities and assets and provide sustainable livelihood opportunities for the coming generation and which contributes net benefits to other livelihoods at the local and global levels and in the short and long term. The rural development has been a major factor of sustainable livelihood by using available resources, manpower and technology. The women and unemployed youths are to be taken as the driving force of any sustainable development in rural India. Strong rural urban linkages will not only help farmers stay back in villages pursuing profitable enterprises, it will also improve access to quality produce by urban consumers. It is noteworthy to mention the views of late Dr. A.P.J. Abdul Kalam, who has advocated his concept of PURA (Providing Urban facilities in Rural Areas).

Agriculture is the single largest livelihood source in Asian countries contributing to about 30 percent of the GDP and sericulture plays a vital role in it. There are certain evidences from various studies that more than 70% of the poor people live in rural area and the reduction of rural poverty continues to be a primary goal of the developing countries like in India. So far, various policies have been pursued to address this concern and among the major ones is rural employment creation. Sericulture is an agro-based labour intensive industry which provides gainful employment to the rural and unemployed youth and helps to uplift the socio-economic status of small and marginal farmers. It is therefore necessary to focus on a broader spectrum of the rural economy. The establishment of rural based agriculture enterprise like sericulture, in particular, could be very effective in creating new job opportunities and providing income for their livelihood. Being a rural agro-based labour intensive industry the Sericulture sector plays a vital role for checking the migration from rural to urban areas. Because of it multifarious advantages such as high employment potential, rural base, relatively low capital requirement, checking migration to urban areas, meeting raw material needs of the silk weaving industry and as such introduction of sericulture has been attempted in several countries but it could be sustained only in a few countries. Considering the merits of the sericulture industry for inclusive growth and the activities aligning with the Millennium Development Goals, the Government of India and the State Governments have taken up various developmental programmes for the development of sericulture and silk industry in India

Silk is the most elegant textile in the world and known as the "Queen of Textiles". On the other hand, it stands for livelihood opportunity for millions owing to high employment oriented, low capital intensive and remunerative in nature. The very nature of this industry with its rural based on-farm and off-farm activities and enormous employment generation potential has attracted the attention of policy makers to recognize the industry as one of the most appropriate avenues for socio-economic development of a largely agrarian economy like India.

Mulberry sericulture is a land based activity, which is labour intensive and provides good returns to the farmers. It has special significance for women as the silkworm rearing is done indoor is not physi-

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Figure 1. Mulberry Garden

cally laborious and can be taken up along with other household activities. Mulberry sericulture has both agricultural components relating to mulberry plantation as well as industrial components relating to reeling, twisting and weaving. Because of demand of silk yarn and fabrics both within and outside the country, mulberry sericulture has promising market. Production of quality silk yarn within the country would help in reducing import of silk yarn from outside.

India continues to be the Second largest producer of silk in the World (Datta and Nanavaty, 2005). Among the four varieties of silk produced, as of 2012-13, Mulberry accounts for 79% (18715 MT), Tasar 7.3% (1729 MT), Eri 13.2% (3116 MT) and Muga 0.5% (119 MT) of the total raw silk production of 23,679 MT. This is against the production of 23060 MT Silk by end of XI Plan (2011-12) in the country. There has been a significant increase in raw silk production in 2013-14, as indicated in the Table 1.

Table 1. World raw silk production

Country/Year	2009	2010	2011	2012
China	84000	115000	104000	126000
India	19690	20410	23060	23679
Brazil	811	770	558	614
Indonesia	19	20	20	20
Iran	82	75	120	123
Japan	72	54	42	30
North Korea			300	300
Thailand	665	655	655	655
Turkey	20	18	22	22
Uzbekistan	780	940	940	940
Vietnam		550	500	450
Others	30	31	47	57
Total	**106169**	**138505**	**129684**	**152868**

Note: *Figures of India is for financial year April – March, Source:*www.inserco.org

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The world raw silk production was 1,52,868 MT in 2012. China leads the world with silk production of 1,26,000 MT or 82.41% of the produce. India is the second largest producer of silk in the world and has 15.49% share in global raw silk production. All the countries except China and India have been witnessing a declining trend in raw silk production in the last two decades.

PRODUCTION AND CONSUMPTION OF RAW SILK

Production of raw silk in India was 26,480 MT in 2013-14(p) of which, mulberry raw silk output aggregated to 19,476 MT (74%). The remaining 7,004 MT (26%) was *Vanya* silks. Mulberry sericulture is mainly practiced in five states namely, Karnataka, Andhra Pradesh, West Bengal, Tamil Nadu and Jammu & Kashmir which jointly account for about 96% of the total mulberry silk production in the country. As the consumption of raw silk (around 29,730 MT) exceeds the production, the additional requirement of around 3,500 MT of silk (particularly Bivoltine mulberry silk of international quality) is imported mainly from China.

RAW SILK IMPORTS

The quantity and value of raw silk imported from 2009-10 to 2013-14and for 2014-15 up to April-2014 are given Table 2.

Exports

The Indian silk goods are being exported to the traditional major markets like the USA and European countries and small markets of Asia Region. There was a slump in silk goods exports from the country from 2008-09 onwards due to melt down in the global economy and sharp depreciation in the value of Indian Rupee against US$. The silk goods export earnings decreased over the years due to global recession. The export earnings reduced in the subsequent years and reach Rs.2303.53 Cr. in 2012-13. However during 2013-14 export earnings increased by 5.28% compared to 2012-13 and reached Rs. 2425.16 crores. Export value of silk goods from 2009-10 to 2013-14 and for 2014-15 up to April-2014 is presented in Table 3.

Table 2. Raw silk imports

Year	Quantity (MT)	Value (Rs. in Crores)
2009-10	7338	933.70
2010-11	5820	927.59
2011-12	5683	1111.53
2012-13	4959	1238.56
2013-14(P)	3259	896.44
2014-15*	262	73.78

Source: DGCIS, Kolkata. (p) Provisional, *April-14

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Table 3. Silk export earnings

Items	2009-10	2010-11	2011-12	2012-13	2013-14 (p)	2014-15*
Natural Silk Yarn	29.42	39.39	19.68	21.96	8.56	0.79
Silk Fabrics	1942.57	2083.82	1497.97	1410.31	847.81	51.60
Readymade Garments	854.94	683.31	765.83	787.15	1453.85	187.87
Silk Carpet	40.59	21.10	20.08	21.14	15.65	0.86
Silk Waste	24.92	36.14	49.77	62.97	99.29	7.27
Total	2892.44	2863.76	2353.33	2,303.53	2425.16	248.39

(p) Provisional, *April-14

Table 4. Performance of sericulture sector

Mulberry	XI Plan (2007-12)		XII Plan (2012-17)	XII Plan Achmt.	
	Target	Achment.	Target	2013-14(p)	2014-15*
Plantation (Lakh ha.)	2.18	1.81	2.40	2.03	2.03
RAW SILK PRODUCTION					
Bivoltine		1685	5000	2,559	355
Cross Breed		16587	18000	16,917	2102
Sub Total	23000	18,272	23,000	19,476	2457
VANYA					
Tasar	420		4562	2619	4
Eri	2390		4238	4237	918
Muga	190	126	200	148	32
Sub Total	3000	4788	9000	7004	954
Grand total	26,000	23,060	32,000	26480	3411
Cumulative Employment Generation (Lakh persons)	77.04	75.6	92.42	78.50	NA

*April-2014 to June-2014, p: provisional

The silk production has shown remarkable progress during the year 2013-14 in-spite of drought, un-seasonal rain, cyclone etc. The target set for the year has been fully achieved. At present, India produces 26,538 MT of raw silk of which the contribution of mulberry silk is 19,506 MT and non-mulberry silk, 7,032 MT. In India, various efforts could successfully tropicalize the bivoltine sericulture suiting to Indian conditions through different approaches such as R & D, synchronization of production process by putting in place an effective management system and incentive support at farmer's level to enhance production and quality. Sericulture industry provides employment to the persons in rural and semi-urban areas in India. Of these, a sizeable number of workers belong to the economically weaker sections of society, including women. India's share in global raw silk production is about 15% forming the second largest producer of mulberry silk. All the countries except China and India have been witnessing a declining trend in raw silk production in the last two decades. Japan was once a major producer of silk but has started abandoning sericulture due to industrialization. Mulberry sericulture is mainly practiced in five

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states namely, Karnataka, Andhra Pradesh, West Bengal, Tamil Nadu and Jammu & Kashmir jointly account for the 96% of the total silk production in the country.

Silk produced in India is unique in its nature with diverse designs, unique craftsmanship, colour combinations, luster and heavily loaded with the ethnic style and nature of the community. Each region has its own traditional distinctive designs and weave and a market in terms of acceptance. Exquisite brocade fabrics of Banaras of Uttar Pradesh, Mysore silks of Karnataka, tie and dye and patola of Gujarat and Rajasthan, ikats from Odisha, Pochampalli from Telangana, Balucheri of Bengal and temple silks of Tamil Nadu are some pride creations of India.India has developed an international market for Indian silk goods by creating a niche market for the handloom silk having its own weaves, textures and design. India earned foreign exchange revenue of US $ 410.62 million through export of silk goods during 2013-14. Silk fabrics and readymade garments are the major items of the exports which accounts for about 95% of the total value of exports. The traditional major markets for Indian silk goods are the USA and European countries, UAE, Saudi Arabia, Hong Kong and Singapore. In India, there is a strong prospect for horizontal and vertical expansion to meet the increased domestic and export demand for silk products.

SERICULTURE IN ANDHRAPRADESH

Andhra Pradesh occupies 1st position in unit productivity and 2nd position in the country next to Karnataka in production of Silk. As a rural agro based industry, Sericulture has now expanded to almost all districts in the state. Ever since its introduction, it is playing a pivotal role in the development of rural economy of the state (Goel *et al*., 2003; Seshagiri *et al*., 2003). Andhra Pradesh produces all the four popular varieties of Silk worm cocoons namely Mulberry, Tasar, Eri and Muga. The state has got very strong and traditional weaving base with more than a lakh number of hand looms mostly concentrated in weaving pockets like Dharmavaram, Pochampally, Gadval, Patur, Peddapuram,Narayanpet, etc., In the last decade number of cotton weavers have taken to silk weaving in centers like Rayadurg and Proddatur because of better income in silk weaving. In Andhra Pradesh, Anantapur district stands on the top for having the largest mulberry acreage and high cocoon production. Presently sericulture is standing as main occupation of the farming community in the Rayalaseema region particularly in Anantapur and Chittoor districts by absorbing the rural labor giving direct and indirect employment to the other communities through Silk Reeling, Twisting, Dyeing, Weaving and Block printing, Sericulture industrial equipment and inputs manufacturers (Seshagiri and Ganapathi Rao, 2002). The Government of Andhra Pradesh has created a separate department and promoted the Sericulture industry both in On-farm and non-farm sectors through the launching of various schemes.

SERICULTURE ENTREPRENEURS AND THEIR CONSTRAINTS

Sericulture is not only a tradition but also a living culture in India. Sericulture is both an art and science of raising silkworms for silk production and ensuring the livelihood security with this enterprise and its related activities. However, the entrepreneurs are facing various challenges for their sustainability in the industry. Fair prices and timely availability of the quality inputs are the major constrains to the farmers and his knowledge base is influenced by the R & D support / Technical guidance by different agencies. At present, availability of skilled labour has become a thrust among the farming community in continu-

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ing in the sericulture enterprise. The prevailing environmental factors and socio-economic status also influences in the successful harvesting of the crops. Various other factors such as financial and other line departments support also play major role in the continuity of the entrepreneur in the industry. These factors influence the entrepreneur for continuation in the enterprise as indicated in Figure 2.Considering the need and constrains of the entrepreneurs, State Govt. of Andhra Pradesh supports them financially for various activities (Table 5).

Figure 2. Status of sericulture entrepreneur

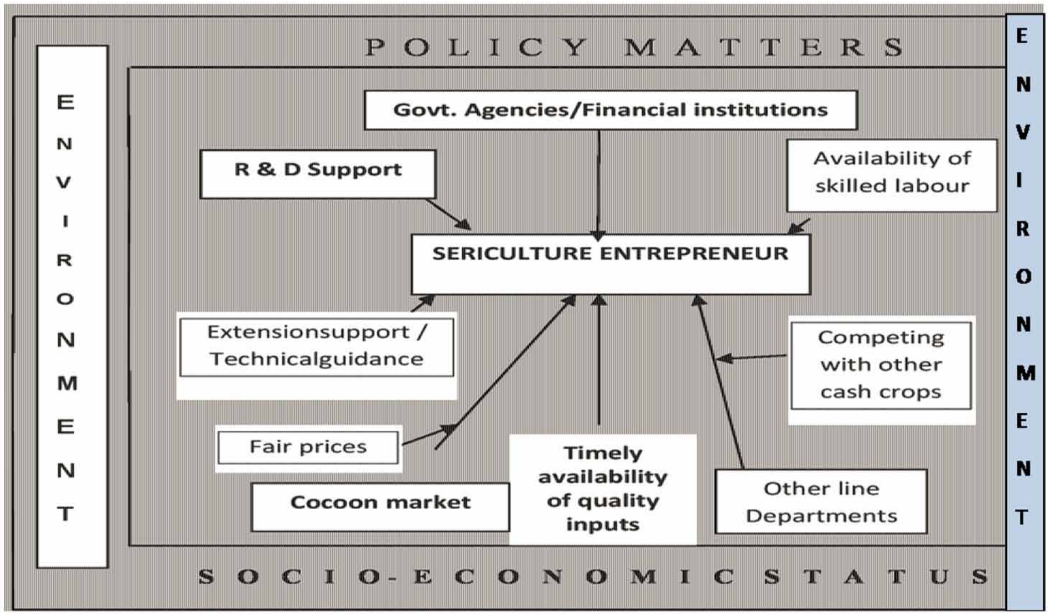

Table 5. Financial assistance

Sl. No.	Item / Activity	Amount (Rs.)
1	For raising Mulberry Garden in 1 acre	6,750.00
2	Construction of Rearing Shed	1,00,000.00
3	Rearing Equipment	37,500.00
4	Farm Mechanization	10,000.00
5	Irrigation facility per Ha. (Bore Well / Drip / Sprinkler)	37,500.00
6	Organic fertilizer like Neem Cake	5,000.00
7	Disinfectants	1,500.00
8	Construction of CRC & Equipment	2,50,000.00
9	Seri Poly Clinic	1,50,000.00
10	Construction of Verandah to a Rearing Shed	15,000.00
11	Production incentive for CB Silk (per Kg)	20.00
12	Production incentive for Bivoltine Silk (per Kg)	40.00

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EMPLOYMENT POTENTIAL FOR RURAL PEOPLE

Silk industry is emerged as a major employment provider in the country which leads to poverty alleviation and inclusive development. 60 lakh persons are engaged in various sericulture activities in the country. It is estimated that Sericulture can generate employment @ 11 man days per kg of raw silk production (in on-farm and off-farm activities) throughout the year. This potential is par-excellence and no other industry generates this kind of employment, especially in rural areas, hence, sericulture is used as a tool for rural reconstruction. It is obvious that mulberry sericulture can be an effective tool in solving the problems of unemployment and poverty alleviation in the rural areas. Silk industry provides employment to 7.9 million people in the country. The labour force participation rate in silk industry is the highest in comparison to any other avocation in the country. Sericulture consists of two phases, one is mulberry cultivation which is basically agriculture in nature through which mulberry leaf, the food of the silkworm is produced and the other one is rearing of silkworms for cocoon production. The income per unit area is comparatively very high and this industry is having very good employment generation potential as the industry is involving mulberry cultivation, silkworm rearing, silk reeling, silk twisting, silk dyeing, silk weaving, silk garments manufacturing and allied activities like bamboo tray, chandrike making and sericulture carpentry. The economic advantages of sericulture industry lie in its high employment potential with low investment. It requires low gestation period and continues to yield for 15-16 years with little expenditure on maintenance. It gives higher returns, unlike other agricultural crops. Thus the industry plays a major role in women empowerment in particular and distribution of equity from rich to poor.

The very nature of the sericulture industry with its rural based on farm and off farm activities and enormous employment generation potential has attracted the attention of the policy makers. Further, the changes in employment and income opportunities in rural areas may be brought about by selecting a highly labour intensive and high income yielding cropping pattern and sericulture has been identified as one such sector which plays a vital role in generating gainful employment opportunities. Every acre of sericulture practiced under irrigated conditions had a potential to employ 247 men and 193 women round the year (Jayaram *et al*., 1998). They have also shown that the small scale mulberry farms provided ample scope for employment of owned family labour and suggested its potential to solve the problem of seasonal unemployment. To reverse the continuing decline in agriculture, restoring farmers confidence in farming and turnaround in rural – urban migration is crucial.

Figure 3. Rearing of silkworms

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Figure 4. Shoot rearing method of silkworms

Keeping in view the potentialities of the sector, Ministry of Agriculture, Govt. of India had earlier notified the inclusion of Sericulture activities up to the stage of cocoon production and silk yarn production in Agri-enterprises up to the stage of yarn production and marketing to be eligible under Rastriya Krishi Vikas Yojana (RKVY Schemes), which are State Plan programmes. Similarly, the Ministry of Rural Development (MORD), Govt. of India has also revised the guidelines of the MGNREGA scheme where in the benefits of the scheme can be availed by the small and marginal farmers for asset creation in their land towards irrigation facility, plantation, horticulture, land development etc. Since, majority of the Sericulture farmers come under the category of small and marginal farmers, the concerned department of Sericulture should get the desired work approved by the Gram Panchayat for inclusion under the project available for wage employment under MGNREGA (Mahatma Gandhi National Rural Employment Guarantee Act).

ENHANCING VILLAGE ECONOMIES FROM EVERY COMPONENT

The strategy for sustainable development adopted so far is required to be revisited keeping in view of the development in the silk industry. The interventions attempted so far are required to be made more focused for taking care of the aspirations of the youth on the short run. At the beginning of the new millennium, Millennium Development Goal (MDG) was adopted with a view to achieve certain goals and specific targets by 2015. Adhering to the MDG, the UN has incorporated some elements of the position taken by India and other developing countries such as that green economy should not result in creation of new green barriers like carbon tax, impose new conditions on aid and finance and increase dependence of the developing countries on rich nations for cleaner technologies. About 57% of the gross value of silk fabrics flows back to the cocoon growers with share of income to different groups 56.8% to cocoon grower, 6.8% to the reeler, 9.1% to the twister, 10.7% to the weaver, 16.6% to the trader. Thus, large chunk of income goes back to the villages from the cities.

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HIGH RETURN WITH LOW GESTATION

The new innovations of mulberry cultivation, silkworm rearing and improved hybrid silkworm seeds have brought an unparallel revolution in the silk industry of the Southern states in India. They do not call for any special heavy investment as the same are developed to suit the existing socio-economic conditions of the farm house-holds. The simplicity in adoption of these technologies and attractive income thereof have great appeal to the farmers with the result that sericulture is spreading fast in new areas covering practically almost all the districts of the Southern states. It is also helping in rapid transformation of the poor sericulture villages into reasonably prosperous rural areas. The new sericulture technologies are very much farmer oriented and have, in fact, transformed sericulture which used to be a subsidiary rural occupation in the past, into a full time highly remunerative agricultural activity better than any other cash crops. In view of the high employment potential and remunerative income generation, sericulture has come to be regarded as one of the important means of alleviating rural poverty and ushering in rural prosperity and is therefore, receiving due attention in rural development programmes both at the State and National levels (Kumaresan, 2011). In physical terms, the impact of sericulture research on the development of silk industry in the southern states has been very spectacular as evident from the quantum jump in productivity and expansion of the industry.

Keeping in view of the advantages of silk in promoting inclusive development, promotion of sericulture will continue to be an important factor in the coming days. Silk has been an inseparable part of Indian culture and tradition as no ritual is considered complete without silk apparel. In India, Sericulture is not only a tradition but also a living culture. The future of silk in the 21st century seems to be bright and its consumption is likely to rise despite its high prices. Sericulture is recommended as one of the most effective tools for rural development in general and poverty alleviation in particular. Sericulture is also recognized for its transfer of income from richer to poorer classes, use of marginal land without affecting food grains production and high export potential (Seshagiri and Ganapathi Rao, 2002). Till recently, sericulture was considered a subsidiary occupation but with the introduction of new technologies had led the industry to highly remunerative cash crop which inturn increasing the mulberry acerage. Mulberry takes only six months to grow for commencement of silkworm rearing. Mulberry once planted will go on supporting silkworm rearing year after year for 15-20 years depending on inputs and management provided. Five crops can be taken in one year under tropical conditions. By adopting stipulated package of practices, a farmer can attain net income levels up to Rs.30000 per acre per annum.

Several socio – economic studies have affirmed that the cost – benefit ratio is quite good in sericulture in comparison with other cash crops. Revenue is generated in silkworm rearing from the sale of cocoons which was Rs. 2,43,000/- acre / annum and the total cost of cocoon production including mulberry cultivation was estimated Rs. 1,81,313/-. The net returns were 61,753/- per acre per annum. Cost – benefit ratio was also calculated and worked out to be 1:1.50. It may be concluded that the revenue obtained from sericulture is fairly higher and its high profitability nature can be made known to the farmers and popularized through extension programmes. The details of the sericulture economics are given in Table 6.

FRIENDLY ENTERPRISE TO WOMEN

An empowered person is someone, who has the power to decide—to say, if they have land, 'Well, I can go farm, I can grow crops, I can plant seeds'—or if they have animals, to say, 'I can sell them without

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Figure 5. Cocoons on Rotary mountages

Table 6. Sericulture economics (one acre plantation under irrigated conditions)

Sl. No.	Particulars	Rate (Rs.)	Amount (Rs.)
A. EXPENDITURE			
1.	Cost of leaf production for 28 MT. of leaf per kg	Rs. 2.28	63840.00
2.	Cost of dfls (Multi x Bi.) 1500 dfls	Rs. 280 per 100 dfls	4,200.00
3.	Man days for rearing [@ 20 man days per 100 dfls (1500 dfls x 20 mandays)]	200/-	60,000.00
4.	Non recurring expenditure		57,387.00
5.	Recurring expenditure		6520.00
	Total Expenditure		**1,91,947.00**
B. RETURN			
7.	Returns @ 60 kg cocoons / 100 dfls (1500 Dfls x 60)	300/- per kg	2,70,000.00
8	Return from selling of left out mulberry twigs /branches etc. (6 MT / year)	3.00 per kg	18,000.00
Total Return			**2,88,000.00**
NET RETURN in Rs.: (B-A)			**96,053.00**
COST BENEFIT RATIO is 1: 1.50			

ASSUMPTIONS	
Mulberry variety	V1
Silkworm Hybrid	Multi x Bi
Average leaf yield / acre @70 MT/ha/yr	28 MT / acre
No. of Dfls brushed /acre/year	1500 dfls
Average cocoon yield / 100 dfls	60 kg
Average rate of cocoon / kg	300.00

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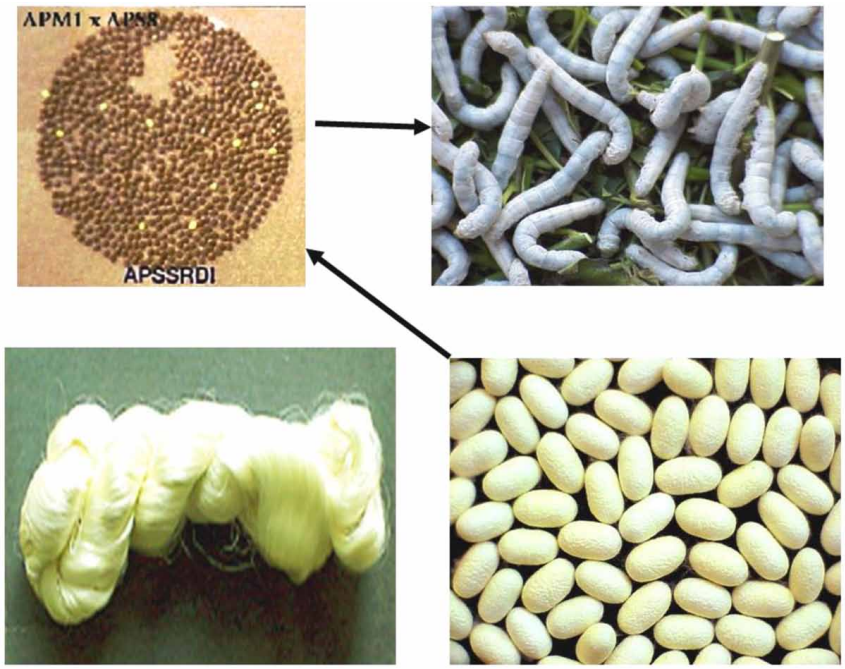
Figure 6. Different stages in end product (silk) production



going to ask permission' This is a person who has the power to decide about their things, their life, their actions.

People who are empowered 'see change in their lives'.

Under the globalization, privatization and liberalization, role of women is becoming more prominent and many of the industries women workers are preferred. As a result, the economic empowerment is getting accelerated and the gender concerns would be sorted out. Many of the studies undertaken proved that the sericulture and silk industry is an ideal tool for women empowerment and gender equality. The policy initiatives are focused towards promoting increased participation of women in sericulture. Several studies conducted on human resources involved in agriculture and an allied activity shows that the women form a major component of workforce. Considering their lions share in agriculture and allied activities as work force, both Central and State Governments have launched several women oriented HRD programmes, formation of women groups for improving their per capita productivity, bargaining power etc., through knowledge up-gradation and skill improvement. As a cottage industry, sericulture provides ample work for women in the rural areas particularly in silkworm rearing and reeling, while men work in the field. The involvement of women in different activities of sericulture is about 53 percent and their contribution in the on-farm activities is lower than that in post-cocoon activities. Being rural based, less specialized skill, mostly indoor activities, less physical energy, continuous job with frequent income, scope for utilizing several by-products for value addition and work is evenly spread over during the day which suits women for taking up sericulture.

Sericulture appears to be more suitable for women because of the advantages such as;

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- Involves mostly indoor activities with low requirement of physical energy.
- Work is spread through out the day with sufficient gap and leisure time.
- Silkworm rearing demands delicacy and infant care, which are inherent qualities of women.
- Low level of technical skill and education are sufficient to carry out the work.
- Needs minimum investment with long life and short gestation period.
- Scope of utilization of several by-products for value addition and better earning.
- Provides job at door steps avoiding long travelling from dwelling places.

Sericulture being a high employment potential agro-based cottage industry provides congenial atmosphere for women employment. Series of activities involved in production of silk encompass both on-farm and non-farm activities. The major economic end products such as leaf, cocoon, raw silk, and fabric provide ample scope for employment of women as there are several independent and inter-dependent economic activities. Women contribute to less than 50 percent of the country's population and most of them are largely rural based, deriving their livelihood through agriculture and its allied enterprises. The women earn the money in agriculture either as a family member or wage earner. The women friendly enterprise like sericulture provides ample scope for women in the rural areas particularly in silkworm rearing and reeling while men work in the field. The various studies indicated that women involvement in sericulture is about 53 per cent.

"Feed the Future" supports the inclusion of poorer and more economically vulnerable populations in economic growth strategies in the agriculture sector in order to have a transformational effect on regional economies and restructure local production, distribution, and consumption patterns for long-term, sustainable development. Because women play a prominent role in agriculture and due to the persistent economic constraints they face, women's empowerment has become a main focus of Feed the Future. Empowering women is particularly important to achieving the Feed the Future objective of inclusive agriculture sector growth.. The concept of inclusive agriculture sector growth is broad and multidimensional. Women's empowerment in agriculture is an important component of that inclusive growth, and Feed the Future seeks to measure and monitor women's roles and engagement in numerous areas of the agriculture sector.

PERFECT ACTIVITY FOR WEAKER SECTIONS OF THE SOCIETY

Sericulture could be practiced even with very low land holding and the enterprise has the features of low gestation, high returns which makes sericulture an ideal programme for weaker sections of the society. Unemployment and poverty are the major challenges of the developing nations and it is necessary to generate productive employment on a large scale. In view of multifarious advantages of mulberry sericulture, it is considered as an effective tool for economic empowerment of the disadvantaged segments. Sericulture covers both land based activities relating to plantation as well as industrial activities like reeling, twisting and weaving. Its labour intensive nature provides a solution to the problems of seasonal unemployment and underemployment (Purushotham and Rama Mohan Rao, 2009). It is a farm based, labour intensive and commercially attractive economic activity falling under the cottage and small scale sector. It particularly suits rural based farmers, entrepreneurs and artisans as it requires low investment but with potential for relatively higher returns (Raju, 2006). It provides income and employment to the rural poor especially farmers with small land holdings and the marginalized and weaker sections of the

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society. Sericulture enterprise recognized for its low investment and quick and high returns which make it an ideal enterprise which fits well into the socio-economic factors of India.

Vanya silk sector which is mostly forest based is practiced in forest belts. The population involved are mostly tribal and socially backward communities in these areas who practice sericulture as a subsidiary occupation at household level. Vanya, the wild silks of India provide livelihood opportunities to tribal inhabitants and it is considered as an important tribal development programme. It provides gainful employment to the people of tribal community / weaker sections and helps to ensure sustainable economic growth of the region. Vast tracts of forest based tasar food plantations available in the country, if judiciously exploited for rearing tasar silkworms, can offer supplementary gainful employment for tribals. Sericulture can be practiced even with very low land holding. Three/Four acre of mulberry garden and silkworm rearing can support a family of three without hiring labour. Features such as low gestation, high returns make sericulture an ideal programme for weaker sections of the society.

FULFILLS EQUITY CONCERNS AMONG VILLAGE

Though silk is a luxury item, it is produced by poor rural people. Benefits of sectoral value-addition primarily accrue to rural households. As the end product is purchased by urban & urban rich and the money goes to rural poor. It helps to prevent migration of rural poor to urban areas. Benefits of sectoral value-addition primarily accrue to rural households.

In the Indian context, issues relating to sustainable development are somewhat more complex as it has to deal with multiple constraints typical to a developing country with a high population and relatively low natural resources. Unfulfilled expectation of the youth is at times leading to anger and anger leading to violence. These have in turn been affecting peace and implementation of development plans and programmes. To overcome such type of problems, providing of employment to rural youth through agriculture and its allied enterprises is one of the means to check them from anti-social activities. Further such type of policies will ensure sustenance of agriculture and its allied enterprises in the villages (Rajagopal Reddy *et al*., 1999)

ATTRACTING AND RETAINING YOUTH IN AGRICULTURE (ARYA):

Majority of Indians lives in villages and real progress is not possible, unless rural development takes place at a rapid pace. *Youth and agriculture are the twin pillars of sustainable* growth in the developing countries. For a healthy rural development, participation of entire population is very much essential. As the Indian social system is having bulk of educated and trained youth, conscious of their social responsibility and willing to render dedicated service to the community can play a pivotal role in rural development. Youth population in India in the age group of 15 – 35 years is around one third of the total population. Out of this total youth population, 20% of them constitute the urban sector while remaining 80% are from the rural side. But majority of the rural youth are living in an environment confronted with many problems including the sluggishness of the village life, economical & social insecurity, the village factions, illiteracy and limited work opportunity. The socio-economic development and prosperity of the country depends to a considerable extent on the type of youth the country possess as the rural youth

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have abilities and capabilities to orient themselves to the main stream of the development process. The youth are considered as the backbone and cream of the nation.

Youth occupy an abiding place in moulding the future of any country, both socially and psychologically, Indian youth form a complex yet potential group which can be mobilized for nation building. The role of youth in transforming the face of Indian sericulture is very crucial [3]. It has been universally accepted that the attitude of an individual plays a crucial role in influencing his behavior. The youth as a vital section of the community have their share in the nations plans and programmes. The greatest potential of the solution to our problems lies in the guidance and training of rural youth to develop themselves into progressive farmers and enlightening citizens of India in the near future. The rural youth work is of great importance for rural development, since it teaches them the process of doing things together. In most of the developing countries, rural youth are growing very rapidly in numbers and will continue to do so in the future ahead. They are the vectors of new ideas and imbibe the necessary impatience and excitement needed to spur up all round development. During this period the youth undergo physiological and psychological changes that are more receptive to new ideas, ready to pay, take and willing to work under one roof. Hence there is a need to kindle their energies for fruitful purposes and develop them in the desired direction.

Directly or indirectly numbers of farm families are depending on Sericulture. The rural youth of both sexes involve because of their family and community background in farming and are active partners in various agricultural activities. Since youth are recognized as effective "agents of change" they can help in the process of dissemination and adoption of modern techniques and methods of sericulture and can take active part in the removal of resistance to innovations among rural people. Sericulture involves various aspects and among all these aspects farm youth are actively involved. They participate in most of the sericulture operations like field preparation, application of manures and fertilizers, inter cultivation, disinfection, feeding the silkworms etc. The greatest potential of the solution to our problems lies in the right guidance and training of the rural youth, who inturn would help the rural youth to develop themselves into progressive farmers and enlightened citizens of India in the near future. They are the nation builders of tomorrow and they are the carriers of the new ideas. They carry the necessary impatience and excitement needed to spur up all round development in the rural communities.

Globally, most young people (around 85%) live in the developing countries, where agriculture provides the main source of income and, therefore, it is vital that young people are brought to the mainstream of agriculture. But, in the recent past, retaining youth in agriculture has been identified as one of the major problems. Today's agriculture reflects a poor social image and hence, rural youth is moving towards urban sector for alternative and better opportunities. The future challenges are complex in nature and magnitude especially due to shrinking natural resources, declining profitability and adversaries of climate change. Obviously, these challenges are not only posing a threat to agriculture and food and nutrition, security but also creating wider socio-economic gaps within the society. Overall, the current agricultural policies do not provide attractive and sufficient avenues for engaging youth in agriculture.

Youth has the capability and capacity to make significant changes in agriculture but needs right policies and proper grooming. Many of them around the world are already making significant contributions to the Millennium Development Goals (MDGs), but their work needs to be acknowledged, recognized and strengthened. The past glory of "Green Revolution" was achieved due to policy support and infrastructure as well as human resource development of youth. There is an urgent need to involve youth in decision-making processes at all levels to reorient agricultural research for development. Each country needs to develop long-term, consensus-based and integrated youth policy, for which there is

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a great need to share experiences at national, regional and global level. There is a high potential for cooperation among agri-stakeholders, particularly through networking of youth at different levels. The future of agriculture warrants impact oriented efforts at scale by involving youth to play a catalytic role in establishing 'Plough to Plate' chain. This depends on greater involvement of youth through effective networking for knowledge sharing and out scaling of innovations. It is through their active involvement that we can move forward to make agriculture an agri-business oriented profession which is very crucial for the prosperity of our farming communities.

To Fight Hunger, Inspire Youth

It is our responsibility to get young people excited about the challenge of feeding the world and then provide the opportunities to become the next generation of leaders. Shirking this responsibility of preparing today's youth for tomorrow is not an option. let's take time to understand the critical role of youth today in ensuring global food security tomorrow.

SERICULTURE INDUSTRY: SWOT ANALYSIS

Various survey reports of Sericulture indicated that, there exists lot of scope for empowerment of rural people through Sericulture. The SWOT analysis for the sericulture industry in the present scenario revealed the following which helps the policy makers for formulating various projects and for streamlining the industry for its sustainability in the long run.

STRENGTHS

- Traditional practice of the enterprise
- Well acceptance of the farming community
- Suitability of the industry for production of all type of silks
- Availability of man power, skills and appropriate technologies for sericulture
- The trend for demand of silk in the domestic market
- No dearth of skills in the weaving and processing sector
- Timely support of scientific fraternity in achieving the higher yields
- Support from the administration
- Water potential
- Eco-friendliness

WEAKNESSES

- Since sericulture is labour oriented industry which requires so much of manpower. In the present scenario the availability of the agriculture labour with operational skills is of great difficult.
- The variability of raw material quality due to small scale of production in the diversified environment.

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- Lack of participation from corporates in sericulture related activities.
- All the allied activites are not co-ordinated each other for their effective functioning.
- High production cost associated with poor quality.
- Volatility of the prices for the outcome of the industry production.
- Slow rate of adoption of improved technologies for higher yields with quality silk.
- Poor economy of the farming community.
- Poor mindset of traditional farmers.
- Non-availability of the certain inputs which is of major concern in certain parts of the sericulture practicing areas.
- Lack of awareness and initiatives.

OPPORTUNITIES

- Because of industrialization, the reduction in production of silk by traditional silk producing countries.
- Improvement of silkworm breeds using conventional and biotechnological tools.
- Promoting private participation in production activities through contract farming.
- Huge man power availability and abundant natural resources.
- Growing demand for Indian silk products in the Global market.
- Application of the products in the health and pharmaceuticals.
- Awareness on the utilization of byproducts of the industry.
- Improving trades under international free trade area.
- Large scope for exploitation of byproducts for producing important products of industrial importance.
- Emerging demand for the its industrial application in the other fields such as food and feed industries, cosmetics, etc.
- Support by the State and Central owned Departments of Sericulture.

THREATS

- Competition from other cash crops such as sugarcane, cotton, etc.
- Because of the globalization, the shifts in the tastes of the consumers.
- Continuous and heavy dependence on imported silk for exports. Any negative change in the importing policy will cause a so much of damage to the industry.
- Tropical stress of the State.
- Unexpected events like invasion of pests and diseases and etc.
- Fluctuations in the international prices and increased dumping of cheap raw material.
- The non consistency in the marketing strategy and lack of proper marketing support to sell the products of the producers.

In light of the above, Govt. of India and various state governments are implementing schemes in pre and post cocoon sector and few more schemes are in the pipeline for popularization of bivoltine seri-

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culture in particular and sericulture in general, farm to fabric concept to encourage corporate sector and women empowerment through sericulture. The sericulture industry achieved significant positive growth in terms of raw silk production and productivity in the recent years due to the improved technologies and through the wide extension network. The industry is having a large potential for the production of higher yields. The policy makers while formulating the projects, consideration may be given for the strength and opportunities of the sericulture industry which are explained above by keeping the track of weaknesses and threats of the industry. For the sustainability and flourishing of the sericulture industry with higher yields, the emphasis may be given to the assistance for establishment of Mulberry Kissan Nurseries, assistance to individual Sericulturists, Establishment of Chawki Rearing-cum- Input Service Centres, setting up of Disinfection Squad and Establishment of Silk Reeling Infrastructure. These five components are expected to complement each other and serve as a strong back bone by way of creating a congenial circumstance for wholesome development of the sericulture industry in the rural sector for their overall development to visualize the vision of Sericulture Department "*To achieve self sufficiency for meeting the domestic silk requirement leading to vibrant rural economy by creating employment and income generating opportunities which results in poverty reduction and also preventing rural to urban migration of the rural poor*".

SOCIO ECONOMIC EMPOWERMENT THROUGH HUMAN RESOURCE DEVELOPMENT

Science and Technology is used as an effective instrument for the overall development of the sericulture industry. Central Silk Board (CSB), Bangalore under the Ministry of Textiles, Govt. of India is the apex body for overall development of sericulture and silk industry in India. The functions assigned to the Board are to promote development of the silk industry by all appropriate measures like undertaking, assisting and encouraging scientific, technological and economic research, improvement of mulberry cultivation and production of quality raw silk. Indian sericulture is not only vast and widely dispersed but also multidisciplinary in nature involving silkworm seed sector, cocoon sector and post cocoon sector. The Central Silk Board, Bangalore is coordinating and implementing collaborative research activities in association with National level R&D Institutions, State Sericulture Research and Development Institutes and Universities for promoting research and development of appropriate technology towards attaining quality and productivity levels of Indian silk. Simultaneously, state owned research institutes like Karnataka State Sericulture Research and Development Institute (KSSRDI) and Andhra Pradesh State Sericulture Research and Development Institute (APSSRDI) are also functioning for the overall development of the sericulture industry in the country. Since inception of these institutes, the institutes are working for the development of highly productive and qualitatively superior silkworm hybrids suitable to tropical eco-climatic conditions of India. The research institutes are actively functioning for creating awareness to the farmers and technical staff of the department through periodic training programmes.

Under the project entitled "*Socio-economic empowerment of tribals through state-of-the–art technologies in Sericulture*" funded by Science and Society division of Dept. of Science & Technology, Govt. of India, a total of 150 "Soliga" tribals have been brought into mainstream sericulture through establishment of model trial farm to demonstrate integrated farm management system for sustainable

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sericulture with the plantation of coffee and other cash crops including fruit yielding varieties along with mulberry trees. This concept of model tribal farm has greatly influence psyche of the tribals in taking up integrated farm management especially due to their small land holdings including their nomadic culture due to shifting cultivation.

As a sustainable economic activity favouring the rural poor in the unorganized sector, sericulture holds special promise for the women. Most of the sericulture rearing activities could be attended by the women while attending to their normal household activities. Sericulture is particularly useful for employment of women who are illiterate and can not go out of their homes due to various limitations / constraints. Involvement of women in various sericulture activities has increased their income level along with their confidence level. Sericulture enterprise assuring the women for their economic support which helped the industry to be recognized as a women friendly enterprise. This inturn helped the women community for their empowerment and gender related bias. Though women form major workforce in all income generating activities of silk production chain, appreciation for her involvement remained unrecognized. Several efforts were made to address the problems of women sericulturists recognizing the major role played by women in different activities. Several training programmes were organized exclusively for the development of women entrepreneurs in the local areas.

Realizing the importance of women in sericulture, various measures were undertaken by the different agencies for encouraging the women for their participation. In this direction, the Andhra Pradesh State Sericulture Research and Development Institute (APSSRDI) has made an attempt to train the women farmers in a project entitled "*Productivity improvement and economic empowerment of women in Andhra Pradesh through technological intervention and valuation in sericulture*" which was initiated by contacting women sericulturist's at different places in traditional sericulture areas of Anantapur districts and explained the objectives of project and its importance to acquire knowledge on practical technologies for overall productivity improvement through sericulture leading to their economic empowerment. Accordingly, the training programmes in organic cultivation practices (6 days duration) and silkworm rearing including pest and disease management (15 days duration) were initiated. The enthusiastic women sericulturists from Anantapur and Chittoor Districts of Andhra Pradesh were identified. The socio-economic status and other related data were collected individually from each trainee at the beginning of the programme.

Organic Cultivation of Mulberry

Four hundred and twenty seven women sericulturists belonging to Chittoor and Ananthapur districts of Andhra Pradesh were imparted practical training for 6 days in mulberry cultivation practices with thrust on organic farming techniques in thirty batches during the year 2006-2009. During the course of training, the trainees were taught, demonstrated and involved in carrying out various practical technologies like soil health measures through economical and effective organic cultivation practices like composting, vermi-compost, green manure crops & mulching, use of bio-fertilizers besides other package of practices in mulberry cultivation so as to obtain higher productivity with improved leaf quality. The ill effects of irrational use of chemical fertilizers were also demonstrated to the women trainees. Mulberry being a foliar crop, the need for INM (Integrated Nutritive Management) and IPM (Integrated Pest Management) measures were also demonstrated. The women trainees acquired knowledge on technical, agronomical practices of mulberry cultivation and evinced confidence over practicing the organic cultivation practices.

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Silkworm Rearing and Pest Management

Three hundred and twenty six women sericulturists were trained in the important practical aspects of handling silkworm both at young and adult stages, disinfection, use of eco-friendly disinfectants, egg incubation and maintenance of hygiene etc. These necessities for silkworm rearing were demonstrated besides creating adequate awareness on the general mistakes being committed by them resulting in crop failures/poor performance. The new innovations like, use of eco-friendly disinfectants, cost effective rearing techniques like shoot rearing etc. were explained and demonstrated. The women sericulturists themselves were involved in the silkworm rearing and were made to understand the importance of disinfection and maintenance of hygiene in addition to the other requirements for successful cocoon crop harvests. The trainees were given timely suggestions to overcome the problems encountered by them as and when contacted. Further, a book in local language comprising of the practical technologies on mulberry cultivation and silkworm rearing aspects including pest and disease management which would serve as a ready-reckoner was provided to each of the trainees.

Andhra Pradesh State Sericulture Research and Development Institute (APSSRDI) has implemented aproject entitled "*Popularization of new silkworm hybrids and disinfectants among the sericulturists of Andhra Pradesh through technology demonstration and validation*" (funded by NABARD). Under this project a total of 300 farmers and most of them youth were trained in two phases. After successful completion of training programmes, the team of Scientists / Extension personnel has collected the information with prescribed questionnaire. During the personal visits, the resource persons have interacted with the trainees at their work site to obtain feedback of the training programme. The trainees expressed general satisfaction over the technical improvements in their sericultural activities after the training programme. In case of mulberry cultivation, the significant change that was observed was the application of bio-fertilizers, usage of recommended dose of fertilizers and vermicompost along with green manuring. The training in silkworm rearing including pest and disease management made the farmers to realize the importance of surface disinfection of silkworm eggs and also the disinfection of rearing house including hygiene maintenance during silkworm rearing. The chawki rearing concept, integrated pest management, self-mounting and shoot rearing reduced the workload or drudgery which inturn saved the money. Further they opined that the information on the input supply of various fertilizers, their ultimate impact on the quality leaf and the importance of high yielding mulberry variety helped them. In total, the information which is collected from the trainees was compiled and categorized such as sericulture profile, opinion about the training programme and their level of knowledge before and after the training programme.

Feedback from the Trainees

More than 90% of the trainees expressed their satisfaction towards the overall training programme and its usefulness for effective maintenance of sericulture enterprise. The trainees have strongly felt that the objectives of the training programme were quite clear and accordingly the day wise training schedule is well planned. Further they have felt that most of the resource persons have encouraged active interaction and participation during the training programme. About 95% of the trainees felt that, the training programme is quite useful since most of the activities were focused to reduce the drudgery in sericulture which is the

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need of the hour. All most all the trainees have felt that the content of the training programme was made easier to follow from illiterate to literate. The resource persons were well versed with sericulture since the experienced Scientists in their specialized field were invited. Some of the progressive farmers were also invited to share their experience with the trainees who have helped them to understand and correct their day to day sericulture activities. Most of the trainees felt that the facilities and the time allotted for the training programme was sufficient.

Knowledge Level of the Trainees After the Training Programme

The resource persons have collected the information about their sericulture knowledge level before and after the training programme and their view of the training programme is as follows.

1. Most of the trainees expressed that, they were aware of a few mulberry and silkworm hybrids but during the training, the sufficient knowledge has been gained particularly with regard to silkworm hybrids which have helped them to choose the silkworm hybrids based on the different seasons. Further knowledge on the input supply of various fertilizers, their ultimate impact on the quality leaf and importance of high yielding mulberry varieties helped them for harvesting successful crops.
2. Among the trainees, about 45% have expressed that they are effectively following the production of quality leaf through IPM and INM packages by eco-friendly approach, compost making, vermi compost and green manures and their effective utilization in raising quality mulberry gardens for silkworm rearing.
3. About 90% of the farmers have opined that before the training programme, they knew the importance of Chawki rearing but after the training much awareness has developed on the scientific method of rearing the chawki worms which in turn influence on the success of the silkworm rearing. After the training, a total of 30% are maintaining the separate chawki gardens with separate package and practices.
4. After the training programme, the knowledge on the new silkworm hybrids helped them for selection of particular silkworm hybrids and the knowledge on their special characteristic features helped them to harvest successful crops. With regard to disinfection practices, 70% of the trainees revealed that before the training programme they were having knowledge on the disinfection but after the training, the effective way of conducting disinfection programme enlightened them to ensure proper disinfection and to meet its purpose.
5. All the trainees opined that, the emphasis on the various important sericultural aspects during silkworm rearing such as moulting, resumption from moult and spinning care have enlightened them to ensure the required optimal conditions. Further the practice of sorting the defective cocoons before the marketing and their proper transportation helped them to obtain maximum price to their produce in the market.
6. The training programme has impacted much on their sericulture practices for carrying out better way which in turn has reflected in the increased cocoon yield of 5 to 7 kgs for 100 dfls besides stability in cocoon crops. Most significant impact of the training programme was that number of crops undertaken by them increased from 3 - 4 crops before training to 5 - 6 crops after the training lead to an increase in the overall income per year/acre.

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REFERENCES

Datta, R. K., & Nanavaty, M. (2005). *Global Silk Industry: A complete source book*. Boca Raton, FL: Universal publishers.

Goel, A.K., Chandrashekaraiah, & Seshagiri. (2003, November). Development of Sericulture in Andhra Pradesh. *Indian Silk*, 13-15.

Jayaram, H., Mallikarjuna, V., & Lakshmanan, S., Ganapathi Rao, R., & Geetha,Devi, R. G. (1998). Labour Employment Under Different Mulberry Farm Holdings - a Comparative Study. *Indian Journal of Sericulture*, *37*(01), 52–56.

Kumaresan, P. (2011). *Sericulture Industry in India – Retrospect and Prospect*. Paper presented in Golden Jubilee National Conference on Sericulture Innovations: Before and Beyond, Mysore, India.

Purushotham, S., & Rama Mohan Rao, P. (2009). Economics of sericulture in Anantapur district of Andhra Pradesh. *Agric. Sci. Digest, 29*(2).

Rajagopal Reddy, C., Rajasekhar Reddy, P., & Venugopal Reddy, L. (1999). Sericulture – Agro based cottage industry for employment and income generation. *Green Technology*, *2*(1&2), 29–36.

Raju, P. J. (2006). Socio economic empowerment of tribals through State of the art technologies in Sericulture. Project completion report, Submitted to DST, Govt. of India, New Delhi.

Seshagiri, S. V., Misra, S., Rajagopal Reddy, C., Vineela, D., Kumar, P. K., & Ramesh, C. (2003). Rural youth empowerment through sericulture – A case study. *Bull. Ind. Acad. Seri.*, *7*(2), 113–117.

Seshagiri, S. V., & Ganapathi Rao, R. (2002, April). Participation of Rural youth in Sericulture – A Case study in Andhra Pradesh. *Indian Silk*, 12-14.

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Chapter 18
Design for Autonomy:
Water Resources in Ladakh

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ABSTRACT

This chapter describes one series of climate-adaptive design innovations found in Ladakh, north India. Five different water management techniques chart the region's unique and highly specialized response to water scarcity, and in so doing highlight important lessons for climate-adaptive planning elsewhere. In this case study, the dispersed, community-based water management strategies practiced in Ladakh suggest a level of design thinking that supports environmental stewardship, economic autonomy, cultural consciousness and social cohesion.

INTRODUCTION

In the face of global climate change, planners and designers can provide valuable expertise to communities in transition. Indeed, changing environmental conditions will necessitate new solutions for the mitigation and adaptation of infrastructural systems, human settlement patterns, and traditional ways of conceptualizing urban life. While the impacts of a changing climate are difficult to project and plan for, instability promises to become a common challenge of the Future City. In this environment, resilient, adaptive, and flexible designs for supporting human development suggest a way forward.

This chapter describes one series of climate-adaptive design innovations found in Ladakh, north India. Five different water management techniques chart the region's unique and highly specialized response to water scarcity, and in so doing highlight important lessons for climate-adaptive planning elsewhere. In this case study, the dispersed, community-based water management strategies practiced in Ladakh suggest a level of design thinking that supports environmental stewardship, economic autonomy, cultural consciousness and social cohesion.

While social capital rarely factors into the design of water infrastructure, it can have major policy and urban planning implications. This consideration is perhaps even more relevant in the tiny high-Himalayan villages of Ladakh, where the meltwater from glaciers and snowfields has always been treated as a

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form of the commons. In this region, subsistence agriculture practices demand a level of collaboration not often felt in more urban settings, as meltwater must be equitably divided amongst landholders, and farmers must work together to direct, store, and disperse this precious resource.

In this context, top-down government-generated planning decisions tend to be out of touch with the largely invisible social, cultural and religious processes that guide most of the decision-making and daily activities throughout the region. Unlike the high authoritarian planning schemes that have characterized other Indian cities, the water management practices described in this paper have instead been developed in and for Ladakh: they are knit into the Ladakhi cultural and social fabric, and are inextricably rooted to the region's environmental context (Scott, 1998). As a result, these design solutions are finely-tuned to the individualized needs of each community, deployed on a case-by-case basis. Whereas larger, government-sponsored infrastructural projects might lack a regional understanding of materials, construction techniques, environmental conditions or social frameworks, these design solutions reflect the context and culture that they serve.

LADAKH: CLIMATE AND CONTEXT

Located within the state of Jammu and Kashmir, in the rain shadow of north India's Himalayan range, Ladakh is a rugged and dry mountain region. Environmental conditions could be considered both extreme and inhospitable, characterized by high altitude, low humidity, and extremely low precipitation. The region is referred to as a cold desert environment, with temperature fluctuations that range from -40C to 35C and scarce rainfall, between 50 and 300mm annually (Bhasin, 1992; Demenge, 2007).

Ladakh's mountainous terrain is sparsely populated, containing some of the highest inhabited villages on earth (Norberg-Hodge, 2000). More than fifty villages exist in the region, supporting populations of 100 to 1,500 people (District Statistics & Evaluation Office, 2013). Moreover, the trans-Himalayan mountain range has effectively cut the region off from the southern portion of the subcontinent, where the "forbidding climate, remoteness and inaccessibility (has) kept Ladakh isolated, except for traders, for centuries" (Mann, 1986, 3).

In this challenging environment, strong social and cultural traditions have effectively tethered people to the land, and to each other. According to scholar R.S. Mann, Ladakhi "people feel that their adaptation (to climate) alone made them survive whenever nature posed threat (sic) to their existence" (Mann, 1986, vi). While humans have effectively and sustainably flourished in this region for more than one thousand years, existing environmental pressures, coupled with unstable weather patterns caused by a warming climate, have brought about changes to age-old patterns of living in recent years (Mingle, 2015; Rizvi, 1998).

Agriculture in Ladakh

While the region remains relatively isolated today, Ladakh has witnessed many sweeping changes over the last four decades, particularly with the rise of tourism and an increasing number of employment opportunities in the local military and government sectors. According to scholar Mohammed Deen Darokhan, this shift has also caused a deterioration in the practice of ancient farming techniques and agricultural reliance overall. Darokhan regards agriculture as "the only sustainable way of life in Ladakh," and worries that villages could "lose the genetic material and cultivation techniques due to a neglect of farming"

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(Darokhan, 1999, 79). Other scholars note that agriculture is inextricably tied to land stewardship and cultural survival, as the traditional agricultural lifestyle has supported many centuries of sustainable human settlement in the region (Norberg-Hodge, 2000; Rizvi, 1998).

While these demographic shifts have become even more marked in the intervening years, culturally, socially, and even economically, traditional agrarian values persist. Most Ladakhi villagers still practice a single integrated system of subsistence agriculture and have very few opportunities for economic participation (Crook & Ostmason, 1994; Gutschow & Mankelow, 2001; Norberg-Hodge, 2000). This is the outcome of many years of farming effort, as generations of farmers have worked with natural cycles "to green the desert and bring biological diversity" to an otherwise barren landscape (Darokhan, 1999, 78). Indeed, the lush green farmlands, thick stands of willow trees, and surprisingly fertile topsoil visible in an otherwise inhospitable desert environment represent many centuries of judicious land stewardship. (Figures 1 and 2 in the Appendix) Perhaps not surprisingly, this difficult agricultural environment also reinforces the value of traditional methods, where "the adoption of agricultural innovations is slow" (Mann, 1986, 173).

The primary crops grown in Ladakh are barley, wheat, buckwheat, millet, peas, mustard seed, apricots, and livestock fodder including alfalfa (Gutschow, 1997; Humbert-Droz & Dawa, 2004; Sagwal, 1991). While agricultural production continues to support subsistence households, some farmers have shifted to cash crops in response to the large presence of the Indian military and tourist industry and their demand for potatoes and vegetables (Tiwari & Gupta, 2007).

Water in Ladakh

In Ladakh, water is primarily used for two purposes: household activities and crop irrigation. Most villages supply household water from groundwater, rather than the surface meltwater used in agriculture. In these cases groundwater is drawn from wells (using hand pumps), mountain springs, or from those two sources via tanker trucks, which refill household barrels or tube wells (Akhtar 2013; Sudhalkar, 2010). While the challenges associated with groundwater depletion in this region are significant, household water use represents but a tiny fraction of the water volume needed to support farming and animal husbandry. As such, surface water management—the collection, retention, and dispersion of flowing meltwater from glaciers and snowfields above—has become a central planning concern of the Ladakhi village. Moreover, subsistence agricultural practices, and the elaborate system of irrigation associated with them, dominate the social, economic, and physical structures of village life (Gutschow, 1997; Norberg-Hodge, 2000).

Annual precipitation is limited, and most irrigation water comes from melting snowfields and glaciers in the northern part of the watershed (Akhtar 2013). While this region hosts the headwaters of the Indus River, water used for farming must be captured as it courses down the mountains from the high Himalayan glaciers to the river below. The floodplains of the river typically lack "viable arable land" and the idea of pumping water from rivers is, in this context, too difficult (Gutschow & Mankelow, 2003, 28). Instead, villages historically drape across the sides of mountains, opportunistically sited between the high glaciers above and the river below.

While the presence or absence of glacial meltwater may initially determine the location of a village, the resulting system of irrigation infrastructure depicts a far more intentional, sophisticated and laborious planning effort. Katiyar et al. note that "Without irrigation vegetable farming is out of the question in Ladakh," and indeed this practice has emerged as a means of contending with an otherwise inhospitable climate and landscape (2012, 312). According to Tibetan scholars, skillful irrigation was

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present in this region in the 10th century, and in many cases early stone canal work has been improved upon for centuries (Bell, 1928).

In this climate and context, irrigation has become an elegant, efficient and equitable system in most villages, honed over many hundreds of years and kept in check by village politics and social norms. Professor and scholar Kim Gutschow describes the power dynamic created by this water management as "webs of water," which bind villagers to each other and to a communal decision making process (Gutschow 1997, 105). Sharing a single water source has led villagers to develop an advanced rotational system for water distribution as well as enduring practices for collective bargaining and oversight. In the summer months, fields might be watered every seven to ten days, depending on the crop and time of the season. If water ceases to flow at the end of the summer, everyone in the village will equally feel the effect of the drought.

Climate Change and Glaciers

According to the *Leh Handbook*, due to the region's "arctic desert condition and (the) scanty rainfall of the district, irrigation depends on the eternal glaciers" (District Statistics & Evaluation Office, 2012, 24). But glaciologists, climate scientists, and journalists agree that the glaciers appear to be eternal no more. New global weather patterns have caused large-scale changes to this landscape, resulting in an overall reduction of glacial mass across the Himalayan range. Journalist Jonathan Mingle notes that the state of "Jammu and Kashmir has lost 20 percent of its total glacial mass in the past six decades," (Mingle, 2015, 397) and cites a study of over 2,000 glaciers across the Indian Himalaya by India's Space Research Organization, which "determined that 75 percent are retreating, at an annual rate of 3.5 percent" (Mingle, 222).

A 2010 USAID report on the state of glaciers and hydrology in High Asia also explains that glacier melt is occurring, leading to impacts such as "too much water (floods), too little water (droughts/ increased aridity), or water at different times (more early in the growing season/less late in the growing season)" (Malone, 2010, 25). This is an acute problem for subsistence agricultural farmers, who rely on relatively stable weather and meltwater patterns to grow their traditional crops, and to determine when to sow, water, and harvest their fields. Unlike farmers working with electricity, pumps, and other advanced technologies, Ladakhi villagers lack access to the tools that could otherwise provide a relative safety net. Instead they have relied almost exclusively upon the glaciers high above their villages to act as a storage device for water over the course of the year.

As climate change impacts snowfall and glacial mass in the region, the water resources available to farmers appear to be shrinking (Grossman, 2105). The 2010 USAID report suggests that the drainages in this region should be addressed by "well-planned management, conservation, and efficient use of the water people currently have available to them" (Malone, 2010, 27). While one could argue that these suggestions have already guided water management practices in Ladakh for centuries, the development of new tools and techniques could help farmers plan for improved water security.

ADAPTIVE DESIGN SOLUTIONS FOR WATER MANAGEMENT

Historically, Ladakhi villlages have relied on low-tech, time-tested water management systems to funnel high glacial and snowfield meltwater down to croplands lower in the valley. The traditional canals,

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water diversion gates, and systems for equitable sharing, have, for centuries, effectively supported subsistence agricultural practices. As scholar Janet Rizvi notes, "The scantiness of rainfall makes Ladakhi agriculture totally dependent on irrigation; but all those sources that lie within the scope of traditional technology have been tapped (1998, 177). Indeed, many scholars suggest that Lakahi irrigation practices have already been fully optimized as a reponse to the arctic desert environment (Crook & Ostmanson, 1994; Norberg-Hodge, 2000; Rizvi 1998).

In recent years, however, the changing weather and diminishing glacial meltwater brought about by climate change has inspired improvisation on these traditional systems. In some instances, entire villages have moved to new waterside locations (Mingle, 2009). In other cases, villages have sought to improve their water management infrastructure with technical assistance from local NGOs and state government agencies. Several relatively new innovations have been adopted by Ladakhi villages, typically in the form of a design intervention that bolsters extant water infrastructure functioning.

These solutions have been developed and deployed on a case-by-case basis, often as a result of stakeholder involvement, using consensus decision-making and sweat-equity. As such, the numerous responses represent a family of design interventions that might be deployed as needed in a wide variety of water scarce environments. This body of adaptive management practices reinforce the systems already in place in Ladakh, and represent an effective small-scale planning solution for the social, cultural, environmental, economic and even religious implications of this place.

Artificial Glaciers

Artificial glaciers might be more accurately called ice dams, as they form large, layered pools of ice over the winter for spring and summer agricultural use. These large-scale landscape infrastructure projects efficiently store and manage glacial meltwater by exploiting annual freeze-thaw cycles and incorporating large storage reservoirs to contain glacial runoff (Ahmed, Higgins & Norphel, 2010). During periods of drought or when Ladakhi farmers otherwise wouldn't have access to meltwater (such as in the early spring), the artificial glaciers melt, releasing their ice stock in the form of irrigation water. The long, cascading pools are located between the high natural glaciers and the village croplands below, using gravity to move the water when farmers open regulating and diversion gates (Higgins, 2012; Norphel, 2010).

These glaciers have been placed above eight different villages in Ladakh, and range in size from a small number of pools at a single site to many dozens of reservoirs that extend over a mile in length. (Figures 3 and 4 in the Appendix) They are typically built using masonry walls with stone collected from the site and local labor, often through work parties organized by the Leh Nutrition Project (Clouse, 2014). In allowing farmers to collect water that is cascading down through the watershed during non-agricultural seasons (fall and winter), and save it for later use (spring and summer), the artificial glacier effectively increases the overall water supply available to farmers (Vince, 2009). Moreover, because these glacial pools serve the entire village and help to stretch the communal supply of water, they are collectively owned, managed, and operated by local farmers.

Ice Stupas

Ice stupas were designed by Sonam Wangchuck in 2014, as scalable ice towers that can store fall and winter water, as ice, for use during the following spring and summer. (Figure 5 in the Appendix) Much like the artificial glacier, ice stupas take advantage of annual freeze-thaw cycles, gravity-fed watersheds,

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and placement between high glaciers and low croplands. Unlike artificial glaciers, however, the ice stupa requires the extensive use of pipes to funnel water through trenches and up to the spout of the stupa's crown, as well as regular maintenance throughout the winter, to move pipes as ice forms.

The ice stupa has several advantages to the artificial glacier. It can be endlessly replicated across a village landscape, unlike the glacier pools, which need to be located on specific slopes and solar aspects. It is scale-able, functioning equally well for small reserves of ice as it for a large, multi-story site. In this sense it is also something that individual farmers can develop on their own accord, rather than relying on the larger village buy-in needed to implement an artificial glacier system.

However, the ice stupa connects to the social, cultural and religious fabric of Ladakh in other ways. In built prototypes over the past two years, builders have purposefully worked with the imagery of the local stone *chorten*, or *stupa*, which serves as a religious icon and prayer site. The ice forms in a similar structural shape, referencing the sacred forms of the stupas that are already built in this landscape. To emphasize this connection, the team of builders invited monks from the nearby Phyang monastery to bless the stupa, and they strung Tibetan prayer flags across the ice mass. In this way, the project developers have helped to root the radical new design intervention within the extant religious, social and cultural vocabulary of the region.

Snow Barrier Bands

Snow barrier bands perform much like the snow fences found in other parts of the world. In Ladakh, they are long, linear masonry walls built at high mountain passes in the upper portion of a watershed. The walls are typically built from stone found on the site, and are usually 3' wide, stand up to 5' tall, and can be many hundreds of feet in length. Used alone or as a part of a larger series, they help to capture snow, hold it on site at the top of the watershed, and then release it in the form of meltwater in the late spring. (Figures 6-7 in the Appendix)

In Ladakh, many ancient villages have been built on the south side of mountain ranges, in order to take advantage of passive solar heating in cold winter months. However, the winter winds blow from south to north, effectively propelling scarce winter snow from the densely populated side of the mountain range to the uninhabited northern slope. Snow barrier bands serve to stop snow before it can tip from a south-facing drainage into a north-facing drainage, thereby increasing the amount of meltwater that will be available to farmers in populated areas.

Snow barrier bands are also derivatives of ancient local building vocabularies. They incorporate masonry walls, which constitute the vast majority of traditional Ladakhi construction, from houses and temples to animal enclosure, crop protection, and fences. Because they serve an entire watershed, whole villages will work together to construct and maintain them, even though they are placed at high mountain passes. In the case of the snow barrier bands built at Warila Pass in 2013, several hundred villagers actively collaborated on the build, which was held over the course of a week at an elevation of 17,500'.

Canals/Kuhls

Water infrastructure systems, such as the *kuhls* or the primary canals that direct meltwater to village croplands, have increased in size and scope over the past decade. Kuhls have been widened, improved with impervious membranes, regulator gates, and pipes, and stretched farther than traditional technolo-

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gies would have otherwise allowed. They now have been engineered to leap over ridges, cross highways, and exploit topography to carry water across many miles to towns outside of a particular drainage.

Kuhls help to address one of the major challenges for today's farmers: the inefficiency of traditional irrigation infrastructure. Ancient channels linking upper glaciers to low-lying fields have been carved out of the landscape over many hundreds of years; these are the mud, wooden, or stone lines carrying water along a path. These waterways lose a large amount of their volume to seepage; in one estimate 90% of the water routed above the village of Stongde, in the neighboring Zanskar valley, vanished before reaching fields (Crook and Ostmanson 1994). Newer, high- and medium-tech kuhls reinforce these crumbling old canals, improving water access by reducing losses due to seepage and poor engineering. (Figure 8 in the Appendix)

These new irrigation projects provide a much more efficient, and often large-scale approach, than pre-existing progenitors. However, the kuhls can still be considered relatively small-scale and supportive design interventions. While they have been built with funding from government agencies (such as the Watershed Development Agency), they often draw construction labor from adjacent villages. Moreover, kuhl construction reinforces traditional Ladakhi cultural and social frameworks, by hardening and improving existing water management systems that work within conventional agricultural concepts.

Zings

Zings are large water reservoirs, usually located just above croplands in order to store meltwater for agricultural use. The reservoirs are typically constructed from masonry or earth berms, and are then lined with concrete or mud. At the upper end they will feature a gravity-fed inlet, while the lower side will have a drain and overflow gate. Water diverted into the zings can be controlled, both to direct it in and to release it into the fields. Zings are connected to the source of the meltwater and to the fields below by the same canals that have historically supported irrigation practices in Ladakhi villages for centuries. (Figure 9 in the Appendix)

These small ponds have a limited capacity, so they cannot provide enormous stores of water. However, they do buy time, enabling farmers to irrigate fields according to their own schedule. For instance, when fields are on a rotation of a split night and day watering schedule, those who have a "night shift" can divert the water to a zing to hold it for use the following day (Gutschow, 1997). By storing water, even temporarily, above the sites where it will be used, the zings ensure that all of the water available to farmers during a season will be used, thus reducing waste.

WEIGHING THE BENEFITS

Unlike many other forward-thinking climate-adaptive design ideas, each of these five water harvesting and management solutions supports the existing agrarian lifestyles honed over centuries in Ladakhi villages. This is particularly relevant in a society where "agriculture is the backbone of every village economy, engaging up to 70% of the working force," and many Ladakhi villagers rely exclusively on local agriculture for their food supply (Pulselli & Pelliciardi, 2014, 347). Rather than reimagine the economic frameworks that will support village life in the years to come, these design interventions seek to improve the productivity of the existing system.

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In assessing the economic implications of such interventions, one must first ask: Are they effective? Most hydrological models, especially those involving untested design interventions, are carried out over a series of years: indeed, one year would not adequately describe patterns or outlying factors. Current data on these five water management strategies lacks this long-term view, and several of the interventions described in this chapter lack even the most rudimentary modeling. Thus, it is still too early to be able to tell whether the interventions work as anticipated, and to what extent they improve water access for cold desert farmers.

Anecdotally, however, each of these five design interventions has been met with much interest and excitement from village farmers (Higgins, 2012). The low cost of implementation, across the board, and the relative flexibility of each of these strategies suggests radically-inclusive access for those who wish to employ these solutions. And in all cases, the water management strategies effectively improve or shore up existing systems, so they represent a relatively low-risk response to climate-change adaptation.

While traditional surface water irrigation has supported life for many hundreds of years, structural flaws are evident in the broader planning system. One of the most difficult planning challenges for Ladakhi villages is that current irrigation methods don't allow for population growth; the system assumes a fixed number of individuals or farms. With better health and life expectancy through access to new medical practices, and with the dissolution of the ancient practices of primogeniture and polyandry, the number of households in the region will likely continue to grow. Because the cultivable land in villages is fixed, individuals may need to seek employment elsewhere or import food for local consumption.

Likewise, the overall volume of water available in the watershed effectively places limits on the size and scale of an individual farmer's cropland; villagers must work together to develop an equitable division of irrigated fields. Ultimately, the volume of water coming from the high glaciers and seasonal snows may not be enough to support the crops grown below. After all, the intensive and highly productive agricultural practices of Ladakh rely heavily upon water resources, and are effectively limited by the region's supply of water.

CONCLUSION

In high mountain villages, the self-sufficiency and relative autonomy of groups have historically been prized survival traits. Small, independent villages act as distinct units, with villagers solving problems as they surface, working together to make decisions, and taking care of one another in times of need. The community-based water management framework implemented in Ladakh acknowledges that these villages have historically functioned as autonomous, self-governing populations, and seeks to reinforce age-old methods of group resilience.

Unlike the top-down planning solutions that may work well for large urbanizing populations, Ladakhi villages demand solutions that are site-specific, small, and dispersed. While broad, overarching schemes for infrastructure projects may be needed in large urban areas, in Ladakh these designs lack the physical, cultural, social, religious, and economic context that will ensure a proper fit.

The five new water management strategies for Ladakh provide a working example of the type of interventions that could work in other cold mountain environments. In suggesting a policy direction for the future, small, dispersed systems, responsive to local conditions, appear to be a promising way forward. In these examples the design intervention recognizes the relative autonomy of each village, both in terms of needs and opportunities; they engage stakeholders in the development of each system, from

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construction to maintenance; they layer over existing water infrastructures to improve efficiency; and they are affordable, scalable solutions, accessible to rural farming villages. These designs suggest an approach to water management that offers co-benefits: interventions are rooted in the communities they serve, connected to the cultural, social and religious context, responsive to the climate and landscape, supportive of rural self-sufficiency and independence, and affordable due to their scale and size.

In many communities water is an invisible resource: not owned, managed or operated by users, perhaps not even a significant factor of the economic, religious, or social functioning of those sites. But in the high Himalaya, water is a form of the commons that is absolutely critical to group survival, and it is made visible by the clear relevance it has to daily life. The various techniques for water planning in this desert region help to illuminate some of the opportunities and challenges inherent to climate change adaptation. In so doing, these five different designs from the Indian Himalaya suggest a model for other water-constrained mountain communities. If, indeed, instability will become the chief characteristic of the Future City, water management solutions will likewise need to become flexible, scalable, layered and dispersed. Finally, in order to effectively deploy these varied approaches, pioneering solutions also must fit in. Climate-adaptive water management practices in Ladakhi villages demonstrate the importance of integrating new design interventions with existing irrigation systems, social fabric, environmental context, religious interest and cultural identity.

REFERENCES

Acharya, S., Katiyar, A. K., Bharti, V. K., Charan, G., Prakash, B., & Srivastava, R. B. (2012). Assessment of irrigation water quality of cold arid Ladakh region. *Journal of Soil and Water Conservation*, *11*(4), 311–315.

Ahmed, N., Higgins, A. & Norphel, C. (2010). *Snow Water Harvesting in the Cold Desert Ladakh: An Introduction to the Artificial Glacier Project.* Leh: Leh Nutrition Project.

Akhtar, A., & Gondhalekar, D. (2013). Impacts of tourism on water resources in Leh town. *Ladakh Studies.*, *30*, 25–37.

Anghchok, D., & Singh, P. (2006). Traditional Irrigation and Water Distribution System in Ladakh. *Indian Journal of Traditional Knowledge*, *5*(3), 397–402.

Bell, C. (1928). *The People of Tibet*. Oxford, UK: The Clarendon Press.

Bhasin, M. K. (1992). *Cold Desert: Ladakh: Ecology and Development*. Delhi: Khamla Raj Enterprises Publications.

Clouse, C. (2014). Learning from artificial glaciers in the Himalaya: design for climate change through low-tech infrastructural devices. *Journal of Landscape Architecture*, *9*(3), 6-19.

Crook, J., & Ostmason, H. (1994). *Himalayan Buddhist Villages: environment, resources, society and religious life in Zangskar, Ladakh*. Bristol: University of Bristol Press.

Darokhan, M. D. (1999). The Development of Ecological Agriculture in Ladakh and Strategies for Sustainable Development. In Ladakh: Culture, History and Development between Himalaya and Karakoram. Delhi: Sterling Publishers.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Daultrey, S., & Gergan, R. (2011). Living with Change: Adaptation and Innovation in Ladakh. *Journal of Climate Adaptation*.

Demenge, J. (2007). *Measuring Ecological Footprints of Subsistence Farmers in Ladakh.* Paper presented at the International Ecological Footprint Conference, International Ecological Footprint Conference, Cardiff, UK.

District Statistics & Evaluation Office. (2012). *District Statistical Handbook for the Year 2011-2012*. Leh: Government of Jammu & Kashmir.

District Statistics & Evaluation Office. (2013). Ladakh Autonomous Hill District Blockwise Village Amenity Directory 2012-2013. Leh: Government of Jammu & Kashmir.

Diwedi, A. (2009). *Forests of Himalaya: Planning and Development*. Delhi: Cyber Tech Publications.

Grossman, D. (2015). As Himalayan Glaciers Melt, Two Towns Face the Fallout. *Yale Environment 360.* Retrieved 08 June 2015 From: http://e360.yale.edu/feature/as_himalayan_glaciers_melt_two_towns_face_the_fallout/2858/

Gutschow, K. (1997). Lords of the Fort, Lords of the Earth, and no lords at all: politics of irrigation in three Tibetan societies. In *Recent Research on Ladakh*: *Proceedings of the 6th international colloquium on Ladakh*.

Gutschow, K., & Mankelow, S. (2001). Dry Winters, Dry Summers: Water Shortages in Zanskar. *Ladakh Studies*, *15*, 28–32.

Higgins, A. K. (2012). *Artificial glaciers and ice-harvesting in Ladakh, India as an adaptation to a changing climate.* (Unpublished Master's Thesis). Yale School of Forestry, New Haven, CT.

Humbert-Droz, B., & Dawa, S. (2004). *Biodiversity of Ladakh: Strategy and Action Plan*. Calcutta: ACB Publications.

Hussain, M. N., & Hussain, M. A. (2011). *Natural Resources of Jammu Kashmir and Ladakh*. Srinagar: Gulshan Books.

Malone, Elizabeth L. (2010). *Changing Glaciers and Hydrology in Asia: Addressing Vulnerabilities to Glacier Melt Impacts.* USAID Report November 2010.

Mann, R. S. (1986). *The Ladakhi: A Study in Ethnography and Change*. Delhi: Anthropological Survey of India.

Leomann Maps (n.d.). *Indian Himalaya Maps, Sheet 3*. Author.

Mingle, J. (2009, November 29). When the Glacier Left. *Boston Globe*.

Mingle, J. (2015). *Fire and Ice: Soot, Solidarity and Survival on the Roof of the World*. New York: St. Martin's Press.

Norberg-Hodge, H. (2000). *Ancient Futures: Learning from Ladakh*. London: Rider Books.

Norphel, C. (2012). *Artificial Glacier: A High Altitude Cold Desert Water Conservation Technique.* Presented at the In Defense of Liberty Conference, New Delhi, India.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Pati, D. R., & Tewari, D. D. (2009). *Conservation of Medicinal Plants*. Delhi: APH Publishing.

Pulselli, F. M., & Pelliciardi, V. (2014). Emergy Evaluation of a Mountain Socio-Economic System and Traditional Agroproduction: A Case Study in Indian Trans-Himalaya. *European Journal of Sustainable Development*, 347-356.

Rizvi, J. (1998). *Ladakh: crossroads of high Asia*. Delhi: Oxford University Press.

Sagwal, S. (1991). *Ladakh Ecology and Environment*. New Delhi: Ashish Publishing House.

Scott, J. (1998). *Seeing Like A State: How Certain Schemes to Improve the Human Condition Have Failed*. New Haven, CT: Yale University Press.

Snow Leopard Conservancy. (2010). *Ri Gyancha: a Biodiversity Resource Kit for Educators in Ladakh*. Delhi: Kalpavriksh.

Sudhalkar, A. (2010). *Adaptation to Water Scarcity in Glacier-Dependent Towns of the Indian Himalayas: Impacts, Adaptive Responses, Barriers, and Solutions.* (Unpublished master's thesis). Massachusetts Institute of Technology, Cambridge, MA.

Tiwari, S., & Gupta, R. (2007). Changing Currents: The Irrigation Practices of Leh Town. *Recent Research on Ladakh*, 217-24.

Vince, G. (2009). Glacier Man. *Science*, *326*(5953), 659–661. doi:10.1126cience.326_659 PMID:19900911

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APPENDIX: FIGURES

Figure 1. Villagers work together in the fields fed by the Phuksey artificial glacier meltwater.
Credit: Carey Clouse.

Figure 2. The rugged desert agricultural landscapes of Ladakh necessitate gravity-fed irrigation strategies.
Credit: Carey Clouse.

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Figure 3. Several cascading artificial glacier pools above the village of Igoo
Credit: Carey Clouse.

Figure 4. Above the village of Nang, eight artificial glacier pools are closely spaced in a narrow canyon.
Credit: Carey Clouse.

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Figure 5. The ice stupa built above Phyang demonstrates the stark contrast between the stockpile of ice and the dry surrounding landscape.
Photo: SECMOL.

Figure 6. Yaks pass through a series of snow barrier bands at the top of Warila Pass, 17,500'
Credit: Carey Clouse.

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Figure 7. Snow barrier bands are simple masonry walls, strategically placed within the landscape.
Credit: Carey Clouse.

Figure 8. This canal directs water from one drainage, over a ridge into another drainage above the village of Sakti.
Credit: Carey Clouse.

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Figure 9. This massive reservoir contains meltwater above the village of Nang.
Credit: Carey Clouse.

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Section 3
Tools and Technologies

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Chapter 19
Web Based Automatic Soil Chemical Contents Monitoring System

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ABSTRACT

The need for finding new, more efficient and sustainable methods of agricultural cultivation and food production has become more critical especially in the developing countries. In order to facilitate this, there are needs to design a precision agriculture system capable of providing farmers with useful data about the conditions of the soil available in their farmlands in a user friendly and easily accessible manner. This work therefore presents a web based automatic soil chemical contents monitoring system. The work combined the use of pH probe, an Arduino sink node and other devices to automate the processing of soil chemical contents data obtained from farmland. Three solutions were used in testing the efficacy of the proposed method and comparing it with the existing method. The result showed that, the proposed design was able to extract the chemical contents of the soil from the farmland and transferred the same to Liquid Crystal Display and a web page.

1. INTRODUCTION

Precision Agriculture (PA) is a farming management concept based on observing, measuring and responding to inter and intra-field variability in crops (Zarco-Tejada et al., 2014; Rasher, 2015). The holy grail of precision agriculture is the ability to define a Decision Support System (DSS) for farm management with the goal of optimizing the returns on inputs while preserving resources (KTNUK, 2015; Whelan

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and McBratney, 2003). PA is technologically feasible as well as being economically and environmentally justifiable. Improving the agricultural process can maximize financial return and increases the stewardship of land, water, and related natural resources (Tayari et al., 2015). There is therefore an optimum need to know the chemical contents of the soil for different crop production (Vellidis et al., 2003). Researches on the effects of soil chemical contents for crop yield on the farms have been extensively studied in the past. With advancements in technology over the past decades, overall plants growth with crop yields have increased significantly while management practices have also changed since those earlier times (Tulberg et al., 2007; Bowman, 2008). These changes have improved the detection of soil contents for today's crops. The new technologies available to producers and researchers with weakness observed in existing knowledge however necessitates new research efforts.

The development of information technology has been having a considerable influence on agriculture. There have emerged a number of new industry-specific technologies and new applications over the past few years, including the ever-widening agricultural application of mobile communications devices and technologies (Szilágyi, 2006). The introduction of Wireless Sensor Network (WSN) technology in agriculture is also evolving rapidly (Ye et al., 2016). While WSNs provide possibilities to sense and gather information of various environmental soil and crop conditions, it remains a challenge for farmers to know real-time data of a farm soil chemical contents as well as incorporating necessary crops to cultivate on such land (Zarco-Tejada et al., 2014).

Arduino microcontroller has proven to be a useful device in precision agriculture. It can be connected with several other devices to measure the activities on the farmland such as irrigation system, soil moisture contents, soil chemical contents, green house monitoring system etc. The results of which can then be viewed on different technology platforms such as, mobile phones, web page, Liquid Crystal Display(LCD), and so on.

There are optimum needs to know the chemical contents of the soil for different crop production. For instance, if the soil is acidic, it may not be the best decision to plant some crop on such soil because such crop may not produce a reasonable yield which may result to loss in the part of farmers. Research on the effects of soil chemical contents for crop yield on the farmland has been studied extensively in the past. With improvements in the technology over the past decades, overall plant growth and crop yields can be increased significantly and management practices can also be changed.

Manipulating the soil contents however is highly dependent on the monitoring and controlling of the chemical contents of the soil (Finžgar et al., 2006). There are several ways by which soil monitoring can be carried out ranging from the traditional methods of measuring soil chemical contents with the use of pH meter to keeping a manual digital record of pH level on a digital display with the aid of pH sensor interface. Measuring and monitoring the soil contents in order to make decisions in research and/or automation is however laborious and error prone (Kumar et al., 2015). Existing works show that measuring of soil chemical contents such as lead, nitrogen, potassium, phosphorous etc. are mostly carry out in the laboratory which are time consuming. In other cases, some farmers do not even test the chemical contents of their soil until they see the output in form of yield from their farm which usually leads to lower yield from their various farm. It is then important that a system capable of monitoring the soil chemical contents with little or no human intervention be provided to help farmers in realizing better output and also in making accurate decisions in research as well as maximization of crop yield. The need to develop an automated system that monitor soil chemical content becomes a necessity.

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2. RELATED WORKS

Mikó (2009) studied the effect of green manuring on soil and different crops. The work carried out an investigation of the effect of soil penetration resistance, soil humidity content, plant phenology, chemical composition of plants, crop yields, and the effect of nitrogen fertilization on soil and crops. Soil penetration resistance was carried out using penetrometer. It was discovered that the difference between soil penetration resistance of plots covered with green manure plants and the control were proven to be higher in deeper layers than of those close to soil surface. The work also demonstrated the steps required in measuring the chemical contents of the soil.

Zografos (2014) developed a system for precision agriculture which provides farmers with useful information about the soil, the water supply, and the general condition of their fields. The system utilizes sensor boards which consist of a microcontroller connected to one or more sensors along with a ZigBee transceiver, transmitting data which are then retrieved at a gateway. The system act as a monitoring system constantly reporting on the status of farms or livestock and as a recommendation system for prospective farmers. The work showed that, it is possible to monitor a farm remotely without the farmer being present on the field. Rigoberto (2015) also developed a system that allow users to monitor the server room temperature through a website by using any computer or mobile device with internet access. The system was implemented using Arduino Uno, Ethernet shield, thermistor, carbon resistor, web server, and database server. The system helps users keep track of the server room temperature from a remote location. The authors demonstrated the possibility of monitoring the result from arduino remotely on a web page. The work however made use of ethernet shield in order to send the result of the aggregated data to the web which required too many cables.

According to Kumar et al., (2015), the studied proposed an in-situ soil pH sensor with nanoparticles of antimony and zinc which overcame the existing drawbacks and requires no power source for its operation. The proposed device is portable, simple and easy to use in-situ pH meter for direct measurement of soil pH. The work detailed soil pH sensing techniques based on nanotechnology, in which nanoparticles of Zinc Oxide (ZnO) was used. The work proposed an implementation of an efficient and improved in-situ soil pH sensing approach.

Design and implementation of a remote greenhouse temperature monitoring system using wireless sensor networks was carried out by Olaoye (2015). The system used the combination of wireless sensors, Arduino sink node, Zigbee transceivers and Zigbee protocol in implementing the receipt and processing of temperature data obtained from a greenhouse. The author concluded that wireless sensor networks can be used to monitor and present temperature data in greenhouse for automation and research purposes. Zigbee Based Soil Moisture Monitoring System was also considered by Kirandeep et al., (2016). The authors presented a system that can help the farmers to get proper information about the amount of water required for irrigation as well as the temperature and humidity of atmosphere. The system works by sending data to remote location using Zigbee based Wireless sensor network. Soil moisture sensor measures the content of water present in the soil. When soil sensor is embedded into soil, it gives percentage of water present in the soil on LCD and laptop. The data received from the sensors is displayed on integrated development environment serial monitor, which gives the value of soil moisture in percentage, atmospheric temperature in degree Celsius and relative humidity in percentage.

Franz et al. (2016) used Cosmic-Ray neutron probes to monitor landscape scale soil water content in mixed land agricultural systems. The work explored the use of the newly established Cosmic-Ray Neutron Probe and method to monitor landscape average Soil Water Content in a mixed agricultural

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land. The work claimed that the ability of the Cosmic-Ray neutron probe to provide real-time and accurate landscape Soil Water Content measurements makes it an ideal method for establishing long-term monitoring sites in agricultural ecosystems to aid in agricultural water and nutrient management decisions at the small tract of land scale as well as aiding in management decisions at larger scales. Kim et al. (2016) also followed this approach by considering the possibility of an automated field-deployable Bioaerosol Monitoring System using Carbon Nanotube-based Biosensors.

In another work, Ye et al. (2016) designed a Zigbee based farmland environmental remote monitoring system. The design realized the function of farmland environment remote monitoring system, and then sends the data to the intelligent decision system for statistical analysis. The work is useful to guide agricultural production by helping farmers to monitor the situations of their farm remotely. Experimental results show that, the system realized remote real-time and accurate monitoring of farmland environment data on external devices such as mobile phone, notebook and personal computers. The idea of Ye et al. (2016) is close to the work of Mitralexis and Goumopoulos (2015). The authors designed, implemented and evaluated the performance of an integrated agricultural monitoring and irrigation system using energy-autonomous wireless sensors and actuators. Monitoring and irrigation of the field were carried out through a web application that collects data from a Wireless Sensor Network deployed in a farmland and also displayed relative information in real time. The work only considered the irrigation, and chemical contents of the soil were not considered. The concept employed in this work however was useful in developing our proposed system.

Liao et al. (2015) also designed a Zigbee and General Packet Radio Service (GPRS) based remote farmland monitoring system. Using these two technologies, the system carried out data collection which were illumination, Carbon dioxide, temperature and humidity of soil for transmission. When compared with traditional monitoring scheme, the proposed method provided a strong scalability and flexibility especially in a harsh environment and improved the monitoring mode effectively while decreasing human cost to some extent. Manikandan and Rajaram (2016) in their own work also developed an automatic monitoring system for a Precision Agriculture using Wireless Sensor Networks. The work considered bridging the gap between water usage and water wastage. The work proposed a low cost and efficient wireless sensor network technique to acquire the soil moisture and temperature from various locations of farm and as per the need of crop controller, take the decision either to make irrigation ON or OFF. Wireless Sensor Network was also used by Gayathri et al. (2015) to monitor corn farmland.

In this paper, we take the advantage of depth of literature in precision agriculture to propose an effective system capable of detection soil chemical contents and providing the same to the farmers wherever they are in an easy and efficient manner.

3. METHODOLOGY

The procedures, techniques, tools and documentation aids which were channeled towards the implementation of this work is hereby presented. Arduino UNO, PH meter probe, GPRS Shield, Connecting Wires, Server unit (Apache CentOS) and 9v Battery were interconnected to produce a soil chemical contents monitoring system. Also, fritzing, Arduino Integrated Development Environment, Hypertext Preprocessor, Structure Query Language (MySQL), Hypertext Markup Language (HTML), JavaScript and Cascading Style Sheet were used as part of the software used in achieving the design.

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3.1. System Architecture

The overview of the system architecture is given in Figure 1. The design consists of pH probe connected with arduino uno board necessary to detect the chemical contents of the soil and transferred the aggregated soil chemical contents to the arduino board. This will be displayed on a Liquid Crystal Display (LCD) and/or a web page. The design can be adapted to more than one farmland. The pH meter and the Arduino sink node were deployed in the farm and form the main components of the monitoring system. The pH measures the pH of the soil and report back to the sink node using pH circuit that was designed for the pH probe. The result was displayed on LCD. The Arduino sink node also aggregates the data on the external memory module and pushes the data to the remote server through the GPRS Shield Module and the Web Service to the remote database. The user or farmer interested in monitoring the chemical contents of a farm uses the web dashboard to view the pH statistics of the farm via a web browser. The web dashboard pulls the data that has been stored via RESTful Application Programmer Interfaces (REST APIs) provided by the web service. The result is then compared to the standard pH value to know the type of elements that is present in the farm, hence predict the type of crop to cultivate on the farm. The components as demonstrated by DFROBOT (2015) were incorporated by connecting the pH electrode to the Bayonet Neill-Concelman (BNC) connector on the pH meter board using the connection lines as shown in Figure 2. The pH meter board was connected to the analog port 0 of the Arduino controller.

The connection of the LCD with the arduino uno interface was achieved through combination of several pins. The physical connection and the schematic diagram are shown in Figure 3 and Figure 4 respectively. The system model was designed using fritzing electronic modeling tool. This is also shown in Figure 5.

Figure 1. Overview of system architecture

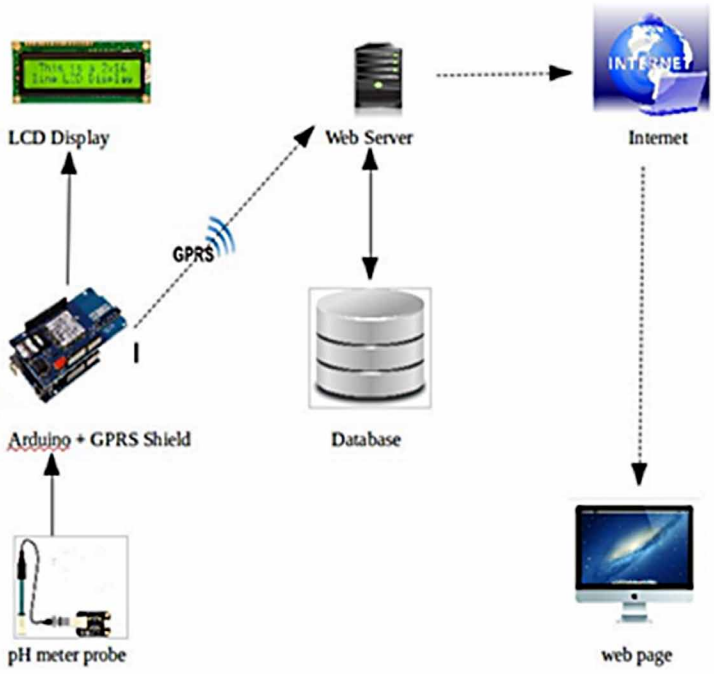

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Figure 2. pH meter probe to a microcontroller

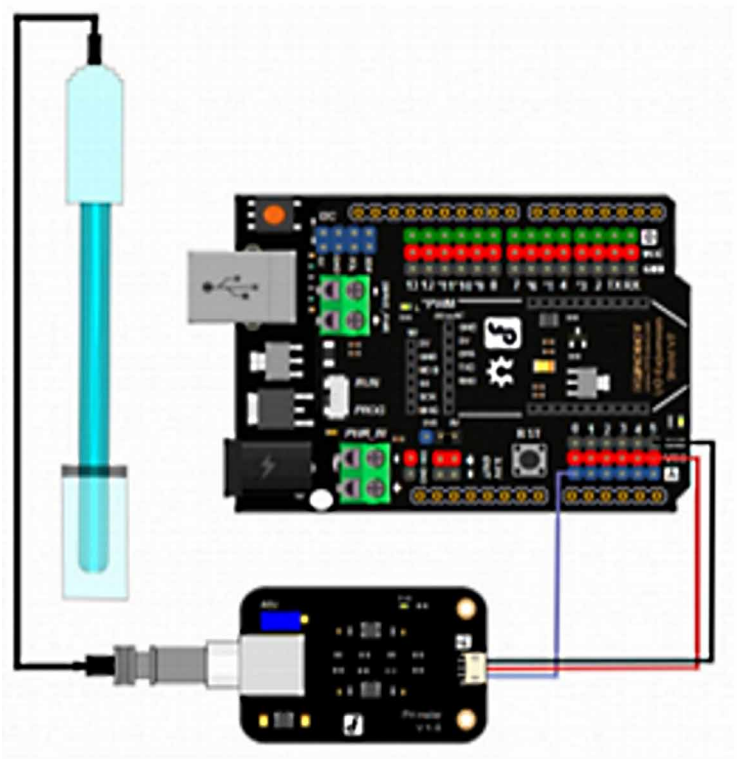

Figure 3. Physical diagram connection of Arduino uno with LCD

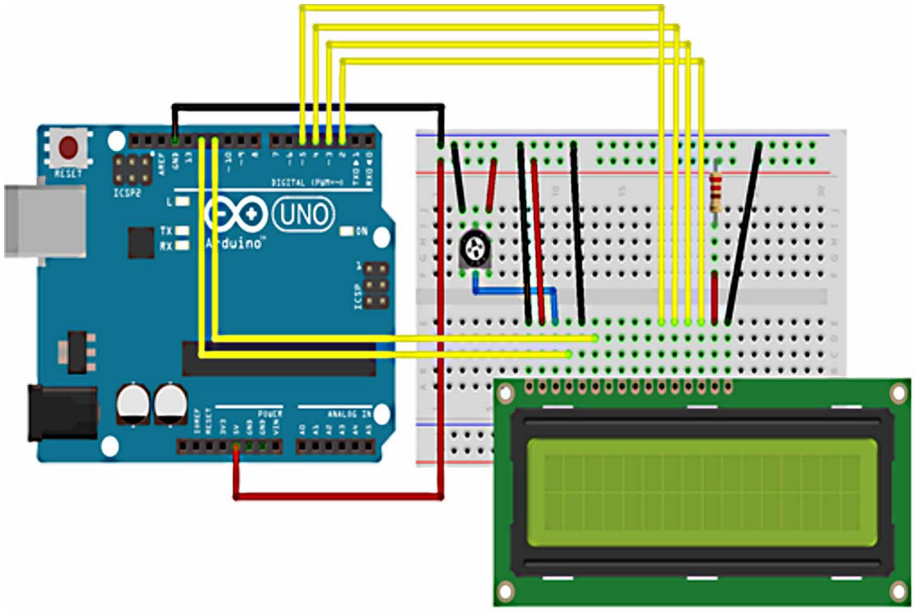

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Figure 4. Schematic connection of Arduino uno with LCD

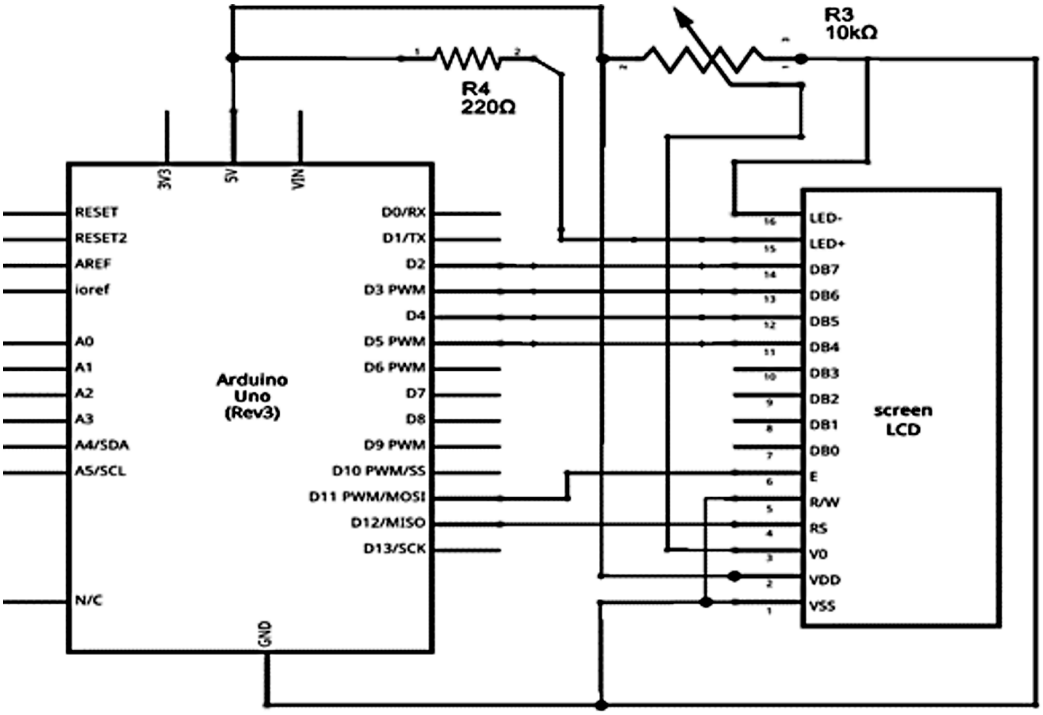
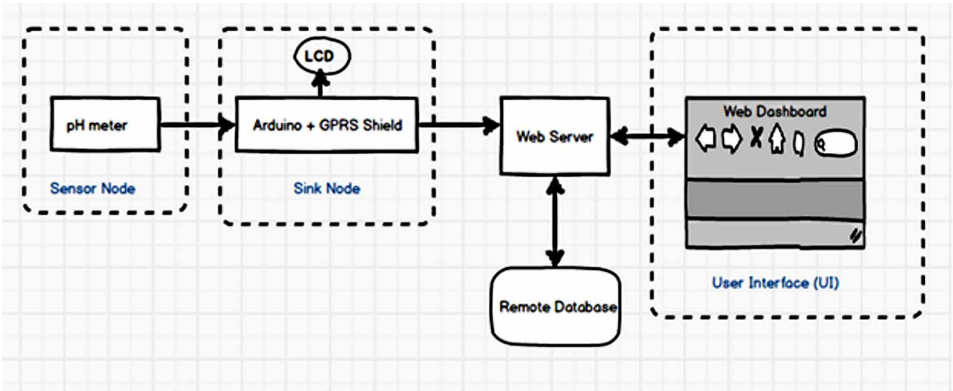


Figure 5. Overview of system model



3.2. Arduino Sink Node

The Arduino board was mounted with pH meter which have been configured using AT commands and acts as the sink node, receiving real-time pH value from the pH meter. The transfer of data was implemented by making Hypertext Transfer Protocol (HTTP) request calls via the GPRS shield Module to the web service hosted on the remote server.

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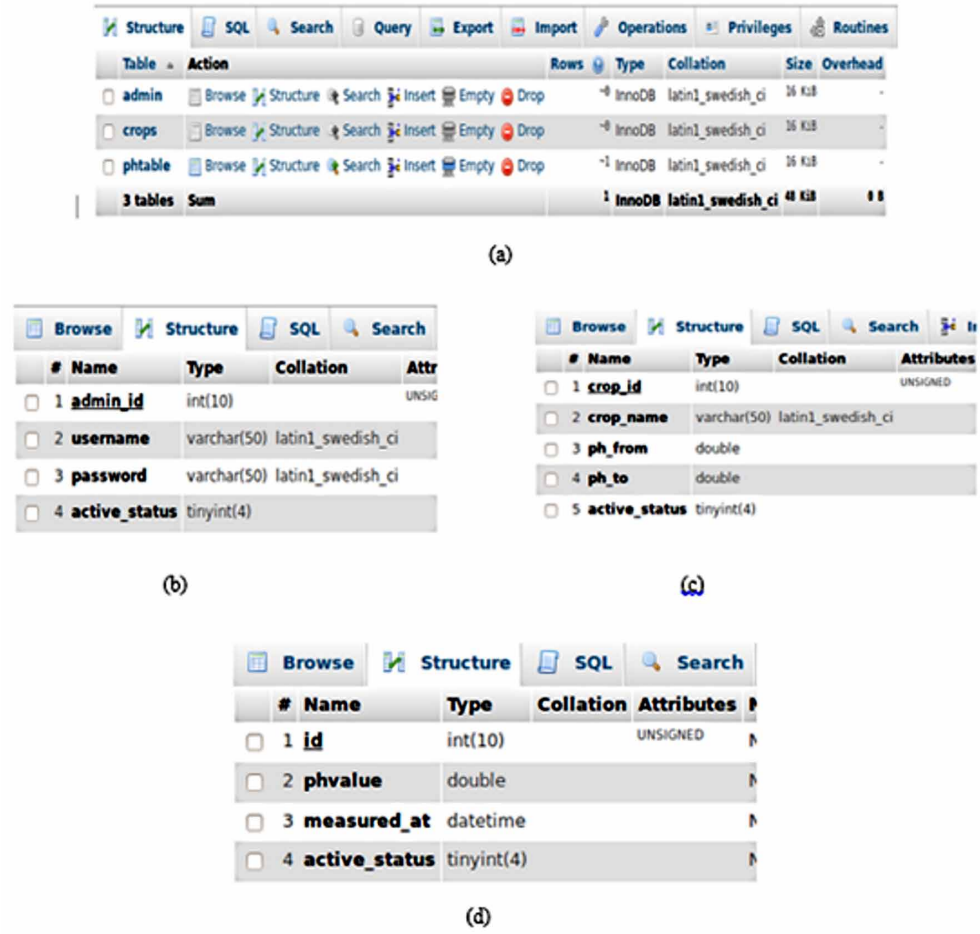
3.3. Web Service

Web service is an essential component of the system which serves as an interface between the database and the rest of the system. The main function of the web service is to display the pH value of the soil measured from the base station to the farmer every 48 hours on the web dashboard, the duration can however be changed depending on the farmers' decision on how frequent the web should be updated. The model of the web service was service oriented because it acts as a utility system providing information and serve as means of communication between web dashboard and database. It was implemented using Yii PHP framework, applying the object-oriented programming paradigm to make the web service robust and allow a high level of code reuse for rapid development. The database used in the development of the web service is a MySQL Database. The developed database served as the location where the data from the base station were stored. The database was relational in nature and has three tables which are admin, crops and pH table shown in Figure 6a. The admin table basically stores the username, password, admin id and the status of the recording (active or inactive) as shown in Figure 6b. The crops table basically

Figure 6. Admin, Crop and pH tables respectively



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stores the crop id, crop name, previous pH value, updated pH value and the status of the recording (active or inactive) as shown in Figure 6c. The pH table as shown in Figure 6d basically stores the pH identity (pH id), pH value, measured time and the status of the recording (active or inactive).

4. RESULTS AND DISCUSSION

The web dashboard presents the data pushed to the database via the web service. It was implemented using PHP, JavaScript, CSS and HTML5. The aggregated pH data is presented in the web and the value can be interpreted based on the elements that are found on such soil at a particular time as shown in Figure 7. The pH value of 7.21 indicates that the likely possible elements in the soil are Calcium and Molybdenum. Table 1 shows the pH ranges and corresponding possible element present. The web dashboard has homepage and crops page which represent the view of soil pH from the farm and list of crops with their corresponding pH respectively.

Also, admin can update the pH value of different crops on crops page of the website by login with username and password and delete or update the pH value and/or name of a crop. The web dashboard was hosted temporarily at http://ptech.com.ng/soilchemical/web/_during the time of testing.

Figure 7. Web interface of the project

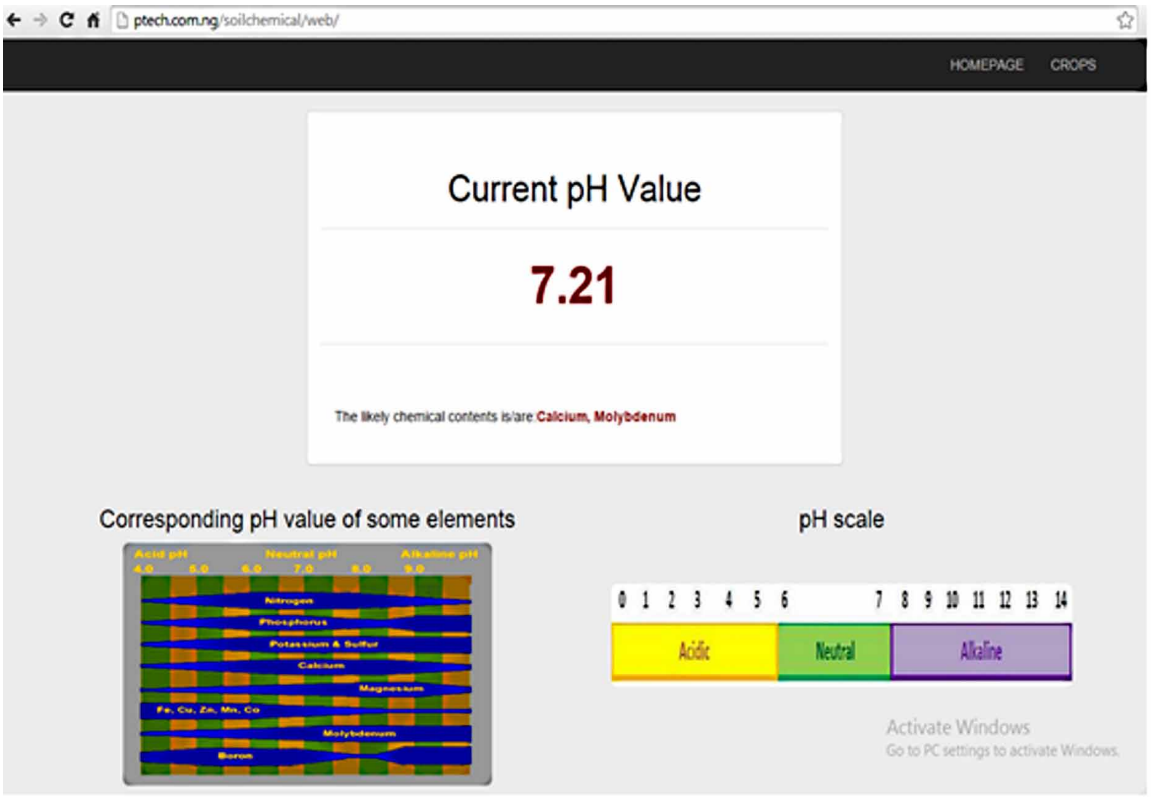

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Table 1. Ph ranges with their corresponding elements

S/N	pH range	Elements
1	4.00 - 5.00	Iron, Copper
2	5.00 – 6.00	Zinc, Boron, Manganese, Cobalt
3	6.00 – 7.00	Nitrogen, Phosphorus, Potassium, Sulphur
4	7.00 – 8.00	Calcium, Molybdenum
5	8.00 – 9.00	Magnesium

Each of the components of the system and the system, as a whole, were tested to ensure that they functioned properly. This is to ensure that the implementation was done satisfactorily based on the model proposed. The different components were tested based on their nature and structure. The web service and web dashboard were tested properly in order to uncover any bug or loop hole in the design. The implementation was tested in Biochemistry Department laboratory, Obafemi Awolowo University, Ile-Ife in Nigeria. The testing was done around 2pm within a period of three hours. This was due to the preparation of the solution to be used for the testing. Solutions were preferred instead of soil due to regular cleaning of pH probe required each time the probe is inserted to the soil. This however does not change the reliability of the outcome of this research work. The result obtained using laboratory method is shown in Table 2 while the result obtained using the proposed method is shown in Table 3. Three solutions were used in testing the efficiency of the designed system. The solutions were tested for both methods at pH values of 4.00, 7.00 and 9.18 respectively. The result obtained showed remarkable agreement with the existing method.

Table 2. Result from the existing and proposed methods (part 1)

pH Value	A	B	C	Average = (A+B+C)/3
4.00	3.99	4.00	3.99	3.99
7.00	7.00	7.00	7.02	7.01
9.18	9.18	9.17	9.17	9.17

Table 3. Result from the existing and proposed methods (part 2)

pH Value	A	B	C	Average = (A+B+C)/3
4.00	3.95	3.98	3.99	3.97
7.00	7.00	6.99	6.99	7.00
9.18	9.16	9.16	9.17	9.16

Note:
A – First measurement of a solution.
B – Second measurement of a solution.
C – Third measurement of a solution.
Average – Sum of A, B and C divided by three.
Where the values of X and Y obtained are; 3.99, 7.01, 9.17 and 3.97, 7.00, 9.12 respectively.

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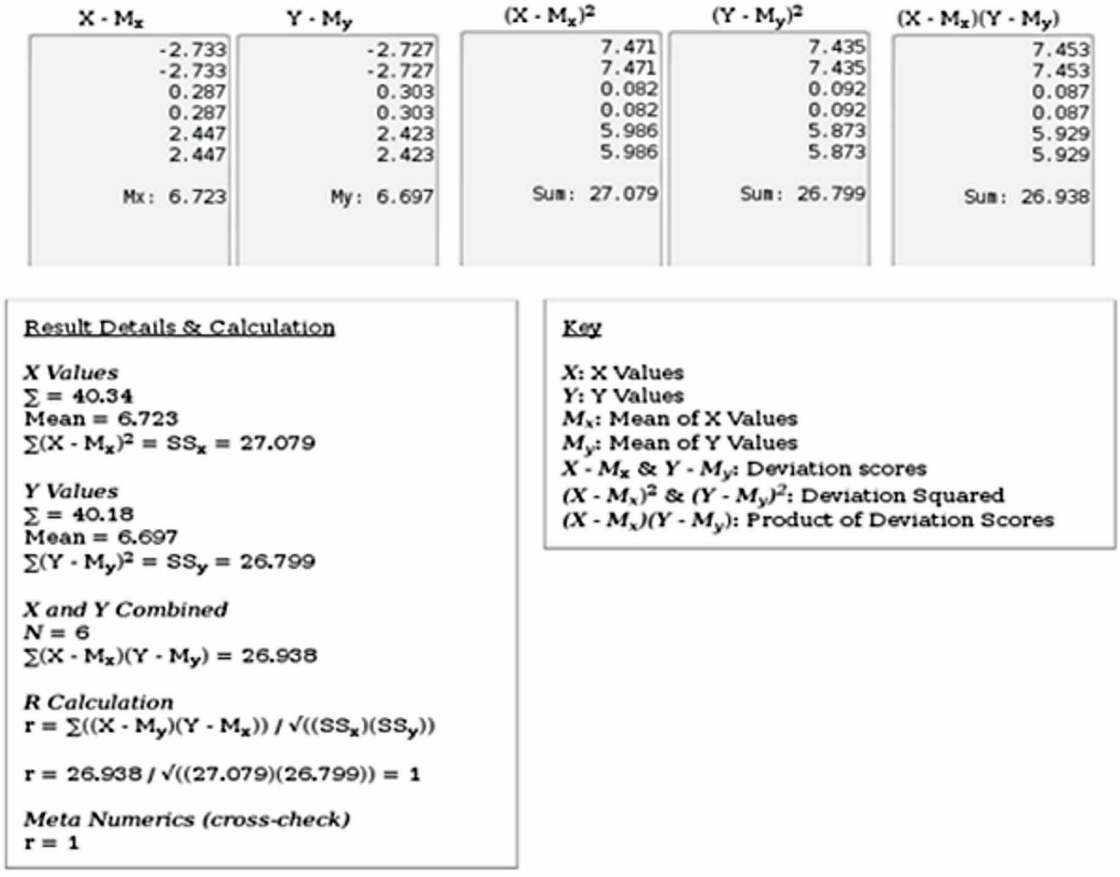
In order to confirm the accuracy of the proposed method, the efficiency of the design was carried out using Pearson correlation as shown in Figure 8. When r known as correlation coefficient is closer to 1, it indicates a strong positive relationship. A value of 0 indicates that there is no relationship. Values close to -1 signals a strong negative relationship between the two variables. The result showed r to be one (r = 1) signifying the reliability and acceptability of our proposed method. We took X to be the result obtained using the traditional method usually being carried out in the laboratory and Y to be the result obtained using our proposed automated method.

5. CONCLUSION

The project produced a system capable of generating the soil chemical contents. Our proposed method agreed with existing one signifying the reliability of our design. The results showed different pH values for different solutions. The values were automatically displayed on LCD and web page. This will facilitate the decision making on the type of crops to cultivate on any farmland if implemented on large scale. With the value of r (correlation coefficient) equals 1, this is a strong positive correlation, which

Figure 8. Calculation using Pearson correlation coefficient



$X - M_x$	$Y - M_y$	$(X - M_x)^2$	$(Y - M_y)^2$	$(X - M_x)(Y - M_y)$
-2.733	-2.727	7.471	7.435	7.453
-2.733	-2.727	7.471	7.435	7.453
0.287	0.303	0.082	0.092	0.087
0.287	0.303	0.082	0.092	0.087
2.447	2.423	5.986	5.873	5.929
2.447	2.423	5.986	5.873	5.929
Mx: 6.723	My: 6.697	Sum: 27.079	Sum: 26.799	Sum: 26.938

Result Details & Calculation

X Values
$\sum = 40.34$
Mean = 6.723
$\sum(X - M_x)^2 = SS_x = 27.079$

Y Values
$\sum = 40.18$
Mean = 6.697
$\sum(Y - M_y)^2 = SS_y = 26.799$

X and Y Combined
$N = 6$
$\sum(X - M_x)(Y - M_y) = 26.938$

R Calculation
$r = \sum((X - M_y)(Y - M_x)) / \sqrt{((SS_x)(SS_y))}$

$r = 26.938 / \sqrt{((27.079)(26.799))} = 1$

Meta Numerics (cross-check)
r = 1

Key

X: X Values
Y: Y Values
M_x: Mean of X Values
M_y: Mean of Y Values
$X - M_x$ & $Y - M_y$: Deviation scores
$(X - M_x)^2$ & $(Y - M_y)^2$: Deviation Squared
$(X - M_x)(Y - M_y)$: Product of Deviation Scores

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means that X variable values agree with Y variable values. This means that the result obtained from the automated method proposed agrees the existing traditional method of testing the chemical contents of the soil from the laboratory. The system will be useful as a decision support system thereby complimenting human experts' knowledge of suggesting the contents of the soil. The system can also allow the condition of soil on a farmland to be monitored remotely eliminating the stress of traveling to the farmland most of the time.

5.1. Future Work

This work has been able to use pH meter to obtain the chemical contents of the soil and transferred the aggregated value to the web page. A lot of research are still needed to be done on technological way of getting chemical contents directly from the soil without a need to interpret the pH value before suspecting the possible chemical contents present in a soil. In our future work, we plan to design an arduino based device that can detect some of or all of the soil chemical contents automatically such as Nitrogen, Potassium, Phosphorous etc. instead of using pH meter for approximation. We also intend to propose an automatic soil chemical contents adjustment system that can automatically regulate soil chemical contents so that farmers would not need to apply the deficit soil chemical contents manually.

REFERENCES

Bowman, K. (2008). Economic and environmental analysis of converting to controlled traffic farming. Proceedings of the *6th Australian Controlled Traffic Farming Conference* (pp. 61-68).

DFROBOT. (2015). Analog pH Meter Kit. Retrieved from http://www.dfrobot.com/

Finžgar, N., Tlustoš, P., & Leštan, D. (2007). Relationship of soil properties to fractionation, bioavailability and mobility of lead and zinc in soil. *Plant, Soil and Environment*, *53*(5), 225–238.

Franz, T. E., Wahbi, A., Vreugdenhil, M., Weltin, G., Heng, L., Oismueller, M., & Desilets, D. (2016). Using Cosmic-Ray Neutron Probes to Monitor Landscape Scale Soil Water Content in Mixed Land Use Agricultural Systems. *Applied and Environmental Soil Science*.

Gayathri, T., Ragul, S., & Sudharshanan, S. (2015). Corn Farmland Monitoring Using Wireless Sensor Network.

Kim, J., Jin, J. H., Kim, H. S., Song, W., Shin, S. K., Yi, H., ... Lee, B. Y. (2016). Fully Automated Field-Deployable Bioaerosol Monitoring System Using Carbon Nanotube-Based Biosensors. *Environmental Science & Technology*, *50*(10), 5163–5171. doi:10.1021/acs.est.5b06361 PMID:27070239

Kirandeep K., Rita M., & Deepak B. (2016). Zigbee Based Soil Moisture Monitoring System. *International Journal of Innovative Research in Computer and Communication Engineering*, 4(6), 11931-11937.

KTNUK. (2015). Mathematics in Agriculture - Round Up. Retrieved from https://connect.innovateuk.org /documents/

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Kumar, S., Kumar, B., Thakur, R., & Kumar, M. (2015). Soil pH Sensing Techniques and Technologies-A Review. *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering.*, *4*(5), 4452–4456.

Liao, J., Zhang, Q., Fang, Y., & Xu, X. (2015). The Remote Monitoring System Design of Farmland Based on ZigBee and GPRS.

Manikandan, K., & Rajaram, S. (2016). Automatic monitoring system for a precision agriculture based on wireless sensor networks. *International Journal of Science Engineering and Computer Technology*, *6*(6), 208.

Mikó, P. (2009). Investigation of The Effects Of Green Manuring On Soil Condition And The Following Crop [Doctoral Thesis]. Faculty of Agriculture and Environmental Sciences, Institute of Genetics and Biotechnology, Godollo, Hungary.

Mitralexis, G., & Goumopoulos, C. (2015, November). Web based monitoring and irrigation system with energy autonomous wireless sensor network for Precision Agriculture. *Proceedings of the European Conference on Ambient Intelligence* (pp. 361-370). Springer International Publishing. 10.1007/978-3-319-26005-1_27

Olaoye, A. (2015). Design and implementation of a remote greenhouse temperature monitoring system using wireless sensor networks [unpublished thesis]. Department of Computer Science and Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria.

Rasher, M. (2015). The use of GPS and mobile mapping for decision-based precision agriculture. Retrieved from http://www.gisdevelopment.net/application/agriculture

Rigoberto, S. (2015). A web-based temperature monitoring system for the college of arts and letters. Electronic Theses, Projects, and Dissertations. Retrieved from http://scholarworks.lib.csusb.edu/etd/129

Szilágyi, R. (2006). Possibilities and Demands of Mobile Internet Based Applications in Agriculture [Doctoral dissertation]. University Of Debrecen.

Tayari, E., Jamshid, A. R., & Goodarzi, H. R. (2015). Role of GPS and GIS in precision agriculture. *Journal of Scientific Research and Development*, *2*(3), 157–162.

Tullberg, J. N., Yule, D. F., & McGarry, D. (2007). Controlled traffic farming—from research to adoption in Australia. *Soil & Tillage Research*, *97*(2), 272–281. doi:10.1016/j.still.2007.09.007

Vellidis, G., Perry, C. D., Rains, G., Thomas, D. L., Wells, N., & Kvien, C. K. (2003). Simultaneous assessment of cotton yield monitors. *Applied Engineering in Agriculture*, *19*(3), 259–272. doi:10.13031/2013.13658

Whelan, B. M., & McBratney, A. B. (2003, February). Definition and interpretation of potential Management zones in Australia. *Proceedings of the 11th Australian Agronomy Conference*, Geelong, Victoria.

Ye, Y., Hao, L., Liu, M., Wu, H., Zhang, X., & Zhao, Z. (2016). Design of Farmland Environment Remote Monitoring System Based on ZigBee Wireless Sensor Network. In *Frontier Computing* (pp. 405–416). Springer Singapore. doi:10.1007/978-981-10-0539-8_41

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Zarco-Tejada, P., Hubbard, N., & Loudjani, P. (2014). *Precision Agriculture: An Opportunity for EU Farmers—Potential Support with the CAP 2014-2020.* Joint Research Centre (JRC) of the European Commission.

Zografos A. (2014). Wireless Sensor-based Agricultural Monitoring System.

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Chapter 20
The Empirical Study on the Evolutionary Game Based Agricultural Products Supply Chain

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ABSTRACT

This research paper is to use a method of Evolutionary Game to investigate the relationship between a large supplier and a franchised supermarket in China. The authors would like to go through their empirical study with their filtered answers from the survey using SPSS software on agricultural supply chain for their quality safety factors. Their research is using factor analysis with five target factors which are: the excess return, cost, the relative size of cooperative enterprises, hitchhiking, and overflows income. Applying these factors to the evolutionary game model, analyze the earning status from the both players under their own policies, then make suggestions or proposals for quality and safety issues of agricultural supply chain management.

1. INTRODUCTION

Regarding the application research of game theory on the food supply chain security, some scholars' studies are focusing on the issues of food supply chain and agricultural supply chain security from the perspective of game theory, while some other scholars are analyzing the relationship between the main body of food supply chain and food enterprises based on evolutionary game theory. Yet, there were no conclusions for the quality safety of agricultural products supply chain, no game analysis on the cooperation between the supplier and the seller. Nor resolved the problems for the quality and safety problems of agricultural supply chain in the presence of node enterprises.

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This research intends to investigate the quality-safety problems of agricultural products supply chain from the perspective of evolutionary game theory. Also to establish an evolutionary game model between upstream and downstream stakeholders of agricultural products supply chains, propose possible solutions to the quality, safety of agricultural products supply chains from the perspective of empirical analysis.

2. PROBLEM DESCRIPTION

Given the consistency of the chain of agricultural supply chain, the paper aimed to study one typical agricultural supply chain. Based on the Lotus Town of Dalian Pulandian City which is located in the foothills of White Cloud Hill in the central Pulandian, is the conjunction center with strong radiating outward traffic of North-South Corridor Tang Hing highway and the Central City Eight Midline Line highway. This location is very conducive to guarantee the timely transport of agricultural products, fresh and shelves. Lotus Town has more than 400 vegetable greenhouses covered an area of 800 acres, 3000 acres of high oil soybean, 5,000 acres of peanuts under plastic mulch. There are several famous local products like "Flagpole bottom" cucumber, and mulberry, which are conducive to the development of the local characteristics of agricultural products, also conducive to brand building. It is more conducive to the development of agricultural supply chain in Lotus Town.

3. DATA COLLECTION

This investigation was conducted mainly in the form of issuing questionnaires and field random sampling survey. Our insurance of questionnaires went through with the main respondents. Based on Lianshan Town area, they were selected from the reginal farmers, suppliers, vendors, consumers and regulators as well (see Figure 1). Total 278 of 320 issued questionnaires were recovered, and 261 responses were confirmed the valid ones after effective screening. The recovery rate was 86.875% with the effective rate of 81.56%. There were 96 males and 165 females among the effective respondents. After issuing, recovering the questionnaires, and excluding invalid ones through initial screening, and analyzed by SPSS18.0 data analytics software. Subjects of the investigation are mainly farmers, suppliers, sellers, customers, regulators. The proportion and numbers of the respondents are listed in Table 1.

Table 1. The fieldwork investigation object of the quality-safety of agricultural products supply chain

Respondents	Proportion
Farmer	16.9%
Supplier	19.5%
Sellers	15.7%
Consumer	41.8%
Regulators	6.1%

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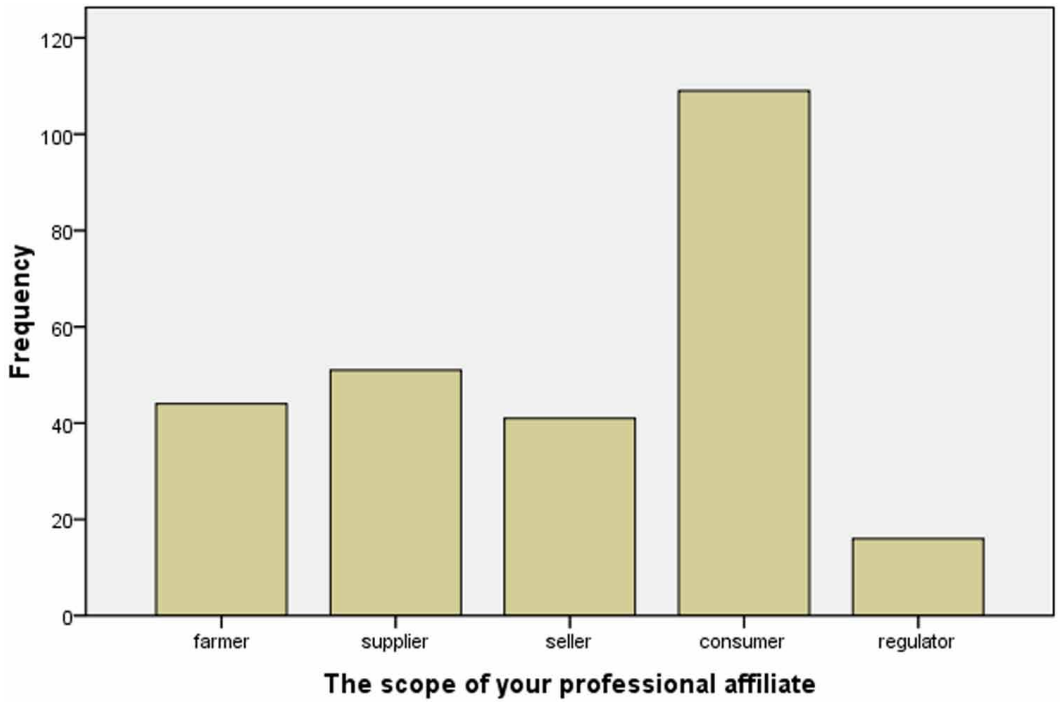
Figure 1. Professional scope of respondent



4. DATA ANALYSIS

In order to investigate whether there is any direct impact that the average monthly income could be any factor to choose large supermarket chains for green agricultural products consumptions, our field survey included a question of respondent's monthly income. In addition, for the same concerns, the respondent's educational background was also included in our questionnaires.

The ranges of respondents' average monthly income are <2,000, 2001-3000, 3001-4000, 4001-5000, and >5001 (the unit is RMB-Yuan) as shown in Table 2.

In the consumption of agricultural products, there are 2.3% of respondents strongly disagree to choose green products, 2.7% of them disagree, 9.2% are neutral, 41.8% agree, and very much in favor of 44.1%. As shown in Figure 2, except those whose income are below 2000 yuan, the majority of respondents

Table 2. The respondent's average monthly wage with their quality-safety field of agricultural products supply chain

The average monthly income (yuan)	The number
≤2000	34
2001—3000	89
3001—4000	80
4001—5000	44
≥5001	14

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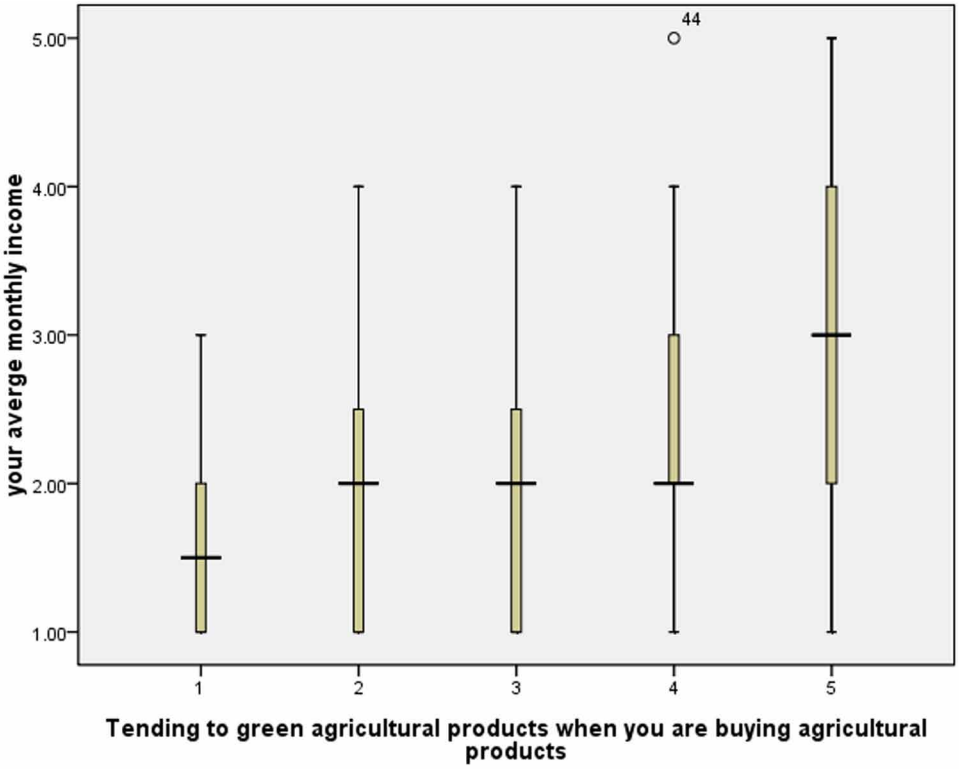
Figure 2. The relevance of the average monthly income and tending to green agricultural products



with middle and higher income are in favor of choosing green agricultural products, and factor more on quality-safety concerns.

The education background of respondents are: 12.6% with junior high school or below, 23.8% with high school, vocational school are accounted for 19.9%, and 32.6% with a university degree, while 11.1% with graduate degree. In the purchase of agricultural products, the attitude of the primary consideration for the quality and safety factors is divided into: strongly disagree, disagree, neutral, agree, and strongly agree. The number of people with different attitude is shown in Table 3. Two survey shown in Figure 3 indicates that with the improvement of people's education, people pay more attentions to the green logo and quality of agricultural products.

Table 3. The respondents of the quality-safety of agricultural products supply chain hold the attitude that considering quality-safety priority when buying agricultural products

Attitude	The number
Strongly disagree	4
Disagree	10
Neutral	34
Agree	106
Strongly agree	107

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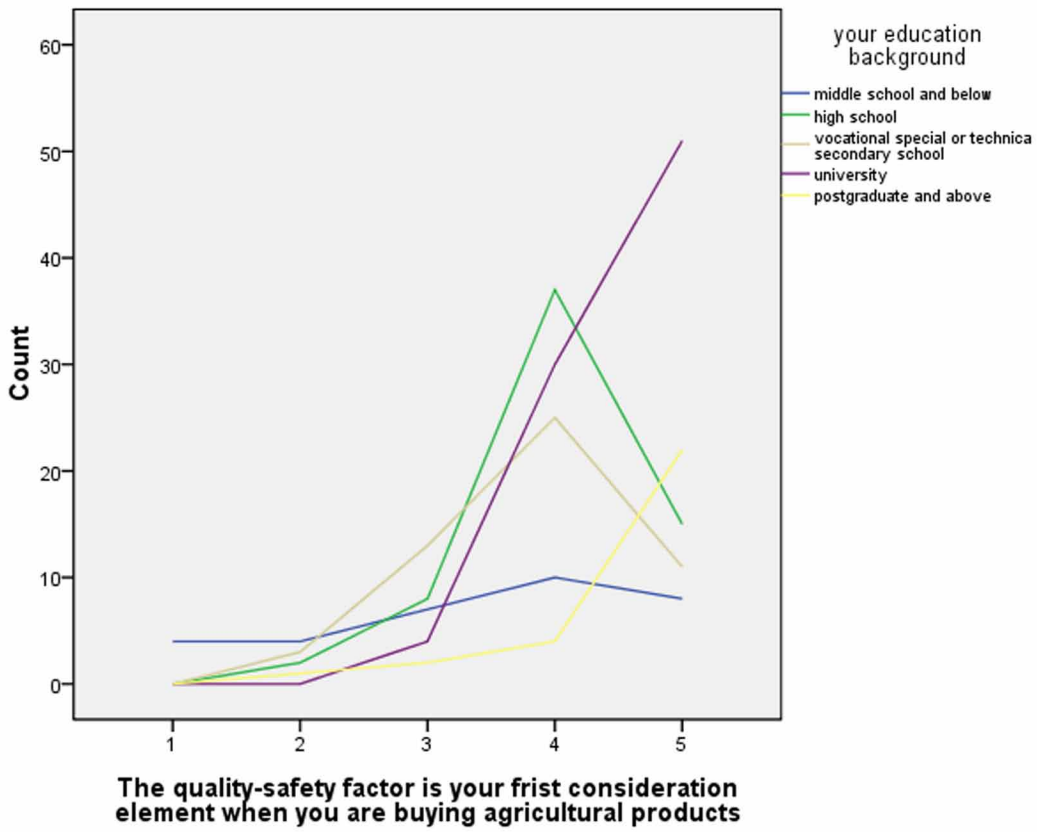
Figure 3. The relevance of degree and considering quality-safety priority when buying agricultural products



**For a more accurate representation see the electronic version.*

4.1. Reliability and Validity of the Questionnaire

Through the entire process of the survey, whether it was from questionnaire, the process of investigation, or the final recovery and data analysis, each link has made a detailed planning and control, which is the guarantee of good validity. After all the survey data archived, our research used SPSS18.0 to carry on the statistical data analysis to ensure the reliability of data. To verify the validity of the questionnaire, we used the Cronbach's Alpha coefficient analysis method. As shown in Table 4, the Alpha value was 0.897 which indicated that the reliability and validity of the survey questionnaire was good, and it was in line with the research requirements. The analysis of construct validity will be elaborated in the section of factor analysis below.

Table 4. Reliability Statistics

Cronbach's Alpha	N of Items
.897	30

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4.2. Factor Analysis of Questionnaire

Based on the specific circumstances, this research utilized factor analysis questionnaire. Firstly, the data adaptability was tested by KMO (Kaister-Meyer-Olkin) and Bartlett's Sphericity test (Bartlett test of Sphericity). As shown in Table 5, the testing result of KMO value was 0.869 which was bigger than 0.5.The observation value of Bartlett Sphericity testing statistic was 1.051E4, its corresponding probability P value was close to 0. When the significance level α value equals to 0.05, considering the observed value of P values is less than the significance level α, the original assumption should be considered false, meaning that there is significant difference between the correlation coefficient matrix and the unit matrix. The $\chi 2$ statistical significance probability value of the Bartlett Sphericity test is 0.000, which is smaller than 0.001, so this group of data is more suitable for factor analysis.

In this paper, several independent factors were extracted from the original variables, and the majority of the original variables are explained by these factors. Five factors were extracted from the initial factors. As the Table 6 shows, the first column is the factor number; the second to the fourth column describe the case where the initial factor solution. It can be seen from the table, the first column factor eigenvalues are 8.053, explaining the original four variables of the total variance 26.843%, the cumulative variance contribution rate was 26.843%. The eigenvalues of the second factors are 4.948, 16.494% of the total variance of four variables, the cumulative variance contribution rate was 43.337%, considering the extraction of all the variables in the initial solution, the total variance of the original variables was explained away. Fifth column to the seventh column describe the situation of factor solution: due to five factors were extracted during the process of the statistical analysis, the five factors explained 79.701% of the original variables of the total variance. On the whole, the original information is lost less, and the absolute value of each variable factor is relatively high, indicating that the original variables in each factor has a more significant correlation, which has reached the purpose of factor analysis. The last three columns describe a case of final factor solution. After rotating the factors, the cumulative variance ratio remained the same, meaning that the degree of co-existing variables were not changed. Since factor rotation reallocated each various factor which explained the variance of the original variables, changed the factor of variance contribution rate, the factors could be explained more easily.

In this paper, five factors that affect the quality and safety of agricultural products supply chain are extracted from the rotated factors load matrix and named as shown in Table 7. Overall, the five factors explained 79.701% of the variance in the data.

1. **Factor 1 (F1):** The excess returns. It consists of total seven factors of Q29, Q30, Q31, Q32, Q33, Q34, Q35. These factors are constituted the various factors that are related to the excess returns, and among which, the Q30, Q29, and Q35 are the most representative and explanatory power of the factor.

Table 5. KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		**.869**
Bartlett's Test of Sphericity	Approx. Chi-Square	1.051E4
	df	435
	Sig.	.000

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Table 6. Total variance explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8.053	26.843	26.843	8.053	26.843	26.843	5.633	18.775	18.775
2	4.948	16.494	43.337	4.948	16.494	43.337	5.317	17.722	36.498
3	4.741	15.804	59.142	4.741	15.804	59.142	4.763	15.876	52.374
4	3.888	12.960	72.102	3.888	12.960	72.102	4.615	15.385	67.759
5	2.280	7.599	79.701	2.280	7.599	79.701	3.583	11.942	79.701
6	.946	3.153	82.854						
7	.842	2.808	85.661						
8	.756	2.520	88.181						
9	.590	1.965	90.146						
10	.408	1.359	91.505						
11	.396	1.319	92.824						
12	.235	.782	93.606						
13	.217	.723	94.329						
14	.214	.714	95.043						
15	.196	.652	95.695						
16	.165	.552	96.247						
17	.163	.542	96.788						
18	.155	.517	97.305						
19	.137	.457	97.762						
20	.124	.413	98.175						
21	.105	.350	98.525						
22	.097	.324	98.848						
23	.091	.304	99.152						
24	.073	.243	99.395						
25	.058	.194	99.589						
26	.028	.094	99.683						
27	.027	.090	99.773						
28	.026	.085	99.859						
29	.025	.082	99.940						
30	.018	.060	100.000						

Extraction Method: Principal Component Analysis.

2. **Factor 2 (F2):** The cost. It consists of total six factors of Q9, Q10, Q11, Q12, Q13, and Q14. These six factors are constituted the various ones related to the cost. Among them, the three factors of Q12, Q14, and Q11have the strongest representative and explanatory power of this factor.

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Table 7. Rotated Component Matrix[a]

Component	Indicator	Component					Nominate
		F1	F2	F3	F4	F5	
F1	Q30	.962					Excess
	Q29	.913					return
	Q35	.911					
	Q32	.907					
	Q33	.882					
	Q31	.765					
	Q34	.746					
F2	Q12		.980				Costs
	Q14		.952				
	Q11		.926				
	Q9		.918				
	Q10		.906				
	Q13		.900				
F3	Q23			.986			The relative
	Q25			.973			size of
	Q27			.970			cooperative
	Q26			.944			enterprises
	Q24			.939			
F4	Q20				.971		Hitchhiking
	Q22				.942		
	Q18				.935		
	Q21				.934		
	Q19				.899		
F5	Q15					.871	Overflow
	Q17					.842	income
% of Variance		18.775	17.722	15.876	15.385	11.942	
Cumulative %		18.775	36.498	52.374	67.759	79.701	

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 5 iterations

3. **Factor 3 (F3):** The relative size of cooperative enterprises. F3 consists of Q23, Q24, Q25, Q26, Q27 total five factors. These five factors are constituted the various factors associated with the relative size of cooperative enterprises. In particular, the Q23 has the strongest representative and explanatory power of this factor.

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4. **Factor 4 (F4):** The hitchhiking. It consists of Q18, Q19, Q20, Q21, Q22 total five factors. There five factors are constituted the various factors associated with the hitchhiking. Among which, the Q20, Q22, and Q18 have the strongest representative and explanatory power of this factor.
5. **Factor 5 (F5):** The overflow income. F5 consists of two factors of Q15 and Q17. These two are constituted the various factors related to the overflow income, and the Q15 has the strongest representative and explanatory power of the factor.

The five factors referenced herein are related to various dimensions influencing the quality-safety of agricultural supply chain. Along with these selected factors, we analyzed and evaluated our target objects. Thus, the structure of this kind of classifications is more systematic and comprehensive.

5. TEST OF HYPOTHESIS MODEL

In the agricultural supply chain, the supplier's strategic set is (provide agricultural products with safety, provide agricultural products with violations), and the strategic set of large supermarket chain is (assume responsibility, assume with no responsibility). Both sides of the game can conduct random strategic selections independently, and repeat the game model. Here, the strategy of assume responsibility refers to the time when the agricultural safety problems occur, the large supermarket chains alone bear the responsibility for compensations. If both parties are simply considering their own interests, and select the strategy of providing agricultural products with violations, and assuming with no responsibility upon the accident of agricultural products safety, both sides may obtain their general profits which are: $\pi 1$, $\pi 2$. If both players have a high sense of responsibility, they can receive excess returns which are r1e, r2e. Herein, r represents the distribution coefficient, e is the excess return. With a high sense of responsibility on both sides, along with good faith cooperation, the two parties can get overflow income $\beta 1m2$, $\beta 2m1$ where β is coefficient for the overflow with the good faith cooperation. m represents the cooperative enterprise size and strength. When upstream stakeholders provide safe agricultural products, and downstream stakeholders assume their responsibilities, the cost of both parties is $\alpha 1m1$, $\alpha 2m2$, α is the cost factor. Finally, when upstream stakeholders provide safe products while downstream stakeholders won't take responsibilities, or downstream stakeholders assume their responsibilities while upstream stakeholders provide agricultural products with violations, it would be a free-rider problem. The latter will be benefited from the former's hitchhiking income $\lambda\beta 2m1$, $\lambda\beta 1m2$, here λ is the pick-up factor.

Table 8. Game matrix of upstream and downstream stakeholders of agricultural products supply chain downstream stakeholders of agricultural products supply chain

	Bear Responsibility	**Not liable**
Provide agricultural products safety	π_1-$\alpha_1 m_1$+$\beta_1 m_2$+$r_1 e$, π_2-$\alpha_2 m_2$+$\beta_2 m_1$+ $r_2 e$	π_1-$\alpha_1 m_1$, π_2+$\lambda\beta_2 m_1$
Providing agricultural products violation	π_1+$\lambda\beta_1 m_2$, π_2-$\alpha_2 m_2$	π_1, π_2

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5.1. Static Game Analyzing

Among the game between the upstream and downstream stakeholders of agricultural products supply chain, when the excess returns is less than the cost of the upstream or downstream stakeholders, the final balancing of the game is (provide agricultural products with violations, assume with no responsibilities). Whereas, when the excess return greater than the cost of the upstream or downstream stakeholders, and when the downstream stakeholders choose to assume responsibilities, the upstream stakeholders will provide agricultural products with safety, while the downstream stakeholders choose not to assume responsibilities, the upstream stakeholders will provide agricultural products with violations. Conversely, when the upstream stakeholders provide agricultural products with safety, the downstream stakeholders will assume responsibilities, while the upstream stakeholders provide agricultural products with violations, the downstream stakeholders would choose not to assume responsibilities (see Table 8). When both sides are in the unknown with other's strategies, to ensure their own interests, they will have two Nash equilibrium.

With the improvement the detection level for the quality-safety of agricultural supply chain, and as well as strengthen of the supervision management of the government, the participants get mutually consistent and reliable information, strengthen their mutual trust, cooperation, to minimize the risk. Both parties eventually achieve the Pareto optimality, namely

$$\left(\pi_1 - \alpha_1 m_1 + \beta_1 m_2 + r_1 e, \pi_2 - \alpha_2 m_2 + \beta_2 m_1 + r_2 e\right).$$

5.2. Evolutionary Game Analyzing

In the games, the ratio of the upstream stakeholders to provide agricultural products with safety is x, the proportion of agricultural products with violations is 1-x, the proportion of the downstream stakeholders to assume responsibilities is y, the ratio of without assuming responsibilities is 1- y.

1. The fitness of the upstream stakeholders providing agricultural product with safety:

$$u_x = y\left(r_1 e + \beta_1 m_2\right) + \left(\pi_1 - \alpha_1 m_1\right)$$

The fitness of the upstream stakeholders providing agricultural products with violations:

$$u_{1-x} = y\lambda\beta_1 m_2 + \pi_1$$

The average fitness of the upstream stakeholders:

$$\overline{u_x} = x\left[y\left(\gamma_1 e + \beta_1 m_2\right) + \left(\pi_1 - \alpha_1 m_1\right)\right] + \left(1 - x\right)\left(y\lambda\beta_1 m_2 + \pi_1\right)$$

The replicator dynamics equation from the upstream stakeholders:

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$$\frac{dx}{dt} = x\left(1-x\right)\left[y\left(\gamma_1 e + \beta_1 m_2 - \lambda\beta_1 m_2\right) - \alpha_1 m_1\right]$$

2. The fitness of the downstream stakeholders to assume responsibilities:

$$u_y = x\left(r_2 e + \beta_2 m_1\right) + \left(\pi_2 - \alpha_2 m_2\right)$$

The fitness of the downstream stakeholders for not to assume responsibilities:

$$u_{1-y} = x\lambda\beta_2 m_1 + \pi_2$$

The average fitness of the downstream stakeholders:

$$\overline{u_y} = y[x(\gamma_2 e + \beta_2 m_1) + (\pi_2 - \alpha_2 m_2)] + (1-y)(x\lambda\beta_2 m_1 + \pi_2)$$

Replicator dynamics equation which is from downstream stakeholders of agricultural products supply chain:

$$\frac{dy}{dt} = y(1-y)[x(\gamma_2 e + \beta_2 m_1 - \lambda\beta_2 m_1) - \alpha_2 m_2]$$

By the replicator dynamic equations we find five stable points, namely (0,0), (0,1), (1,0), (1,1) (p*,q*), $p^* = \frac{\alpha_2 m_2}{r_2 e + \beta_2 m_1 - \lambda\beta_2 m_1}$, $q^* = \frac{\alpha_1 m_1}{\gamma_1 e + \beta_1 m_2 - \lambda\beta_1 m_2}$.

The evolutionary stability can be determined by analyzing the local stability of the Jacobian matrix which was created by the cooperative and competitive systems.

$$J = \begin{pmatrix} \left(1-2x\right)\left[y\left(\gamma_1 e + \beta_1 m_2 - \lambda\beta_1 m_2\right) - \alpha_1 m_1\right] & x(1-x)(\gamma_1 e + \beta_1 m_2 - \lambda\beta_1 m_2) \\ y\left(1-y\right)\left(r_2 e + \beta_2 m_1 - \lambda\beta_2 m_1\right) & \left(1-2y\right)\left[x\left(r_2 e + \beta_2 m_1 - \lambda\beta_2 m_1\right) - \alpha_2 m_2\right] \end{pmatrix}$$

$$\det J = \left(1-2x\right)\left[y\left(\gamma_1 e + \beta_1 m_2 - \lambda\beta_1 m_2\right) - \alpha_1 m_1\right]\left(1-2y\right)\left[x\left(r_2 e + \beta_2 m_1 - \lambda\beta_2 m_1\right) - \alpha_2 m_2\right]$$
$$-x\left(1-x\right)\left(\gamma_1 e + \beta_1 m_2 - \lambda\beta_1 m_2\right) y\left(1-y\right)\left(r_2 e + \beta_2 m_1 - \lambda\beta_2 m_1\right)$$

$$trJ = \left(1-2x\right)\left[y\left(\gamma_1 e + \beta_1 m_2 - \lambda\beta_1 m_2\right) - \alpha_1 m_1\right] + \left(1-2y\right)\left[x\left(r_2 e + \beta_2 m_1 - \lambda\beta_2 m_1\right) - \alpha_2 m_2\right]$$

$$r_1 e + \beta_1 m_2 < \alpha_1 m_1 + \lambda\beta_1 m_2, r_2 e + \beta_2 m_1 < \alpha_2 m_2 + \lambda\beta_2 m_1 \quad (1)$$

Table 9 shows the evolutionarily stable results.

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Table 9. Evolutionary stable results (1)

Balance Point	det J	tr J	Local Stability
(0,0)	+	-	ESS
(0,1)	-	Uncertain	Saddle Point
(1, 0)	-	Uncertain	Saddle Point
(1, 1)	+	+	Unstable point

When the upstream stakeholders' excess return is less than the input costs, the excess return of the downstream stakeholders is less than its cost of inputs, the evolutionary stable results (0,0). Figure 4 describes the process of evolution. The final evolution result will converge to the set of (provide agricultural products with violations, assume with no responsibilities).

$$r_1 e + \beta_1 m_2 < \alpha_1 m_1 + \lambda \beta_1 m_2, r_2 e + \beta_2 m_1 > \alpha_2 m_2 + \lambda \beta_2 m_1 \tag{2}$$

Table 10 shows the evolutionarily stable results.

Figure 4. Phase diagram of the evolution (1)

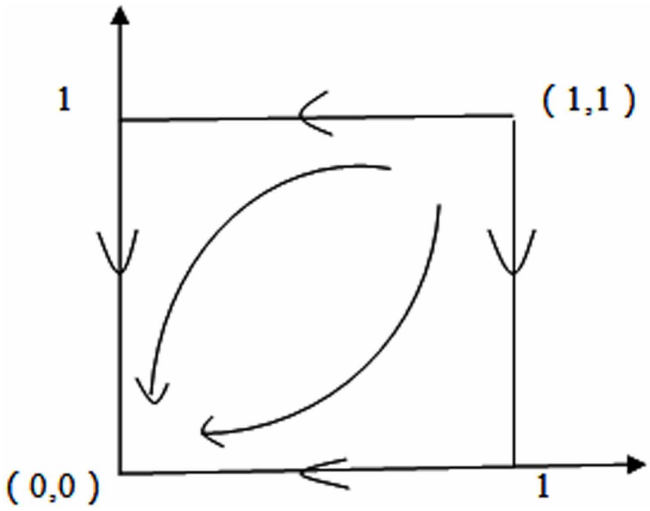

Table 10. Evolutionary stable results (2)

Balance Point	det J	tr J	Local Stability
(0,0)	+	-	ESS
(0, 1)	-	Uncertain	Saddle Point
(1, 0)	+	+	Unstable point
(1, 1)	-	Uncertain	Saddle Point

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When the upstream stakeholders' excess return is less than the input costs, the excess return of the downstream stakeholders is greater than input costs, as the evolutionary stable results (0,0).

Figure 5 depicts the phase evolution of the process. The final evolution result will converge to the set of (provide agricultural products with violations, not to assume responsibilities).

$$r_1 e + \beta_1 m_2 > \alpha_1 m_1 + \lambda \beta_1 m_2, r_2 e + \beta_2 m_1 < \alpha_2 m_2 + \lambda \beta_2 m_1 \tag{3}$$

The Table 11 shows the evolutionary stable result

When the upstream stakeholders' excess return is greater than the input costs, the excess return of the downstream stakeholders is smaller than its input costs, as the evolutionary stable results (0,0). Figure 6 depicts the phase evolution of the process. The final evolutionary result will converge to the set of (provide agricultural products with violations, assume with no responsibilities).

$$r_1 e + \beta_1 m_2 > \alpha_1 m_1 + \lambda \beta_1 m_2, r_2 e + \beta_2 m_1 > \alpha_2 m_2 + \lambda \beta_2 m_1 \tag{4}$$

Table 12 shows the evolutionary stable results.

Figure 5. Phase diagram of the evolution (2)

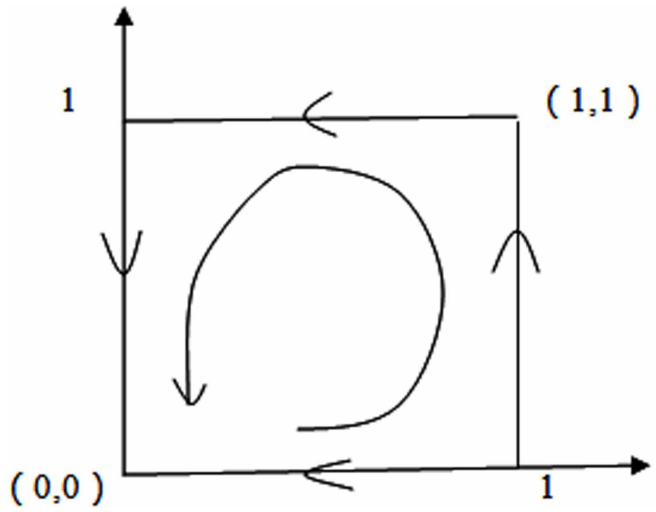

Table 11. Evolutionary stable results (3)

Balance Point	det J	tr J	Local Stability
(0,0)	+	-	ESS
(0, 1)	+	+	Unstable point
(1, 0)	-	Uncertain	Saddle Point
(1, 1)	-	Uncertain	Saddle Point

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Figure 6. Phase diagram of the evolution (3)

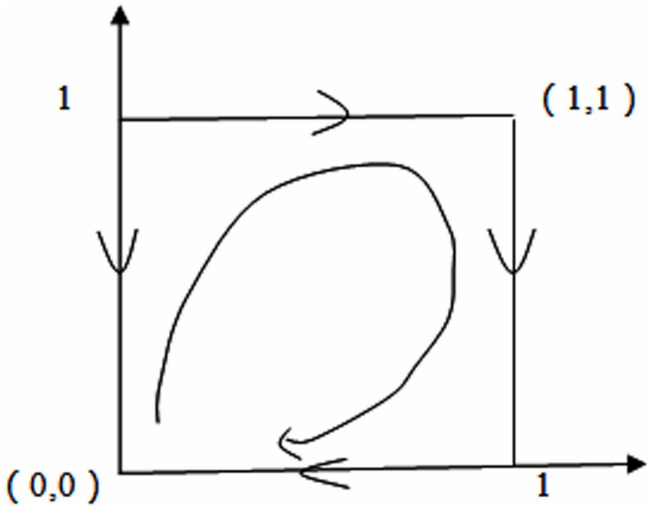

Table 12. Evolutionary stable results (4)

Balance Point	det J	tr J	Local Stability
(0,0)	+	-	ESS
(0, 1)	+	+	Unstable point
(1, 0)	+	+	Unstable point
(1, 1)	+	-	ESS
$\left(p^*, q^*\right)$	-	0	Saddle Point

When the upstream stakeholders' excess return is greater than the input costs, the excess return of the downstream stakeholders is also larger than its input costs, which is the evolutionary stable results (0,0), (1,1) from the evolution of the phase diagram. There are still two unstable points (0,1), (1,0) and the saddle point (p *, q *). Figure 7 depicts the process of the view of dynamic evolution from the saddle point and instability point even into the fold between the two game sides which converges on the critical line in different states. The evolution of the game results will change along with the saddle point and converges to a different equilibrium.

6. CONCLUSION

6.1. Test Results

It can be seen that the relative size of the cost and the excess return of upstream and downstream stakeholders of agricultural products supply chain will directly affect the ultimate evolutionary stable results.

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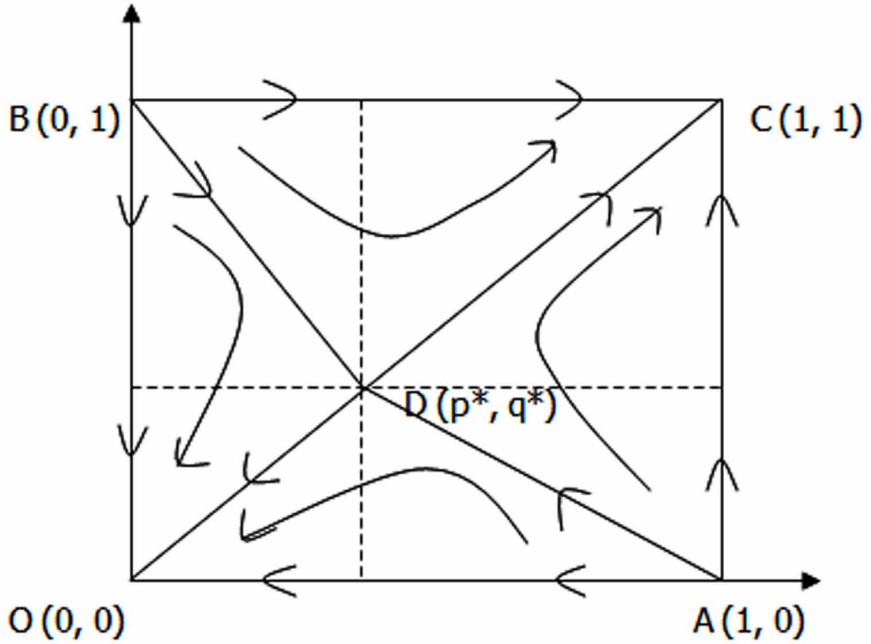
Figure 7. Phase diagram of the evolution (4)



1. **In Case of the Excess Returns Are Less Than the Cost of the Upstream or Downstream Stakeholders:** By means of the evolutionary stable results of (0,0) from the three former evolutionary phase diagrams, whether what the initial state it starts from, the final results will converge to the evolutionary set of (provide agricultural products with violations, assume with no responsibilities).
2. **In Case of the Excess Returns Are Greater Than the Input Costs of Upstream and Downstream Stakeholders:** When the evolutionary stable results set to (0,0), (1,1), it means the upstream and the downstream stakeholders select to provide agricultural products with violations and not to assume responsibilities, or select to provide agricultural products with safety and assume responsibility individually. There are two unstable points (0,1), (1,0) and a saddle point (p *, q *) in the evolutionary phase diagram. The Figure 7 depicts a dynamic evolution with the critical line that was converged by a fold line between the saddle point and unstable point with the two parties during the game process. As seen in the upper right area ADBC, the system converges to the strategy set of (provide agricultural products with safety, assume responsibilities), and in the lower left area AOBD, the system converges to the strategy set of (provide agricultural products with violations, assume with no responsibilities).

In a long evolutionary process, the outcome of the game will be varying along with the saddle point change, and will converge to different equilibriums.

1. The smaller the cost coefficient α, the greater of the top right area is, and the evolutionary game should become more possible to converge to (1,1). When the supply chain of agricultural products is becoming more and more refined, the chain is getting shorter and shorter, the market pays more attentions to standardization, the cost will be reduced accordingly. Meanwhile, the cost will be

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affected by the changes of cooperative enterprise operations management, the new technologies, the improved policy environment, and other factors. In order to reduce the cost factor for upstream stakeholders of agricultural products supply chain, the large-scale management must be formed, the establishment of supply alliances, the standardized management not only reduces costs but also ensure to offer the quality and safety of agricultural products. For the downstream stakeholders, the government policy support and incentive, such as willingness to assume responsibility of enterprises to implement certain compensations, rewards, and reducing the costs.

2. The degree of synergy between the two sides of the game affects the overflow coefficient β. If the upstream stakeholders provide safe agricultural products, the downstream stakeholders assume responsibilities, both sides of the game launched an effective cooperation, and there is no evasion of responsibility, then one party can get the overflow income from the other side. The larger the overflow coefficient, the bigger the upper right ADBC area of the fold line is, the greater the probability of convergence of the evolutionary game (1,1) is.
3. The higher the excess return, the greater the probability that the result of evolutionary game will converge to (1,1). Because getting excess return by both players is the shift in the relationship, so the game both parties can only be benefited mutually by improving the excess return e.
4. When the corporate strength between both game sides has any gaps, the free-riding behavior may occur. In the case of upstream stakeholders providing agricultural products with violations, the downstream stakeholders are willing to assume responsibilities, when a product safety accident occurs, the government regulators should force suppliers take responsibility to reduce their hitchhiking earnings. Similarly, when the product-safety is provided by the upstream stakeholders, not assuming responsibility from the downstream stakeholders, in order to curb free riding behavior and reducing corresponding free-rider gains, raising the purchase threshold and signing accident-responsibility-sharing agreement should be a necessary action to take.
5. The larger the gaps between the two sides of the game, the smaller the upper right area of ADBC is, and the more likely the game results will converge to the (0,0). Conversely, the smaller the gaps between the two sides, the more probabilities of the game results converge to the (1,1), and more possibilities of providing agricultural products with safety, and assuming greater accountability will be. In order to get a rational situation, the cooperation strength between two sides should be equivalent, then it about to converge to the (1,1), and ultimately to achieve stable results.

6.2. Policy Recommendations

According to the above analysis of the game model, the long-term equilibrium outcome of the game may have two distinct states. The final equilibrium point is determined by the value of each parameters in the payoff matrix and the initial state of the game.

6.2.1. Increase the Excess Return

Because of the higher excess returns, the evolutionary game strategy between the upstream and downstream stakeholders of agricultural products supply chain will converge to (1,1) which is the strategy set of (provide agricultural products with safety, assuming responsibilities). Therefore, raising the excess earnings will improve the quality-safety of agricultural products supply chain.

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6.2.2. Reduce Collaboration Costs and Improve Penalty Costs

Due to the cost factor α is smaller, the evolutionary game strategy between the upstream and downstream stakeholders will converge to (1,1). Therefore, reducing the costs of the upstream and downstream stakeholders should make both sides do not have to worry about their benefits from the impact of high costs. It can also avoid the adverse effects for reducing costs by paying the price of cutting the strategy of quality-safety of agricultural products.

6.2.3. Reduce the Relative Size of Cooperative Enterprises

When a node enterprises on an agricultural supply chain to cooperate, along with the increased size of the game between the two sides, the game results will converge to (0,0), namely the set of (provide agricultural products with violations, assume with no responsibilities). The inconsistency of the relative size can easily lead to the problem of earnings gap. To avoid such problems, happen and get a rational situation, the cooperation strength between two sides should be equivalent, so that to avoid the income gap impacts on the quality and safety of the agricultural products supply chain.

6.2.4. Minimize Free-Riding

When the corporate strength between both game sides has any gaps, the free-riding behavior may occur. When the free-riding factor gets higher and higher, the game results will converge to (0,0). Hitchhiking may easily lead to make noncompliance of agricultural products mixed into and then flow to the consumer market, affecting the quality and safety of agricultural products supply chain

6.2.5. Increase Overflow Income

With the effective cooperation carried by both sides of the game on the agricultural supply chain, one side can obtain spillover income from the other side, and the more spillover income, the more possibly the evolutionary game will converge to (1,1). Increasing overflow income can make both sides of the game to promote cooperation in good faith, and also better able to improve the quality and safety of agricultural supply chain.

REFERENCES

Chenxiaolin, & Fengjunwen. (2007). Evolutionary game based study on the quality and safety of agricultural products. *Technical Economy, 26*(11), 79-84.

Cornelia, A. (2011). Farmers' choices in the vegetable supply chain: Problems and possibilities. *Agricultural Economics and Rural Development*. *Institute of Agricultural Economics*, *8*(2), 221–234.

Engle, S. (2006). Over labeling and lobbying: The case of credence goods. *Environmental Modeling and Assessment*, *11*(11), 115–130. doi:10.100710666-005-9030-6

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Folkerts, H., & Koehorst, H. (1998). Challenges in International food supply chains: Vertical co- ordination in the European agribusiness and food industries. *British Food Journal*, *100*(8), 385–388. doi:10.1108/00070709810247762

Frank, S., & Henderson, D. (1992). Transaction costs as determinants of vertical coordination in US food Indus- tries. *American Journal of Agricultural Economics*, *74*(2), 941–950. doi:10.2307/1243192

Gigler, J. K., Hendrix, E. M. T., Heesen, R. A., van den Hazelkamp, V. G. W., & Meerdink, G. (2002). On optimization of agricial by dynamic programming. *European Journal of Operational Research*, *139*(1), 613–625. doi:10.1016/S0377-2217(01)00191-6

Hennessy D.A., Roosen J., Miranowski J.A., & Inra. (2001). Leadership and the provision of save food. A*merican Agricultural Economics Association, 83*(4), 862-874.

Henneta, J. C., & Arda, Y. (2008). Supply chain coordination: A game-theory approach. *Engineering Applications of Artificial Intelligence*, *21*(1), 399–405. doi:10.1016/j.engappai.2007.10.003

Huang, Y., Huang, G. Q., & Newman, S. T. (2011). Coordinating pricing and inventory decisions in a multi-level supply chain: A game-theoretic approach. *Transportation Research Part E, Logistics and Transportation Review*, *47*(2), 115–129. doi:10.1016/j.tre.2010.09.011

Kooten, O. V., Aramyan, L. H., & ... . (2007). Performance Measurement in agri-food Supply Chains: A case study. *Supply Chain Management: An International Journal*, *12*(4), 304–315. doi:10.1108/13598540710759826

Liying. (2011). Theoretical and empirical study on the agriculture-supermarket jointing in China. Liaoning, Shenyang Agricultural University.

Maze, B. A., Polin, S., Raynaud, E., Sauvee, L., & Valceschini, E. (2001). Quality signals and governance structures within European agro-food chains: A new institutional economics approach. *Paper presented at the 78th EAAE Seminar and NJFSeminar330, Economics of Contracts in Agriculture and the Food Supply Chain*, Copenhagen (pp. 15-16).

Pouliot S, &Summer D.A. (2008). Traceability, liability, and incentives for food safety and quality. *American Agricultural Economics Association, 90*(1), 15-27.

Reynolds, N., Fischer, C., & Hartmann, M. (2009). Determinants of sustainable business relationships in selected German agri-food chain. *British Food Journal*, *111*(8), 776–793. doi:10.1108/00070700910980919

Tatum, J. D., Belk, K. E., George, M. H., & Smith, G. C. (1999). Identification of quality management practices to reduce the incidence of retail beef tenderness problems: Development and evaluation of a prototype quality system to produce tender beef. *Journal of Animal Science*, *77*(5), 2112–2118. doi:10.2527/1999.7782112x PMID:10461989

Veen-Dirks, P. M. G. V., & Verdaasdonk, P. F. A. (2009). The dynamic relation between management and control and government structure in a supply Chain context. *Supply Chain Management: An International Journal*, *14*(6), 466–478. doi:10.1108/13598540910995237

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Wangshuang, Liugaosheng et al. (2013). Evolutionary game based analysis of food safety. *Macro management, 5*(3), 1-3.

Xieruiying, & Wangjining. (2012). Evolutionary game based analysis on the behavior of producers and sellers in food safety chain. *Communication of Finance and Accounting, 12*(7), 144-146.

Xinglijuan, & Tianshuangliang. (2011). The analysis of evolutionary game on the behavior of food safety supervision. *Journal of Chongqing University of Arts and Sciences (Natural Science Edition), 30*(1), 13-16.

Yangkun, & Qiqinghua. (2012). Game model based research of food safety regulatory in China. *Journal of Wuhan Polytechnic University, 31*(2), 77-80.

Yangqing, & Shiyaneng. (2011). Evolutionary game based analysis on the food safety supervision. *Journal of Wuhan University of technology (information engineering edition), 33*(4), 670-672.

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Chapter 21
IoT Based Agriculture as a Cloud and Big Data Service: The Beginning of Digital India

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ABSTRACT

Cloud computing has transpired as a new model for managing and delivering applications as services efficiently. Convergence of cloud computing with technologies such as wireless sensor networking, Internet of Things (IoT) and Big Data analytics offers new applications of cloud services. This paper proposes a cloud-based autonomic information system for delivering Agriculture-as-a-Service (AaaS) through the use of cloud and big data technologies. The proposed system gathers information from various users through preconfigured devices and IoT sensors and processes it in cloud using big data analytics and provides the required information to users automatically. The performance of the proposed system has been evaluated in Cloud environment and experimental results show that the proposed system offers better service and the Quality of Service (QoS) is also better in terms of QoS parameters.

1. INTRODUCTION

Emergence of ICT (Information and Communication Technologies) plays an important role in the agriculture sector by providing services through computer-based agriculture systems (Singh and Chana, 2015). But these agriculture systems are not able to fulfill the needs of today's generation due to processing of large amount of data, lack of important requirements like processing speed, data storage space, reliability, availability, scalability etc. and even resources used in computer-based agriculture systems are not utilized

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efficiently. Agriculture-as-a-Service (AaaS) applications exhibit Big data characteristics. For example, the volume of agriculture dataset captured by environments such as Open Government Data Platform India (data.gov.in, 2015), India Agriculture and Climate Data Set (Sanghi et al.), and regional land and climate modelling in China (Shangguan et al., 2012) can be in order of 1000000 records with size of 3.5 GB. The data is coming in large data variety and volume from both users in the form of images like damaged crop images due to weather, insects etc. and devices through Internet of Things (IoT) sensors and satellites (GPS systems) that send weather related images. As a result of regular capturing and collection of datasets, they grow with the velocity of 80.72 KB/minute or more (data.gov.in, 2015). To solve the problem of existing agriculture systems, there is a need to develop a cloud-based service that can easily manage different types of agriculture related-data based on different domains (crop, weather, soil, pest, fertilizer, productivity, irrigation, cattle, and equipment) through these steps: i) gather data from various sensors through preconfigured devices, ii) classify the gathered data (heterogeneous, high volume of big data) into various classes through analysis, iii) store the classified information in cloud repository for future use, and iv) automatic diagnosis of the agriculture status. As large number of users are using agriculture systems operating on large datasets simultaneously, there is a need of highly scalable and elastic distributed computing environment such as cloud computing. In addition, cloud-based autonomic information system should be able to identify the QoS (Quality of Service) requirements of user request and resources should be allocated efficiently to execute the user request based on these requirements.

The main aim of this paper is to design architecture of Agriculture-as-a-Service (AaaS) that manages various types of agriculture-related data based on different domains. This is realized through the following objectives: i) propose an autonomic resource management technique which is used to a) gather the information from various users through preconfigured devices, IoT sensors, GPS (Global Positioning System), etc. b) extract the attributes, c) analyze the information by creating various classes based on the information received, d) store the classified information in cloud repository for future use and e) diagnose the agriculture status automatically and ii) perform resource allocation automatically at infrastructure level after identification of QoS requirements of user request.

The rest of the paper is organized as follows. Section 2 presents related work of existing agricultures systems. Proposed architecture is presented in Section 3. Section 4 presents Autonomic Resource Management. Sections 5 describe the experimental setup and present the results of evaluation. Section 6 presents conclusions and future scope.

2. RELATED WORK

Existing research reported that few agriculture systems have been developed with limited functionality. Related work of existing agriculture systems has been presented in this section.

2.1. Existing Agriculture Systems

Ranya et al. (2013) presented ALSE (Agriculture Land Suitability Evaluator) to study various types of land to find the appropriate land for different types of crops by analyzing geo-environmental factors. ALSE used GIS (Global Information System) capabilities to evaluate land using local environment conditions through digital map and based on this information decisions can be made. Raimo et al. (2010) proposed FMIS (Farm Management Information System) used to find the precision agriculture requirements for

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information systems through web-based approach. Author identified the management of GIS data is a key requirement of precision agriculture. Sorensen et al. (2010) studied the FMIS to analyze dynamic needs of farmers to improve decision processes and their corresponding functionalities. Further they reported that identification of process used for initial analysis of user needs is mandatory for actual design of FMIS. Zhao (2002) presented an analysis of web-based agricultural information systems and identified various challenges and issues still pending in these systems. Due to lack of automation in existing agriculture system, the system is taking longer time and is difficult to handle dynamic needs of user which leads to customer dissatisfaction. Sorensen et al. (2011) identified various functional requirements of FMIS and information model is presented based on these requirements to refine decision processes. They identified that complexity of FMIS is increasing with increase in functional requirements and found that there is a need of autonomic system to reduce complexity. Yuegao et al. (2004) proposed WASS (Web-based Agricultural Support System) and identified functionalities (information, collaborative work and decision support) and characteristics of WASS. Based on characteristics, authors divided WASS into three subsystems: production, research-education and management.

Reddy at el. (1995) proposed GIS based DSS (Decision Support System) framework in which Spatial DDS has been designed for watershed management and management of crop productivity at regional and farm level. GIS is used to gather and analyze the graphical images for making new rules and decisions for effective management of data. Shitala et al. (2013) presented mobile computing based framework for agriculturists called AgroMobile for cultivation and marketing and analysis of crop images. Further, AgroMobile is used to detect the disease through image processing and also discussed how dynamic needs of user affects the performance of system. Seokkyun et al. (2013) proposed cloud based Disease Forecasting and Livestock Monitoring System (DFLMS) in which sensor networks has been used to gather information and manages virtually. DFLMS provides an effective interface for user but due to temporary storage mechanism used, it is unable to store and retrieve data in databases for future use. The proposed QoS-aware Cloud Based Autonomic Information System (AaaS) has been compared with existing agriculture systems as described in Table 1.

All the above research works have focused on different domains of agriculture with different QoS parameters. None of the existing agriculture systems considers self-management of resources. Due to

Table 1. Comparisons of existing agriculture systems with proposed system (AaaS)

Agriculture System	Mechanism	QoS-aware (Parameter)	Domains	Data Classification	Resource Management	Big Data
ALSE (Elsheikh et al., 2013)	Non-Autonomic	**Yes** (Suitability)	Soil	Yes	No	No
FMIS (Nikkila et al., 2010)	Non-Autonomic	**No**	Pest and Crop	No	No	No
WASS (Hu et al., 2004)	Non-Autonomic	**No**	Productivity	No	No	No
AgroMobile (Prasad et al., 2013)	Non-Autonomic	**Yes** (Data accuracy)	Crop	Yes	No	No
DFLMS (Jeong et al., 2013)	Non-Autonomic	**No**	Crop	No	Yes	No
Proposed System (AaaS)	Autonomic	**Yes** (Cost, Time, Resource Utilization, Latency, Throughput and Attack Detection Rate)	Crop, Weather, Soil, Pest, Fertilizer and Irrigation	Yes	Yes	Yes

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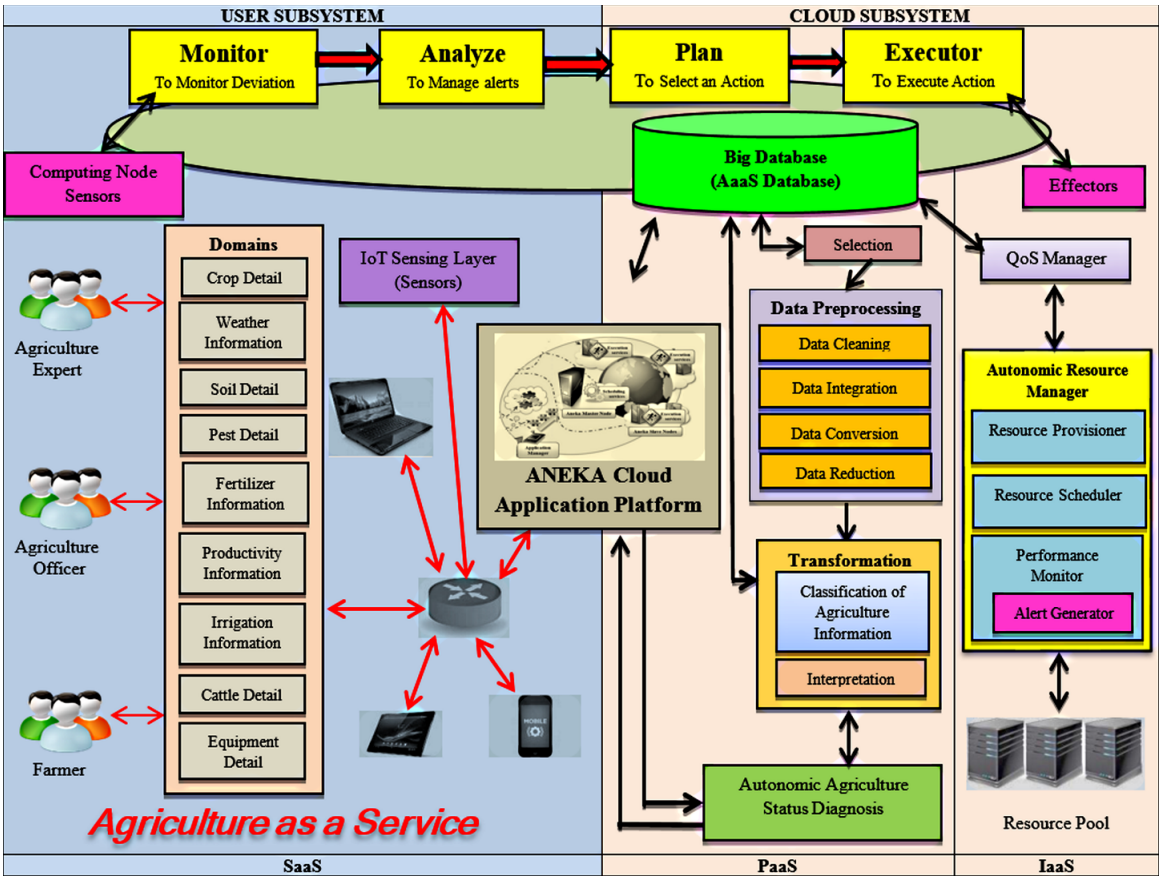
lack of automation of resource management, services become inefficient which further leads to customer dissatisfaction. The proposed system is a novel QoS-aware cloud based autonomic information system and considers various domains of agriculture and, allocates and manages the resources automatically which is not considered in other existing agriculture systems.

3. AGRICULTURE-AS-A-SERVICE ARCHITECTURE

The existing agriculture systems are not able to fulfill the needs of today's generation due to lacking in important requirements like processing speed, data storage space, reliability, availability, scalability etc. Even resources used in computer based agriculture systems are not utilized efficiently. To solve the problem of existing agriculture systems, there is a need to develop a cloud-based autonomic information system that delivers Agriculture-as-a-Service. This section presents architecture of cloud-based autonomic information system for agriculture service called *AaaS* that manages various types of agriculture-related data based on different domains. Architecture of AaaS is shown in Figure 1. QoS parameters (execution time and cost) must be identified before the allocation of resources. AaaS is the key mechanism that

Figure 1. Agriculture-as-a-Service architecture



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ensures that the resource manager can serve large amount of requests without violating SLA terms and dynamically manages the resources based on QoS requirements identified by QoS manager. The services of AaaS has been divided into three types: SaaS (Software as a Service), PaaS (Platform as a Service) and IaaS (Infrastructure as a Service). In SaaS, a user interface is designed in which users can interact with system. Aneka is a .NET-based application development PaaS, which is used as a scalable cloud middleware to make interaction between cloud subsystem and user subsystem. In IaaS, an autonomic resource manager manages the resource automatically based on the identified QoS requirements of a particular request. The architecture of AaaS comprises of two subsystems: i) user and ii) cloud.

3.1. User Subsystem

This subsystem provides a user interface, in which different type of users interact with AaaS to provide and get useful information about agriculture based on different domains. Nine types of information of different domains in agriculture has been considered: crop, weather, soil, pest, fertilizer, productivity, irrigation, cattle, and equipment. Users are basically classified in three categories: i) agriculture expert, ii) agriculture officer, and iii) farmer. The agriculture expert shares professional knowledge by answering farmer queries and updates the AaaS database based on the latest research done in the field of agriculture with respect to their domain. Agriculture officers are the government officials that provide the latest information about new agriculture policies, schemes, and rules passed by the government. Farmer is an important entity of AaaS who can take maximum advantage by asking his queries and getting automatic reply after analysis. Users can monitor any data related to their domain and get their response without visiting the agriculture help center. It integrates the different domains of agriculture with AaaS. The queries received from user(s) are forwarded to cloud repository for updates and response sends back to particular user on their preconfigured devices (tablets, mobile phones, laptops etc.) via internet.

3.2. Cloud Subsystem

This subsystem contains the platform in which agriculture service is hosted on a cloud. Details about users and agriculture information are stored in a cloud repository in different classes for different domains with unique identification number. The information is monitored, analyzed, and processed continuously by AaaS. The analysis process consists of various sub processes: selection, data preprocessing, transformation, classification and interpretation as shown in Figure 1. Different classes for every domain and sub classes for further categorization of information have been designed. In storage repository, user data is categorized based on different predefined classes of every domain. This information is further forwarded to agriculture experts and agriculture officers for final validation through preconfigured devices. Further, a number of users can use cloud-based agriculture service so the QoS manager and autonomic resource manager in cloud subsystem have been integrated. QoS manager identifies the QoS requirements based on the number and type of user queries as discussed in previous research work (Jeong et al., 2013; Singh and Chana, 2015; Singh et al., 2015). Based on QoS requirements, autonomic resource manager identifies resource requirements automatically and allocates and executes the resources at infrastructure level. Performance monitor is used to verify the performance of system and also maintain it automatically. If the system will not be able to handle the request automatically then the system generates an alert.

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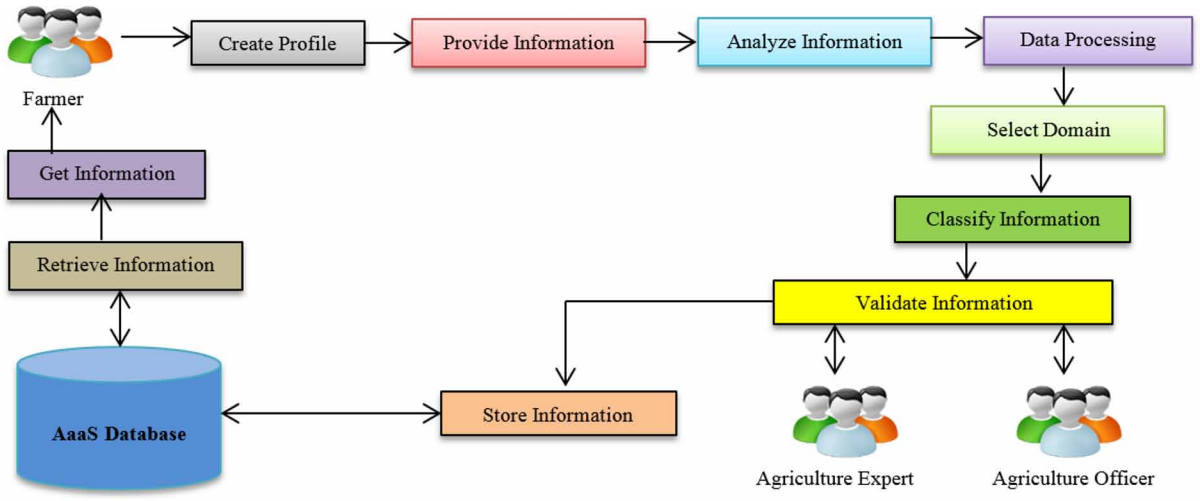
3.2.1. Cloud-Based Agriculture Service

Cloud-based agriculture service provides a user platform through which user can access agriculture service as shown in Figure 2. Firstly, agriculture service allows user to create profile for interaction with AaaS. After profile creation, the user is required to provide his personal details along with the details of information domain. AaaS analyses the information to verify whether the data is complete or not for further processing by performing various checks. Further data is processed and redundancy of data is removed and data is used to select domain to which data belongs. Information is classified properly in order with unique identification number. This information is forwarded to agriculture experts and agriculture officers for final validation through preconfigured devices. After successful validation of information, it is stored in *AaaS* database. If user wants to know the response of their query, then system will automatically diagnose the user query and send the response back to that user.

3.2.2. Detailed Methodology

AaaS allows users to upload the data related to different domains of agriculture through preconfigured devices and classified them based on the domains specified in database. Subtasks of information gathering and provided in AaaS are: i) selection, ii) preprocessing, iii) transformation, iv) classification and v) interpretation. In *selection*, target datasets are created based on the relevant information that will further be considered for analysis in next sub process. In *preprocessing*, different users have different information regarding agriculture. To develop a final training set, there is need of preprocessing steps because data might contain some missing sample or noise components. In AaaS, data preprocessing contains four different sub processes: i) data cleaning, ii) data integration, iii) data conversion and iv) data reduction. Data *transformation* provides an interface between data analysis sub process (classification) and data preprocessing. After data preprocessing, this process converts the labeled data into adequate format suitable for classification. In *classification*, AaaS classify the agriculture information of different users of different domains based on the extracted data. K-NN (k-Nearest Neighbor) classification mechanism

Figure 2. Functional aspects of AaaS



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has been used in this research work to identify the different class labels of users. K-NN is supervised machine learning technique which is used to classify the unknown data using training data set generated by it. K-NN used to identify the productivity level through Training Instance Dataset (TID). Figure 3 describes the K-NN Algorithm.

In K-NN algorithm, distance is computed from one specific instance to every training instance to classify that unknown instance. Both k-nearest neighbor and *k* minimum distance is determined and output class label is identified among *k* classes. During training phase, K-NN Algorithm utilizes training data. Figure 4 illustrates the classification process used in this research work.

K-NN model is used to identify the productivity level through Training Instance Dataset (TID). Five levels of productivity (A - E) have been fixed as shown in Table 2. The level *'A'* indicates the productivity is very high while level *'E'* indicates the productivity is very low. Based on the given information, TID identifies the class in which given data belongs.

Figure 3. Pseudo code of K-NN algorithm

Algorithm 1: K-NN Algorithm

Learning Phase:

To create the Training Instance Dataset (TID)

Classification Phase:

for every unknown instance dp_a

1. Identify dp_1, dp_2, ... dp_k, the k most nearest instances from TID, where dp_1, dp_2, ... dp_k, are *data points* $\in$ *region (r).*
2. Set class label (cl) is equal to most repeated cl of k nearest instances.
3. Return cl

end for

Figure 4. Classification process

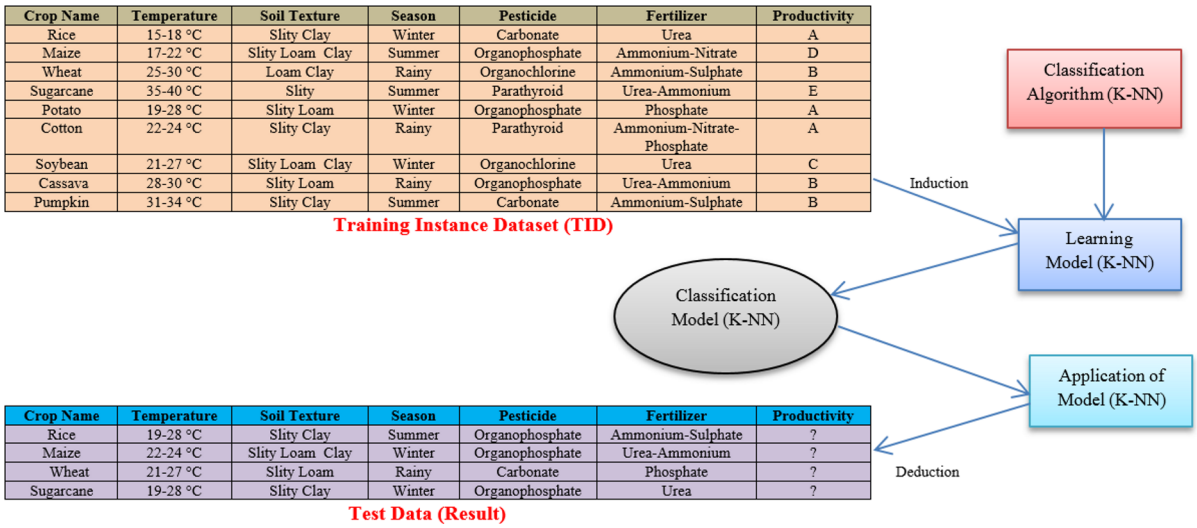

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Table 2. Productivity Levels

Productivity Level	Description
A	Very High Productivity
B	High Productivity
C	Neutral Productivity
D	Low Productivity
E	Very Low Productivity

Test data is an input of this model and it is compared with TID and identifies the class in which data laid using following rule:

Rule: **If** {Crop Name ^ Temperature ^ Soil Texture ^ Season ^ Pesticide ^ Fertilizer} **then** *Productivity*

The final step is to *interpret* the agriculture data submitted by different users of different domains which helps user to understand the classified datasets. AaaS is capable to diagnose the agriculture status based on the information entered by user and send the diagnosed agriculture status to particular user automatically. Six attributes have been considered: Crop Name, Temperature, Soil Texture, Season, Pesticide and Fertilizer and one output: Productivity. Based on these six attributes, AaaS designs rules. Values for six variables are considered as TID. For example, refer to Table 3.

AaaS uses the rule shown in Table 3 to find the productivity level using TID (see Table 4).

Similarly, any type of query related to different domains can be asked by users and AaaS executes the user query and send response back to particular user automatically based on the rules defined in *AaaS* database. Through AaaS, users can easily diagnose the agriculture status automatically.

3.2.3. Infrastructure Management (IaaS)

Efficient management of infrastructure in cloud is mandatory to maintain the performance of the Agri-Info. It comprises of two sub units: QoS Manager and Resource Manager.

Table 3. User wants to retrieve the productivity level using AaaS

User Query						
Crop Name	**Temperature**	**Soil Texture**	**Season**	**Pesticide**	**Fertilizer**	**Productivity**
Soybean	21-27 °C	Slity Loam Clay	Winter	Organochlorine	Urea	?

Table 4. AaaS response utilized to in order to find the productivity level using TID

AaaS Response						
Crop Name	**Temperature**	**Soil Texture**	**Season**	**Pesticide**	**Fertilizer**	**Productivity**
Soybean	21-27 °C	Slity Loam Clay	Winter	Organochlorine	Urea	**C**

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3.2.3.1. QoS Manager

User submits a request to Agri-Info to retrieve some specific agriculture related information. Agri-Info identifies the QoS parameters required to process the user request through analysis based on user request. Based on the key QoS requirements of a particular user request, the *QoS Manager* puts the user request into critical and non-critical queues through QoS assessment. For QoS assessment, *QoS Manager* will calculate the execution time of user request and find the approximate user request completion time. If the completion time is lesser than the desired deadline then it will execute immediately with the available resources and release the resource(s) back to resource manager for another execution otherwise calculate extra number of resources required and provide from the reserved stock for current execution.

3.2.3.2. Resource Manager

Further, two resource scheduling policies (Singh and Chana, 2015) are used to schedule the resources for execution of user queries: time based and cost based scheduling policy. *Time based scheduling policy* works as per following: First, the allocation agent begins to compute the Deadline Time of the user request in the given budget. Allocate resources based on time, the user request which has shortest Deadline Time will execute first. If the two requests have same deadline time then that request will execute first that has lesser execution time. The allocation agent then schedules all the requests with smallest execution time request to the resources that provide high QoS. The rules for time based scheduling policy are described in Table 5 along with their conditions.

Cost based scheduling policy works as per following: First, the allocation agent begins to compute the cost of each request then sort, as the priority is given to the request which has maximum budget. If the two requests have same budget then that request will execute first that has lesser execution time. The allocation agent then schedules all the requests with high budget request to the resources that provide high QoS. Finally, all other requests are scheduled on the available resources set. The rules for cost based scheduling policy are described in Table 6 along with their conditions.

4. AUTONOMIC RESOURCE MANAGEMENT

Working of autonomic element of Agri-Info is based on IBM's autonomic model that considers four steps of autonomic system: i) monitor, ii) analyze, iii) plan and iv) execute as shown in Figure 1. The objective of resource provisioning in autonomic resource management is to provision the resources to process user requests. The requests submitted should be executed within their budget and deadline. Requests submitted by user to resource provisioner are stored as bulk of workloads for their execution.

Table 5. Rules of time based resource scheduling

Request Pending	Urgency	Add Resource	Request
Yes	Yes	Reserve	Submit
Yes	No	Available	Submit
No	-	-	Finish

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Table 6. Rules of cost based resource scheduling

Request Pending	$R_A > 0$	$E_t > W_d$	$B_A > P_r$	Status
Yes	True	True	True	Add Resource
Yes	False	True	True	Add Resource
No	-	-	-	Finish
Yes	True	False	True	Finish
Yes	True	True	False	Finish

R_A = Resource Available, E_t = Estimated Time, P_r = Resource Price, W_d = Desired Deadline and B_A = Available Budget.
Details of both time and cost based scheduling policy is given in previous research work (Singh and Chana, 2015).

All the submitted workloads are analyzed based on their QoS requirements. Based on importance of the attribute, weights for every cloud workload are calculated. After that, workloads are clustered based on k-means based clustering algorithm for better resource provisioning (Singh et al., 2015). If the value of workloads executes within deadline and budget and [Resource Consumption and Requests Missed is lesser than Threshold Value] then it will provision resources otherwise generate alert for analyses the workload again.

After successful provisioning of resources, Resource Scheduler (RS) takes the information from the appropriate workload after analyzing the various workload details which user request demanded (Singh and Chana, 2015). Knowledge Base contains details of all the resources available in resource pool and reserve resource pool. Based on Cloud consumer details, RS assigns resources and executes Cloud workloads. During execution of a particular cloud workload, the Resource Executor (RE) will check the current workload. If the resources are sufficient for execution then it will continue with execution otherwise request for more resources. If the value of Resource Consumption and Requests Missed is lesser than threshold value, then RE will execute workloads otherwise RE will generate alert. After successful execution of Cloud workloads, RE releases the free resources to resource pool and RE is ready for execution of new cloud workloads. During execution of user requests, performance is monitored continuously using sub unit performance monitor to maintain the efficiency of Agri-Info and generates alert in case of performance degradation. Alerts can be generated in two conditions generally: i) if resource consumption is more than threshold values of resource consumption to execute user request (*Action:* Reallocates resources) and ii) if the number of missed requests are greater than the threshold value (*Action*: Predict QoS Requirements Again). Same action is performed twice, if Agri-Info fails to correct it then system will be treated as down. Components of autonomic system are described below:

4.1. Sensors

Sensors get the information about performance of other nodes using in the system and their current state. Firstly, the updated information from processing nodes is transfer to manager node then manager node transfers this information to sensors. Updated information includes information about QoS parameters (execution time, execution cost and resource utilization etc.).

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4.2. Monitor

Initially, Monitors are used to collect the information from sensors for monitoring continuously performance variations by comparing expected and actual performance, and monitors the value of resource consumption and missed requests. Actual information about performance is observed based QoS parameters and transfers this information to next module for further analysis.

4.3. Analysis and Plan

Analyze and plan module start analyzing the information received from monitoring module and make a plan for adequate actions for corresponding alert. Following formula is used to calculate Resource Consumption (Equation 1):

$$Resource_{Consumption} = \sum_{i=1}^{n} \left(\frac{\text{Actual Resource Usage}}{\text{Predicted Resource Usage}} \right) \tag{1}$$

where $\text{Actual Resource Usage}$ is usage of resource to execute particular number of user requests and $\text{Predicted Resource Usage}$ is resource usage estimated before actual execution and *n* is the number of resources. Assumed: $\left[\text{Predicted Resource Usage} \leq \text{Actual Resource Usage}\right]$. Value of $ResourceConsumption$. is more than 1 generally because $\text{Actual Resource Usage}$ is more than $\text{Predicted Resource Usage}$ but ideally it will be 1 when both are equal. In this research rk, maximum values for $ResourceConsumption$ has been fixed and that is called threshold value. Following formula is used to calculate number of requests missed $\left(Requests_{Missed}\right)$ in a particular period of time (Equation 2):

$$Requests_{Missed} = [Number\ of\ Requests\ Executed\ Successfully - Number\ of\ Requests\ Missed\ Deadline] \tag{2}$$

For successful execution of resources, value of $Requests_{Missed}$ is lesser than threshold value. Algorithm 1 is used to analyses the performance of management of resources.

With the help of (Equation 1) and (Equation 2), resource consumption is calculated and allocates the resources for execution and then compares the resource consumption with threshold value $\left(Th_c\right)$. If resource consumption is less than threshold value and value of $Requests_{Missed}$ is less than threshold value $\left(Th_m\right)$ then execution of resources continues otherwise no resource is allocated and process of reallocation is started using Algorithm 1. After meeting this condition, resources are allocated for further execution and value of resource consumption and $Requests_{Missed}$ are checked periodically. In case of more value than threshold, alert will be generated by performance monitor.

4.4. Executor

Executor implements the plan after analyzing completely. To reduce the execution time and execution cost and improve resource utilization is a main objective of executor. Based on the output given by

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Algorithm 1. Analyzing and Panning Unit (AU)

1. ***# AUTONOMIC ANALYZING AND PANNING***
2. **if** (Required Resources > Provided Resources) **then**
   Allocate new resource from reserve resource pool with minimum $Resource_{consumption}$ and $Requests_{Missed}$ and [$Resource_{consumption} \leq Th_c$ && $Requests_{Missed} \leq Th_m$]
3. **end if**
4. **for all** resources
5. **if** ($Resource_{consumption} \leq Th_c$ && $Requests_{Missed} \leq Th_m$) == '*FALSE'* **then**
6. Restart the resource and start execution
7. **else if**
8. Declared resource as dead node and removed
9. Resource(s) is required to process data without degradation in performance
10. **if** (Availability of Resource(s) == '*TRUE')*
    Allocate new resource from resource pool with minimum $Resource_{consumption}$ and $Requests_{Missed}$ and [$Resource_{consumption} \leq Th_c$ && $Requests_{Missed} \leq Th_m$]
    else
11. Resource(s) is required to process data without degradation in performance
    Add new resource from reserve resource pool with minimum $Resource_{consumption}$ and $Requests_{Missed}$ and [$Resource_{consumption} \leq Th_c$ && $Requests_{Missed} \leq Th_m$]
12. **end if**
13. **end for**

analysis and executor tracks the new user request submission and resource addition, and take the action according to rules described in knowledge base.

4.5. Effector

Effector is used to exchange updated information and it is used to transfer the new policies, rules and alerts to other nodes with updated information.

5. PERFORMANCE EVALUATION

The aim of this performance evaluation is to demonstrate that it is feasible to implement and deploy the agriculture as a service on real cloud resources. Tools used for setting up cloud environment for performance analysis are Microsoft Visual Studio 2010 (SaaS), Aneka (PaaS), SQL Server 2008, and Citrix Xen Server (IaaS). Aneka has been installed along with its requirements on all the nodes that provide cloud service. Nodes in this system can be added or removed based on the requirement. AaaS is installed on main server and tested on virtual cloud environment that has been established at *CLOUDS Lab, University of Melbourne, Australia*. Different number of virtual machines have been installed on different servers, and deployed the AaaS to measure the variations. In this experimental setup, three different cloud platforms are used: Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS) as shown in Figure 5.

At ***SaaS level***, Microsoft Visual Studio is used to develop e-agriculture web service to provide user interface in which user can access service from any geographical location. At ***PaaS level***, Aneka cloud application platform is used as a scalable cloud middleware to make interaction between IaaS and SaaS, and continually monitor the performance of the system. At ***IaaS level***, three different servers (consist of virtual nodes) have been created through Citrix Xen Server and SQL Server has been used for data storage. Scheduler as shown in Figure 5, runs at IaaS level on Citrix Xen Server. Computing

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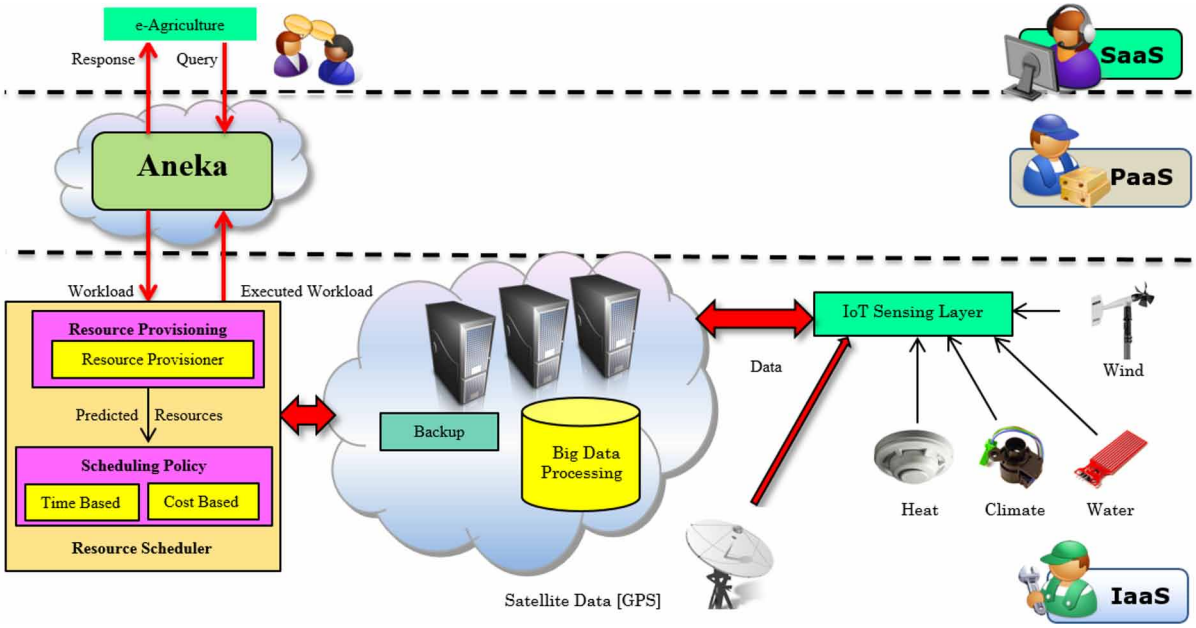
Figure 5. Deployment of components at runtime and their interaction



nodes used in this experiment work are further categorized into three categories as shown in Table 7. The execution cost is calculated based on user request and deadline (if deadline is too early (urgent) it will be more costly because there is a need of greater processing speed and free resources to process particular request with urgency). There is individual price is fixed (artificially) for different resources because all the resources are working in coordination manner to fulfill the demand of user (demand of user is changing dynamically).

Experiment setup using 3 servers in which further virtual nodes (12 = 6 (Server 1) +4 (Server 2) +2 (Server 3)) are created. Every virtual node has different number for Execution Components (ECs) to process user request and every EC has their own cost (C$/EC time unit (Sec)). Table 1 shows the characteristics of the resources used and their Execution Component (EC) access cost per time unit in Cloud dollars (C$) and access cost in C$ is manually assigned for experimental purposes. The access cost of an EC in C$/time unit does not necessarily reflect the cost of execution when ECs have different

Table 7. Configuration Details of Cloud Environment

Resource_Id	Configuration	Specifications	Operating System	Number of Virtual Node	Number of ECs	Price (C$/EC Time Unit)
R1	Intel Core 2 Duo - 2.4 GHz	1 GB RAM and 160 GB HDD	Windows	6	18	2
R2	Intel Core i5-2310-2.9GHz	1 GB RAM and 160 GB HDD	Linux	4	12	3
R3	Intel XEON E 52407-2.2 GHz	2 GB RAM and 320 GB HDD	Linux	2	6	4

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capabilities. The execution agent needs to translate the access cost into the C$ for each resource. Such translation helps in identifying the relative cost of resources for executing user requests on them. Due to limited number of resources, cost increases with increase in user requests. Cost is varying in two different cases: i) relaxed deadline and ii) tight deadline. In both cases, when the deadline is low (e.g. 200 secs), the number of user requests processed increases as the budget value increases. When a higher budget is available, the execution agent uses expensive resources to process more user requests within the deadline. Alternatively, when scheduling with a low budget, the number of user requests processed increases as the deadline is relaxed. Different number of experiments has been performed by comparing AaaS (QoS-aware Autonomic) as discussed in *Section 4* with non-autonomic resource management technique (non-autonomic) in which no autonomic scheduling mechanism is considered while allocating resources to process the user requests.

5.1. Datasets

Datasets used in this research work are downloaded from the Open Government Data Platform India (data.gov.in, 2015), India Agriculture and Climate Data Set (Sanghi et al.), and regional land and climate modelling in China (Sanghi et al.) can be in the order of 1000000 records, with size of 3.5 GB. The data is coming in large data variety and volume from both users in the form of images like damaged crop images due to weather, insects etc. and devices through Internet of Things (IoT) sensors and satellites (GPS systems) that send weather related images. As a result of regular capturing and collection of datasets, they grow with the velocity of 80.72 KB/minute or more (Sanghi et al.). Five different tables used to process the different types of data as described in Table 8 to Table 12.

Table 8. Crop Information

CropId	Crop Name	Crop Type	Soil Texture	Min Land	Growing Period	Seed Type	Price	Quantity
C1	Rice	Kharif	Slity Clay	5 Acre	3 Months	Wet	1200 Rs./Kg	2 Kg/Acre
C2	Maize	Rabi	Slity Loam Clay	4 Acre	4 Months	Dry	1600 Rs./Kg	1 Kg/Acre
C3	Wheat	Zaid	Loam Clay	3 Acre	3 Months	Wet	1000 Rs./Kg	2 Kg/Acre
C4	Sugarcane	Cash	Slity	4 Acre	6 Months	Dry	800 Rs./Kg	6 Kg/Acre

Table 9. Weather information

Crop Name	Temperature	Season	Pressure (CFM)	Wind Speed	Rainfall	Location
Rice	15-18 °C	Winter	0.75 to 1.5	16 Km/h	300–650 mm	Ambala
Maize	17-22 °C	Summer	0.05 to 0.5	12 Km/h	100–150 mm	Amritsar
Wheat	25-30 °C	Rainy	1.5 to 5.2	17.3 Km/h	200–250 mm	Ganga Nagar
Sugarcane	35-40 °C	Summer	1 to 10	8 Km/h	400–600 mm	Pathankot

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Table 10. Soil information

Soil Texture	Bulk Density	Inorganic Material	Organic Material	Water	Air	Color	Structure	Infiltration
Slity Clay	2.60 to 2.75 grams per cm^3	Sand and clay	Plant and animal residues	25%	28%	Brown	Plate-like	15 mm/hour
Slity Loam Clay	2.7 to 2.75 grams per cm^3	Sand and Slit	Animal residues	22%	18%	Red	Prism-like	10 mm/hour
Loam Clay	2.60 to 2.75 grams per cm^3	Clay and Slit	Plant residues	37%	21%	Brown	Block like	18 mm/hour
Slity	2.60 to 2.75 grams per cm^3	Sand, Slit and Clay	Plant and animal residues	31%	29%	Black	Sphere like	22 mm/hour

Table 11. Pest information

Crop Type	Crop Disease	Effect	Treatment	Pesticide Name	Solubility in Water	Price	Outcome
Kharif	Bacterial brown spot	Degrade soil fertility	Reduce Irrigation	Carbonate	Yes	Rs. 1500/L	Improve Productivity
Rabi	Zonate eye spot	Degrade productivity	Distribute Soil	Organophosphate	No	Rs. 2200/L	Improve soil fertilization
Zaid	Dwarf bunt	Increase risk of other disease	Spray irrigation	Parathyroid	Yes	Rs. 2300/L	Reduce risk of other diseases
Cash	Ergot	Degrade productivity	Drip Irrigation	Parathyroid	Yes	Rs. 1800/L	Reduce productivity

Table 12. Fertilizer information

Crop Type	Fertilizer Name	Nutrient Composition	Price
Kharif	Urea	Nitrogen in form of urea (amide) (N)	7000 Rs./10 Kg
Rabi	Ammonium-Nitrate	Ammoniacal Nitrogen, Nitrogen Nitrate and Urea Nitrogen	9100 Rs./10 Kg
Zaid	Ammonium-Sulphate	Ammoniacal nitrogen and Sulpher	6200 Rs./10 Kg
Cash	Urea-Ammonium	Ammoniacal nitrogen and Neutral ammonium citrate Soluble phosphate	13200 Rs./10 Kg

5.2. Performance Metrics

The following metrics are used to calculate the execution cost, execution time, resource utilization, latency, detection rate and scalability for processing user requests as taken from previous work (Singh and Chana, 2015; Singh et al., 2015; Singh and Chana, 2016):

Execution Time is a ratio of difference of request finish time $\left(WF_i\right)$ and request start time $\left(WStart_i\right)$ to number of requests. Following formula is used to calculate Execution Time (ET) (Equation 3):

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$$ET_i = \sum_{i=1}^{n} \left(\frac{WF_i - WStart_i}{n} \right) \tag{3}$$

where n is the number of requests to be executed.

Execution Cost is defined as the total amount of cost spent per one hour for the execution of request and measured in Cloud Dollars (C$). Following formula is used to calculate execution cost (C) (Equation 4):

$$C = ET_i \times Price \tag{4}$$

Latency is a defined as a difference of time of input cloud workload and time of output produced with respect to that workload. Following formula is used to calculate Latency (Equation 5):

$$Latency_i = \sum_{i=1}^{n} \left(time\ of\ output\ produced\ after\ execution - time\ of\ input\ of\ cloud\ workload \right) \tag{5}$$

where *n* is number of workloads.

Resource Utilization is defined as a ratio of actual time spent by resource to execute workload to total uptime of resource for single resource. Following formula is used to calculate resource utilization (Equation 6):

$$ResourceUtilization_i = \sum_{i=1}^{n} \left(\frac{actual\ time\ spent\ by\ resource\ to\ execute\ workload}{total\ uptime\ of\ resource} \right) \tag{6}$$

where *n* is number of workloads.

Security is measured in terms of detection rate. Experiment has been conducted with different type of attacks (DoS, R2L, U2R and Probing) and different tools used to launch different attacks are metasploit framework for DoS, Hydra for R2L, NetCat for L2R and NMAP for probing. *Detection Rate* is the ratio of total number of true positives to the total number of intrusions (Sorensen et al., 2010):

$$Detection\ Rate = \frac{Total\ Number\ of\ True\ Positives}{Total\ Number\ of\ Intrusions} \tag{7}$$

Scalability is measured in terms of throughput. It is the ratio of total number of workloads to the total amount of time required to execute the workloads. Following formula is used to calculate throughput (Equation 8):

$$Throughput = \frac{\text{Total Number of Workloads} \left(W_n \right)}{Total\ amount\ of\ time\ required\ to\ execute\ the\ workloads \left(W_n \right)} \tag{8}$$

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5.3. Experimental Results

Experiment has been conducted with 180 user requests for verification of execution cost, execution time, resource utilization, latency, detection rate and scalability. With increasing the number of user requests, the value of latency is increasing. The value of latency in QoS-aware autonomic system is lesser as compared to non-autonomic based resource scheduling at different number of user requests as shown in Figure 6. The maximum value of latency is 193 seconds and minimum value of latency is 59 seconds in QoS-aware autonomic resource management technique. Average latency in QoS-aware autonomic is 15.22% lesser than non-autonomic resource management technique. The value of average cost for both QoS-aware cloud based autonomic resource management technique and non-autonomic resource management is calculated with different number of user requests as shown in Figure 7. Average cost is increasing with increase in number of user requests. At 180 user requests, average cost in QoS-aware autonomic is 25.36% lesser than non-autonomic resource management technique. QoS-aware autonomic performs excellent with different number of user requests. Execution cost in QoS-aware autonomic is 27.65% lesser than non-autonomic resource management technique.

As shown in Figure 8, the execution time is increasing with increase in number of user requests. At 90 user requests, execution time in QoS-aware autonomic resource management technique is 24.66% lesser than non-autonomic resource management technique. After 120 user requests, execution time increases abruptly in non-autonomic resource management technique but QoS-aware autonomic performs better than non-autonomic technique. Average execution time in QoS-aware autonomic is 18.960% lesser than non-autonomic resource management technique. With increasing the number of user requests, the

Figure 6. Effect of change in number of user requests on latency

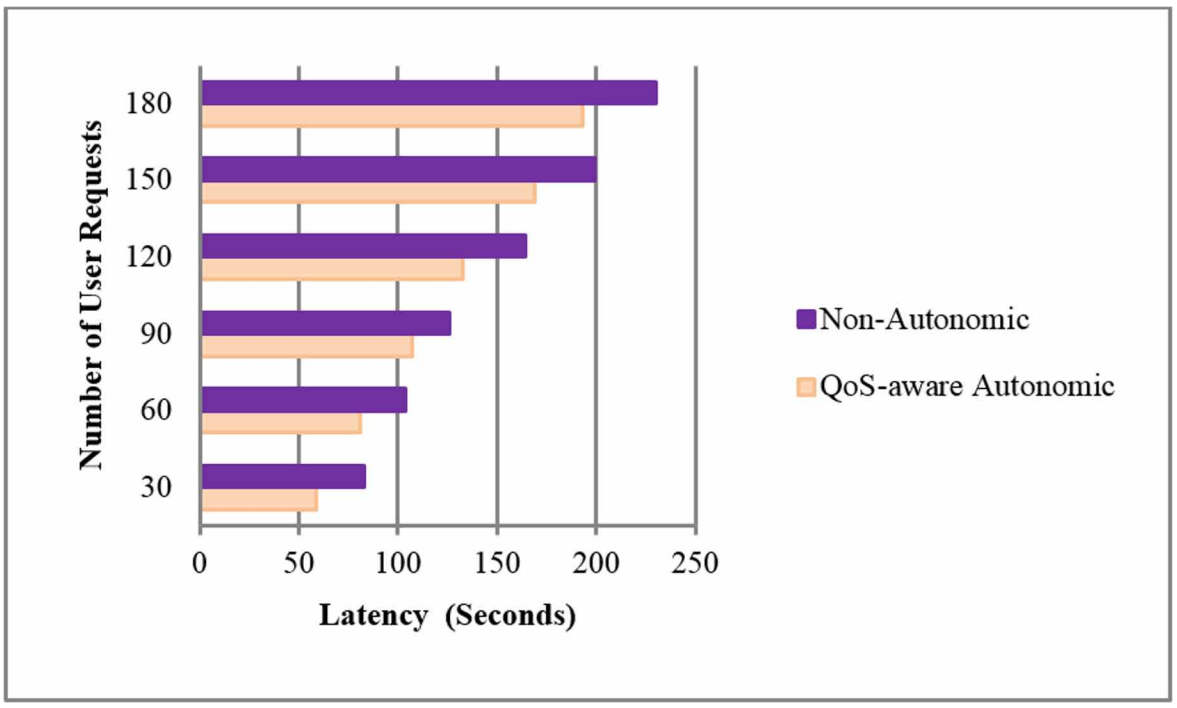

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Figure 7. Effect of change in number of user requests on execution cost

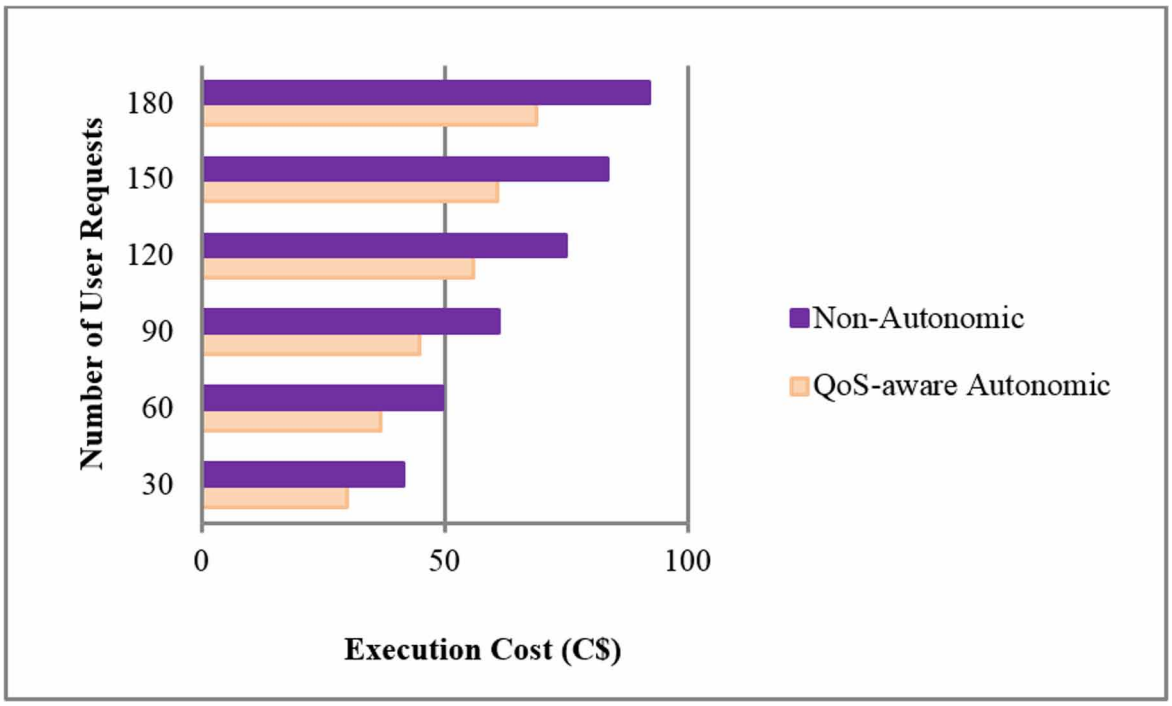
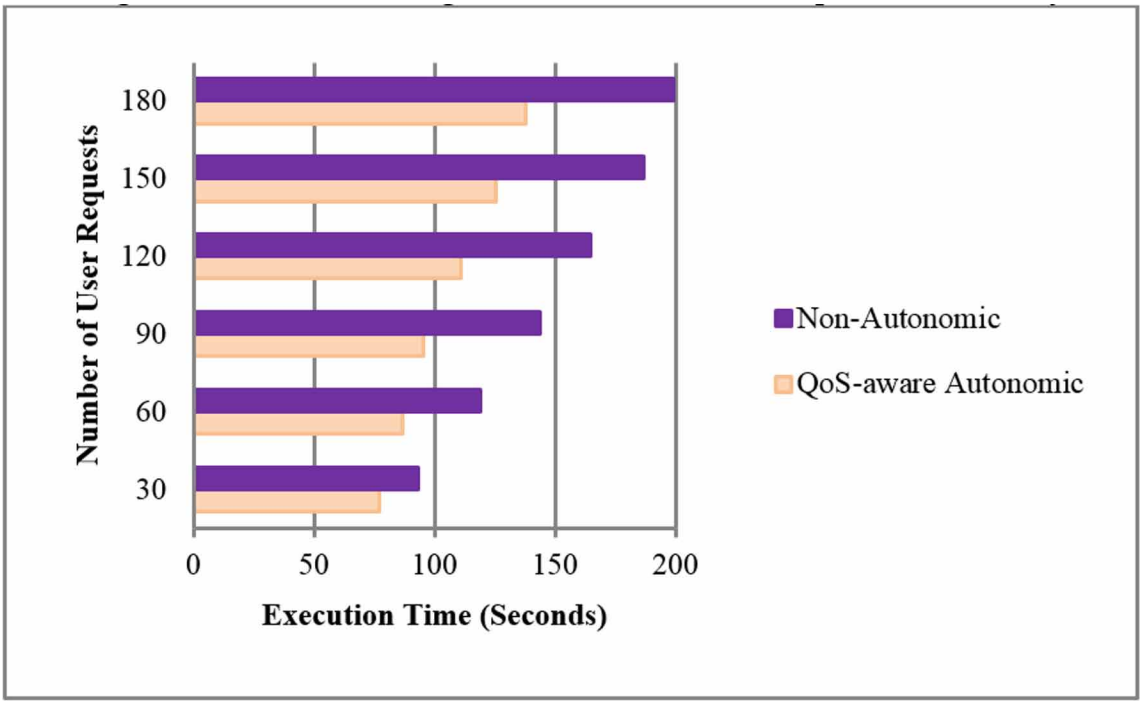


Figure 8. Effect of execution time with change in number of user requests



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percentage of resource utilization is increasing. The percentage of resource utilization in QoS-aware autonomic resource management technique is more as compared to non-autonomic resource management (non-autonomic) at different number of user requests as shown in Figure 9. The maximum percentage of resource utilization is 94.66% at 180 user requests in QoS-aware autonomic but QoS-aware autonomic performs better than non-autonomic technique. Average resource utilization in QoS-aware autonomic is 31.96% more than non-autonomic resource management technique.

Scalability is measured in terms of throughput. Number of software, network and hardware faults (fault percentage) has been injected to verify the throughput of the proposed system with 100 user requests. Figure 10 shows the comparison of throughput of both QoS-aware autonomic resource management approach and non-QoS based resource management technique (non-autonomic) at 100 user requests and it is clearly shown that QoS-aware autonomic performs better than non-autonomic. In this experiment, it has been found the maximum value of throughput at fault percentage 45% i.e. QoS-aware autonomic has 26% more throughput than non-autonomic. Detection rate increases with respect to time and it considers the number of blocked and detected attacks. For new attack or intrusion detection, database is updated with new signatures and new polices and rules are generated to avoid same attack. Experiment has been conducted for known attacks; it is clearly shown in Figure 11 that QoS-aware autonomic performs better than snort anomaly detector (non-autonomic). Further signatures of some known attacks have been removed from database to verify the working of proposed system.

Table 13 describes the comparison of execution time used to process different number of workloads (90 and 180) on cloud environment for proposed system with different number of Virtual Machines (VMs). The number of VMs used to execute the workloads was incremented gradually showing how

Figure 9. Effect of change in number of user requests on resource utilization

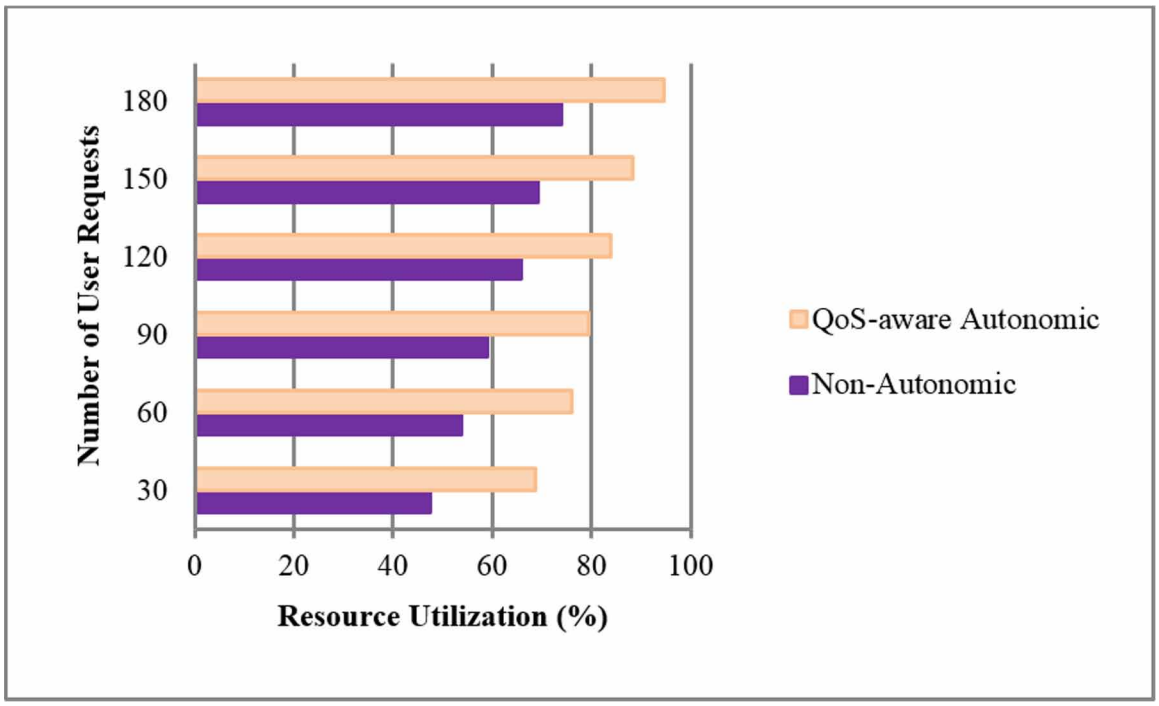

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Figure 10. Throughput [100 user requests] vs. Fault percentage (%)

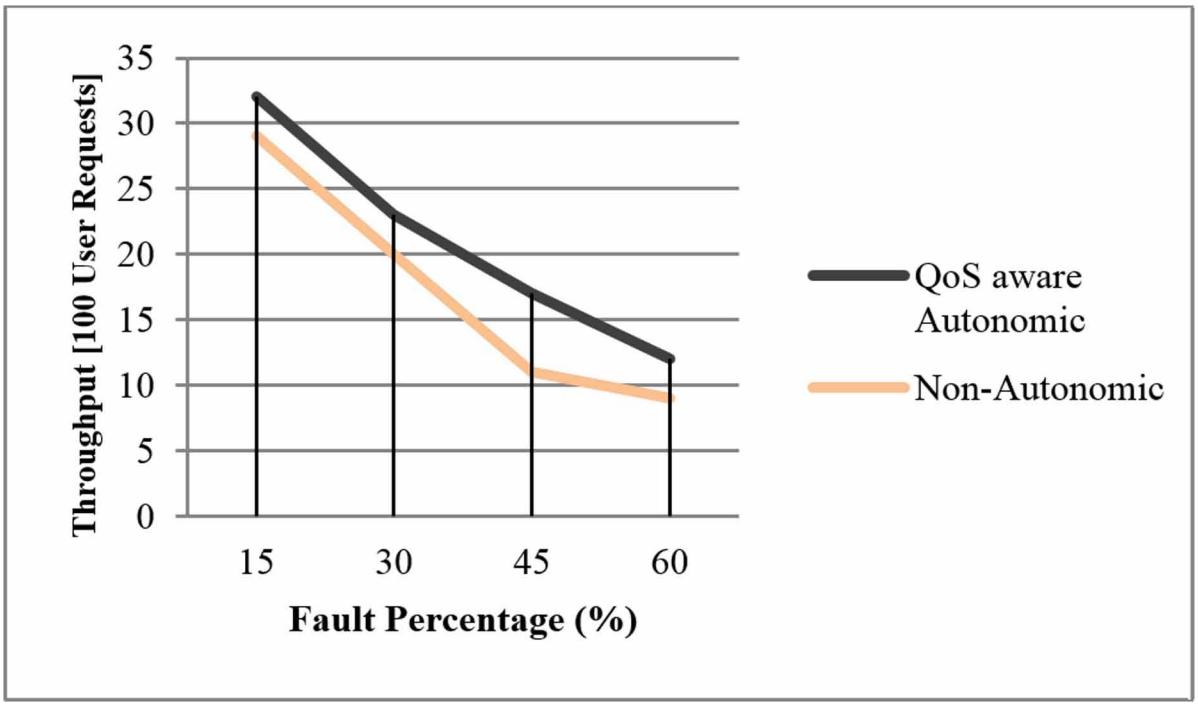

Figure 11. Detection rate vs. Attacks

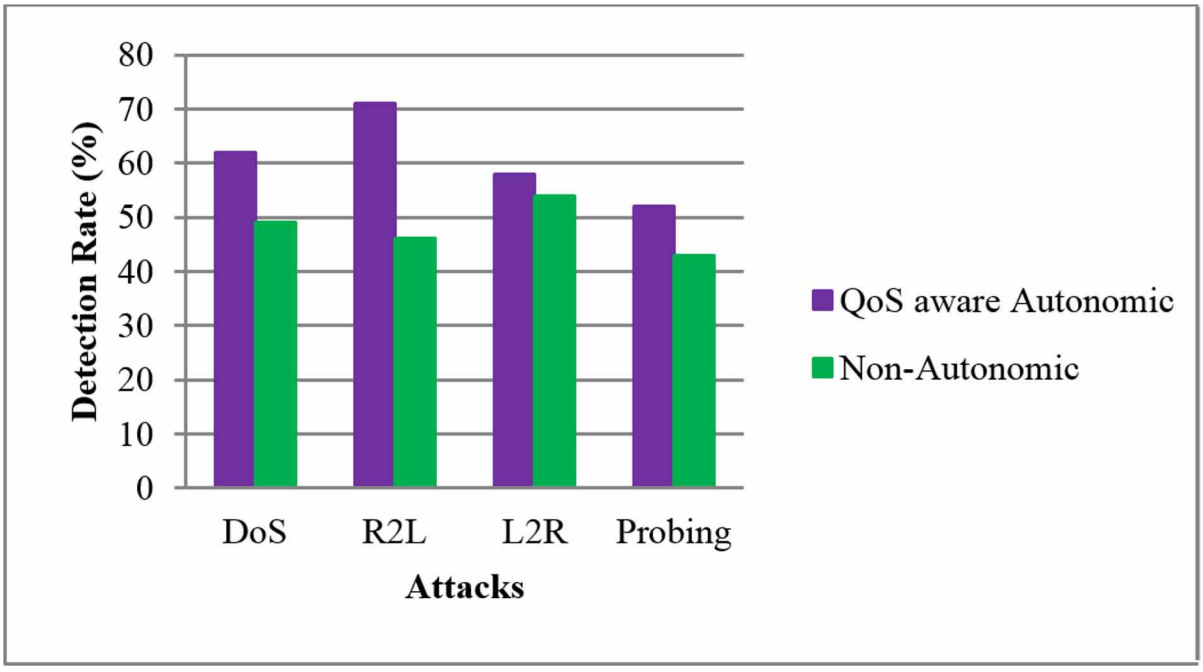

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Table 13. Total execution time of a bulk of cloud workloads distributed in three servers

Number of Workloads	Virtual Nodes			Total Workers	Execution Time (Seconds)
	R1	R2	R3		
45	1	0	0	1	436.12
45	1	1	0	2	428.69
45	2	1	0	3	418.97
45	2	2	0	4	407.55
45	3	2	0	5	398.17
45	4	2	0	6	380.30
45	4	2	1	7	361.66
45	4	3	1	8	345.18
45	5	3	1	9	331.21
45	5	3	2	10	315.03
45	5	4	2	11	299.97
45	6	4	2	12	276.16
90	1	0	0	1	1803.11
90	1	1	0	2	1771.18
90	2	1	0	3	1759.66
90	2	2	0	4	1736.15
90	3	2	0	5	1691.77
90	4	2	0	6	1668.96
90	4	2	1	7	1636.11
90	4	3	1	8	1625.19
90	5	3	1	9	1578.21
90	5	3	2	10	1551.68
90	5	4	2	11	1529.11
90	6	4	2	12	1503.11

the total execution time was reduced when more VMs were added to the cloud. With one virtual node running on Server R1, execution of 45 workloads finished in 436.12 seconds. With 12 virtual nodes (6 running on R1, 4 running on R2 and 2 running on R3), the application took 276.16 seconds. It is noted that the execution time is reduced with adding additional virtual nodes.

5.4. Statistical Analysis

Statistical significance of the results has been analyzed by Coefficient of Variation $\left(Coff.\ of Var.\right)$, a statistical method. $Coff.\ of Var.$ is statistical measure of the distribution of data about the mean value. $\mathrm{Coff.\ of\ Var.}$ is used to compare to different means and furthermore offer an overall analysis of performance of the technique used for creating the statistics. It states the deviation of the data as a proportion of its average value, and is calculated as follows (Equation 9):

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$$Coff.\ of Var.\ = \frac{SD}{\mathrm{M}} \times 100 \tag{9}$$

where SD is a standard deviation and M is mean. $Coff.\ of Var.$ of execution time and have been studied of QoS-aware autonomic resource management technique and non-autonomic resource management technique as shown in Figure 12 and Figure 13. Range of $Coff.\ of Var.$ (0.25% - 1.69%) for execution time and (0.37% - 1.96%) for cost approves the stability of QoS-aware autonomic resource management technique as shown in Figure 12 and Figure 13. Small value of $Coff.\ of Var.$ signifies QoS-aware autonomic resource management technique is more efficient in resource scheduling in the situations where the number of user requests has changed. Value of $Coff.\ of Var.$ decreases as the number of user requests is increasing.

Figure 12. CoV for execution time with each scheduling algorithm

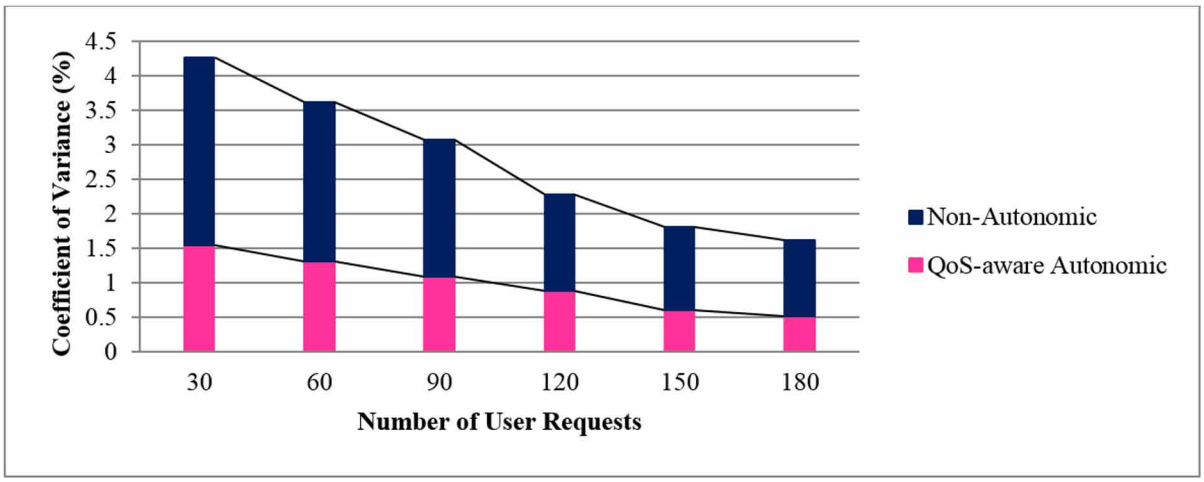
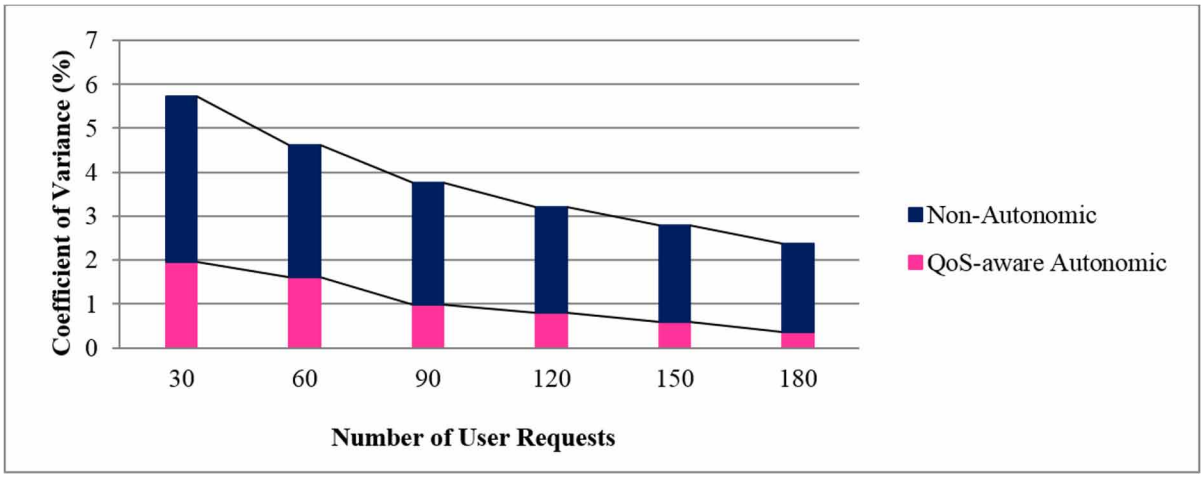


Figure 13. CoV for execution cost with each scheduling algorithm



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6. CONCLUSION AND FUTURE DIRECTIONS

Cloud-based autonomic information system (AaaS) for agriculture service has been presented, which manages the various types of agriculture-related data based on different domains through different user preconfigured devices. K-NN (*k*-Nearest Neighbor) classification mechanism is used to classify the agriculture data. Further, classified data is interpreted and users can easily diagnose the agriculture status automatically through AaaS. In addition, AaaS uses two resource scheduling polices (time and cost) for efficient resource allocation at infrastructure level after identification of QoS requirements of user request. The performance of proposed system has been evaluated in cloud environment and experimental results show that the proposed system performs better in terms of execution time, cost, resource utilization, latency, scalability and security. In future, the proposed technique can be extended by incorporating other QoS parameters like network bandwidth, availability, customer satisfaction, computing capacity etc. Proposed technique can be extended by developing pluggable scheduler, in which resource scheduling can be changed easily based on the requirements.

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REFERENCES

Agriculture Data, Government of India. (n. d.). Retrieved from https://data.gov.in/catalogs/sector/Agriculture-9212

Elsheikh, R., Mohamed Shariff, A. R. B., Amiri, F., Ahmad, N. B., Balasundram, S. K., & Soom, M. A. M. (2013). Agriculture Land Suitability Evaluator (ALSE): A decision and planning support tool for tropical and subtropical crops. *Computers and Electronics in Agriculture*, *93*, 98–110. doi:10.1016/j.compag.2013.02.003

Hu, Y., Quan, Z., & Yao, Y. (2004). Web-based Agricultural Support Systems. *Proceeding of the Workshop on Web-based Support Systems* (pp. 75-80).

India Agriculture And Climate Data Set. (n. d.). Retrieved from https://ipl.econ.duke.edu/dthomas/dev_data/datafiles/india_agric_climate.htm

Jeong, S., Jeong, H., Kim, H., & Yoe, H. (2013). Cloud Computing based Livestock Monitoring and Disease Forecasting System. *International Journal of Smart Home*, *7*(6), 313–320. doi:10.14257/ijsh.2013.7.6.30

Narayana Reddy, M., & Rao, N. H. (1995). *GIS Based Decision Support Systems in Agriculture*. National Academy of Agricultural Research Management Rajendranagar.

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Nikkilä, R., Seilonen, I., & Koskinen, K. (2010). Software architecture for farm management information systems in precision agriculture. *Computers and Electronics in Agriculture*, *70*(2), 328–336. doi:10.1016/j.compag.2009.08.013

Prasad, S., Peddoju, S. K., & Ghosh, D. (2013). AgroMobile: A Cloud-Based Framework for Agriculturists on Mobile Platform. *International Journal of Advanced Science and Technology*, *59*, 41–52. doi:10.14257/ijast.2013.59.04

Ruixue, Z. (2002). Study on Web-based Agricultural Information System Development Method. *Proceedings of the Third Asian Conference for Information Technology in Agriculture*, China (pp. 601-605).

Shangguan, W., Dai, Y., Liu, B., Ye, A., & Yuan, H. (2012, February 29). A soil particle-size distribution dataset for regional land and climate modelling in China. *Geoderma*, *171*, 85–91. doi:10.1016/j.geoderma.2011.01.013

Singh, S., & Chana, I. (2015). QoS-aware Autonomic Resource Management in Cloud Computing: A Systematic Review. *ACM Computing Surveys*, *48*(3), 1–46. doi:10.1145/2843889

Singh, S., & Chana, I. (2015). QRSF: QoS-aware resource scheduling framework in cloud computing. *The Journal of Supercomputing*, *71*(1), 241–292. doi:10.100711227-014-1295-6

Singh, S., & Chana, I. (2015). Q-aware: Quality of service based cloud resource provisioning. *Computers & Electrical Engineering*, *47*, 138–160. doi:10.1016/j.compeleceng.2015.02.003

Singh, S., & Chana, I. (2016). EARTH: Energy-aware Autonomic Resource Scheduling in Cloud Computing. *Journal of Intelligent and Fuzzy Systems*, *30*(3), 1581–1600. doi:10.3233/IFS-151866

Sørensen, C. G., Fountas, S., Nash, E., Pesonen, L., Bochtis, D., Pedersen, S. M., ... Blackmore, S. B. (2010). Conceptual model of a future farm management information system. *Computers and Electronics in Agriculture*, *72*(1), 37–47. doi:10.1016/j.compag.2010.02.003

Sørensen, C. G., Pesonen, L., Bochtis, D. D., Vougioukas, S. G., & Suomi, P. (2011). Functional requirements for a future farm management information system. *Computers and Electronics in Agriculture*, *76*(2), 266–276. doi:10.1016/j.compag.2011.02.005

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Chapter 22
ICTs for Agricultural Development and Food Security in Developing Nations

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ABSTRACT

Development has many faces and complete wellbeing of human population is the most important one of them which in more than one ways involves agriculture and the farming population. Providing needed information at the right time to the rural population is the first step in their empowerment and ICTs can play an immensely important role in providing that information by increasing the dialogue between development professionals and rural people at every stage of development process. According to recent statistics released by ITU, over the last 15 years, ICTs have grown in unprecedented ways providing huge opportunities for social and economic development and this growth can be an advantage to rural advisory services. Providing correct and personalized information needs expert opinions and so multi-stakeholder engagement makes the process more efficient and ICTs provide a very unique and important platform for such collaboration, thus bringing together different stakeholders for efficient partnership. The various tools and technologies can also be tailored according to the needs of end users. But in spite of the advantages, ICTs can only be universally accepted and used when the challenges of accessibility, acceptability, funding, and sustainability are overcome. There are no formula for sure success with ICTs and situation is the best determinant of the strategy to be used and so, a balanced and strategic use of ICTs depending on the clients' needs can best utilize its potential for agricultural development and food security in developing nations.

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INTRODUCTION

Global development has many faces and all of them concern human development – taking people out of poverty, assuring food security for everyone, and ensuring a fairly comfortable life. This is a difficult task considering one in nine people in the world suffer from hunger. The problem becomes complicated with the uneven distribution of the famished population with higher concentration in countries of Sub-Saharan Africa where one in four people suffer from chronic hunger, as well as Southeast Asia which has the largest number of undernourished persons (FAO, 2015). One of the largest missions taken worldwide in recent times to ensure human development was the Millennium Development Goals (MDGs) adopted at the Millennium Summit of 2000 of the United Nations, where the member countries promised global partnership and set time bound quantified targets with a deadline of 2015. These MDGs were formulated with the goal of all round human development by eradicating hunger and poverty, providing universal primary education, promoting gender equality and women empowerment, reducing child mortality, improving maternal health, combating major life threatening diseases across the world, ensuring environmental sustainability, and developing a global partnership for development (Millennium Project, 2006). The MDGs targeted world poverty in its many dimensions and by 2015, though the target of halving extreme poverty has been met, it was far from being well distributed across the continents. While a few Asian countries accounted for most of the decline, the absolute number of poor has risen in Sub Saharan Africa.

Poverty and food insecurity in the world right now is predominantly rural with 78 per cent of the world's extreme poor living in rural areas with the majority dependent on agriculture. In addition, almost 60 per cent of child labour worldwide is found in agriculture. The world has the capacity to produce enough food to feed everyone equally, even with the estimated 60 per cent increase in production to meet the projected demands of 2050, yet still, the rural poor - mostly consisted of subsistence producers, family farmers, and landless labourers – live on less than $1.25 USD per day. After 2015, the development agenda shifted from goals and targets to measurements and means. As a result, discussions on building on innovative ways to address the world's most pressing challenges began and Sustainable Development Goals (SDGs) were implemented. One of the five agents of change identified for transforming development economies is family farmers and small scale producers. Agricultural growth is up to five times more effective than any other sectoral growth in resource poor low income countries in reducing poverty (FAO, 2015) but the problem is more than sustainable agricultural production; it is of connecting the farmers and making them informed, and helping them to organize themselves to get the most out of their investment in their agricultural fields. In so doing, Information and Communication Technologies (ICTs) can be a very important aid to rural advisory services.

INFORMATION EMPOWERMENT

Information is a critical input in agriculture and given at the right time, it can prove to be the most important one (Saravanan and Suchiradipta, 2015b). Providing needed information at the right time to the rural population is the first step in their empowerment and ICTs can play an immensely important role in providing that information by increasing the dialogue between development professionals and rural people at every stage of the development process. Information empowerment of rural people helps them to be active partners in development efforts and not mere beneficiaries. ICTs make the job easier

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through TV, radio, computer, mobile phones, and recently social media. But in developing countries, information poverty is one of the more significant and insidious obstacles to effective exploitation of information processing and other types of technology (Sadowsky, 1996).

According to recent statistics released by ITU, over the last 15 years, ICTs have grown in unprecedented ways providing huge opportunities for social and economic development. Since 2000, internet penetration has increased 7 fold from 400 million users in 2000 to 2.2 billion users in 2015. Mobile subscriptions are up from 738 million to 7 billion and developing countries provide a wide opportunity for further development with new users and more population to reach (ITU, 2015). Social media, the recent addition to the world of ICTs, is gaining popularity very fast with a global penetration of 29 per cent, a 12 per cent increase from 2014 with a major boost from increased mobile subscriptions. Facebook is the most popular social media platform with about 1.5 billion users worldwide (Kemp, 2015) and the number increasing every day. But conditions in least developed countries (LCDs) are still challenging. Internet penetration is 9.5 per cent for population and 7 per cent for households, mobile broadband subscription is only 12 per cent of the population and fixed broadband subscription negligible at 0.5 per cent. Also, the fact that monthly fixed broadband prices are three times higher and mobile broadband prices are two times higher in developing countries than in developed countries (ITU, 2015) is only adding to the cause with poor households finding it difficult to invest in internet services.

ICTs in Rural Advisory Services (RAS)

With increasing diversities in agriculture, more stakeholders and increasing need to produce more to reach farmers at the right time with correct and needed information is not limited only to the extensionists. Moreover, information being one of the most critical inputs in agriculture, farmers are willing to pay for it, thus making extension a profitable business. But providing correct and personalized information needs and expert opinions on a timely basis is a complex process and so multi-stakeholder engagement makes it more efficient. ICTs provide a very unique and important platform for such collaboration, thus bringing together different stakeholders for efficient partnership.

Philosophy and Principles of ICTs for Agricultural Development (Adopted From Saravanan et al., 2015a)

ICTs are better enablers for information and knowledge access and sharing among agricultural innovation system actors compared to conventional methods. They also complement the conventional extension advisory methods. The guiding principles (World Bank, 2011; Saravanan 2011b; Saravanan, 2013) of ICTs for a more efficient extension and advisory services (EAS) are:

- **Relevant Content:** Contextualized or farmer specific, need based, timely and quality content is the major aim of ICT based EAS.
- **Appropriate ICT:** Among a variety of ICTs, choose the formats, channels, tools, devices and applications that best match the purpose, content and clientele.
- **Integration of Methods, Actors and Services:** Integrating ICTs with other conventional extension methods (like Farmer Field Schools (FFS), Community Knowledge Workers (CKWs), etc), pluralistic actors (public, private, Farmer Based Organisations (FBOs), etc) with their services along the value chain will create synergy in extension and advisory services.

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- **Information PLUS:** To convince the clientele, (i.e. show and tell). ICT based information alone is not enough and needs to be combined with field demonstrations, exposure visits, group discussions etc. Not just advisory information, but a complete resource package across the agricultural value chain[1] needs to be provided.
- **Human Element:** Commitment of the extension stakeholders to use ICTs, development of ICT champions with the legacy of promoting continuous leaders and followers are important.
- **ICTs Complementary to EAS:** ICTs can play only a complementary role in extension. If they are used appropriately, they create synergy and better impact with conventional extension efforts.
- **Institutionalizing ICTs:** Institutional policy and guidelines to use, developing the ICT literacy and competency among the human resource and infrastructure development should be an integral part of the institutional set-up.
- **Reasonably Long Term and Continuous Engagement with ICTs**: To see the better outcome, ICTs need to be integrated with the conventional extension approaches for a reasonably (at least for 5 years) long period.

Broad Areas of ICT Implementation for Agricultural Development (Adopted From Saravanan et al., 2015a)

ICTs based extension advisory methods are implemented along the agriculture value chain activities such as pre-production, production, post-harvest and marketing, financial services (credit, payment, savings, insurance, etc.), climate and other data. Five broad areas[1] of ICTs implementation are:

1. **Offering Localized and Customized Information, Advisory and Other Services:** Farmers call centres (FCCs), mobile apps, radio, TV etc.
2. **Helping to Create, Document, Store, Retrieve, Share and Manage the Information:** Web portals, crop specific portals, knowledge banks, expert systems and agricultural information management systems etc.
3. **Enabling Collaboration, Sharing and Partnerships for Innovation Among Extension Actors:** Social media, Dgroups etc
4. **Enabling Farmers and Others to "Gain a Voice":** Community radio, tele-centres, videos, communities of practice (COPs) etc.
5. **Facilitating Capacity Development of Farmers, Extension Professionals and Other AIS Actors:** E-learning mechanisms (Open Distance Learning (ODL), Learning Object Repositories (LOR), Massive Open Online Courses (MOOCs) and other e-learning mechanisms etc.), training by using ICTs, survey and monitoring tools and applications.

ICTs have been used in various forms depending on the need of the clientele, location specificity, availability and accessibility of technology and so on. Major forms of ICT tools and applications in Rural Advisory Services (RAS) are discussed below:

- **Radio and Television:** Radio and TV are the earliest forms of ICTs used in agricultural extension and advisory services and are the most popular with the rural communities. They have been very helpful in dissemination of information and technologies among the farmers in rural areas but

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their very nature inhibits interactivity or location specificity which restricts their scope in information dissemination in an era of technology. In recent times though, community radio stations have tackled the problems of location specific information and have made the rural people major stakeholders in information dissemination and discussions about community development.

- **Interactive Multimedia Compact Discs (IMCDs), Decision Support Systems (DSS), and Expert Systems:** Multimedia is a combination of text, graphics, art, sound, animation, and video elements where the viewers can control what elements are delivered and when. This is known as interactive multimedia. IMCDs offer learners complete and individual control over their learning and encourages better understanding between individual learners and the subject matter. Decision support system (DSS) is a computer program application that analyzes data and presents it so that users can make decisions more easily. DSS uses Artificial Intelligence (AI) and expert systems to present data in a format suitable to the users. Expert systems are tools for information generation from given information by simulating human reasoning about a problem domain. The knowledge acquisition process for building an expert system facilitates the integration of knowledge and experiences of different specialties which help generate advice based on its knowledge base and reasoning mechanism from all developed extension documents.
- **Web Portals:** Web portals are digital platforms that provide organized gateways to information or act as aggregators of knowledge from various stakeholders. They are specifically designed single access points to information collected from diverse sources. In agricultural extension and advisory services context, web portals can be of two types – those providing technical and market knowledge to end users at the grassroots level, and those helping with capacity development of extension personnel. Financially and socially, portals can have far reaching impact on users. Illiteracy – both educational and technological – can be a barrier in accessing web portals by grassroots level users but with the help of extensionists, they can be of much help to the rural communities (Saravanan et al., 2015b). A few examples of some successful initiatives to use web portals for agricultural communication are discussed below.

University Web Portal

TNAU Agrictech Portal has been catering to the needs of farmers, extensionists and other stakeholders in agriculture and allied sectors since 2009. It offers a diverse range of information from crop related to weather information, daily market prices, schemes and programs for farmers, daily news, events and publications supported by multimedia, expert systems and many others. The portal can also be accessed in Tamil and English languages and offers a keyword search facility. Farm technology portal (http://agritech.tnau.ac.in) was designed by integrating the allied sectors of agriculture, horticulture, agricultural marketing and agriculture business, agricultural engineering, sericulture, seed sector, forestry, fisheries and animal husbandry. This dynamic portal page holds more than half a million pages in Tamil and English with multiple media content. According to Google Analytics, from April 1st 2015 the daily visitors ranged between 26000-28000, new visitors numbered 1,44,100 at the rate of 57%, the new sessions were 2,33,168 with an average session duration of 4:09 minutes, number of page views were 7,39,706 with a bounce rate of 62%. The average page/session was 3:17 minutes.

The online input information service ensures timely sourcing of critical inputs to farmers in the state. By using the last mile connectivity, Short Message Messages (SMS), more than 10,000 million SMS

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have been sent to farm beneficiaries in English and Tamil through m- kisan mobile linked interface. The agritech portal is linked to social media networks like blogs, twitter and YouTube, and Facebook messages are updated on agriculture related news on a daily basis both in English and Tamil.

Crop Specific Portal

"Rice Knowledge Management Portal" (www.rkmp.co.in), as the name exemplifies, facilitates efficient management of the enormous knowledge on rice crop on a single click. With more than 16,000 pages of validated and localised content in seven vernacular languages and 18 stakeholder platforms, this is considered as the largest repository of knowledge on any single crop across the globe. Today, a rice farmer from any corner of the country is able to get all the rice related reliable information specific to their region in the language of his choice. The dream of any extension professional to provide the right information at the right time and context in the local languages to the farmers is realized through Rice Knowledge Management Portal - the one stop shop for rice related information.

Web Portal for Agriculture Videos

Access Agriculture (www.accessagriculture.org) is a video based web portal started in 2012 with training videos in agriculture and allied sectors, business skill development and market development. It has something to offer to all agricultural stakeholders. The online videos can also be downloaded and language of the audio can also be requested as per preference of the user. The web portal also has social media presence in Facebook and LinkedIn and has a video social media site called AgTube.

Web Portal by the Extension Organisation

eXtension (www.eXtension.org) is an interactive learning environment delivering the best, and most researched knowledge from the land-grant university minds across America. eXtension connects knowledge consumers with knowledge providers - experts who know their subject matter inside out. eXtension is unlike any other search engine or information-based website. It's a space where university content providers can gather and produce new educational and information resources on wide-ranging topics. Because it is available to students, researchers, clinicians, professors, farmers as well as the general public, at any time from any Internet connection, eXtension helps solve real-life problems in real time.

Web Portal for Integrated Rural Advisory Services

As part of the India Development Gateway initiative of Government of India, Vikaspedia portal (www.vikaspedia.in) is aimed at creating a versatile collective knowledge repository and demand driven information in the development oriented sectors including Agriculture. This multilingual portal is serving as a collaborative content creation, knowledge sharing and utilization platform for the stakeholders in agriculture and allied sectors[14]. Currently, Vikaspedia is one of the largest knowledge portal hosting information/knowledge in 10 Indian languages, offering information on success stories, best practices, government schemes, technologies, market information and related value added services in Agriculture.

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- **Online Learning Platforms:** Learning platforms are interactive online services that provide learners with resources to support and enhance educational delivery and management. They are virtual learning environments that make the process interactive with integrated discussion boards, chat rooms and other such facilities where contents are both expert suggested and user generated. These kinds of learning platforms also serve as online repositories and can be very helpful for all agricultural stakeholders to increase their expertise on practical topics while sharing experiences with their colleagues across the globe and leaning from others' experiences. A good example of online learning platforms is Massive Open Online Courses (MOOCs) that have recently become very popular among all agricultural stakeholders.
- **Mobile Phones:** Mobile phones are devices that can create, store, access and share information anytime, anywhere and teamed up with extension and advisory services can help improve the livelihood of rural people by taking timely information to their fingertips at potentially low cost. They also provide the unique opportunity of instant feedback and one on one interaction with experts. mExtension can facilitate the creation of scalable, replicable and commercially sustainable advisory services for rural clients and women can especially benefit from the services if access to mobile phones can be ensured (Saravanan and Suchiradipta, 2015c).
- **mExtension:** Agricultural extension and advisory services are provided through a number of modes – push and pull SMS, interactive voice response (IVR), mobile apps (mApps), and so on – sometimes individually and sometimes integrated. While SMS and IVR services are accessible from both feature and smart phones, mApps require smart phones. Services can be free or subscription-based. Cost does not seem to affect popularity as shown by services such as IKSL in India, iCow in Kenya, Kilimo Salama in Kenya and Rwanda, and e-Krishok in Bangladesh. Mobile-based advisory services are mostly targeted at farmers and the rural population but collaboration among stakeholders in agricultural innovation systems (AIS) for providing content is not unknown. The advisory services also vary from providing solely agricultural information (e.g. Gobi Sahana Sarana in Sri Lanka) to providing micro insurance to rural people (Kilimo Salama in Kenya and Rwanda), real time market information (e-soko active in 10 African countries), farmer-specific fertiliser recommendations (NMRiceMobile in Bangladesh, China, India, Indonesia, Phillipines and West Africa) or integrating agricultural and weather information along with entertainment to attract large numbers of rural people (Nokia Life Tools) (Saravanan and Suchiradipta, 2015c).
- **Social Media:** Social media are web based tools of electronic communication that allow users to personally and informally interact, create, share, retrieve, and exchange information and ideas in any form (text, pictures, video, etc.) that can be discussed, archived and used by anyone in virtual communities and networks (Saravanan and Suchiradipta, 2015d). While social media has been playing a significant role in personal communication and development communication across the globe, in the agriculture sector its popularity has also been increasing. Increased use of social media in agvocacy (agvocacy is the combination of two words agriculture and advocacy, and means talking for and about agriculture) can increase the dialogue among agricultural stakeholders and make information access much easier for rural smallholders. Also, with proper planning, a social media communication strategy can be scalable across geography (local, regional, national, global), topics of interest (e.g. business, career, agronomic practices, crops, etc.), and type of clients (women, young people, smallholders, etc.) (Saravanan et al., 2015c).

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Extension professionals are using social media to form networks and farmers are taking to social media to talk to peers and consumers. All big things in agriculture – new technology or innovations, seminars and meetings, workshops and trainings, reports, publications – get tweeted or hashtagged. Facebook, Twitter, YouTube, and blogs are the major platforms for agricultural information dissemination. The uses of socially integrated messaging apps are also increasing in the rural areas. But still, there is a difference in the intensity of use in developed and developing countries – basically due to economic conditions and infrastructure availability. In spite of the differences, use of social media is picking up in rural areas of developing and least developed countries as well (Suchiradipta and Saravanan, 2016)

GFRAS Global survey on use of social media in agricultural extension and rural advisory services conducted online during 2015 across 62 countries and 229 respondents provided interesting responses. Facebook was found to be the most popular social media platform used by extension professionals. The major activity on social media was searching for news events and sharing information. A major impeding factor for social media use was the lack of authenticity of information shared online. Social construction of information (development and publication of information socially by the users) was considered the most important feature of social media (95.1%). Ninety five percent of the respondents believed social media can play an important role in bridging the gap between stakeholders in Agricultural Information services (AIS). Reaching clients (77.4%) was a major use of social media in AEAS. Training in social media use was uncommon, and 71% of the respondents said they need training on social media use. If and when there was training conducted by the respondents' organizations, it mainly focused on the specifics of different social media platforms and awareness creation on the use of social media in agricultural extension. But on an organizational level, social media is still not given much importance by higher authority and social media policy restricts rather than encourages its use. Also, weak or non-existent connectivity in rural areas, high cost of data charges, illiteracy of the clients and low participation and lack of interest of clients are reported to be major problems. Overall, the survey found that social media is a very useful tool in agricultural extension and rural advisory services. To quote one respondent, "social media is not only a tool for reaching large audiences; it is also an opportunity to develop relationships." (Suchiradipta and Saravanan, 2016)

The use of social media is becoming more and more pronounced in agriculture and a few of the popular social media accounts and handles across various platforms, as in Table 1, will give a better idea into their works.

ICTs have provided many opportunities for collection, processing, storage, retrieval, managing and sharing of information in multiple format for providing a wide range of services (information, awareness, promotional, advisory, knowledge, technology transfer, training, education, and much more) to farmers and other agricultural innovation system (AIS) actors in a timely, comprehensive, cost-effective, and interactive manner (Saravanan et al., 2015a). But one important factor that impacts the success of ICT based projects is the suitability of the technology used. In areas where the majority of the end users are illiterate, TV, radio, voice based mobile advisory services and video- based web portals are more appropriate; community radio and mobile phones are more suitable media to engage women farmers. Young farmers can be most engaged on social media platforms like Facebook, Twitter and Whatsapp, and depending on the electronic device availability with the client, the development organizations need to provide basic infrastructure like internet kiosks to access the information provided. To make ICTs a real success and not a piecemeal approach in RAS, more attention needs to be paid to the 'I' and 'C' of

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Table 1. Examples of use of social media in agriculture

Name of Group/ Community/ Pages	Description	Target Users	Region
FACEBOOK			
By farmers			
Livestock Information and Marketing Centre (https://www.facebook.com/groups/Livestock.TN/)	Members (farmers, extension personnel, scientists, market functionaries, consumers, local leaders, *etc*.) of this *group* share information related to livestock production, management, marketing, *etc*. A separate page is also on Facebook related only to marketing of livestock. (https://www.facebook.com/Livestock.Market)	Agricultural stakeholders related to livestock	India
Mkulima Young (Young Farmer) (https://www.facebook.com/mkulima.young)	This *page* is an information sharing platform for young farmers started by Joseph Macharia, a young farmer himself. Mostly agro-advisory and market information are shared.	Young farmers	Kenya
Turmeric Farmers' Association of India (https://www.facebook.com/turmeric.farmers)	This *page* was created by turmeric farmers to stabilize the price of turmeric in the market. To date, the farmers connect through the page and share information to keep turmeric price stable and increase marketing opportunities of turmeric.	Turmeric farmers	India
National Ecological Producers Association (APNE) (https://www.facebook.com/anpe.peru)	Information related to ecological farming is shared through the page.	Farmers	Peru
By extension centres			
Krishi Vigyan Kendra, Namakkal (https://www.facebook.com/krishi.namakkal)	Krishi Vigyan Kendra, Namakkal communicates information related to farmers' training programmes, availability of inputs *etc*. through this account	Subject Matter Specialists of KVK, farmers, agricultural stakeholders	India
By extension professional networks			
Agricultural Extension in South Asia (AESA) (https://www.facebook.com/groups/428431183848161/)	Members post links to relevant publications on extension and advisory services, announcements of workshops and conferences, major policy decisions on extension, reports of meetings/ workshops and blogs relevant to the broader theme of extension	Agricultural Extension stakeholders	South Asia
Global Forum for Rural Advisory Services (GFRAS) (https://www.facebook.com/groups/gfras/)	This page provides information related to advocacy and leadership on pluralistic, demand-driven rural advisory services.	AEAS Professionals and others	Global
By extension personnel			
Vivasayam Karkkalam (Let us Learn Agriculture) (https://www.facebook.com/groups/madhualan)	Mr. Madhu Balan, a public extension officer started a Facebook group to cater to the information needs of famers in 2012. This group exchanges information on improved farm technologies, initiates discussion with other farmers and extension personnel, share information and photos on best practices by other farmers, government schemes, *etc*. Question and answers, information on Terrace garden and hydroponics are the most discussed topics in this group.	Farmers and others who are interested in agriculture	India
TWITTER			
Farmers			
AgChat (https://twitter.com/agchat)	The AgChat (Twitter online discussion group by the AgChat Foundation) started in 2009 by a group of American farmers is widely used in USA, UK, Australia, New Zealand and Ireland for facilitating discussions of industry issues between farmers and agribusinesses	Farmers, entrepreneurs, farm product consumers	USA, UK, Australia, New Zealand, Ireland
Agriculture Proud (https://twitter.com/AgProud)	Twitter handle of Ryan Goodman, a young farmer and rancher from Montana, US. Through his Twitter account he shares his experiences of farm life and answers questions from fellow farmers, agriculture enthusiasts, and consumers.	Agriculture enthusiasts, consumers, and fellow farmers	USA
Young Farmers (https://twitter.com/F4YFKenya)	Information shared through this Twitter handle of the Foundation for Young Farmers shares information for better agriculture with the objective to attract more youth to farming.	Young farmers	Kenya

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Table 1. Continued

Name of Group/ Community/ Pages	Description	Target Users	Region
Extension centres			
USDA (https://twitter.com/USDA)	The Twitter handle of U.S. Department of Agriculture shares latest news, events, and information in agriculture	Farmers, extensionists, development practitioners	USA
INGENAES (https://twitter.com/INGENAES)	This Twitter handle of Feed the Future initiative Integrating Gender and Nutrition within Agricultural Extension Services shares information and gender-appropriate, nutrition-enhancing technologies to improve life and livelihood of women farmers	Researchers, extensionists, farmers	Global
eXtension4U (https://twitter.com/eXtension4U)	Twitter handle of eXtension.org, a research based learning network of cooperative extension of USA. Sound research based information is shared through the handle.	Farmers, researchers, policy makers of USA related to Agric. Research and Dev	USA
Professional networks			
MEAS (https://twitter.com/MEAS_extension)	Twitter handle of the project Modernizing Extension and Advisory Services shares good practice strategies and related information to ultimately raise farm income and enhance livelihood of rural poor of 12 selected countries of Asia and Africa.	Development practitioners	Global
GFRAS (https://twitter.com/infogfras)	This page provides information related to advocacy and leadership on pluralistic, demand-driven rural advisory services.	Extensionists, development practitioners, researchers, policy makers	Global
e-Agriculture (https://twitter.com/e_agriculture)	Twitter handle of e-Agriculture, a global initiative to enhance sustainable agricultural development and food security by improving the use of ICTs. Information shared is related to recent developments, efforts, publications and stories of ICT use in agriculture.	Farmers, researchers, development practitioners	Global
BLOGS			
Individual blog			
Gate to Plate Blog (Michele Payn-Knoper) (http://www.causematters.com/blog/)	Through this blog, agriculturist, entrepreneur and founder of Cause Matters Corp. shares her views about food and agriculture.	Farm product consumers, agriculture enthusiasts, farmers	USA
Ecoagriculturist (Oluwabunmi Ajilore) (https://ecoagriculturist.wordpress.com/)	The blogposts are related to sustainable agriculture, environment, youth involvement in agriculture, ICT4Ag, and other related topics. The blog was also a winner of the YoBloCO Awards of CTA in 2014.	Farmers	Nigeria
The Unconventional Farmer (Gil Carandang and Patrick Gentry) (http://theunconventionalfarmer.com/flog/)	Featured in top 50 farm blogs by www.seametrics.com, this blog covers natural farming techniques from Japanese and Korean natural farmers. Topics range from farming techniques to animal care for urban and rural farmers.	Farmers, agriculture enthusiasts	Global
Institutional blog			
AGRF Blog (African Green Revolution Forum) (http://www.agrforum.com/blog/)	The AGRF was established in 2010 to initiate discussions and develop concrete plans for achieving Green Revolution in Africa. The blog is a part of the initiative where issues related to African agriculture and ways to develop are discussed by various authors working in different capacities in the agriculture sector. The posts are by invitation only to maintain professionalism.	Policy makers, private actors, civil society actors, researchers, farmers, agribusinesses	Africa
Agricultural entrepreneurship (Penn State Extension) (http://farmbusiness.blogspot.in/)	This blog is especially helpful for agripreneurs for getting information on marketing, economics, and other recent news in agricultural industry. Since 2008, 348 blog posts have been made by the eight contributors.	Agripreneurs	USA

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Table 1. Continued

Name of Group/ Community/ Pages	Description	Target Users	Region
TNAU Agritech Portal blog (Tamil Nadu Agricultural University) (http://tnauagritechportal.blogspot.in/)	The blogs of TNAU Agritech Portal deals with everything agriculture – from sowing to harvesting, crop protection to crop management, weather, recent happenings in the agriculture industry, schemes and programs for farmers, ICTs, and many more. A total of 940 blog posts have been made since 2012, 541 of which are made in 2015 itself, by 43 members consisting of extensionists, researchers, academicians, and farmers.	Farmers, agripreneurs, extensionists	India
YOUTUBE			
Farming First (https://www.youtube.com/user/FarmingFirst/)	This channel highlights the mission of the agricultural development coalition of the same name, founded in 2009. Made up of 131 organizations worldwide, Farming First prioritizes the protection of natural resources, knowledge sharing, local infrastructure, harvests, market access, and innovative research (www.foodtank.com).	Policy makers, researchers, agricultural enthusiasts and practitioners	Global
CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) (https://www.youtube.com/user/CCAFS)	The videos shared by the channel features stories of smallholder farmers, interviews with leading agricultural experts across the globe, and innovative information on climate-smart agriculture (www.foodtank.com).	Researchers, farmers, policy makers	Global
IFADTV (https://www.youtube.com/user/IFADTV/)	It is a well produced and highly engaging channel from the International Fund for Agricultural Development (IFAD). Videos feature news stories about smallholder farmers in addition to interviews with agriculture experts (www.foodtank.com).	Policy makers, farmers, extensionists	Global
Farmers Weekly Video (https://www.youtube.com/user/FarmersWeeklyVideo/)	It is produced by U.K.-based Farmers Weekly, a multimedia independent information service for farmers and agricultural businesses. Videos contain information on how to make agri-businesses sustainable, advice on farming careers, and information on different crop inputs (www.foodtank.com).	Farmers, extensionists, agribusinesses	U.K.

(Suchiradipta and Saravanan, 2016)

ICTs rather than the 'T' only (Saravanan and Suchiradipta, 2015a). This requires shifting the focus to specific target groups and engaging them fruitfully to ensure successful implementations of ICTs. Youth everywhere can be the most important stakeholder in this process.

Youth and ICTs in Agriculture

ICTs for Youth (ICT4Y) in Agriculture

ICTs and youth can prove to be a great catalyst in agriculture. ICTs are the developmental tool kits to empower the rural youth to fight against the odds of poverty, backwardness and illiteracy and come out victorious in their agricultural fields. It is not a mere technological innovation to come and go but application of ICTs in agriculture is a permanent solution to many of the problems of the sector in developing countries. It will also bridge the gap between the present and past making young people the catalyst for the change among their peers. Moreover, forming an opportunity of employment for the rural youth does not only help them but saves the society from many odds. ICTs empower the rural youth and channel their energy in a desired direction.

Of the other direct impact of ICTs on youth in agriculture are forming virtual peer groups to share their experience. The youths from various parts of the world with the Web 2.0 can gain exposure to what is happening in the agricultural front in other parts of the world and thus gain a better understanding of their own situation. This helps them to take better decisions in their own condition. It also gives them the

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opportunity to give their voice in the policy making process. ICTs increase the productivity and inspire the youth to venture in agripreneurship. ICTs also increase the social status of the farmers and the need for social recognition attracts others to the use of technology in their conditions. It also increases the negotiating power of the farmers and makes them more informed for so as not to be cheated by others.

The role of ICTs, thus, can be felt in every sphere of life of the farm youth. As shown in the Figure 1, it is a lifelong process of learning from their own experiences, from others in the community (both actual and virtual) or from access to the worldwide knowledge repository and also passing that knowledge to those who need it. Not only that, it also helps in their skill formation and proper planning and management of their investments thus ensuring an inclusive individual and community development.

In many countries, mobile phones have reduced the work of farmers allowing they to devote to other works. They do not have to walk long distances in order to transfer money from the bank or get information about market prices. It has also inspired the farm youth to take entrepreneurial steps in innovative ways to make agriculture remunerative and thus reduce the drudgery involved.

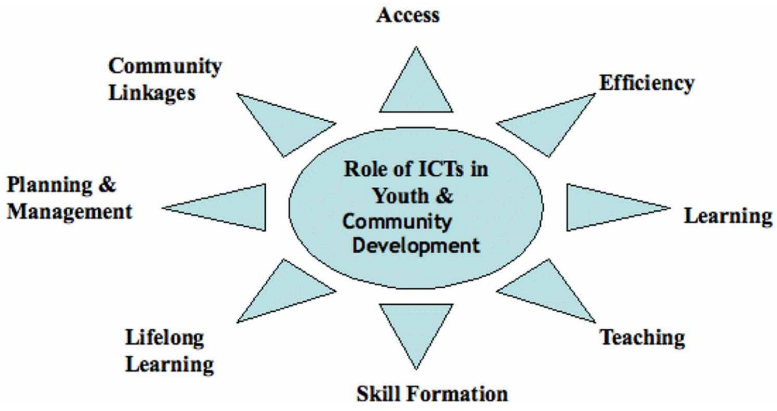
Youth for ICTs (Y4ICT)

All the discussions till now have been on how the ICTs can revolutionize agriculture. But like all other technologies, it needs a carrier to take it forward and implement it. ICTs are powerful only as long as they are used to their fullest potential. The youth who form a major portion of the developing world can get the best out of them because of their natural affinity to technology. It is important for the young people to participate in the ICT initiatives and their implementation, as they know best the needs of their community and themselves. It also adds the bottom-up approach to the project implementation making it more realistic and fruitful. The youth can play a big role in bridging the digital divide that exists in developed and developing countries and also the rural and urban areas. They can not only help themselves but also the other community members to get the best out of their land (Suchiradipta and Saravanan, 2013).

Youth and ICTs: Example of a Fruitful Relationship

In North-East India, Jhum cultivation (Slash and Burn Agriculture) is the most predominant form of agriculture. The prevalence of number of tribal dialects makes communication difficult for change

Figure 1. Potential of ICTs in youth and community development (Haddad, 2007)



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agents. Hence, considering the farming situation and difficulty in communication of appropriate farm information, an e-extension project (e-Arik) was initiated since 2007 in East Siang district of Arunachal Pradesh state. To overcome communication difficulty and also to motivate rural farm youth and others to take up profitable farming activities, four educated tribal farm youth were used as 'farmer facilitators' along with ICTs. They were given advanced farm technological training at the constituent college of the Central Agricultural University (CAU) and KVK. The farm youth helped to create general agricultural and rural development awareness among tribal farmers, facilitated eco-friendly and sustainable farm technology dissemination, developed vocational efficiency among farmers, formed farmer groups for self-help, facilitated use of local resources, helped to make timely decisions by the farmers themselves and suggested alternative ways to solve farming and other rural problems in twelve selected villages. By the efforts of farm youth facilitators by following 'farmer to farmer communication' approach and using ICT tools, 44 percent and 92 percent of farmers adopted the information on climate smart practices on paddy (Oriza sativa) and Khasi Mandarin (Citrus reticulata) crops respectively. After three years of project initiation, 55 percent of farmers developed new Khasi Mandarin orchards in their Jhum field, which means they are permanently moving from age old Slash and Burn agriculture to settled cultivation. Even after the completion of the project, trained farm youth are serving as a link between agricultural development departments and tribal farmers for facilitating advanced farm trainings and advisory services and they become 'local knowledge managers' to foster agricultural development in the remote tribal villages" (Saravanan, 2011a & b).

IMPLEMENTATION OF ICTs IN RAS

Appropriateness of ICTs depends on the situation and their use is most successful as a catalyst of development and to do so a few logical steps need to be followed. While the steps may be indicative of the logical delivery of ICT projects, they are not absolute in any terms, but very much flexible depending on the need of the situation and best judgements of the extension organisation, based on detailed need assessment surveys among clientele and other stakeholders (Saravanan et al., 2015a).

1. **Need Assessment:** EAS is most useful and applicable when information and services provided are localized and need based and so for the ICT projects to be successful, the first and foremost action of a host organization should be need assessment of the target community.
2. **Benchmark Survey:** Standards or points of reference are very important for ICT enabled services to meet their objectives and this makes benchmark surveys a necessity. They are also useful as standards of monitoring and evaluation.
3. **Content Development:** Localized and customised content needs to be developed based on the results of need assessment and benchmark surveys to avoid the problem of blanket recommendation.
4. **ICT Selection, Development and Testing:** Based on localised needs, content, and target groups, the appropriate ICT tool needs to be selected, developed and pilot tested for determination of suitability.
5. **Awareness Programs and Registration:** One major drawback in ICT projects is lack of awareness of target users about its existence or benefits and to solve that, innovative awareness campaigns need to be conducted to make them aware of the projects. In the case of subscription based services, it is more important as the users need to register to receive the benefits.

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6. **Extension, Advisory and Other Services:** Based on demand and needs of the users, the services are to be provided to the targeted groups.
7. **Partnership and Integration of Services:** Depending on the need of the project and the services provided, collaboration among stakeholders needs to be formed and integration of services are to be determined to provide quality service to the users.
8. **Monitoring and Stabilization:** Continuous monitoring is an important function, especially in the pilot phase, to determine the suitability of the project to target users and accordingly modify the services offered to ultimately scale up the project in a profitable manner.
9. **Impact Assessment:** It remains one of the most important steps in implementation of ICT projects as the impact ultimately decides the degree of success of the projects in bringing the desirable changes in the target group as well as the factors deciding its sustainability for the long run.

SWOC ANALYSIS OF ICTs IN RAS

ICTs no doubt have the immense benefit of reaching the unreached, thus making it one of the most important supplements to RAS. This gives a huge opportunity to reach the BoP farmers and provide them necessary information to commercialize their agricultural practices and become self-sufficient. Then again, ICTs are only useful when the farmers can access the infrastructure, which is oftentimes non-existent in rural parts of the developing world, mostly when they are literate and tech savvy and also can bear the cost of the devices necessary. However, once these challenges of funding of projects, sustainability and acceptance by rural people are overcome, ICTs can become the most important catalyst in development of the rural population in the developing countries. The various strengths, weaknesses, opportunities and challenges of ICTs in RAS are presented in Table 2.

Figure 2. Steps for implementation of ICT enabled RAS (Saravanan et al., 2015a)

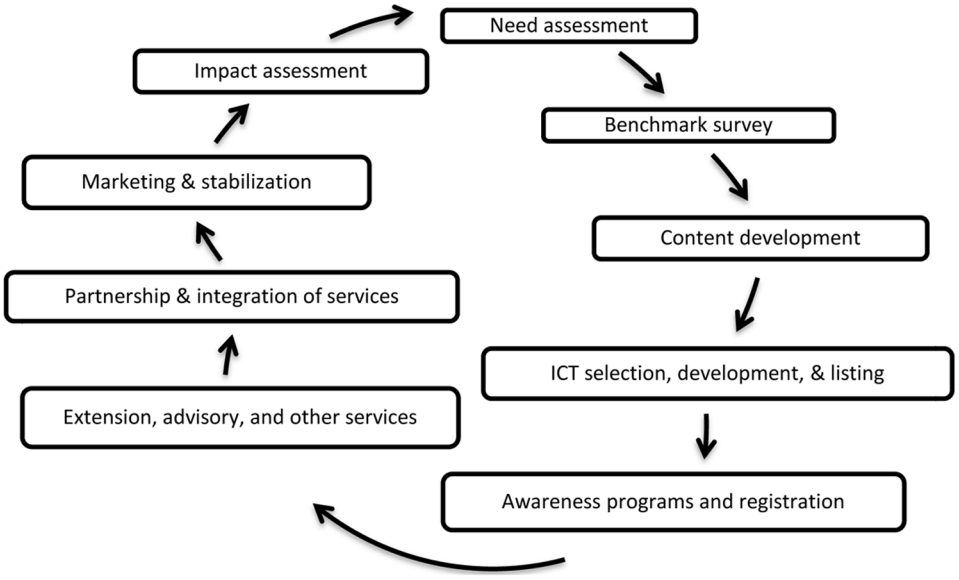

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Table 2. Strengths, weaknesses, opportunities, and challenges of ICTs in RAS

Strengths	Weaknesses	Opportunities	Challenges
Better access to services Cost-effective Timely Any time anywhere Supplements the role of extensionists Better research-extension-client system linkages	Success depends on human commitment Lack of personal touch in RAS Lack of ICT skill and competency Lack of institutional ICT policy in RAS Long-term sustainability	Continuous improvement of ICT infrastructure Penetration of high end mobile phones Reducing cost of ICT infrastructure and services Multiple players in RAS services provision using ICTs	Farmer-specific and relevant content Language barriers Low literacy of rural farmers Imparting skill and competence among RAS stakeholders to use ICTs Duplication and contradictory information flow

(Saravanan et al., 2015a)

Capacities Required for Using ICTs in Agricultural Development

ICT is an umbrella term used for different types of communication technologies that sometimes require completely different kind of skill set to productively develop, implement, and use them for development purposes. Also, depending on the target user, content modification becomes a very important issue. All these require professional capacities in both technology and social sciences. Table 3 below discusses the various capacities needed for successful implementation and ways to develop the major ICT tools predominant in agriculture.

Governance in ICTs for Agricultural Development

In the context of Agricultural Innovation Systems (AIS), to provide a quality extension and advisory services to the users, development and maintenance of the ICT projects needs to be a well thought out and planned measures involving more than one stakeholder working together. And this calls for a well-structured system that involves aptly positioned stakeholders to avoid overlapping roles. Depending on the type of ICT application, the type of governance varies and it is detailed in Table 4.

Table 3. Capacities required in and ways to develop ICT based interventions

ICTs	Capacities Required	Ways to Develop
Social media	Basic knowledge and skill in using internet and social media	Creating interest groups, awareness and training programmes and regular interaction and sharing
Radio, TV, tele-centres	Minimum knowledge of operating the stations and creation of suitable programs for selected medium. RAS professionals should create and deliver appropriate content.	Training in script writing, and content treatment. Need and location specific program creation and inclusion of farmers in the programs
Web portals, expert systems, Mobile apps, MOOCs	Proficiency in IT, expertise in choosing and packaging the content. Knowledge of web content development, content creation, interactive portal management, etc.	Specialized training for developing IT and subject matter experts. Integrating and updating content regularly, interactivity and knowledge base creation

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Table 4. Governance of ICT based projects in agriculture

ICTs	Maintenance	Partnership	Stakeholders	Roles
Social media	Individually maintained by extension organizations	Generally does not arise. Groups and communities can be managed in partnership mode.	All agricultural stakeholders can be brought on same platform	Host organization connects to clients and other stakeholder for better coordination and information sharing among the actors in AIS
Radio, TV, tele-centres	Programs recorded by extension organization, TV stations broadcast	PPP model, collaboration among public organizations.	Extension organizations, radio/TV stations or tele-centres, agricultural institutions, farmers	While extension organizations develop content of program, it is recorded by the radio/TV station or tele-centre crew. Agricultural institutions can act as information resource and farmers are the end users
Web portals, expert systems, Mobile apps, MOOCs	Hosted by extension organization, they provide information to farmers	Depending on stakeholders involved, it can be manned from PPP to profit oriented models.	Extension organization, web content developer/ app developer/course content developer, agricultural institutions (optional), and farmers	Development and management is a collaborative task, considering the involvement of many stakeholders. While the developers need to give constant upgrade, enhancements, maintenance and support, the RAS/ subject matter organization deals with content to be fed and expert service if needed to keep the information up-to-date. Farmers and others are end users.

Costs for Using ICTs for Agricultural Development

Cost of using/ developing ICTs ranges from free to a few million USD depending upon the infrastructure and scale of coverage. Capacity development activities also require considerable amount of money (Table 5).

CRITICAL ANALYSIS OF MAJOR ICTs

It is true that ICTs have transformed communication but in terms of its global reach, there are many more landmarks that need to be crossed. With increased access to the internet and increasing number

Table 5. Tentative costs of hosting different ICT based initiatives

ICTs	Items	Indicative Cost Involved
Social media	Internet with ICT device	ICT device cost (mobile phone/ or tablet or laptop or computer) and internet charges.
Radio, TV, tele-centres	ICT infrastructure, training for the facilitators, content creation	Depending on air time, the cost can vary from a few hundred to several thousand USDs. However, most of the state/ NGO owned TV, Radio stations can be used freely by the agricultural advisory institutions for extension and advisory services.
Web portals, expert systems, Mobile apps, MOOCs	Hiring a software specialist, training for maintenance, content collation, multimedia content, hosting etc	• Creating a basic website (USD 300 – USD 2,000), CMS integration (USD 2,000 -10,000), simple semantic portals (with 500 nodes of content USD 10,000 – 25,000) and multi-site semantic portals with multiple portlets (USD 25,000 – 60,000) and maintenance of web portals also requires considerable cost. • Expert systems may cost USD 1,000- 10,000 depending upon the design, software, and size of contents. • mApp development can be free of cost to USD 70,000 depending on its architecture and web interface

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of communication technologies with diversified working principle, a multifaceted situation is gaining traction which requires immediate attention to details for faster and wider acceptance. This specifically brings attention to the need for critically examining the advantages as well as the drawbacks of all these tools and build upon the information to make them an integral part of rural agricultural advisory systems worldwide. Table 6 deals on the same in details.

Problems

Implementers' Perspective

1. **Connectivity and Infrastructure:** Poor connectivity in rural areas, absence of electricity, transportation, markets and other infrastructural inadequacies restrict the implementers in using ICTs for development.
2. **Technical Workforce:** Technical human resource for ICT projects is very important for their smooth functioning. Functions like regular and timely updating of databases, developing location specific information, web integration and arrangement of links in case of web portals, transforming data/information in accessible formats for all type of users need technical workforce, which needs to be specifically trained in the tasks which is another challenge for the implementing agencies (Saravanan and Suchiradipta, 2015a).
3. **Sustainability of Funding:** ICT projects at the initial or pilot phase are more often than not funded by an external agency but after the pilot phase, in most of the cases, funding dries up and so do the projects. Financial sustainability is often addressed too late or never and so, irrespective of the influence of the projects on rural farming, communities have to wrap up, thus disappointing the beneficiaries and making them disinterested in such future attempts.
4. **Effective Participation of Communities:** Lack of proper planning, differences in project objectives and community needs, limited capacity building program of projects, lack of or limited interest of the community in projects due to their temporary nature, uninvolved communities as major stakeholders in projects, etc. (Saravanan, 2012) are some important factors that keep agricultural communities away from the ICT projects.
5. **Lack of Leadership:** To diffuse ICTs and implement them in a large scale in rural areas, effective leadership is needed at both institutional and community level. Opinion leaders in communities often lack interest in them and the younger generation does not have enough followers to effectively diffuse them in the communities, which makes a barrier in increased use of ICTs by rural communities.
6. **Farmers' Access to ICTs:** The rural smallholders often do not have access to any ICTs – personal or otherwise - which makes information delivery through those media or applications redundant.
7. **Institutional Barriers:** Lack of flexibility in content delivery, limited innovation, lack of institutional ownership, limited technical human resource, conflict of interest among project partners, limited research collaboration, red-tapism, and project tourism attitude, etc. (Saravanan, 2012) often take the focus away from the major objective of the projects – development of communities.

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Table 6. Critical analysis of major ICTs

	Information and Communication Technologies (ICTs)														
	TV		Radio		Mobile Phones (Basic/ Feature)		Computer/ Laptop/ Smart phones								
							Without Internet			With Internet					
	TV Broadcasting	Video with DVD	Radio Broadcasting	Community Radio	Text	Voice	Expert Systems/ DSS/ IMCDs	Digital Video	Animation	Web Site/ Web Portal/ Knowledge Banks/Online Repositories	Tele/ Video Conference	Mobile Apps	e-Learning Platforms (MOOCs)	Social Media
Target groups	Farmers, agripreneur, input dealers, stakeholder in value chain, extensionist	Farmers, agripreneur, extensionist	Farmers, agripreneur, input dealers, stakeholder in value chain, extensionist	Women farmer, agripreneur, stakeholder in value chain, input dealer	Literate farmers, agripreneur, input dealer, stakeholder in marketing channel, extensionist	Farmers, agripreneur, input dealer, stakeholder in marketing channel, extensionist	Literate farmers, extensionist, agripreneur	Farmers, agripreneur, extensionist	Illiterate farmers, extensionist	Literate farmers, agripreneur, input dealer, stakeholder in marketing channel, extensionist, policy maker	Farmer, extensionist	Mostly literate farmers, entrepreneur, input dealer, stakeholder in marketing channel and value addition, extensionist	Extensionist, researcher, academician, farmer, agripreneur, policy maker	Literate farmers, agripreneur, input dealers, stakeholder in marketing channels, extensionist, research and academic institution, experts, policy maker
Major RAS functions	Awareness, advisory, technology transfer, mass advisory, promotional, documenting and sharing of ITK	Advisory, technology transfer, awareness, documenting and sharing ITK	Awareness, advisory, technology transfer, mass advisory, promotional	Awareness, advisory, technology transfer, knowledge sharing, mass advisory, feedback	Awareness, advisory, market information and linking, credit and banking access, mass advisory, promotional, linking with AIS actors	Advisory, market and information linking, mass advisory, feedback, awareness, promotional, linking with AIS actors	Advisory, knowledge sharing, technology transfer, mass advisory	Knowledge sharing, documenting and sharing ITKs, technology transfer, training, knowledge sharing	Advisory, technology transfer, awareness	Advisory, documenting and sharing ITKs, market information and linking, input linking, M&E, enumeration, survey, linking with AIS actors, feedback	Training, advisory, linking with AIS actors, feedback	Awareness, advisory, knowledge sharing, market information and linking, credit and banking access, input linking, feedback, promotional, technology transfer, M&E	Training, education	Awareness, promotional, advisory, knowledge sharing, documenting and sharing ITKs, technology transfer, market information and linking, mass advisory, linking with AIS actors, feedback
Advantage	-Suitable for all stakeholders -Good medium for demonstrations	-Easy way of demonstration -Portability -Popularity in rural community	-Portability -Low cost -Popularity in rural community	-Tool of social learning -Increased women participation	-Low cost -Location and farmer specificity -Timely information	-Low cost -Portability -Easy feedback -Accessible for illiterates -Increased access to public information	-Easy access to expert advice -Location and farmer specific solution -Instant solutions	-Suitable for demonstrations -Low cost -High popularity -Increased women participation	-Suitable for awareness creation -Innovative and interesting	-Integrated information -Location specificity -Interactive -Open access	-Expert advice -Good scope for training	-Interactive -Updated information -Customization of information based on personal needs	-Integrated information -Location specificity -Interactive -Open access	-Interactivity -User generated content -Easy access in multiple devices -Increases dialogue among development practitioners
Limitation	-One way communication -Location specificity -Relevancy of personal context -Popularity	-Availability of playing device with farmers - Relevancy of personal context	-Location specificity -	-Lack of skill -Lack of funding	-Illiteracy -Network coverage - Relevancy of personal context -Popularity in agricultural use	-Network coverage -Relevancy of personal context - Popularity in agricultural use	-Illiteracy -Access to kiosks -Popularity among rural community -Updated database	-Access to player -Very specific type of information -Relevancy in personal context	-Limited scope -Less popular	-Illiteracy -Needs technical expertise -Possibly outdated content -Limited customization for individuals -Limited access by women farmers	-Limited access Limited scope -Unavailability of infrastructure in rural areas -Rarely used	-Illiteracy -Accessible only in smart phones -Information not personalized	-Illiteracy -Needs technical expertise -Possibly outdated content -Limited customization for individuals -Limited access by women farmers	-Illiteracy -Limited access -Costly data charges -Redundancy of information -Unauthenticated information

(Source: Saravanan et al., 2015a; Saravanan et al, 2015 b; Saravanan et al., 2015c; Saravanan and Suchiradipta, 2015c)

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End Users' Perspective

1. **Illiteracy:** ICTs, for example mobile phones, social media, web portals, online knowledge repositories, etc. require functional literacy at the least but even that is absent in many rural areas of developing and least developed countries. Furthermore, education illiteracy which is technical illiteracy remains another constraint. And in such cases, the illiterate farmers have very few options in accessing information and so reach is limited.
2. **Infrastructure:** Basic infrastructures in rural areas still have a long way to go. While in some areas telecommunication structures are poor or absent, in many parts of the world, electricity is yet to reach. Added to that is the absence of other infrastructures likes markets, credit facilities, transportation and so on, that limits or discourages the use of ICTs by the rural communities.
3. **Cost of Technology:** Affordability of technology is also a hindrance in its use to many smallholders. While devices like kiosks, computers, video players, etc. can be accessed from telecentres, mobile phones and other such personal devices are often out of reach for many farmers in developing countries. Also, the cost of data and other charges become expensive for many to afford (Suchiradipta, 2012).
4. **Information Explosion:** While a large amount of information is available in the public domain to access by anyone, this information can be confusing to many users. While filtering of important information is done by extensionists to suit the needs of the individual farmer, the farmers may not always be as competent in filtering those which may be more confusing than helpful.
5. **Lack of Awareness and Promotion:** Since ICTs are new introductions in extension services in many rural areas, proper awareness is needed in making the rural communities interested in using them. Also, because of lack of promotion, they often do not participate in the initiatives as active stakeholders.

Evidence of Impact and Potential Scalability of ICTs for Agricultural Development

Impacts of development efforts are generally multifaceted and their impact on social and personal lives of the benefactors is both direct and indirect, making them harder to point out clearly. With a two-sided argument existing around ICTs, mapping out the impact indicators can go a long way in evaluating the impact of the ICT based efforts and clearly state the achievements and limitations. They can also help with the potential scalability of ICT projects across the world, where crossing the hurdle of pilot stage is still a big concern. Table 7 discusses the same in details:

Issues of Sustainability in Using ICTs for Agricultural Development

Major factors that determine the sustainability of ICT use are the ICT tools used, the domain of the service providers (public or private) and the cost incurred in providing the services. Generally, advisory through TV, Radio and community radio, social media are free of cost services. Mobile, web, interactive multimedia CDs, Videos etc. are fee based value added services or free of cost depending upon the host institutions. Governments/ public sector service providers mostly provide free of cost services (Farmers call centres, Front line SMS etc). Private sector actors are generally implementing financially sustain-

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Table 7. Impact indicators and potential scalability of ICT based projects in agriculture

ICTs	Impact Indicators	Potential Scalability
Social media	Large number of YouTube channels hosted by farmers, popularity of the Twitter handle of AgChat, highly active social media pages in extension like GFRAS, AESA and farmers' pages like Mkulima Young provide the evidence of impact. Participation of the members in the continuous engagement and discussions, creation and sharing of contents, increase in the membership subscription and feedback of members can serve as impact indicators for social media.	Facilitation of social media platforms is key for achieving the growth of audience and scalability is continuous with the increase of members' enrolment which requires high level of participation and engagement of stakeholders
Radio, TV, Tele-centres	Significant knowledge enhancement through radio programs has been noticed among farmers is exposed to radio programs[5]. Before-after comparison of knowledge is an important impact indicator of broadcast services indicator.	Increasing number of programs in the prime time can give the agricultural programs larger audience and increased popularity
Web portals/ web sites/ MOOCs	e-Chaupal initiative in India for market price dissemination increased the price of soybean by 1.7 per cent and the result was instantaneous. It increased farmers' share in producers' money and reduced the cost incurred[7]. Access Agriculture, through videos hosted in the web portal, has changed the life of farmers across Asia and Africa, especially of women by taking information to them and organizing and empowering them[8].Time and cost saved, income increased, increased market participation, etc. after use of information provided through web portals, can act as impact indicators for web based information services.	Continuous monitoring and evaluation and based on the findings making necessary changes depending on clients' response is the best way to scale up web portals/expert systems and MOOCs
Mobile based advisory services	Higher market participation by farmers, reduced wastage, increased transaction, and declined search and transportation costs can serve as indicators of effectiveness of mExtension services. Information through mobile phones have strengthened local livelihoods, natural resources, increased awareness and networking opportunities, especially among women. Time saved, cost saved, income increased after use of information provided through mExtension services can act as impact indicators	Financial sustainability of mobile based services is the major issue in their scaling up and profitable business model is a necessity. Also, development beyond thepilot phase is most important for long term sustainability.

able and profitable models (e-Choupal in India, iCow and Kilimo Salama in Kenya, FCC in Uganda, and IKSL in India etc). However, for the profit oriented services, end users' perception of usefulness of information is the ultimate determinant of the success of the business model.

Sustainability of ICT projects beyond pilot phase has been a major drawback in their long term existence and there is more than one factor that influences their sustainability. The business model is very important factor since finances are the major cause of their cessation beyond the pilot stage. Also, profit oriented or financially sustainable services are more user demand oriented as subscription is important for incoming cash flow and with satisfactory service, users are found to be willing to pay for the services as in case of e-Choupal and IKSL in India, iCow and Kilimo Salama in Kenya, FCC in Uganda among many others. The funding agency also decides the business model to some extent, for example, as with government funding, cost-free services are more common whereas with public or private funding, profit motive is also a major factor along with development. The cost of providing the services impacts the business model to some extent.

Another factor that impacts sustainability of ICT projects are demand based information delivery. Agriculture being location specific, crop specific and time specific, blanket recommendations are helpful to none. Customized demand based information and advisory in ICTs are not choices but a necessity for long term sustainability.

Also, with changing dynamics of agriculture and time, farmers are focusing more on commercialization and so are demanding to be highly engaged to advisory service providers as important and active

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stakeholders of the system rather than mere beneficiaries of top-down development approach. Applications like social media, mApps, mobile and web based advisory services enable high user engagement and help them to customize the information they retrieve, thus making it personalized and applicable. This is an important feature in sustainability of ICT projects for long term.

CONCLUSION AND RECOMMENDATIONS

With increased technological advancement and its increased use in rural areas, farming communities are to gain a lot from the use of ICTs in information access related to their life and livelihood. Information is more important in agriculture and ICTs have the potential to be an aid in taking the much needed information to the farming communities. Inspite of the potentials, problems are many as discussed earlier and to overcome those, some steps become necessary, as discussed below:

1. **Implementation from Where Users Are:** Information provided to smallholders, irrespective of the means of delivery, needs to be location specific and timely. For any ICT based application, that is an opportunity as well as a challenge as the easier means of communication requires it to be updated regularly. And since access is easier compared to other traditional means, to gain and retain the users' faith in the service, the information needs to be location specific, and if possible, personalized.
2. **Youth Involvement:** The youth are the first to adopt any technological innovation in a social system and their involvement in planning and implementation is very important for overall success of the projects (Suchiradipta and Saravanan, 2013). Moreover, they can be leaders in community and family in diffusion of technologies for agricultural information.
3. **Institutionalization of ICTs:** To make ICTs an integral part of extension, the concerned institutes need to make their use an integral part of the work environment and the employees need to be encouraged about their use. Institutions also need ICT policies to encourage their use along with setting standards and boundaries that define the use of ICTs like social media focusing on the objectives and mandates of the institutions.
4. **Providing Basic Infrastructures:** Use of ICTs can only help the rural communities so far without any basic infrastructures like transportation, markets, credit facilities, etc. to translate the information acquired into practical action. Providing these basic facilities in rural areas is as important as the information, maybe more and so, in collaboration with competent authorities, development of infrastructure also needs to be prioritized.
5. **Appropriate Partnerships:** Appropriate partnerships are very important in the implementation of ICT projects for ensuring a smooth flow of resources (especially the funds to purchase and maintain ICTs), participation of local communities and institutions, regular updating of recent information in timely manner, effective management of stakeholders, and avoiding conflict for smooth functioning.
6. **Partnership with Local Institutions:** ICT applications are best applicable to smallholders when specific to their situations and to develop data and information that is timely and location specific, forging partnership with local research stations, universities, and other local institutions is desirable. Moreover, this makes getting up-to-date data easier and link-ups fruitful (Saravanan and Suchiradipta, 2015a).

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REFERENCES

FAO. (2015). *Five agents of change for a sustainable world.* Accessed on 24 September 2015 from, http://www.fao.org/post-2015-mdg/news/detail-news/en/c/281554/

Haddad, W. (2007). *ICTs for Education: A Reference Handbook.* Accessed on October 12, 2008 from, http://www.ictinedtoolkit.org/usere/p_page.php?section_number=0

ITU. (2015). *ICT facts and figures 2015*. Retrieved from http://www.itu.int/ict

Kemp, S. (2015). *Digital, social and mobile worldwide in 2015*. Accessed on August 12, 2015 from, http://wearesocial.net/blog/2015/01/digital-social-mobile-worldwide-2015/

Millennium Project. (2006). *Millennium Development Goals – What they are*. Accessed on September 24 2015 from, http://www.unmillenniumproject.org/goals/

Sadowsky, G. (1996). *The Internet Society and Developing Countries*. Accessed on October 25, 2015 from, http://www.isoc.org/oti/printversions/1196prsadowsky.html

Saravanan, R. (2011a). Tribal Farm Youth for Facilitating Agricultural Advisory Services by ICTs: A Success Story from North-East India. *Abstract Volume of the National Seminar on Attracting Farm Youth to Sustainable Agriculture*.

Saravanan, R. (2011b). *e-Arik: Using ICTs to Facilitate "Climate-Smart Agriculture" among Tribal Farmers of North-East India*. ICTs and Agricultural Adaptation to Climate Change Case Study. Centre for Development Informatics, University of Manchester. Accessed on April 5, 2012 from www.niccd.org/NICCD_AgricAdapt_Case_Study_eArik.pdf

Saravanan, R. (2012). e-Initiative for Agricultural Extension: Browsing for Logout? *Proceedings of the AFITA/WCCA 20012-8th Asian Conference for Information Technology in Agriculture (AFITA) and World Conference on Computer in Agriculture (WCCA)*. Retrieved from http://www.afita.org/graph/web_structure//files/Seminar%20%2807%29-01%281%29.pdf

Saravanan, R. (2013). e-Agriculture prototype for knowledge facilitation among tribal farmers of North-East India: Innovations, impact and lessons. *Journal of Agricultural Education and Extension*, *19*(2), 113–131. doi:10.1080/1389224X.2012.718247

Saravanan, R., & Suchiradipta, B. (2015a). Role of ICTs in family farming: Experiences and way forward. In Family Farming and Rural Economic Development. New India Publishing Agency.

Saravanan, R., & Suchiradipta, B. (2015b). Invest in IT to boost agricultural services. *Smart Agri Post: Empowering Agripreneurs, 1,* 22-24. Retrieved from http://www.smartagripost.com/wp-content/uploads/2015/07/Smart-Agripost-July-20153.pdf

Saravanan, R., & Suchiradipta, B. (2015c). *mExtension – Mobile Phones for Agricultural Advisory Services*. Note 17. GFRAS Good Practice Notes for Extension and Advisory Services. GFRAS: Lindau, Switzerland. Retrieved from www.g-fras.org/en/download.html?download=349:ggp-note-17-mextension-mobile-phones-for-agricultural-advisory-services

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Saravanan, R., & Suchiradipta, B. (2015d). *Social media: Shaping the future of agricultural extension and advisory services. GFRAS interest group on ICT4RAS discussion paper*. Lindau, Switzerland: GFRAS.

Saravanan, R., Suchiradipta, B., Chowdhury, A., Hambly Odame, H., & Hall, K. (2015c). *Social Media for Rural Advisory Services*. Note 15. GFRAS Good Practice Notes for Extension and Advisory Services. GFRAS. Retrieved from www.g-fras.org/en/download.html?download=355:ggp-note-15-social-media-for-rural-advisory-services

Saravanan, R., Suchiradipta, B., Meera, S. N., Kathiresan, C., & Anandaraja, N. (2015b). *Web Portals for Agricultural Extension and Advisory Services*. Note 16. GFRAS Good Practice Notes for Extension and Advisory Services. GFRAS. Retrieved from www.g-fras.org/en/download.html?download=356:gfras-ggp-note-16-web-portals-for-agricultural-extension-and-advisory-services

Saravanan, R., Sulaiman, R. V., Davis, K., & Suchiradipta, B. (2015a). *Navigating ICTs for Extension and Advisory Services*. Note 11. GFRAS Good Practice Notes for Extension and Advisory Services. GFRAS. Retrieved from www.g-fras.org/en/download.html?download=351:ggp-note-11-navigating-icts-for-extension-and-advisory-services

Suchiradipta, B. (2012). *Mobiles for mobilizing Agricultural Extension in India*. Credit Seminar presented in School of Social Sciences. *College of Post Graduate Studies, Central Agricultural University, Umiam, Meghalaya*, *793*, 103.

Suchiradipta, B., & Saravanan, R. (2013). Youth and ICTs for Agricultural Development. In K. Narayana Gowda, M. S. Nataraju, & V. Veerabhdraiah (Eds.), *Youth in Agriculture and Rural Development*. New Delhi: New India Publishing Agency.

Suchiradipta, B., & Saravanan, R. (2016). *Social media: Shaping the future of agricultural extension and advisory services*. GFRAS interest group on ICT4RAS discussion paper. GFRAS. Available at www.g-fras.org/en/knowledge/gfras-publications.html?download=414:social-media-shaping-the-future-of-agricultural-extension-and-advisory-services

World Bank. (2011). *ICT in agriculture: Connecting small holders to knowledge, networks, and institutions*. e-Source Book. Report no. 64605. Washington, DC: The World Bank. Available at: http://www.ictinagriculture.org/content/ict-agriculture-sourcebook

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Chapter 23
Exploring Alternative Distribution Channels of Agricultural Products

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ABSTRACT

Fresh fruits and vegetables constitute the basis of many people's daily nutrition habits and different distribution systems have been developed to cover daily supply needs. Important components of alternative distribution channels among others are high quality, high standards and consumer-producer trust. Although numerous studies have been conducted on alternative types of distribution channels, there is a lack of research on consumer behaviour towards these ways of distribution. The aim of this article is to identify consumer attitudes and preferences towards alternative agricultural distribution channels regarding fresh fruits and vegetables. In addition, this article contributes to the understanding of consumer behaviour, by pointing out the factors that affect the final purchase of agricultural products.

INTRODUCTION

Globalization and recent economic trends have created highly complex supply chains and as a result their design, organization, interactions, competencies, capabilities and management have become key issues (Ashby et al., 2012). A close study of past research has shown only some traces of a structured approach to supply chains including their weak aspects and the risks involved (Svensson, 2000, Sheffi, 2001,

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Zsidisin et al., 2000, Guertler and Spinler, 2015, Dekker et al., 2013, Cantor et al., 2014, Heckmann et al., 2015). In order to have an integrated supply chain, a totally new approach needs to be implemented, whose development involves other related disciplines, such as market research and operational strategic management, incorporating empirical research theories and methodologies (Cheng and Grimm, 2006, Wisner, 2003). The aim of any commercial operation, including the agrifood sector, is obviously competitive advantage, which can be created by synchronizing supply chain strategy with competitive policy (Porter, 1985). This can be accomplished by establishing a wide spectrum of alternative and opportunity networks, such as distribution channels, that form a coordinated, integrated whole (Achrol, 1997, Tsang, 2000).

Important components of alternative distribution channels among others, are high quality, high standards and consumer-producer trust (Whatmore, 2003). A customer-centered approach (Spiller, 2008) and a short distribution channel direct product provision from producer to consumer, are fundamental to optimal distribution. It was found that short supply chains incorporate farmers' markets, street stalls and street markets, direct farm sales and more recently the Internet. A key priority of agriculture and rural development is to strengthen both the means of distribution and the processes and functions of the short supply chain (Burt and Wolfley, 2009, Mauleón, 2003, Falguera et al., 2012). A competitive perishable food industry, can not only provide healthy and safe food to consumers but also may constitute a factor in stabilizing the economy by generating jobs, for instance, even during the global economic crisis (Mattas and Tsakiridou (2010).

Although numerous studies have been conducted on alternative types of distribution channels, there is no specific research in the field on consumer behaviour towards the use of alternative distribution channels of agricultural product in Greece.

LITERATURE REVIEW

To begin with, the salient characteristics of innovativeness which reinvigorate supply chain management have appeared in conceptual and empirical studies (Chapman et al., 2003, Roy et al., 2004, Soosay et al., 2008, Panayides and Venus Lun, 2009), while Yu et al., (2014) stress that integrated green supply chain management has a positive result on operational performance. In their explanation on the historic evolution of Decision Theory in management, French et al.(2009) state that for an up-to-date, successful decision-making process, the characteristic of sustainability is needed.

There are many researches that focus on the estimation that there is a lack of structured approach regarding supply chains that also include the weak aspects and the risks involved (Sheffi, 2001, Svensson, 2000, Guertler and Spinler, 2015, Dekker et al., 2013, Cantor et al., 2014, Heckmann et al., 2015). Ashby et al (2012) find that the design, organization, interactions, competencies, capabilities and management of complex supply chains have become key issues. Xue et al., (2014) investigate that alternative channel structures are affected by supply chain, and consumer behavior is affected by alternative channel structures. A key priority of agriculture and rural development is to strengthen both the means of distribution and the various processes and functions of the short supply chain (Burt and Wolfley, 2009, Mauleón, 2003, Falguera et al., 2012). Mattas and Tsakiridou (2010) focus on a competitive perishable food industry during the global economic crisis, besides providing healthy and safe food for consumers, may become a factor of stabilizing the economy. Generally, there is growing interest in alternative food systems within the context of environmental and social sustainability (Cleveland et al., 2014).

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As concerns the Local food networks focus on sustainable food production, distribution and consumption through collaboration to establish local, self-reliant economies (Katchova and Woods, 2013). As concerns the Fair trade, is associated with people's rights to an acceptable standard of living, quality of life, equal participation opportunities, and ecological sustainability (Micheletti and Stolle, 2012).

By adopting green marketing, firms can emphasize their social responsibility and promote their businesses as friends of the environment (Almossawi, 2014). The promotion of green purchasing behaviour to young people is a growing tendency (Almossawi, 2014). Furthermore, consumer perception, organic product characteristics, such as product labelling, product innovations and the range of products on the market, is increasing (Schleenbecker and Hamm, 2013).

The new construct of Consumer Sustainability Consciousness enables an understanding of sustainable consumption products and consumer behaviours through an integrated Triple Bottom Line (TBL) perspective (Carvalho. et al., 2015). There are specific models of personalities of on-line consumes based on emotions, attitudes and perception that affect purchasing behaviour (Schröder et al., 2015). Consumer purchasing behaviour of minimally processed fresh fruit and vegetables has implications for marketing strategies (Stancu et al., 2016). Rödiger and Hamm, (2015) find that price affects consumer behaviour in their willingness-to-pay for organic food has mixed and contradictory results. The use of EU quality labels on food products is slowly but steadily affecting consumer purchasing decisions (Grunert and Aachmann, 2016). Suprem et al, 2013, find that the application of technology systems is an emerging area and plays an important role in the agrifood sector.

As results based on previous researches about the characteristics and criteria of alternative agricultural distribution channels, it becomes obvious that there is a great interest for further studies regarding the attitude and behaviour of consumers towards these alternative channels of distribution. The objective of this research is to investigate consumer attitudes and preferences towards alternative distribution channels regarding agricultural products and especially, fresh fruits and vegetables. Thus this study contributes to the understanding consumer behaviour, highlighting the factors that affect the final purchase of agricultural products. This objective includes the main research on how willing consumers are to trust alternative ways of distribution.

The research hypothesis constitutes a possible answer to a research question and it is determined after a review of a relevant literature, which leads the researcher to expect a specific relationship between variables (Syed, 2009). Based on the research objective, the following hypotheses are defined and examined:

H1: There is a relationship between the use of alternative distribution channels for purchasing agrifood products and consumer's socio-economic characteristics or consumer behaviour is affected by alternative channel structures (reveals from 2 and 3 section of questionnaire).

H2: A key priority of agriculture and rural development is to strengthen both the means of distribution and the various processes and functions of the alternative distribution channels (reveals from 2 and 3 section of questionnaire).

H3: There is growing interest in alternative food systems within the context of environmental and social sustainability (reveals from the first section of questionnaire).

H4: The new construct of Consumer Sustainability Consciousness enables an understanding of sustainable consumption products and consumer behaviors through an integrated Triple Bottom Line (TBL) perspective (take into account the sustainability issue, the Social- environmental-economic perspective and reveals from 2 and 3 section of questionnaire).

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H5: Consumer purchasing behaviour is influenced by inter-personal suggestion (reveals from the first section of questionnaire).

H6: The application of technology systems is an emerging area and plays an important role in the agri-food sector (reveals from the first section of questionnaire).

H7: Consumer purchasing behaviour of minimally processed fresh fruit and vegetables has implications for marketing strategies (this reveals from the results from all the research and it is affairs of the study contribution).

METHODOLOGY

The research took place in Thessaloniki during January to March 2016 using a random sampling approach and collecting 420 valid questionnaires. Descriptive statistics, cross-tabulation and Qualitative-Research (Q-R) hybrid methodology were applied in order to measure consumer behaviour towards alternative distribution channels of agricultural products.

The present study illustrates that consumers are interested in alternative distribution channels and the supply of fresh fruits and vegetables. The results of the survey may offer constructive conclusions for policy makers, entrepreneurs, consumers and the academic sector. In particular, the present study concluded, that consumers trust alternative distribution channels for purchases of fresh fruit and vegetables, since they believe that these channels increase employability. The study concludes that there is space for further development and promotion of alternative distribution channels in the agricultural and food sector.

In accordance with relative literature in the same cases due to investigate consumer behaviour use this methodology model (Kim and Lee, 2015). Especially, Q methodology has been applied to explore subjective perspectives in many research cases (Zanoli et al., 2015, Chapman et al., 2015, Kraak et al., 2014). For the analysis through SPSS tool, we could use frequency, cross-tabulation and concerning the core of Q–R hybrid methodology, Multivariate Analysis of Variance (MANOVA) (Chen et al., 2015). Especially, Q methodology includes a qualitative research and R methodology based on empirical approach, although this study will design a Q tool as a Q–R method that forms a link between qualitative and quantitative research.

More specific, the aim of this study is to discover and interpret a systematic classification of customer types based on the subjectivity of Q theory in a qualitative approach. Following, the theoretical and conceptual interpretations are verified and generalized in sequence by combining the Q and R empirical methods. The results of this research can be applied in the investigation on consumer behavior towards alternative distribution channels of agricultural products (Kim and Lee, 2015). With this method we could explore local resident's experiences and perceptions, could examine 42 statements concerning attitudes towards alternative distribution channels of agricultural product and mainly fresh fruits and vegetables.

The Q method is a qualitative research approach based on process theory that examines human (consumers') behavioral and motivational traits in the field of market research. It is a model based on subjectivity research that investigates human characteristics, such as feelings and emotions, preferences and choices, tastes and ideals. The individual 'subjective' experience each consumer has with the real- world functions within an "internal frame of reference", forming the 'schemata' that appears in questionnaires with words and phrases such as 'me', 'to me' 'in my opinion', 'in my view', etc. (Kim and Lee, 2015).

Q method is a new scientific approach in consumer behavior research that enables the formulation of hypotheses by focusing on discovery rather than preconceived concepts (Kim et al., 1993, Kim and

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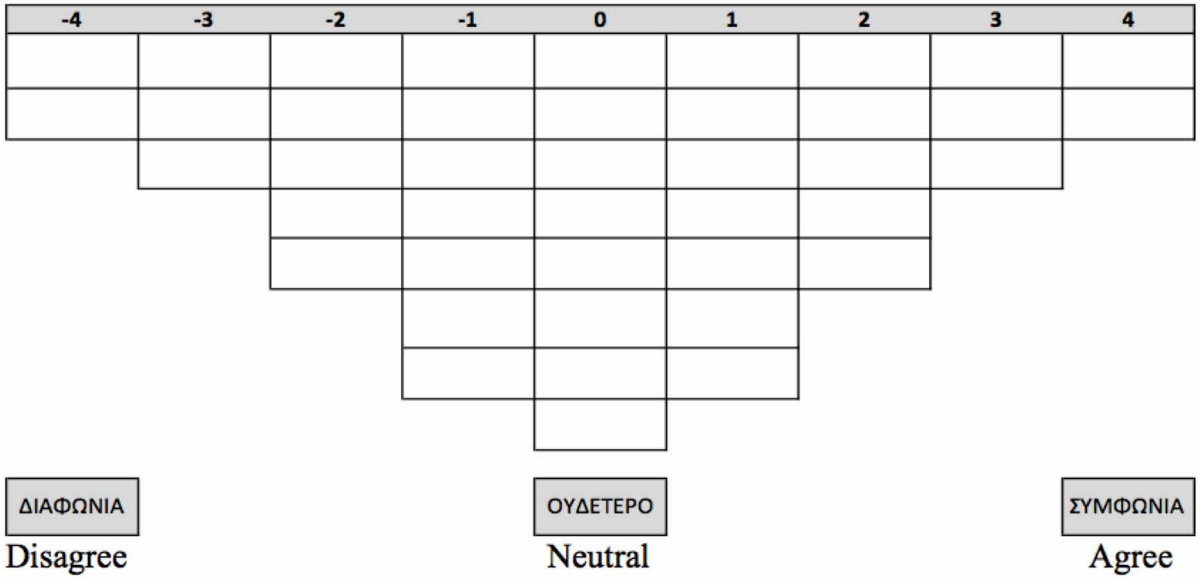
Lee, 2015). In comparison to the R method, which is a simpler type of quantitative study, the Q method is far more complex. Variables in Q concern a person, not items as in R. The R method requires a relatively large sample size so as to estimate the population characteristics, whereas Q sampling is a much more intricate process. It involves the careful attention of the researcher in order to obtain every case of subjectivity that is expressed. Q method, which involves the study of human beings, compares the intra-individual differences of one stimulus rather than inter-individual ones (Kim and Lee, 2015).

Q-Methodology

In order for methodology Q to be conducted, 42 statements based on recent bibliography were created, and they were printed in 42 numbered cards. Then, the participants were asked to read the statements in the cards and then divide them in 3 categories. In the first category, they put the statements they disagree with, in the second those statements which they had a neutral attitude towards and in the third category belonged the statements they agree with. Then, the participants were asked to categorize these 42 cards in the survey's questionnaire, as it is shown in picture 1. Initially, two statements that the participants disagreed with were listed in position -4 (absolutely disagree), then three statements were listed in column -3 (strongly disagree), five statements were listed in column -2 (disagree), and seven statements in column -1 (moderately disagree). The same charting of statements was conducted for the statements, which the participants agreed with or they felt neutral about (Figure 1).

In a few words, the participants were asked to list 42 statements in a questionnaire of 42 cells, where 17 statements were distributed in the 17 cells that expressed absolute disagreement till partial disagreement, 17 statements in the cells that expressed agreement, partially or absolutely, and eight statements in the column intended for neutral attitude, the process of filling out the questionnaire was approximately 60 minutes.

Figure 1. The Q deck of Q methodology in which participants were asked to fill in 42 statements in 42 cells



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In total, 80 questionnaires were filled out by consumers which know about alternative distribution channels and the fruit and vegetables that are being distributed through them. Every completed questionnaire of qualitative survey represents the subjective opinions of every participant regarding alternative distribution channels, agricultural fruit and vegetables, agricultural products, supply chains and the effect of capital controls on the raw fruit and vegetable market.

After the questionnaires had been filled out, the data were inserted in the PQMETHOD program, via which Factor analysis was conducted. Each factor represents the opinions of the participants. From the analysis above two factors have derived. In particular, in the first factor the statements which participants agreed with the most are presented in Table 1, while the statements which participants disagreed with the most are presented in Table 2.

Results

In Table 1, it is evident that social media, act as a means of advertising which affect consumer attitude towards fruit and vegetable. It is also evident that how much customers trust the producers is very important. Plus, capital controls affect which alternative distribution system of raw fruit and vegetable consumers are going to choose. Then, in factor number, the interest of consumers in the further development of alternative distribution channels is evident, while they believe that farmers should be educated on new technologies, which will enforce the alternative distribution channels of agricultural products.

From the statements that express disagreement, in factor 1, we can conclude that customer-centred approach in not an important factor in today's market, while environmental conscience is absent from the

Table 1. Factor 1 – Statements, which customers mostly agreed with

Statement	Rank
Social media affect the purchase of raw fruit and vegetable via alternative channels distribution.	+4
Trust towards raw fruit and vegetable producer is of crucial importance for choosing the alternative distribution channel	+4
Capital controls affect consumers' preference, when they choose alternative distribution channels.	+3
I am interested in up-dating and modernizing of alternative distribution systems	+3
I believe that farmers should receive proper training on new technologies, so that distribution channels will be enhanced and developed.	+3

Table 2. Factor 1 – Statements that participants mostly disagree with

Statement	Rank
Promoting a "green" purchasing behaviour of young people is a growing trend.	**-4**
There is a luck of structured approach regarding supply chains, which include their weaknesses and risks.	**-4**
Designing, organising, interactions, and possibilities as well as management of complicated supply chains have become important issues.	**-3**
In today's market customer centred approach is important.	**-3**
Alternative distribution channels are affected by the supply feature in the chain and consumer behaviour is affected by the alternative structures in the channel.	**-3**

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purchasing behaviour of young consumers. Furthermore, one can observe that customers disagree with poorly structured supply chains, with the effect of supply chains on alternative distribution systems and on consumers' attitude. Lastly, it derives that the design, structure and perspectives, as well as management of complicated supply chains are not important issues to the participants.

In Tables 3 and 4 the statements of the second factor are presented (Factor2) which represent the strong agreement and strong disagreement of the participants. In particular, in Table 3 gender appears to affect very much the purchase of products, especially via internet, and it is also observed that customers become more and more familiar with the alternative distribution channels. Furthermore, the use of alternative distribution channels could possibly affect and change consumers' way of living, while suggestions from one person to another on a personal level seem to affect purchasing behaviour. Therefore it is believed that the use of technology systems will greatly affect the agricultural and food sector.

In Table 4, it is evident that statements which cause disagreement in Factor 1, are also included in Factor 2, in a different ranking position nonetheless. Results regarding "disagreement statements" enforce the consumers' beliefs regarding "green" purchasing attitude of young people, supply chains, and the necessity of adopting a customer oriented approach in today's market.

Eleven statements derived from this survey which cause either agreement or disagreement in both factors, and they are presented in Table 5. It is believed that these statements represent the positive (or negative) attitude of consumers towards the sectors of alternative distribution channels and agricultural products.

In particular, on a statistical level smaller than 0.01 (p-value<0.01), participants agree that the new models of alternative distribution channels contribute to the decrease of unemployment and poverty. Furthermore, social media, as a means of promoting fruit and vegetable, affect consumer purchase at-

Table 3. Factor 2 – Statements consumers strongly agree with

Statement	Rank
I believe that gender strongly affects online products purchase.	*+4*
My way of living has changed dramatically since I started buying products via alternative distribution channels.	*+4*
The use of Technological systems play an important role in agricultural and food sector.	*+3*
Purchasing behaviour is affected by suggestions on a personal level.	*+3*
The more I use an alternative distribution system, the more familiar I feel towards it.	*+3*

Table 4. Factor 2 – Statements participants mostly disagreed with

Statement	Rank
Promoting a "green" purchasing behaviour of young people is a growing trend.	-4
There is lack of structured approach regarding supply chains, which include their weaknesses and risks.	-4
In today's market customer centred approach is important.	-3
Designing, organising, interactions, and possibilities as well as management of complicated supply chains have become important issues.	-3
Alternative distribution channels are affected by the supply feature in the chain and consumer behaviour is affected by the alternative structures in the channel.	-3

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titude. Therefore, tradesmen of fruit and vegetable can use social media to advertise their products, in order to affect and attract consumers.

Furthermore, it is evident that the use of alternative distribution channels makes the purchase of agricultural products easier in comparison to the conventional distribution methods. The above statement sets the prerequisites for promoting alternative distribution channels by entrepreneurs and policy makers, since the development of these channels will create new jobs and customers will be more pleased by the whole purchase experience. In order to promote alternative distribution channels, motives should be in order to attract farmers to get educated on new technologies, so that alternative channels will be promoted. Furthermore, the excellent designing and structure of the channels should be a priority, since these two elements set the base for their sustainability. Consequently, the people already involved in the channels and people who wish to get involved should examine the organizing and designing, so they will create the bases for the channels' sustainability.

Furthermore, farmers and traders of fruit and vegetables can provide solutions regarding the post-crop value of the products, since this is an important factor which affects customers even when they purchase in conventional markets. Lastly, it is important that there is the belief that globalization and complexity of the supply chains haven't affected alternative distribution channels, and this proves that they are powerful alternatives for fruit and vegetable as well as agricultural products distribution.

In Table 6, the statements which are differentiated regarding agreement and disagreement between the two factors are presented. These statements create the prerequisites for further inquiry, in order to answer why consumers have an opposing attitude towards alternative distribution systems of raw fruit and vegetable.

Table 5. Statement with unanimity in both factors

Unanimous Statements	F1	F2	p-value
New models of alternative distribution channels of agricultural products, contribute to the decrease of unemployment and poverty.	2	1	<0.01
Social media affect the purchase of raw fruit and vegetable via alternative channels distribution.	4	1	<0.01
Trust towards raw fruit and vegetable producer is of crucial importance for choosing the alternative distribution channel	4	1	<0.01
I believe that farmers should get educated on new technologies, so that alternative distribution channels are enhanced.	3	1	<0.01
Proper designing and structure of the channels should be a priority, since these two elements are the base for their sustainability.	1	2	<0.01
By using an alternative distribution channel, I realise that the purchasing process is easier in comparison to conventional channels.	1	2	<0.01
A key priority of agriculture and rural development is to reinforce the means of delivery and operating procedures of alternative distribution channels.	-2	-2	<0.01
The recent economic developments and globalization have created very complex supply chains.	-2	-2	<0.01
Alternative distribution channels are affected by the supply chain, and consumer behaviour is influenced by alternative channel structures.	-3	-3	<0.01
The designing, organization, interactions, the possibilities and the management of complex supply chains have become key issues.	-3	-3	<0.01
Although the nature of fresh fruits and vegetables are "sensitive" in the sense that they can easily be damaged and lose their nutrients, I prefer to purchase them from alternative distribution channels.	-1	-1	<0.05

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Table 6. Distinctive statements between two factors

Distinctive factors	F1	F2	p-value
I believe that the encouragement and the trend for consumers to purchase products environmentally friendly encourage consumers to adopt "green" purchasing behaviour.	2	-2	<0.01
Connecting local food systems with educational programmes for children and adults and professionals, the purchasing behaviour of consumers and their mentality can change, creating a higher demand for local products.	1	-1	<0.01
Consumers' interest in organic products is increasing while offer is changing as well.	1	-2	<0.01
By adopting a "green" marketing policy businesses can be socially responsible and promote themselves as environmentally friendly.	1	-1	<0.01
Consumers' purchase behaviours is affected by interpersonal suggestions.	-1	3	<0.01
The price defines the behaviour of consumers towards buying organic products.	-1	1	<0.01
Consumers' purchase behaviour regarding fruit and vegetable consumption have consequences on marketing strategies.	-1	1	<0.01
I believe that apart from financial and commercial benefits, local distribution networks provide more social cohesion for the population.	1	-1	<0.01

In particular, it can be investigated why consumers of factor 1 agree that encouraging consumers to buy environmentally friendly agricultural products, encourages the spreading of "green" purchasing behaviour, while consumers of factor 2 disagree. Furthermore in factor 1 it is observed that educational programmes for children, adults and professionals that focus on local food distribution systems can affect consumers' behaviour towards local products.

Consumers of factor 2, seem to agree with the above situation, creating this way the prerequisites for their investigation, so that the necessary data will be found and policy makers and entrepreneurs can use them in order motivate consumers towards local products and the corresponding distribution channels.

In the organic product sector, consumers of factor 1 seem to agree with the statement that the increase in offer of differentiated organic products will positively affect customers' buying interest. This belief provides the necessary information which helps entrepreneurs and farmers of organic products to attract more customers and increase their income. However, consumers of factor 2 seem to disagree with this statement, creating this way the motive for further investigation of the causes and characteristics, so that the differentiated organic product market and their advertising is conducted via targeted criteria.

Conclusions

It derives from this study, that consumers are highly interested in alternative distribution channels and raw fruit and vegetable supply. This behaviour creates the necessary conditions so motives for the development of alternative distribution systems are created. The results of this study can contribute useful information to the policy makers, to entrepreneurs, consumers and academics. In particular, through this study is concluded that alternative distribution channels, which consumers trust for their fruit and vegetable and agricultural product purchase, contribute to the increase of employment and the reduction of poverty. Therefore, there is the need for developing and further promoting alternative distribution channels.

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Furthermore, due to capital controls, the massive development of the internet and its use by consumers, it is believed that creating incentives and educating farmers on new technologies can positively affect the purchase behaviour of consumers. Since new technologies are expected to play an important role in agricultural and food sector, the policies that will encourage farmers and everybody that is involved in distribution channels to get educated on these technologies and adapt them, are believed to encourage development and expansion of local economy, by promoting local products. However, for this purpose to be achieve, it is important that there is an excellent designing and organisation of the alternative distribution systems, so there is a solid foundation for their sustainability.

Furthermore, the use of social media in order to promote agricultural products and in particular raw fruit and vegetable is a method for attracting consumers and for increasing the purchase of raw fruit and vegetable. Therefore, the necessary foundations are created for further investigation of the consumers' characteristics, who are affected by the advertising of fruit and vegetables and the factors that positively affect purchasing behaviour, so that promoting fruit and vegetables can be enhanced. Consequently, it is important that the social space is created, where local products and distribution channels are advertised. This social space will be an opportunity for proper up-dating of customers regarding the above sectors, so that customers will trust them more and develop a trend towards them.

Lastly, after the end of this study the necessary foundation for further investigation of the factors, that customers disagree with, regarding alternative distribution channels, raw fruit and vegetable purchase and the use of technology, which will enhance their development.

RESULTS OF DESCRIPTIVE RESEARCH

Consumers' Profile

Out of the 420 consumers that participated in the survey in the region Thessaloniki, 49% were male and 51% male. 4.8% of the participants were 18 to 25 years old, 11% were 26-35 years old, 43.3% were 36-45, 23.8% were 46-55 years old, 8.3% were 55-56 and 8.8% were above 66 years old. As far as education is concerned 4.3% of the participants had a Masters or PhD degree. 51% have completed their undergraduate studies in Universities, 42.4% are Private College graduates and graduates from technological faculties, while are Lyceum (high school) graduates, Gymnasium graduates and are primary school graduates represent 2.4% of the total number of consumers. Furthermore 40.7% of the consumer sample is married while 57.6% is single. Lastly, the income of the 3.1% of consumers was less than 750€, 37.9% earns 751 to 1000€, 6.4% earns 1001- 1500€, 19.3% earns 1501-2000€, 16.7% earns 2001-2500€, while 13.3% earns 2501-3000€, 1% earns 3001- 3500€, and 2.4% earns more than 3501€ (Table 7).

Purchasing Behaviour

In Figure 2, the use of alternative distribution channels by consumers is presented. Particularly 15% of consumers buy their agricultural products directly from producers on a daily basis, 34.8% more than once a week, 26.4% once a week, 17.6 once a month and 6.2% never buy directly from producer. 43.3% of consumers buy their vegetables from the local grocery's store once a week, 12.4% more than once a

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Table 7. Consumers' social and economic characteristics

Factor	Variable	Frequency	Percentage %
Gender	Male	206	49.0
	Female	214	51.0
Age	18-25	20	4.8
	26-35	46	11.0
	36-45	182	43.3
	46-55	100	23.8
	55-65	35	8.3
	66 and older	37	8.8
Marital status	Married	171	40.7
	Single	242	57.6
	Divorced	7	1.7
Education	Primary School graduate	2	0.5
	Gymnasium Graduate	3	0.7
	Lyceum Graduate	5	1.2
	Private colleges and Technological faculties	178	42.4
	University Graduates	214	51.0
	Master's degree or PhD	18	4.3
Monthly Family income	<200€	13	3.1
	201 – 400€	159	37.9
	401 – 600€	27	6.4
	601 – 800€	81	19.3
	801 – 1.000€	70	16.7
	1.001 – 1.500€	56	13.3
	1.501 – 2.000€	4	1.0
	> 2.001€	10	2.4

week, 1.2% on a daily basis, 38.3% every month and 4.8% never buy vegetables from these shops. 61.9% of consumers choose local specialized stores once a week, 23.8% more than once a week, 1.2 on a daily basis, 9% once a month and 4% never uses specialized stores. Furthermore 80.2% of consumers buy their agricultural products once a week at a supermarket, while 13.8% once a month and 6% never buy their products at a super market. Open-air flea markets are used by 55.2% of consumers on a weekly basis, 37.6% once a month. While 7.1% never buys agricultural products at an open-air market. E-commerce is used by 54.8% on a weekly basis. While 34.8% uses e-commerce every month and 10.5% never uses e-commerce. From the above data it is evident that the majority of consumers uses alternative distribution channels for the purchase of agricultural products.

In Figure 3 it is evident that 83.8% of consumers use e-commerce for the purchase of raw fruit and vegetables, 72.4% buy straight from the producer, and 32.4% prefer Fair trade products.

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Figure 2. Frequency of consumer use of alternative distribution channels

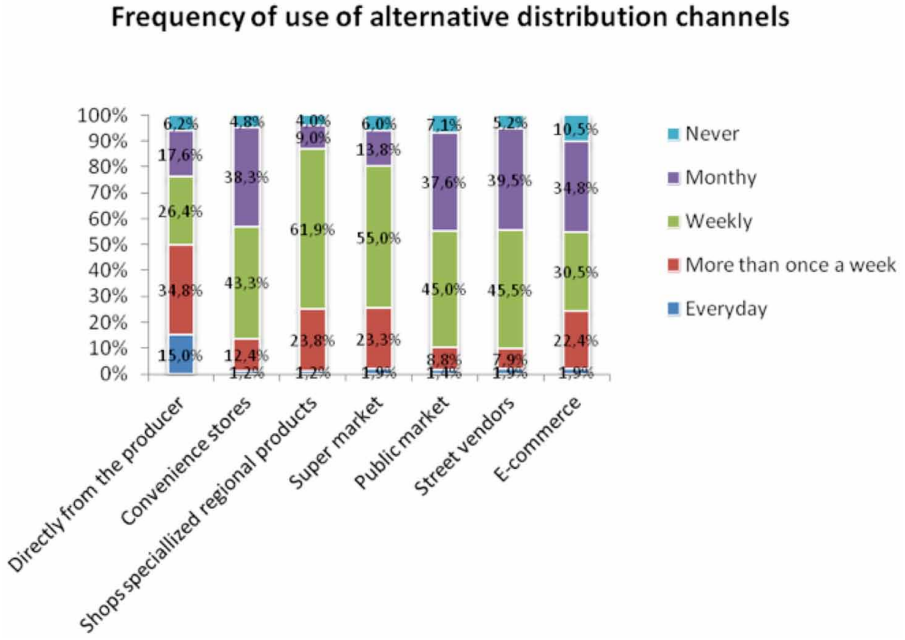
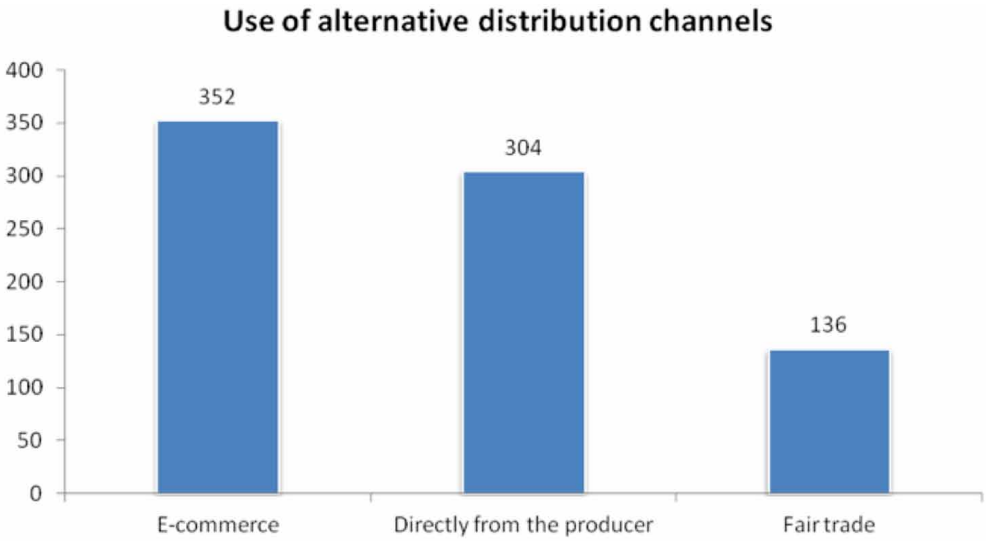


Figure 3. Use of alternative distribution channels



In Figure 4, 91% of consumers trust the fresh fruit and vegetables which are cultivated in the wider region.

Furthermore in Figure 5 it is shown that 68.8% of consumers who use e-commerce believe that agricultural product prices are satisfactory, 13.3% believe prices are low and 9.5% believe that prices are high. Consumers that buy agricultural products directly from producers (66.7%) believe that prices are

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Figure 4. Consumers' trust in fresh fruit and vegetables which are cultivated in the wider region

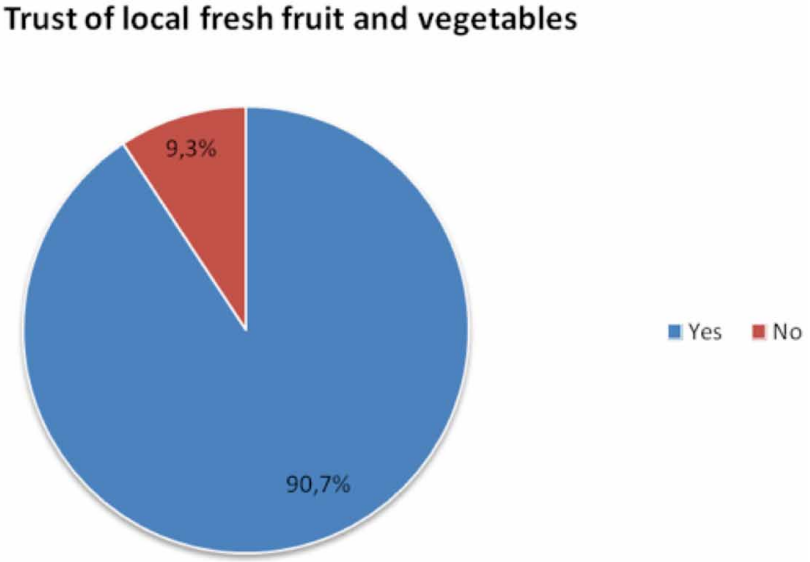
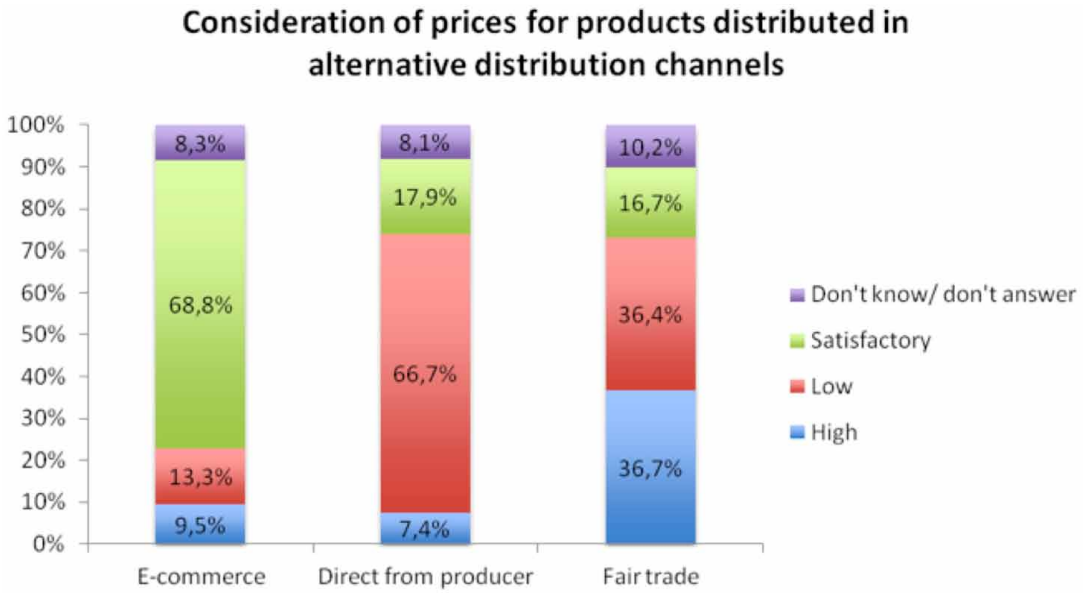


Figure 5. Consumers' opinion on the prices of products that are distributed via alternative distribution channels



low and 17.9% that prices are satisfactory and 7.4% stated prices are high. As far as fair trade is concerned, 36.7% of consumers believe that the prices of agricultural products are high, 36.4% think they are low, and 16.7% believe that the prices of agricultural products are satisfactory.

Table 8 shows the statements on the purchasing behaviour of consumers towards alternative distribution channels. Specifically, 90.7% of consumers said that the use of alternative distribution channels

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Table 8. Statements regarding the purchasing behaviour of consumers towards alternative distribution channels

Statement 1: Easy access to food purchase
Statement 2: The price of raw fruit and vegetables are lower
Statement 3: Limited variety of raw fruit and vegetable
Statement 4: Customer service is direct
Statement 5: Customers can directly check the origin of raw fruit and vegetable
Statement 6: Fresh fruit and seasonal vegetables are available
Statement 7: Raw fruit and vegetables are available on a daily basis
Statement 8: A healthier diet is promoted
Statement 9: Participation in protecting the environment
Statement 10: The alternative distribution channels support sustainability and sustainable development
Statement 11: Alternative distribution channels appeared in Greece due to the economic crisis
Statement 12: Capital controls affect the choice of the alternative distribution channel

is distinguished for the easy process of purchasing products. 46.7% believe that the prices of fruit and vegetables are lower in alternative distribution channels. 23.1% of consumers say that alternative distribution channels offer a limited variety of fresh fruit and vegetables. Furthermore, 39.3% of consumers say that the service is direct and 39.5% believe that it is possible for them to check the origin of fresh fruit and vegetables. Moreover, 73.3% of consumers said that the alternative distribution channels provide fresh fruit and seasonal vegetables. 79.7% of consumers agree that fresh fruit and vegetables are available on a daily basis in alternative distribution channels and 79.8% of consumers believe that their nutrition is improved. 79.2% of consumers said that by purchasing via alternative distribution channels they participate in environmental protection and that these channels ensure sustainability and sustainable development (78.1%). 71.4% of consumers believe that alternative distribution channels appeared in Greece due to the economic crisis. Lastly, 74.3% of consumers agree that Capital controls affect the choice of the alternative distribution channel.

Figure 6 shows the factors why customers choose alternative distribution channels. Specifically, consumers said they choose alternative distribution channels because they believe that the products are safer (81.4%), healthier (78.8%), have high quality (77.9%) and high nutritional value (77.4%). In addition, 72.3% of these consumers stated that the products- in the alternative distribution channels of their choice- are suitable for the nutrition of their children and 74% said that they have better prices in comparison to conventional means of distribution of agricultural products. 55.5% of consumers agree that they choose alternative distribution channels because environmental consciousness plays an important role in their lives and 65.7% of consumers choose alternative distribution channels, because they meet their standards and values.

Fair Trade

In Figure 7, it is shown that 32% (n = 136) of the sample consumers use Fair trade. They products that they choose are cereal, chocolate and coffee.

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Figure 6. Factors that affect consumers when the choosing an alternative distribution channel

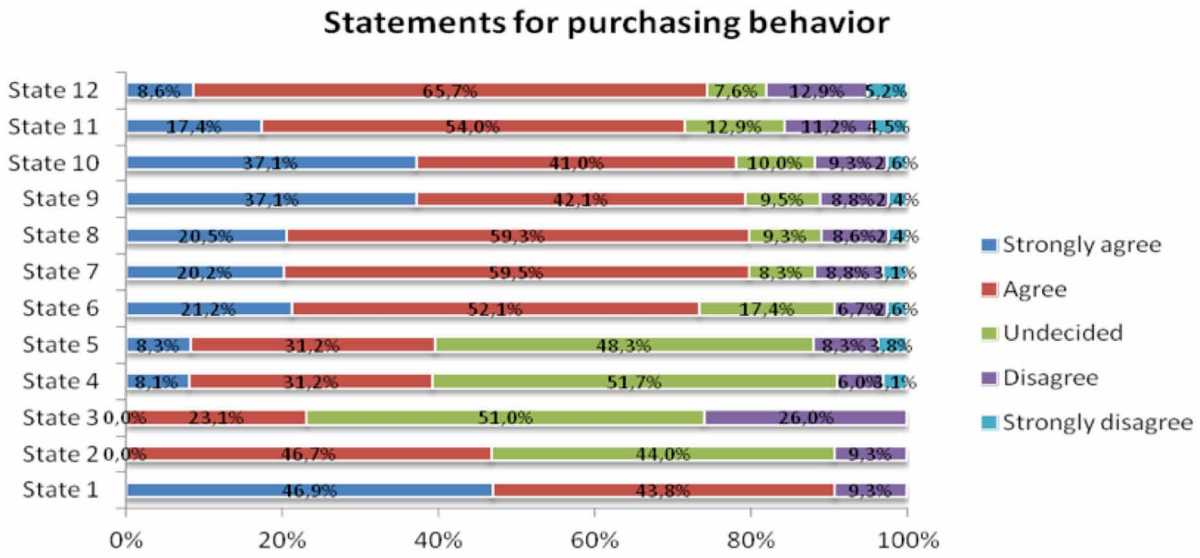
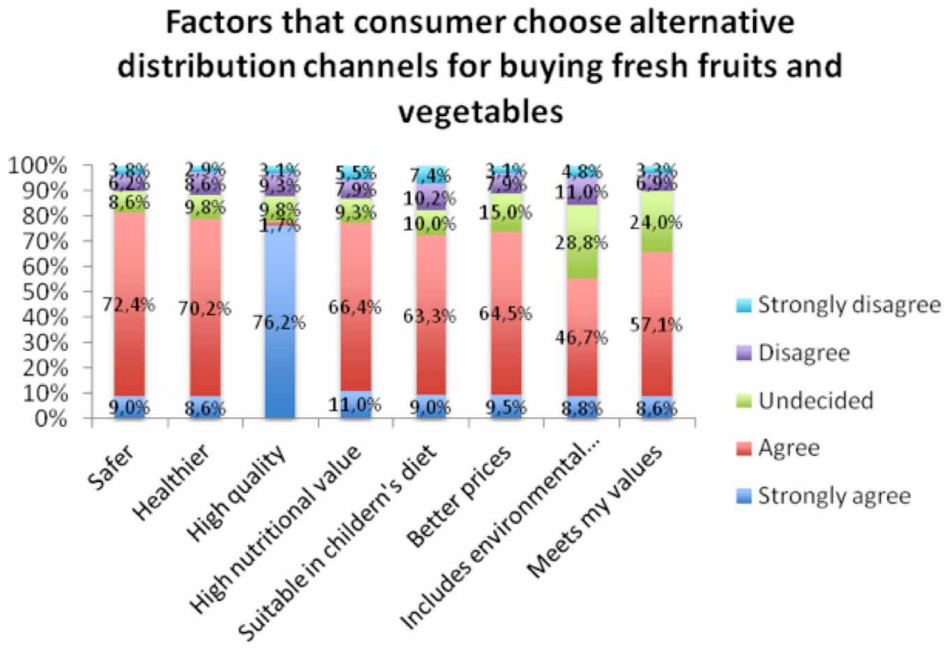


Figure 7. Distribution of consumers who choose Fair Trade



In Figure 8, the tendency of consumers towards Fair trade is presented. Consumers mainly buy cereal, chocolate and coffee.

The most important factors for choosing Fair trade products are social contribution and the improvement of the quality of life in the lands, where these products are produced.

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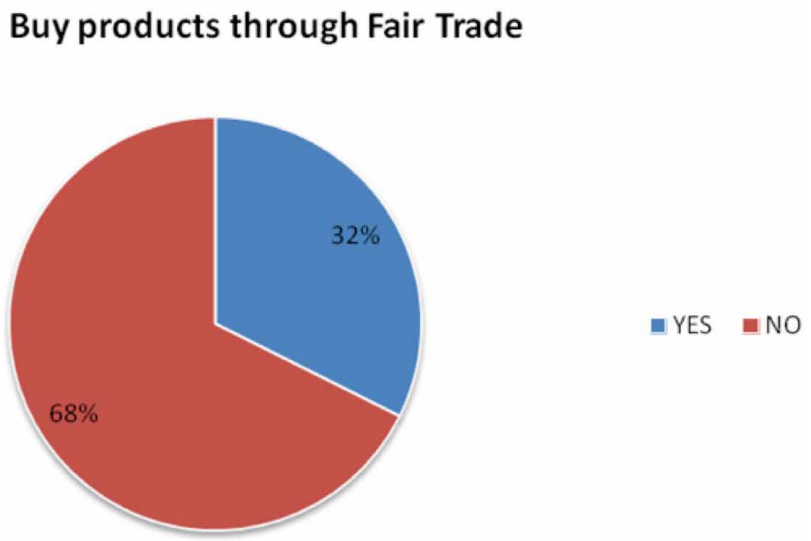
Figure 8. Products that consumers buy through Fair Trade



Consumer Behaviour Towards Fresh Fruit and Vegetable

In Figure 9, the most important factors that affect consumers when buying fresh fruit and vegetables are presented. The most important factors are improvement of their health (89.3%), price, habit, quality (88.6%), land of origin (88.1%), appearance (88.6%), technology (88.1%) and authenticity (87.6%).

In Figure 10 we learn how people get informed about the alternative distribution channels. Particularly, consumers are affected mostly by commercials (50.2%), by social media (53.8%) TV (51.2%), family (49.8%) and friends (49.8%).

As we can see in Figure 11, last week, 9% of consumers spent less than 20€, 55% spend 21 to 40€, 31% spend 41 to 60€, while 4% spends 61 to 90€ and 1% more than 90€.

When consumers were asked to compare the amount of money they spent on fresh fruit and vegetables before and after the implementation of capital controls, 93% of consumers answered that they do not spend the same amount of money. Therefore, capital controls have affected consumer behaviour regarding the purchase of fruit and vegetables (Figure 12).

In Figure 13 we can see that the majority of consumers (85%) believes that the prices of fruit and vegetables, since the implementation of capital controls, are high. Only a mere 6% of the total number of consumers believes that prices are low and no one believes that they are the same and only 5% think prices are satisfactory.

In Figure 14, it is shown that 82.6% of consumers believe that bank controls have enhanced the internet as a fundamental channel for transactions by individual consumers.

In Figure 15, it is evident that there is an increase of transactions by credit card, before as well as after the implementation of capital controls. Particularly, before the implementation of capital controls in Greece, 35% of consumers paid by credit card 1-3 times a month and 45.7% 3-4 times a week, 13.3% less frequently than that, 6% never used a credit card and no one used credit cards for their transactions.

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Figure 9. Factors that affect customers when buying fresh fruit and vegetables

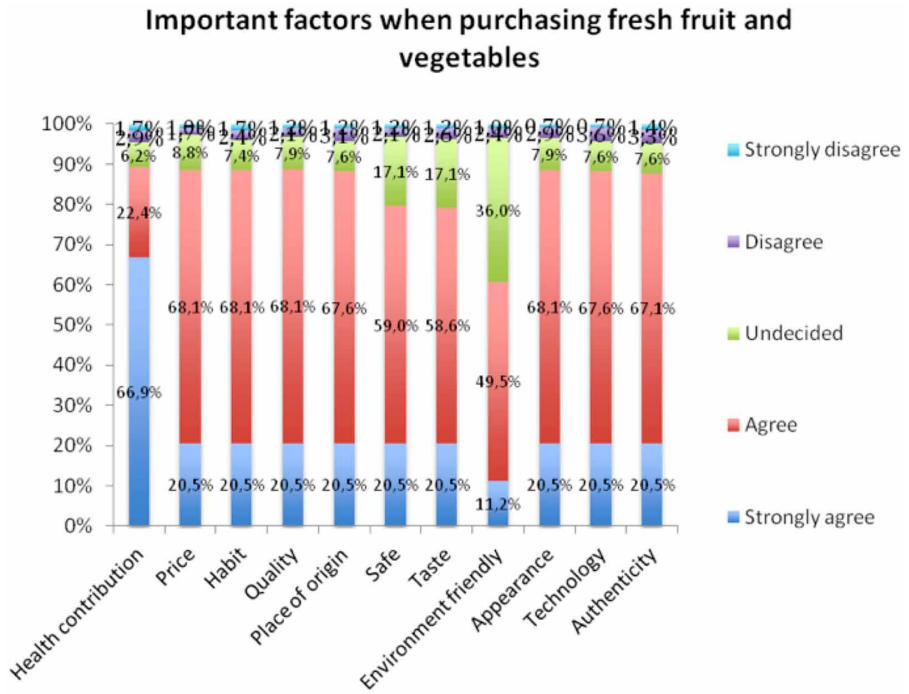

Figure 10. Sources of information regarding raw fruit and vegetables

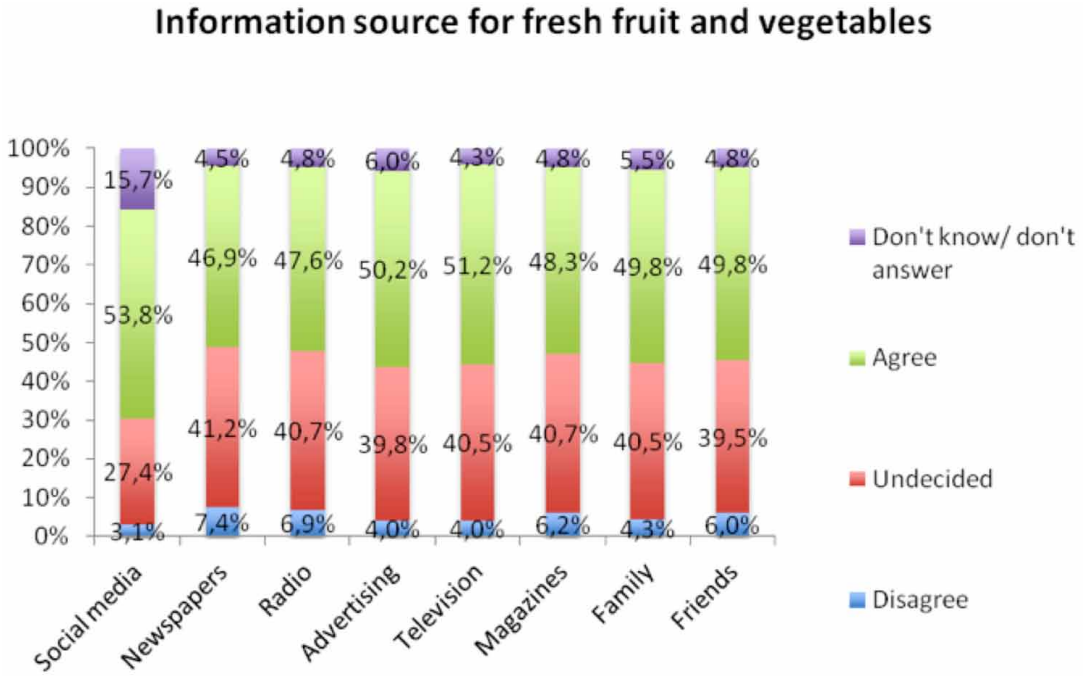

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Figure 11. Last week's expenditure on raw fruit and vegetables

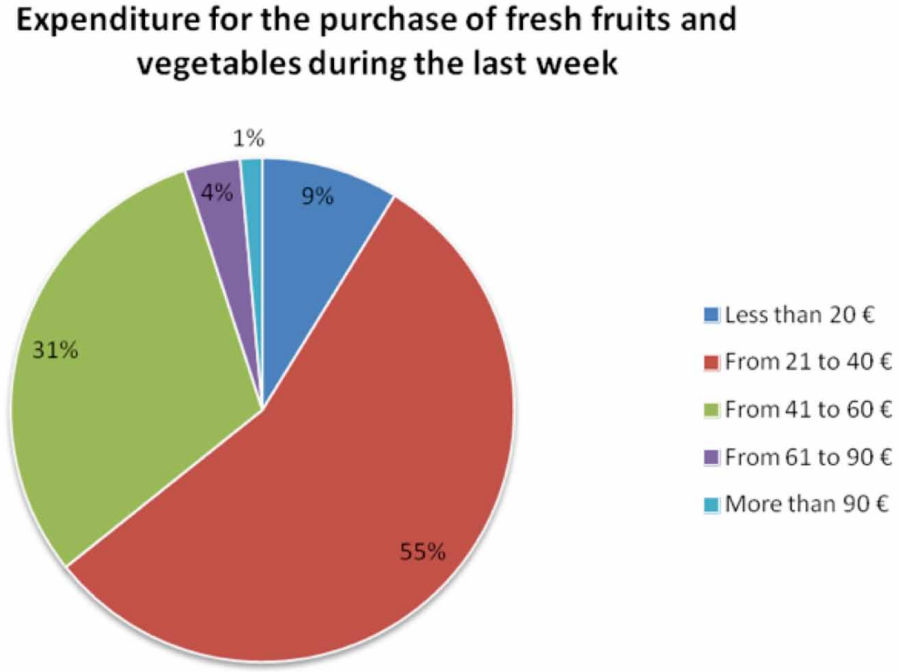

Figure 12. Comparison of expenditure on fresh fruit and vegetables before and after Capital control system

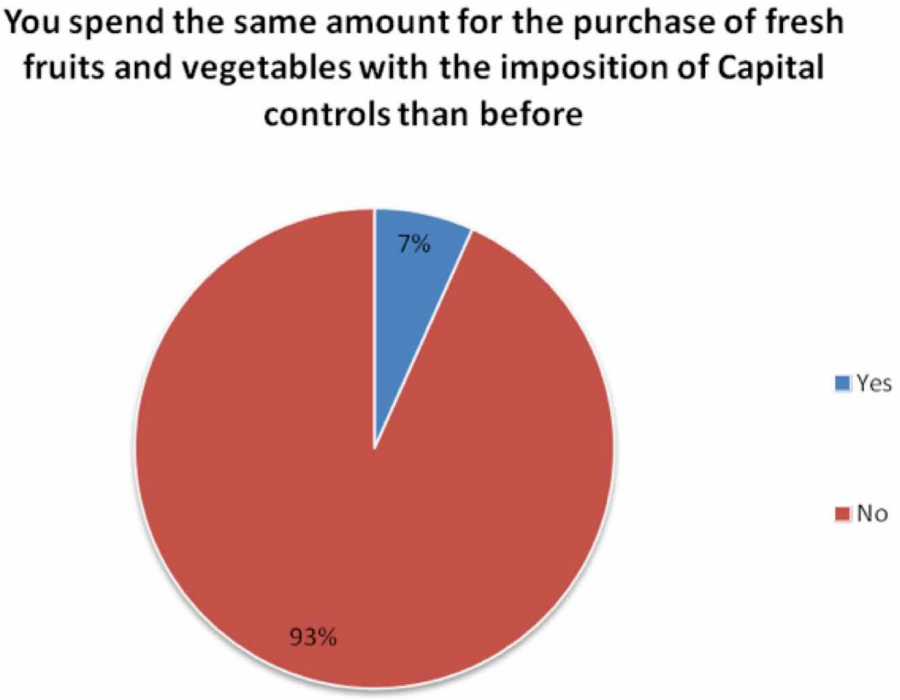

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Figure 13. Consumer opinions on the prices of fruit and vegetables after the implementation of capital controls in Greece

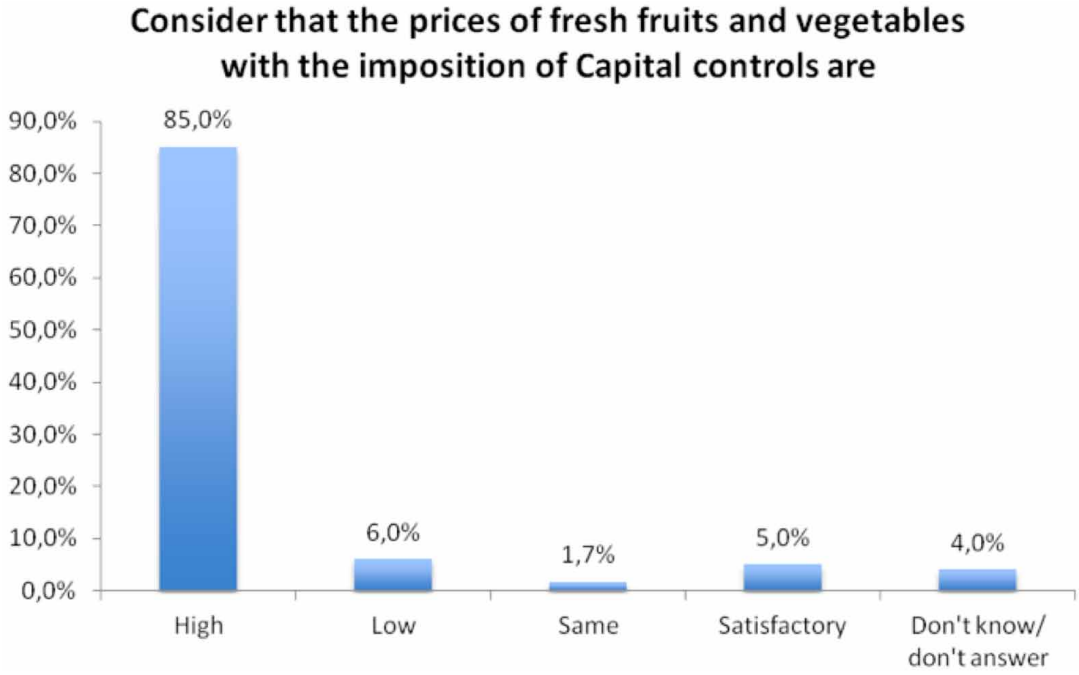

Figure 14. Estimation that the bank holiday upgraded the Internet as a key channel of transactions by individuals/consumers

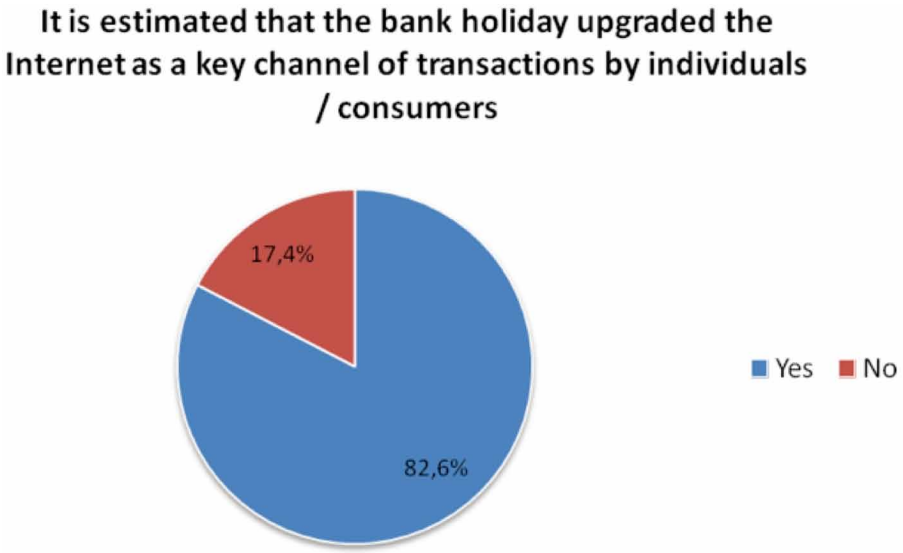

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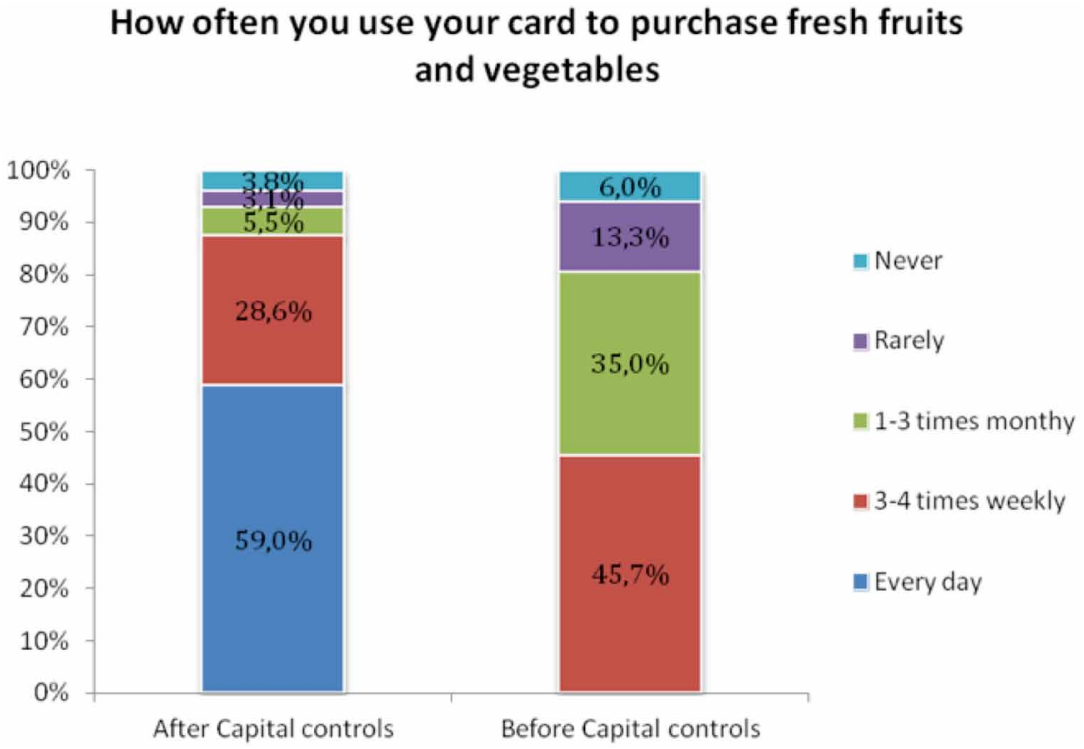
Figure 15. Use of credit cards for the purchase of fresh fruit and vegetables before and after the implementation of capital controls in Greece



After the implementation of capital controls, 59% of consumers use credit cards on a daily basis, 28.6% 1-3 times per week, and 5.5% 1-3 times a month, 3.1% uses credits cards less frequently and 3.8% never use a credit card for their transactions.

Quantitative Analysis Hypotheses Testing

For the Testing of quantitative analysis hypotheses, the methodology of one-way Manova and Q methodology were used. Paricularly, hypotheses 1,3,4 and 6 are tested via Manova Methodology, while hypotheses 2,5 and 7 are checked via Q methodology. So, in the present chapter the results of the quantitative testing (Manova) are presented.

For the investigation of the first case the variables "purchase of fresh fruit and vegetables direct from the producer," "purchase of fresh fruit and vegetables from e-commerce" and "use of alternative distribution channel: Fair Trade" were selected as dependent variables. In the part of the independent variables consumers' age and monthly family income were selected.

Hypothesis 1: There is a relationship between the use of alternative distribution channels for the purchase of agricultural and socio-economic characteristics of consumers.

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Table 9 shows the results of Manova for the first case. In particular, the purchase of fresh fruit and vegetables through e-commerce is significantly associated with age, since F-value=2.561, p<0.05. So, the use of e-commerce for the purchase of fruit and vegetable differs among consumers of different age. The purchase of fresh fruit and vegetables through e-commerce is significantly associated with income, since F-value = 3.727, p < 0.01.

Moreover, the use of alternative channel: "Directly from the producer", on an one-variable level is correlated with monthly income (p<0.05), but there was no correlation with age. So, the use of the channel "directly from producer" for the purchase of fruit and vegetable differs regarding only monthly family income.

The use of fair trade for the purchase of agricultural products is related with consumers' age (F-value = 2.704, p < 0.020) and the monthly family income (F-value=4.332, p<0.01). So, consumers who use Fairtrade for the purchase of agricultural products differ significantly regarding income and age.

In order to assess the third case the selected dependent variables were "purchase of fresh fruit and vegetables from e-commerce", "purchase of fresh fruit and vegetables direct from the producer" and "use of alternative distribution channel: Fair Trade." The independent variable is the statement "Alternative channels of agricultural products ensure sustainability and sustainable growth and development" and the factor "The channels includes in the distribution a type of environmental consciousness" for the use of alternative distribution channels by consumers.

Hypothesis 3: There is growing interest in the use of alternative distribution channels regarding the environment, sustainability and sustainable development.

Table 10 shows the results of Manova methodology for the testing of the third hypothesis. It seems that the use of the fair-trade channel by consumers is correlated with the statement that: "Alternative distribution channels ensure sustainability and sustainable development. Moreover, sustainability and sustainable development it seems that affect consumers who buy directly from producers, since there is a correlation (F-value = 2.224) on a significance level of p=0.066.

Table 9. Results of Manova for the first hypothesis – correlation between the use of alternative distribution channels and socio-economic characteristics of consumers

Independent variables	Dependent Variables	Mean Square	F	Sig.
Age	Which alternative agricultural channel do you use - Fair trade	0.439	2.704	0.020
	Where do you buy fresh fruit and vegetables – Directly from Producer	1.286	1.079	0.371
	Where do you buy fresh fruit and vegetables – e-commerce	1.979	2.561	0.027
Monthly Family Income	Which alternative agricultural channel do you use - Fair trade	0.703	4.332	0.000
	Where do you buy fresh fruit and vegetables – Directly from Producer	5.181	4.347	0.000
	Where do you buy fresh fruit and vegetables – e-commerce	2.88	3.727	0.001
Age x Monthly Family Income	Which alternative agricultural channel do you use - Fair trade	0.398	2.451	0.001
	Where do you buy fresh fruit and vegetables – Directly from Producer	1.043	0.875	0.619
	Where do you buy fresh fruit and vegetables – e-commerce	0.838	1.085	0.363

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Table 10. Model Manova results for the third hypothesis - correlation between the use of alternative distribution channels and variables relating to the environment, sustainability and sustainable development

Independent variables	Dependent Variables	Mean Square	F	Sig.
Sustainability and sustainable development	Where do you buy fresh fruit and vegetables – Directly from Producer	2.629	2.224	0.066
	Where do you buy fresh fruit and vegetables – e-commerce	0.851	1.036	0.388
	Which alternative agricultural channel do you use - Fair trade	0.520	3.469	0.008
Environmental awareness	Where do you buy fresh fruit and vegetables – Directly from Producer	0.995	0.841	0.499
	Where do you buy fresh fruit and vegetables – e-commerce	0.948	1.154	0.331
	Which alternative agricultural channel do you use - Fair trade	0.303	2.021	0.091
Sustainability and sustainable development x Environmental awareness	Where do you buy fresh fruit and vegetables – Directly from Producer	1.943	1.644	0.071
	Where do you buy fresh fruit and vegetables – e-commerce	0.900	1.095	0.361
	Which alternative agricultural channel do you use - Fair trade	0.506	3.381	0.000

Regarding environmental consciousness, there is a correlation with the use of Fair trade channel on a significance level $p = 0.091$. Moreover, the use of fair trade and purchases directly from producers are correlated with the multivariable "Sustainability and sustainable development X environmental consciousness" on a significance level of $p = 0.00$ and $p = 0.071$ accordingly.

However, there was no correlation between "environmental consciousness and sustainable development" and the use of e-commerce by consumers for the purchase of fresh fruit and vegetables. This outcome highlights the need of informing consumers though the internet about the benefits of e-commerce, sustainability and sustainable development.

In order to test hypothesis 4, we investigated the relationship between the dependent variables of Triple bottom line (environment, economy, social responsibility) with the use of alternative distribution channels. Particularly in the economic field, the dependent variable is the statement "The price of fruit and vegetables is lower", for the environment the dependent variable is the factor in the choice of alternative distribution channels "During the distribution they include an environmental distribution" and regarding social responsibility the dependent co-variable is "use of alternative distribution channel: Fair Trade", as consumers use it primarily because it enhances the living standards in the area that produces the products. The independent variables are "purchase fresh fruit and vegetables via e-commerce" and "directly from the producer."

Hypothesis 4: Triple bottom line

Table 11 shows the results of the correlations of the Manova model on the fourth hypothesis. Particularly regarding the sector of economy, there seems to be a correlation between the consumers who purchase agricultural products straight from producers (F-value = 5.826, $p<0.01$) and via e-commerce (F-value = 40.188, $p < 0.01$). As far as environmental consciousness is concerned, there is a correlation with the purchase behaviours and tendencies of consumers who buy agricultural products through e-commerce (F-value = 6.303, $p < 0.05$) and directly from producer (F-value = 7.594, $p < 0.01$). Lastly, regarding

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Table 11. Results of Manova model for the fourth hypothesis - correlation between the use of alternative distribution channels and variables relating to the environment, economy and social responsibility (Triple bottom line)

Independent Variables	Dependent Variables	Mean Square	F	Sig.
Environmental awareness	Where do you buy fresh fruit and vegetables – Directly from Producer	8.971	7.594	0.006
	Where do you buy fresh fruit and vegetables – e-commerce	4.880	6.303	0.012
Prices of fresh fruit and vegetables are lower	Where do you buy fresh fruit and vegetables – Directly from Producer	6.882	5.826	0.003
	Where do you buy fresh fruit and vegetables – e-commerce	31.116	40.188	0.000
Purchase of Agricultural goods via Fair Trade	Where do you buy fresh fruit and vegetables – Directly from Producer	0.360	0.305	0.581
	Where do you buy fresh fruit and vegetables – e-commerce	13.730	17.734	0.000

social responsibility, as we can see in table 4.4, there is a correlation with the consumers who prefer e-commerce for their purchases (F-value = 17.734, $p < 0.01$). From the above data we conclude that economy, environmental consciousness and social responsibility (triple bottom line) plays an important role in the choice of alternative distribution channels by Consumers.

In order to test hypothesis 6, part of the dependent variables included "purchase of fresh fruit and vegetables directly from the producer," "purchase of fresh fruit and vegetables from e-commerce" and "use of alternative distribution channel: Fair Trade". Regarding the independent variables the selected variables were "important factor when buying fresh fruit and vegetables: "Technology" and "information regarding fresh fruit and vegetables through social networks".

Hypothesis 6: The application of technology systems is an emerging field and plays an important role in the food processing sector.

Table 12 reveals that the relationship between alternative distribution channels of agricultural products (agricultural sector) and Technology systems. Specifically, on an one-variable level, the use of

Table 12. Manova model results for the sixth hypothesis - correlation between the use of alternative distribution channels and variables regarding technology

Independent Variables	Dependent Variables	Mean Square	F	Sig.
Important factor when buying fresh fruit and vegetables: Technology	Where do you buy fresh fruit and vegetables – Directly from Producer	2.002	1.688	0.152
	Where do you buy fresh fruit and vegetables – e-commerce	4.692	5.479	0.000
	Which alternative agricultural channel do you use - Fair trade	1.284	12.74	0.000
Information source: Social networks	Where do you buy fresh fruit and vegetables – Directly from Producer	1.800	1.518	0.209
	Where do you buy fresh fruit and vegetables – e-commerce	0.660	0.771	0.511
	Which alternative agricultural channel do you use - Fair trade	0.406	4.027	0.008
Technology x Social networks	Where do you buy fresh fruit and vegetables – Directly from Producer	2.427	2.046	0.033
	Where do you buy fresh fruit and vegetables – e-commerce	2.083	2.432	0.011
	Which alternative agricultural channel do you use - Fair trade	0.437	4.342	0.000

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Fair Trade relates to the technology factor (F-value=5.479, p<0.01) but not with the social networks (p-value> 0.05. Therefore, technology in relation to sources of information correlates with the agricultural purchases through e-commerce. Similarly, regarding purchases directly from producer there is a statistically significant correlation with the technology factor and the information through social media.

The "Fair Trade" channel is correlated on one-variable and a multivariable level with the factor "information through social media".

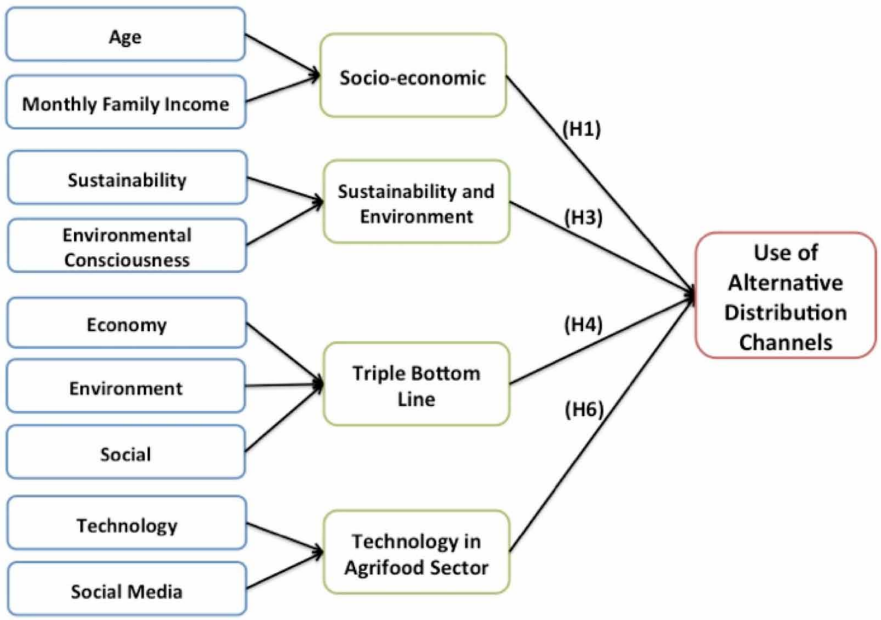
Summary

In the research, which was conducted in Greece, the hypotheses H1, H4 and H6 have been confirmed, while H3 was not confirmed, since the dependent variables are not correlated with the use of e-commerce for the purchases of fruit and vegetables. However, the variable "sustainability and sustainable development is correlated with the distribution channel: "directly from producer" and with the use of fair trade, while the variable "environmental consciousness" is correlated with the use of fair trade (Figure 16).

CONCLUSION

The present study illustrates that consumers are currently showing a considerable amount of interest in alternative distribution channels and the supply of fresh fruits and vegetables. This attitude, on the behalf of consumers, creates the necessary conditions, in order to provide the necessary incentives for the development and enhancing of alternative distribution channels. The results of the survey may offer constructive conclusions for policy makers, entrepreneurs, consumers and the academic sector. In par-

Figure 16. Hypothesis testing



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ticular, the present study concluded, that the fact that consumers trust alternative distribution channels that consumers for purchases of fresh fruit and vegetables, enhances the increase of employability and promotes the reduction of poverty. The need for the further development and promotion of alternative distribution channels, with the aim of creating new jobs, stimulating the local economy and local agricultural producers, has already emerged.

In addition -due to the imposition of controls on capital transactions, the development of the Internet and its use by consumers- it is estimated that the creation of incentives and further training for farmers on new technologies can provide a positive impact on consumer behaviour towards the purchase of agricultural products. Due to the fact that new technologies are expected to play an important role in the food processing sector, policies that will provide opportunities for training and will encourage farmers and others in the agri-food sector to adopt these policies, are expected play an important role in the development local economy, through the promotion of local products. However, a functional design and organization of alternative distribution channels is more than necessary, in order to create the basis of their sustainability. The spreading of this idea from mouth to mouth is a crucial factor, since consumers are affected by family or friends for the use of alternative distribution channels. Therefore, the implementation of the right policies, by those involved is going to have a positive effect on the use of alternative channels distribution.

Furthermore, the use of social networks as a means for the promotion of agricultural products and certain fresh fruit and vegetables, is a method to attract consumers and increase fresh fruit and vegetables market. Thus, the necessary basis for further investigation of the characteristics of consumers (who use and are affected by the promotion of fresh fruit and vegetables) and the factors (that positively influence consumer behaviour) should be created, so their effective use and the targeted promotion of agricultural products can be achieved. Subsequently, it is important to create a social space, where local agricultural products and distribution channels can be advertised and promoted. In such places, consumers will have the opportunity to get informed about the above sectors, so they can trust these alternative channels even more and use them more frequently.

The implementation of policies that will connect supply chains with the alternative distribution channels, in order to reduce operating costs and increase revenue, will play an important role. Consumers' opinion that this is not a priority for agriculture, creates the conditions to expand the use of supply chains in alternative distribution channels by farmers. This expansion will benefit consumers because prices will be reduced. It will also benefit producers because their revenues will be increased and the state will also be positively affected by the increase of tax income.

Therefore, from the above data, it becomes clear that the implementation of policies that will enhance the use of new technology (Technology), promotion of alternative distribution channels (Marketing) and training of professionals involved with the alternative distribution channels (Training) will enhance the development of local products and the local economy. We should also take into account the socioeconomic characteristics of consumers. The education level, gender, family income and employment are the main factors why the use of new technology, promotion and the training of professionals will enhance the expansion of alternative distribution channels and the local economy.

The policies for promoting new technologies, marketing and training of those involved in alternative distribution channels, while taking into account the socioeconomic characteristics of consumers. The objective of these guidelines- if the socioeconomic characteristics of consumers are taken into account- is: the increase of sales of local products and the development of the local economy. Similarly,

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entrepreneurs and agricultural producers who distribute their products through alternative distribution channels, are expected to benefit from increased sales and revenues.

Finally, the data of this research will enhance further investigation, by the academic sector, regarding the policies which are mentioned above. Providing incentives for the use of distribution channels, implementing new technological tools and training of farmers will play an important role in the development of the local economy.

REFERENCES

Achrol, R. (1997). Changes in the theory of interorganizational relations in marketing: Toward a network paradigm. *Journal of the Academy of Marketing Science*, *25*(1), 56–71. doi:10.1007/BF02894509

Almossawi, M. (2014). Promoting green purchase behavior to the youth. *British Journal of Marketing Studies*, *2*, 1–16.

Ashby, A., Leat, M., & Melanie Hudson-Smith, M. (2012). Making connections: A review of supply chain management and sustainability literature. *Supply Chain Management*, *17*(5), 497–516. doi:10.1108/13598541211258573

Baxter, R. (2012). How can business buyers attract sellers' resources?: Empirical evidence for preferred customer treatment from suppliers. *Industrial Marketing Management*, *41*(8), 1249–1258. doi:10.1016/j.indmarman.2012.10.009

Borden, N. H. 1965. *The Concept of the Marketing Mix*.

Borghi, A., Gallo, M., Strazza, C., & Del Borghi, M. (2014). An evaluation of environmental sustainability in the food industry through Life Cycle Assessment: The case study of tomato products supply chain. *Journal of Cleaner Production*, *78*, 121–130. doi:10.1016/j.jclepro.2014.04.083

Burt, L., & Wolfley, B. (2009). *Farmer-to-Consumer Marketing: The Series, PNW 201–206, Oregon State University*. Oregon State University, Washington State University,University of Idaho.

Cantor, D. E., Blackhurst, J. V., & Cortes, J. D. (2014). The clock is ticking: The role of uncertainty, regulatory focus, and level of risk on supply chain disruption decision making behavior. *Transportation Research Part E, Logistics and Transportation Review*, *72*, 159–172. doi:10.1016/j.tre.2014.10.007

Carvalho, B. L., Salgueiro, M. D. F., & Rita, P. (2015). Consumer Sustainability Consciousness: A five dimensional construct. *Ecological Indicators*, *58*, 402–410. doi:10.1016/j.ecolind.2015.05.053

Chapman, R., Tonts, M., & Plummer, P. (2015). Exploring perceptions of the impacts of resource development: A Q-methodology study. *The Extractive Industries and Society*, *2*, 540–551.

Cheng, L.-C., & Grimm, C. M. (2006). The application of empirical strategic management research to supply chain management. *Journal of Business Logistics*, *27*(1), 1–55. doi:10.1002/j.2158-1592.2006.tb00240.x

Chinnici, G., D'Amico, M., & Pecorino, B. (2002). A multivariate statistical analysis on the consumers of organic products. *British Food Journal*, *104*(3/4/5), 187–199. doi:10.1108/00070700210425651

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Dekker, H. C., Sakaguchi, J., & Kawai, T. (2013). Beyond the contract: Managing risk in supply chain relations. *Management Accounting Research*, *24*(2), 122–139. doi:10.1016/j.mar.2013.04.010

Ellis, S. C., Henke, J. W. Jr, & Kull, T. J. (2012). The effect of buyer behaviors on preferred customer status and access to supplier technological innovation: An empirical study of supplier perceptions. *Industrial Marketing Management*, *41*(8), 1259–1269. doi:10.1016/j.indmarman.2012.10.010

Essig, M., & Amann, M. (2009). Supplier satisfaction: Conceptual basics and explorative findings. *Journal of Purchasing and Supply Management*, *15*(2), 103–113. doi:10.1016/j.pursup.2009.01.001

Falguera, V., Aliguer, N., & Falguera, M. (2012). An integrated approach to current trends in food consumption: Moving toward functional and organic products? *Food Control*, *26*(2), 274–281. doi:10.1016/j.foodcont.2012.01.051

Guertler, B., & Spinler, S. (2015). When does operational risk cause supply chain enterprises to tip? A simulation of intra-organizational dynamics. *Omega*, *57*, 54–69. doi:10.1016/j.omega.2015.03.005

Heberling, M. T., Templeton, J. J., & Wu, S. (2012). Green Net Regional Product for the San Luis Basin, Colorado: An economic measure of regional sustainability. *Journal of Environmental Management*, *111*, 287–297. doi:10.1016/j.jenvman.2012.02.035 PMID:22483369

Heckmann, I., Comes, T., & Nickel, S. (2015). A critical review on supply chain risk – Definition, measure and modeling. *Omega*, *52*, 119–132. doi:10.1016/j.omega.2014.10.004

Kovacs, G., Spens, K., Mortensen, M., Freytag, P., & Stentoft, J. (2008). Attractiveness in supply chains: A process and matureness perspective. *International Journal of Physical Distribution & Logistics Management*, *38*(10), 799–815. doi:10.1108/09600030810926501

Ladhari, R., & Tchetgna, N. M. (2015). The influence of personal values on Fair Trade consumption. *Journal of Cleaner Production*, *87*, 469–477. doi:10.1016/j.jclepro.2014.10.068

Mattas, K., & Tsakiridou, E. (2010). Shedding fresh light on food industry's role. The recession's aftermath. *Trends in Food Science & Technology*, *21*(4), 212–216. doi:10.1016/j.tifs.2009.12.005

Mauleón, J.-R. (2003). Contribution of short food chains to rural development in the Basque Country, XX Congress of the European Society for Rural Sociology (Working Group 1.2. Food consumption and farming). University of the Basque Country, Department of Sociology.

Meier, M. S., Stoessel, F., Jungbluth, N., Juraske, R., Schader, C., & Stolze, M. (2015). Environmental impacts of organic and conventional agricultural products – Are the differences captured by life cycle assessment? *Journal of Environmental Management*, *149*, 193–208. doi:10.1016/j.jenvman.2014.10.006 PMID:25463583

Pereira, J. V. (2009). The new supply chain's frontier: Information management. *International Journal of Information Management*, *29*(5), 372–379. doi:10.1016/j.ijinfomgt.2009.02.001

Porter, M. E. 1985. Competitive Advantage: Creating and Sustaining Superior Performance, New York.

Rödiger, M., & Hamm, U. (2015). How are organic food prices affecting consumer behaviour? A review. *Food Quality and Preference*, *43*, 10–20. doi:10.1016/j.foodqual.2015.02.002

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Schiele, H. (2008). Location, location: The geography of industry clusters. *The Journal of Business Strategy*, *29*(3), 29–36. doi:10.1108/02756660810873191

Sheffi, Y. (2001). Supply chain management under the threat of international terrorism. *International Journal of Logistics Management*, 12.

Solomon, M. (2009). *Consumer behavior, buying, having and being*. New Jersey, USA: Pearson Education Inc.

Spiller, F., Zuhlsdorf, A., & Mellin, M. 2008. Customer satisfaction in farmer-to consumer direct marketing. International Food and Agribusiness Management Association.

Suprem, A., Mahalik, N., & Kim, K. (2013). A review on application of technology systems, standards and interfaces for agriculture and food sector. *Computer Standards & Interfaces*, *35*(4), 355–364. doi:10.1016/j.csi.2012.09.002

Svensson, G. (2000). A conceptual framework for the analysis of vulnerability in supply chains. *International Journal of Physical Distribution & Logistics Management*, *30*(9), 731–750. doi:10.1108/09600030010351444

Sydorovych, O., & Wossink, A. (2008). The meaning of agricultural sustainability: Evidence from a conjoint choice survey. *Agricultural Systems*, *98*(1), 10–20. doi:10.1016/j.agsy.2008.03.001

Syed, F. K., Sherjeel, S.A. (2009). *What is the difference between a research question and a research hypothesis?* AuthorHouse.

Tsang, E. W. K. (2000). Transaction Cost and Resource-Based Explanations of Joint Ventures: A Comparison and Synthesis. *Organization Studies*, *21*(1), 215–242. doi:10.1177/0170840600211004

Veatch, B., & Maren, E. (2007). Agricultural Sustainability: Principles, Processes, and Prospects, S. Raman. Food Products Press, Haworth Press Inc., 10 Alice Street, Binghamton, NY 13904-1580, USA (2006). *Industrial Crops and Products*, *26*(1), 105–106. doi:10.1016/j.indcrop.2007.01.007

Whatmore, S., Stassart, P., & Renting, H. (2003). What's alternative about alternative food networks. *Environment & Planning*, *35*(3), 389–391. doi:10.1068/a3621

Wisner, J. D. (2003). A structural equation model of supply chain management strategies and firm performance. *Journal of Business Logistics*, *24*(1), 1–26. doi:10.1002/j.2158-1592.2003.tb00030.x

Xue, W., Caliskan Demirag, O., & Niu, B. (2014). Supply chain performance and consumer surplus under alternative structures of channel dominance. *European Journal of Operational Research*, *239*(1), 130–145. doi:10.1016/j.ejor.2014.04.044

Zsidisin, G. A., Panelli, A., & Upton, R. (2000). Purchasing organization involvement in risk assessments, contingency plans, and risk management: An exploratory study. *Supply Chain Management*, *5*(4), 187–198. doi:10.1108/13598540010347307

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APPENDIX

Table 13. Cronbach's alpha - Reliability and Validity of the variables for the use and frequency of use of alternative distribution channels

Alternative distribution channels	Cronbach's alpha
Directly from the producer	0.853
Local grocery's store	
Special local product stores	
Super market	
Flea Markets	
Itinerant traders	
E-commerce	
Use of E-commerce	
Fair Trade	
Use directly from the producer	

Table 14. Cronbach's alpha - Reliability and Validity of the variables regarding the statements for alternative distribution channels

Statements for alternative distribution channels	Cronbach's alpha
Statement 1: Easy access to food purchase	0.890
Statement 2: The price of fruit and vegetable is lower	
Statement 3: There is a limited variety of raw fruit and vegetable available	
Statement 4: Customer service is immediate	
Statement 5: Customers can directly check the origin of raw fruit and vegetable	
Statement 6: Raw fruit and vegetable are provided	
Statement 7: Raw fruit and vegetable are available are available on a daily basis	
Statement 8: Consumers' healthy nutrition is promoted	
Statement 9: Consumers can protect the environment at the same time	
Statement 10: The alternative channels ensure sustainability and sustainable development.	
Statement 11: Alternative channels of agricultural products appeared in Greece, due to the financial crisis.	
Statement 12: Capital controls affect the choice of the alternative distribution channel of raw fruit and vegetables.	

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Table 15. Cronbach's alpha - Reliability and Validity of the variables regarding the factors for the choice for alternative distribution channels

Factors of choice- People choose alternative distribution channels they are:	Cronbach's alpha
Safer	*0.939*
Healthier	
High Quality	
High nutritional value	
Appropriate for children's nutrition	
Better prices	
Environmental Consciousness	
They meet my standards and values	

Table 16 Cronbach's alpha - Reliability and Validity of the variables- factors regarding Fairtrade

Factors for choosing Fair Trade products	Cronbach's alpha
Safer	*0.849*
Social Contribution	
Improvement of the quality of living in the area where the product is produced	
Healthier	
High quality	
High nutritional value	
Appropriate for children's nutrition	
Better prices	
Environmental Consciousness	

Table 17. Cronbach's alpha - Reliability and Validity of the variables- factors that consumers take into account when buying fruit and vegetables

Important factors regarding the purchase of fruit and vegetables	Cronbach's alpha
Their contribution to people's health	*0.982*
Price	
Habit	
Quality	
Place of origin	
Safety	
Taste	
Environmentally friendly	
Appearance	
Technology	
Authenticity	

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Table 18. Cronbach's alpha - Reliability and Validity of the variables of the source of information regarding raw fruit and vegetables

Source of information regarding raw fruit and vegetables	Cronbach's alpha
Social media	*0.932*
Newspapers	
Radio	
Commercials	
Television	
Magazines	
Family	
Friends	

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Chapter 24
Mobile Networks and Indian Agricultural Sector

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ABSTRACT

Information dissemination in agricultural sector for its growth using information and communication technology (ICT) as a tool is need of the hour. This can be achieved using information systems. ICT benefits are helpful in exchange and dissemination of information among farming stakeholders. By using the latest tool of mobile technology, farmers can get the current information related to their farming jobs around the clock and at any location, as the mobile network have touched every part/location of the India. Using the features of the mobile-phones like GPS etc. one can get the localized information. Only need is to structure the abundant information available across the various organizations. So, a mobile based agricultural information system framework 'mAgIDS' has been proposed employing the hybrid mobile application architecture approach. Client-server architecture using the location Application Programming Interface (API) has been proposed. Inference mechanism of the system has implemented on the basis of improved fuzzy rule promotion technique.

INTRODUCTION

Agriculture and its related functions are indisputably the largest source of livelihood to large number of Indian rural population. Agriculture sector accounts for approximately 14% of India's Gross Domestic Product (GDP) and 11% of its export. 68.8% of Indian population lives in rural areas. Income of 31.55% of this rural population depends upon agriculture and its related activities. Also, agricultural produce is a source of raw material for a large number of industries. Average rate of agricultural growth in India was 2.38% during 10th five year plan (2002-07) that rose to 3.6% per annum during 11th five year plan (2007-12). In 2012-13, the first revised estimate of agricultural growth has been declared at 1.42% per annum. In advance estimates for India-Macro Economic survey for 2013-14 (Annonymous, 2014), 4.64%

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of agricultural growth has been expected to be contributed in Indian GDP. It is important to increase growth of agriculture production (Government of India, 2013) using technology to achieve targeted 8% GDP contribution during 12th five year plan (2012-17) and to meet escalating demands for food due to high population growth, increase in per capita income *etc*. To improve the quality and quantity of agricultural produce, a tremendous amount of efforts are being put by various organizations like Indian Council of Agricultural Research (ICAR), Central and State Agricultural Universities (SAUs) and their Regional Research Stations (RRSs), Krishi Vigyan Kendras (KVKs) along with other public and private organizations. It is very important for these organizations to disseminate appropriate, precise and latest information to farmers for timely action to improve the agricultural output. There is a greater need to lay emphasis on the dissemination of scientific information from laboratory and test fields to its actual stakeholders using latest technological tools. These institutions work dedicatedly for the welfare of agricultural community but their initiatives have been usually criticized for their limited coverage, sustainability and its effect on agricultural community. Therefore, it is required that agricultural inputs should be timely disseminated to its appropriate quarters using latest information technological tools provided relevant quarters are ready to adopt these tools required for information transfer. Improvement of agricultural and rural development is being focused through emerging field of E-Agriculture using improved information and communication processes. Print and electronic media such as news-papers, pamphlets, libraries, televisions and information centers (like Kissan Call Centers *etc.*) are playing very important role in providing information to the farmers. These information centers are basically providing information to farmers using the available resources to them. Improved data management for better decision-making can be achieved by the utilization of information with appropriate information and communication technology (ICT). Enhanced focus on research planning, monitoring and evaluation lead to better research and hence it can provide more benefits to farmers. For providing online information to distantly located stakeholders ICT can be used in breaking the blockades of these remote places, which is the major concern for information dissemination.

Information Systems

An Information system (IS) uses Information Technology (IT) to sustain various operations and management of people's activities. (Silver, Markus, & Beath, 1995) discusses two views on IS namely IS-centered view comprising of hardware, software, procedures, data and people, and managerial view that incorporates people, business processes *etc.* ISs are specifically designed to enable individuals to execute these tasks for which the individual understanding is not so proficient, such as, handling bulk amount of information, performing scientific calculations, and controlling many parallel processes. Thus, such systems are very helpful for providing the best and up to date information to associated stakeholders. IS acts as an interface between individuals, algorithmic processes, data and technology (Information System, 2011). It also refers to the manner in which individuals interact with technological tools in support of assembly of allied, planned actions or tasks that can fabricate a particular service or product or serve a specific goal for stakeholders. It can be envisioned as flowchart of a sequence of events to achieve a certain product or service. The activities of an IS are committed to process information by means of capturing, communicating, keeping, recovering, handling and exhibiting the information. As such, IS inter-relates with data and activity systems. These are a type of communication systems in which data is represented and processed to generate information which is useful to the end users. Human decision-

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making and action is supported by considering it as a semi-formal language. ISs are seen as having the ICT component to help in controlling the performance of business processes. When an individual realizes and appraises the processed information then it becomes knowledge (Kürşat DEMİRYÜREK, 2010). These are social systems whose performance is inclined to the aims, principles and philosophies of people, as well as the performance of the technology (Angell & Smithson, n.d.).

Information and Communication Technology

World Bank report (World Bank, 2011) mentions that private and public sector are involved in research to find efficient answers to address short and long term concerns and challenges in agriculture that includes means and methods for responding to the information needs of the farmers. ICT based solutions have incredible potential to improve agriculture in emerging countries like India. The costly, bulky and energy-consuming equipment which were once available to the very few to store and analyze agricultural and scientific data, are now easily available with the farming community. With the booming wireless, Internet and mobile communication industries and reducing cost of electronic gadgets, ICT has become a part of daily routine of poor smallholder farmers. Its ability to bring recharged momentum to agriculture appears more convincing in view of increasing investments in agricultural research, strong attention in the development & spread of ICT by the private and public sector and the expansion of organizations committed to the agricultural development programmes. As described in (Vu, 2011), emerging nations need a more strategic focus on promotion of ICT penetration as a vital source of development, this includes the up-gradation of the ICT infrastructure and reduction of costs of its use and focus to increase the vital effects of its penetration. This can be helpful in improvement of the availability of information and technology, nurturing the novelty and exchange, and augmenting the excellence of decision making.

Emergence of digital convergence, explosive growth of wireless communications and increasing penetration of broadband technologies all over the world have made the adoption of ICT necessary to explode socio-economic development (Armenta, Serrano, Cabrera, & Conte, 2012). Availability and utilization of Telecom Infrastructure is invariably linked to the living standards and economic development in emerging countries (Garbacz & Jr, 2007). Pricing for telecom services like mobile phones and value added services have emerged as a vital factor that drives the quick adoption of mobile phones in emerging nations like India, Sri Lanka, China *etc.* Information about the affordability of ICT services (i.e. fixed line phones, mobile phones and fixed and mobile broadband Internet subscriptions) as adjudged against average gross national income per capita is expressed in terms of ICT Price Basket has been devised by International Telecommunication Union (ITU) (International Telecommunication Union (ITU), 2011a). Recent statistics indicate that cost for Internet access and mobile phones have decreased considerably throughout the world. Specifically, the cost of ICT has significantly decreased in Asian countries in previous decade. Thus, access to ICT services has become quite reasonable in these nations. This situation has unlocked the gate for a range of mobile-based services and applications that can be implemented in the region.

Creation, assessment and manipulation of information have been enabled by ICT as a combination of IT and communication technology (Information and communication technology, 2011). It can play a considerable task in conserving the attributes of information as it comprises computer, communication and information. These are concerned for handling, trading and supervising data, information and knowledge. Benefits of ICT include:

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- Preservation of properties of information during its processing, exchange and management;
- Capability to record text, diagrams, multimedia, procedure descriptions *etc.*, in digitized formats;
- Production of duplicates of requisite information at lower cost;
- Transfer knowledge and information instantaneously all over the world through networks;
- Processing of large information rapidly using predefined algorithms;
- Achieving greater interactivity in connecting, appraising, creating and sharing useful knowledge and information.

The encouraging effect of ICT is quite evident in service oriented sector, where the productivity has gone high. Business process outsourcing, financial sectors *etc.* are taking full benefit of the ICT revolution.

Agricultural Information Needs and ICT

The application of ICT in agriculture is important. E-Agriculture (Information and communication technology, 2011) is an emerging area that focuses on the escalation of rural and agricultural development through superior information and communication processes. It involves the conceptualization, strategy, expansion, appraisal and use of innovative ways to ICT in the rural area, with a major attention on agriculture. Various E-Agriculture initiatives include information dissemination system (IDS), weather projection, seed sowing using sensor, irrigation monitoring *etc.* It is expected that scope of E-Agriculture will further evolve, as the understanding in the agricultural area improves.

Information requirements of farmers have also increased as the agricultural sector has been affected by latest global technological advancements. The international market requirements and ecological issues along with the national food security must be addressed by the agricultural development. Indian agriculture being a part of the global agricultural system has to keep momentum with continuous and immensely changing technologies and have to develop new products and product varieties, expanding and harnessing ICT for development of ISs, new market tactics, new services and so on (P. Singh, 2004).

In past, pamphlets, posters, radio, television *etc.* were used for the dissemination of information to the farmers. Huge amount of time was wasted in reaching the information to the appropriate quarters. The need for providing the accurate agriculture related information to the concerned at appropriate time leads to application of ICT in agriculture.

Concepts of virtual community or e-community, E-publications of agricultural literature, various information networks, institutional repositories, social networks sites and information kiosks *etc.* are being employed for dissemination of agricultural information. Various ICT initiatives/tools like multimedia, web and mobile applications are being deployed for the dissemination of information among various stakeholders.

Need for Mobile Communication in Agriculture

Advancement and accessibility of ICT has been the ultimate communication revolution during the last few years. The decreasing cost of hardware, expansion of communication set-up and its availability at district and block level has opened up vast potential for agro-worker to reach the rural community in a more dedicated, accurate and specific manner. Understanding of hardware, software, ICT indicators and home/global networks can be a value addition to the knowledge base of extension functionaries. One such tool is mobile phone network. It is simple, economical and convenient to use. Illiterate people

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are also easily adopting the usage of the smart mobile phones as compared to the laptops/computers. Access to mobile networks is now available even in the remote regions. It is possible for everyone and everything to be connected and this connectivity has a huge impact on society. For community development, it is pronounced as the most transformative tool (Kirk et al., 2011). This connectivity not only offers people the ability to stay in touch with friends and family but it also provides access to finance, improved healthcare solution, supply chain efficiencies and increasingly automated mobility. ICT services are commercially successful and therefore, it is believed that these are more sustainable in long term and provide more benefits to society.

Countries like India have a rising mobile market, deep diffusion of mobiles and elementary ICT infrastructure. Mobile phone subscription has increased tremendously over the years and during 2005-10, there was 50.7% per annum rise in mobile phone subscription (UNESCAP, n.d.). In a report (International Telecommunication Union (ITU), 2011b), the number of mobiles subscription per 100 inhabitants was 61.4, where households having a computer were 6.1. Mobile phones is a reasonable tool for communication and learning than personal computers (The Economist, 2011). Mobile communication has become an important tool for voice and data transfer. Telecom Regulatory Authority of India (TRAI) has released data showing that there are 893.31 million mobile subscribers in India as on 31st January, 2014. About 40.75% of these subscribers belong to rural areas with a rural tele-density of 42.43 as against urban tele-density of 139.42 (TRAI, 2014). The mobile subscription base has been projected about 900 million in 2015-16 as compared to 90 million in 2005-06 (S. K. Singh, 2008). The base is already touching this projection in the year 2013-14. Mobile devices are now becoming the most suitable means to disseminate agriculture related information to farmers in rural areas with 1.21% monthly growth of rural mobile subscription. These devices have lot of benefits over computers/laptops such as low cost, easy interface and convenient usage by farmers and higher penetration in the emerging nations (Gichamba & Lukandu, 2012). Growth in the mobile subscriber base will have vital impact for the prospective plans of mobile service and infrastructure providers, handset manufactures and vendors. This projected growth may be due to Internet and customized applications for individual use on their mobile handset. Agriculture sector can also harness the advantage of this growth.

Mobile networks access is broadly available at district and block level as well as in remote areas. This has opened up wide opportunities for agricultural scientists and extension workers to work with agricultural community in more focused and personalized manner.

Information Dissemination Systems

Various initiatives have been taken by different organizations to cater to the needs of the agricultural stakeholders. These include development of Information dissemination systems like Experts System (ES) and Decision Support System (DSS) *etc.* Most of these have been focused for the use by the extension specialist and computer literate farmers. These systems have static database of information and knowledge, which is constantly being used to deliver the results. Agriculture is a complex process which has unpredictable and uncertain solutions. To get the inference for such solutions soft computing techniques are used. These techniques deal with inaccuracy, vagueness, fractional truth, and approximation to achieve practical, robust and low cost solution. As such it forms the basis of a considerable amount of machine learning techniques. Usage of these techniques in agricultural systems has given tremendous scope to provide the precise output.

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Mobile Based Systems for Localization

Localized information needs of the farmers are very vital. Certain agricultural activities are prominent in some regions and may be irrelevant to the other nearby regions. Information processing and dissemination to the farmers on the basis of their geographical area is very crucial. Information provided in the native language is a boon for the farmers. This can generate interest among the farmers for information. Mobile systems /handsets with some additional features may help in getting the localized information. So, there is a need for the development of mobile based information dissemination systems for transferring the localized multi-lingual information from the knowledge repositories so that the information may be available round the clock.

Possible Gaps in Information Dissemination

Various ESs, DSSs for agricultural activities have been developed but most of these are standalone or web based systems or relevant to market related agricultural activities like commodity exchanges, web based information repositories *etc.*, These are confined to the knowledge base of domain expert and knowledge engineer.

Following are the possible Gaps for information dissemination in agricultural based activities:

Lack of Exploiting Soft Computing Techniques in Agriculture Decision Making and Information Dissemination

Agriculture itself is a vast field having complex activities in its domain. Understanding these complicated activities along with the techniques of soft computing, which are approximation to the accuracy of the decision and information dissemination, is a cumbersome job for an agricultural researcher. This area has been focused in this study.

Lack of Mobile Network Usage for Agricultural Information Dissemination

Various experts', decision support and fuzzy logic based systems for agricultural activities and processes have been developed. But most of these are standalone or web based system or they are related to agricultural marketing activities like commodity exchanges, AGMARKNET (www.agmarknet.nic.in), e-Choupal *etc.* IT knowledge is the basic requirement for a farmer to use these kinds of systems. It is felt that the mass understandable and economical technology needs to be exploited for dissemination of agricultural related information. The mobile phone network is one such popular technology that can be exploited easily for such information dissemination. Mobile phone networks are available in almost all the geographical areas of India and used by majority of farmers (Jain, Kumar, & Singla, 2011).

Localization of the Desired Agricultural Activity

Web based systems are not able to guess the exact location of the agricultural activity under review. Therefore it is required to use the telecommunication infrastructure to accurately define the location of agricultural activity under consideration. By getting this accurate information, the soft computing based information systems can give localized information for better decision making. It is possible to

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exploit the power of mobile technology to transfer this knowledge to the concerned at any location on 24x7x365 basis. The knowledge can be made available in the native language of the farmers. In this study, localization of desired agricultural activity has been achieved using the features of mobile phone like Global positioning System (GPS) for location detection, multilingual for local language of the farmers.

Information Dissemination in Agricultural Sector

Agricultural and its allied activities are the sources of income for most of the Indian rural population. Therefore it is very important to enhance their agricultural productivity, which is a complex and cumbersome activity. It requires a lot of practice and latest information about the latest tools, implements, procedures and knowledge about the various activities involved in practicing agriculture. Various methods have been used to transfer these latest information to the farmers that include, pamphlets, farmer fests, multimedia involving television and radio talks, public and private organizations (like ICAR's and SAU's research station, KVK's, ITC, TATA Consultancy Services), Internet based web and mobile applications etc.

ICAR is premier organization committed to developing and governing agriculture under Ministry of Agriculture, Government of India. It has a number of specialized research institutes for different crops, animals, soils, regions *etc.* Under its leadership, the agricultural education, research and extension programmes are also governed which involves the state agricultural and veterinary universities and other organizations. These institutes are committed to the transfer of knowledge and information available to them through research and other means to the farmers through different types of extension initiatives.

Role of ICT in Agriculture

The potential of ICT to contribute towards agriculture and rural development of a nation has been well recognized e.g. Establishment of Rural ICT centers in Iran has played an efficient role in rural development through improving e-governance in these areas (Alibaygi, Karamidehkordi, & Karamidehkordi, 2011). In order to make the most of this potential, nations have two issues: firstly, empowerment of small farmers with ICT services and assets, which can improve their productivity, incomes as well as which can secure their food security and livings, and secondly harnessing ICT commendably to compete in swiftly changing and complex global markets. These issues can be addressed by execution of a complex set of strategy, innovation, investment, and capacity-building processes *etc.*, in consultation with concerned stakeholders. This can inspire the growth of localized applicable, cheap, and viable ICT setup and facilities for the rural economy (World Bank, 2011).

The association of the usage and adoption of ICT by farmers practicing conventional extension systems as well as policy suggestions for bridging the evolving digital gap within the agricultural community have been described in (Anastasios, Koutsouris, & Konstadinos, 2010).

Nokia life tool is an example of agriculture based information systems on mobiles, which is a payment based information service intended for developing markets. It provides a vast variety of information service. It covers education, entertainment, healthcare and agriculture ("Nokia Life Tools - Wikipedia, the free encyclopedia," n.d.). mKrishi, an initiative of TATA Innovation Lab, is the one of the good mobile application involved in disseminating the agriculture related information to the farmers at the nominal cost. It associates farmers with a system that assists them to make sound decisions about agriculture which can drive higher profits and preserve the environment. With the help of Integrated Voice Response (IVR) technologies the software can also transport voice messages between farmer and the

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expert. aAQUA which stands for almost All Questions Answered, is an online question & answer and community discussion forum for generating and providing information significant to farmers (Ramamritham, 2004), (Ramamritham, Bahuman, Duttagupta, Bahuman, & Balasundaram, 2005). It allows members using a web browser on a computer to create, view and manage content in local languages. A large number of farmers have reported fairly affirmative changes in quality of yield, crop diversification due to Agropedia and aAQUA (Yadav, 2011) thus improving their income. Agropedia is a good resource of the agricultural information ("Agropedia," n.d.).

Use of Multimedia in Agriculture

Green revolution in India is possible because of the transfer of technology from the research fields to the farm field. In earlier years, the print media played vital role in transforming the agricultural productivity from extremely low to reasonably good point. Information dissemination using the CDs and DVDs have further strengthened agricultural output.

Multimedia, which includes all the customary forms of communication like – audio, video, photographs, graphics, animation and text, is an admirable tool for extension and communication. Each learning task is most effectively taught through the optimum usage of relevant media. Multimedia describes fusion of text, records, visuals, animation, optical storage, image processing and sound. Using the multimedia data types such as video, graphics, images or animation, any participant can introduce illustrative material to facilitate better communication. Incredible images and animations, audio, audio-visual clips and raw textual information can inform, educate, persuade and entertain the users. This can help in electrifying the public's mind. Thus, the process of transfer of technology, from the laboratories and research field, among the stakeholders must be strengthened and must reach the farmers at the earliest (Philip, Vennila, & Gomathy, n.d.).

Multimedia as transfer of technology can function in the field of agricultural extension. It can be used to illustrate the issues in an interactive, interesting and effective format. Photographs, pictures *etc.* of symptoms of diseases, insect pest damage and of insects can be made available using multimedia for their effective monitoring and management. Solutions of the problems can also be depicted using figures, photographs or pictures. Using a chat room, crop pest specialists can be consulted to know how to identify accurately and control the pests. Quality of extension material and process can be supplemented time to time by multimedia and virtual reality.

Now a day, work is being done to attain the second green revolution. This can be achieved by harnessing the power of ICT. Usage of various tools of ICT can be very helpful to agricultural community. The Digital Green (Gandhi, Veeraraghavan, Toyama, & Ramprasad, 2007) system propagates targeted agro-info to small and marginal land holders in India through digitized video. Concept of participatory learning is implemented in the system. Database of videos, which is generated by farmers and experts, is included in it. These videos are distributed to the farmers through a repository. Farmers are motivated and trained by these recorded experience. Development of Internet and online agricultural repositories has further added to enhance the agricultural output. The strengthening and broadening field of Internet over the mobile phones in developing nations can provide an exclusive interface for adoption of agricultural technologies using ICT.

Government policies and announcements can be made available to farmers and extension workers from time to time with the use of multimedia. The information on weather parameters, cropping systems availability of high yielding varieties, other related information on varieties, irrigation, fertilizer manage-

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ment, Integrated Pest management (IPM) *etc.* can be made available to farmers using multimedia and convince them easily. Multimedia offers immense potential today as well as for the future and it will help extension worker and scientist to integrate modelling, visualization and decision making processes associated with farming systems. This will definitely accelerate development in the field of agricultural extension and ultimately farmers of the country will be able to harvest the benefits at the desired level.

Web and Mobile Applications

ICT enables users to build, retrieve and handle the information. It is combination of IT and communications technology (Information and communication technology, 2011). In modern arena, it lays emphasis on the role of integrated communications and amalgamation of tele-communications, smart information managing arrangements and multimedia arrangements. Being an arrangement of three major technologies: Computer, Communication and Information Management, it is playing a vital role in preserving the characteristics of information. These tools are smeared for handling, trading and managing data, information and knowledge. With the help of various ICT tools, it is possible to produce exact copies of such information at considerably lesser cost, rapid transfer of information and knowledge globally through communication networks, develop standardized algorithms to synthesis quickly the vast quantities of information, achieve greater interactivity in producing, transferring, appraising, and sharing beneficial knowhow and information.

Mobile and Internet based communication are precise, fast and economical mode to transfer the information from research farms and laboratories for disseminating agriculture related information to farmers. It has also reached almost all the districts and administrative blocks of India (Chauhan, 2010). Farmers are eager and become concerned to get rapid, true and reliable information in globally changing agricultural scenario. Transfer of requisite and latest agricultural information to the farmers in scattered locations at diverse geographical situation in India is a very tough job. Still it can be said that development of technology and its dissemination to the farmers is a continuous process (Mehta, 2003). This has been tried to be accomplished by the various web portals (Raj, 2013).

Portable Chemical Analysis (PCA) using a mobile phone has been presented in (García et al., 2011). Built-in camera is used for clicking the image of a single-use colorimetric chemical sensor. A software application processes this image to obtain its characteristic H (hue) value related to analytic concentration. Using mobile phone the water and sand samples have been analysed using the reflectance measurement (Iqbal & Bjorklund, 2011). The screen of phone work as a light source and the detection is done by front view camera. PCA for the taxonomy of several compounds and their concentrations in water has been done using the reflected intensities of red, green, white and blue colours. For Arsenic detection in groundwater, discoloration caused, because of its presence in groundwater, was analysed with the help of model coloured sand samples. In (Sumriddetchkajorn, Chaitavon, & Intaravanne, 2013), it has been experimentally demonstrated that for analysis of chlorine concentration in water can be estimated with the help of embedded digital camera in a mobile device, which can be used to function as a colorimeter. The feasibility of using mobile phones cameras for DNA detection has been investigated in (Lee, Chou, Yeh, Chen, & Chen, 2011).

In (Confalonieri et al., 2013), a smartphone application has been discussed and it implements (App-L & App-G) methods for Leaf Area Index (LAI) estimation. LAI is an important parameter in environmental and agronomic studies. It can estimates the amount of radiation captured by the canopy and describes crop water requirements. It can be judged with the help of the developed application. This application

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is based on the usage of the sensors present in the most of the smart-phone and their processing powers. Gap fraction estimation at 57.5° (to obtain values that are almost free of leaf inclination) for luminance estimated above and below the canopy has been used in the first method (App-L). The gap fraction has been estimated via automatic processing of pictures obtained below the canopy using the second method (App-G). The data has been collected in scatter-seeded paddy farm-field in northern Italy. The performances of two methods implemented in application were assessed using this data. The results were matched with those of the LAI-2000 and AccuPAR ceptometer, by determining the methods' accuracy and linearity. The performances of App-G were similar to those shown by these instruments, whereas App-L attained the best true value, although it has resulted in lower precision, necessitating a great number of replications to provide trustworthy estimations. It has been shown that the proposed application can be considered as a substitute to commercially available instruments and useful in perspectives characterized by cost-effective resources or when the maximum portability is necessary.

A quick and mobile nitrogen management risk assessment tool, Nitrogen Index application for android smart-phones, has been developed that can be carried to the field and elsewhere (Delgado, Kowalski, & Tebbe, 2013). A desktop version of the Nitrogen Index, which can be used on desktop and laptop computer, has also been developed. Users can email the results from their Nitrogen Index application developed for smartphones/tablets in the field to their computer back at the office (or a farmer's or consultant's computer) using their portable device's Internet service. This portable technology can enable the use of small devices such as smart-phones to conduct an assessment on site and visit with a farmer at any given field site where a wireless connection is available. The Nitrogen Index is a quick tool, and its assessments of nitrogen loss risk are correlated with observed values. Nitrogen Index application is first of its kind in the world and it is assumed as the beginning of more advances to come in the field of portable agricultural technology. New advances in software (e.g., applications) and technology are bringing us to a new frontier of technology transfer, and portable technologies (e.g., smartphones, tablets) are making possible the development of '*smart* agriculture'.

Agricultural Information in Farmer's View

Mobile phone subscription is increasing day by day in rural areas of India. Farmers require the timely and precise information. To study the requirements of the farmer for information dissemination a survey had been conducted on a sample of farmers in Punjab, India(Jain, Kumar, & Singla, 2014). This survey included the usage of internet on mobile, computer for agricultural information needs. The information from the survey was compiled and it is found that 63% know Internet usage and only 38% of farmers surf the Internet to get agriculture-related information. Approximately 99% of farmers use mobile phones efficiently having multimedia features, etc., 95% of farmers opted for getting the information using SMS services etc.

Presentation of Agricultural Information

A lot of agricultural information is available and it is needed to be presented to the user so that he can best make the use of it to increase agricultural; productivity. Various information systems, expert systems, decision support systems have been developed in this direction.

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Among ICTs for agriculture, Kissan Call Centre, an initiative of Government of India, e-Sagu (www.esagu.in), e-Arik (www.earik.in), India development gateway (www.indg.in) and e-aAqua (www.*aaqua.org*) are prominent examples (Saravanan, 2008), (Saravanan, 2010).

AgrIDS (Reddy & Ankaiah, n.d.) is a framework for an IT-based agricultural information dissemination system integrating IT and agriculture. The system have been developed using web technology and it aims to provide fresh and expert agricultural advice to needy farmers quickly and personalized manner for crop productivity improvement. It also aims to increase the cost-effectiveness of farmer by escalating the efficiency of agricultural inputs and decreasing the production cost. Some of the agricultural information systems have been provided in Table 1. Using Internet and communication networks, AgIS should capture various parameters like precise location, quality of soil, soil health, rainfall, agro-climatic conditions *etc.* of farm location to suggest best practices. Soft-computing techniques can process this set of parameters concurrently to deliver timely, precise and appropriate inferences. Various parameters like localized information along with generic information from the farmer are required to reach at a decision.

Farmers may not be comfortable or be trained to enter localized information into the computing systems. Automation can help to capture certain parameters. For example, longitude and latitude of the mobile device can be obtained using the communication networks automatically and this can be passed to the AgIS server, which in turn, can obtain the various other parameters like the type of soil, ground water level, weather conditions, prominent diseases *etc.* of the location. Soft-computing techniques, implemented at server level, process the generic and local information collected automatically using the AgIS. Processed information in the form of resultant expert like inference of agriculture practice can be delivered to the farmers in their native language, which can be helpful to them in decision making. It can enable them to improve their agricultural productivity and livelihood. However, there is need to involve agriculture experts, software developers and computer scientists to develop such a system in the local

Table 1. Some agricultural information systems and their hyperlinks

Agricultural Information System	URL
aAQUA (almost All Question Answered)	http://www.aaqua.org
KISSANKERLA	http://www.kissankerla.net
Ministry of Agriculture: Farmer portal	http://farmer.gov.in
TNAU Agritech Portal	http://www.agritech.tnau.ac.in
DACNET	http://dacnet.nic.in
e-Krishi	http://www.ekrishi.org
InDG (India Development Gateway portal)	http://www.indg.in
RKMP (Rice Knowledge Management Portal)	http://www.rkmp.co.in
Agropedia	http://agopedia.iitk.ac.in
Mahindra's Kisan Mitra	http://www.mahindrakisanmitra.com
IFFCO Agri-Portal	http://www.iffco.nic.in
Agriwatch Portal	http://www.agriwatch.com
mKrishi, Tata Consultancy Services Limited	http://www.tcs.com/offerings/technology-products/mKRISHI/Pages/default.aspx

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language of farmers. In some cases, language experts are also required to translate scientific knowledge into the local language. All the diverse partners need to understand the practices of other professions, so that this kind of system should be in place.

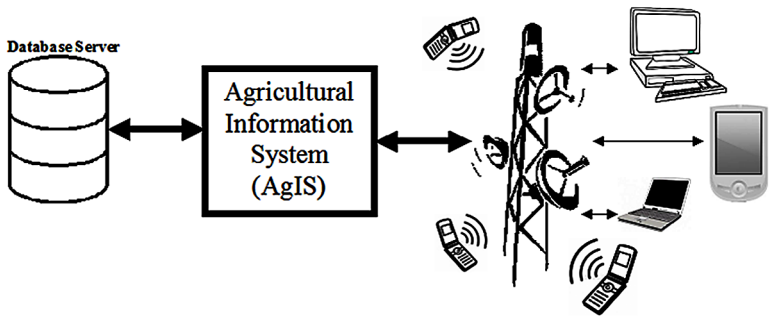
The task of creating IS based on mobile application supporting native language of farmers to cater to the complex spectrum of Indian agriculture is a giant task. Complicated information may be compiled in a structured and user friendly AgIS available round the clock. Low cost mobile phone technology and its availability with most of the farmers can provide localized information to them. Content of AgIS in local languages can engender interest in farmers and others at grassroots level. Majority of farmers are not aware of such systems. Awareness can be generated by extension specialists at ADO, BDO, SAUs, and KVKs *etc.* Use of soft computing techniques to process information required in conjunction with mobile networks and technologies, for dissemination of complex agricultural information, is one of the ways in the future to deliver expert advice to farmers.

Mobile Based Agricultural Information System Framework

Creation of databases and applications to cater to the complex spectrum of Indian agricultural scenario is a challenging opportunity. Dissemination of agricfultural information to the farmers freely in their local language is a giant task which can be achieved using the knowledgebase of existing set-up of SAUs, agricultural research institutions, state agricultural departments *etc.* Skilled manpower available in these organizations can be useful in developing mobile applications. A structured AgIS can be formulated using this information stored in the database which can be made available round the clock freely using the electronic devices like mobile-phones, laptops, desktops *etc.* as shown in Figure 1. In the present conditions, penetration of Internet is increasing but the farming community is not well conversant with the use of Internet and computer. The commonly available mobile handset e.g. smart-phones are capable of installing these mobile based information systems for providing the localized information. Various backend techniques to process the information may be deployed for developing AgIs.

Harnessing the power of mobile based communication technology can provide the localized information which is very crucial at one location but may be irrelevant at another location. The Application Programme Interface (API), which is available in the mobile phone, can tell us the precise location and it may be used for fetching the various other parameters at that location such as soil type, soil fertility, agro-climatic conditions, ground level of water using the hybrid mobile application *etc.*

Figure 1. Basic architecture for flow of agricultural information from/to AgIS



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The following section discusses and proposes architecture to develop a mobile based dynamic and hybrid system, named as '*Mobile based Agricultural Information Dissemination System* (*mAgIDS)*' for various agricultural processes and activities based on the location of the mobile device being used and to propose the possible solutions as provided by the experts of agricultural process in the preferred language of the farmer.

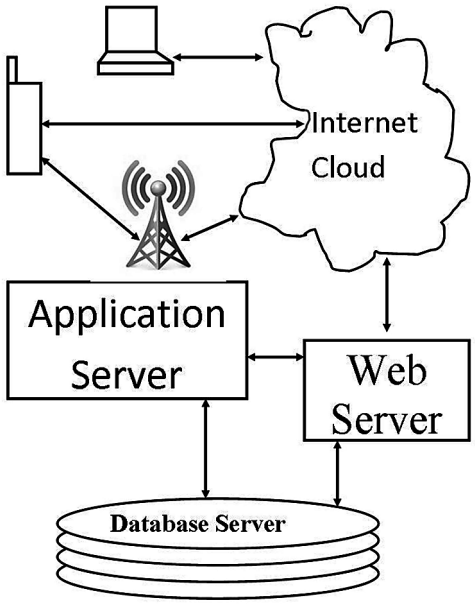
Hybrid Mobile Application Architecture

Hybrid applications are those which install on the competing device but interact with the webserver for various data processes and requirements. The proposed architecture of the hybrid application is based on client-server methodology as shown in Figure 2. The application installed on an electronic device, for example, a mobile phone, is available to the web server through the Internet Cloud using either of the means like mobile operator provided Internet, Wi-Fi, hotspot *etc.* Web server interacts with database and application server for various internal processes and activities.

Database Server

The database server stores location maps, various agricultural activities and processes, their symptoms in the form of rule base, their weights as provided by agricultural experts to a symptom of an activity, user information and storage of final results of a selected location unit.

Figure 2. Hybrid mobile application architecture



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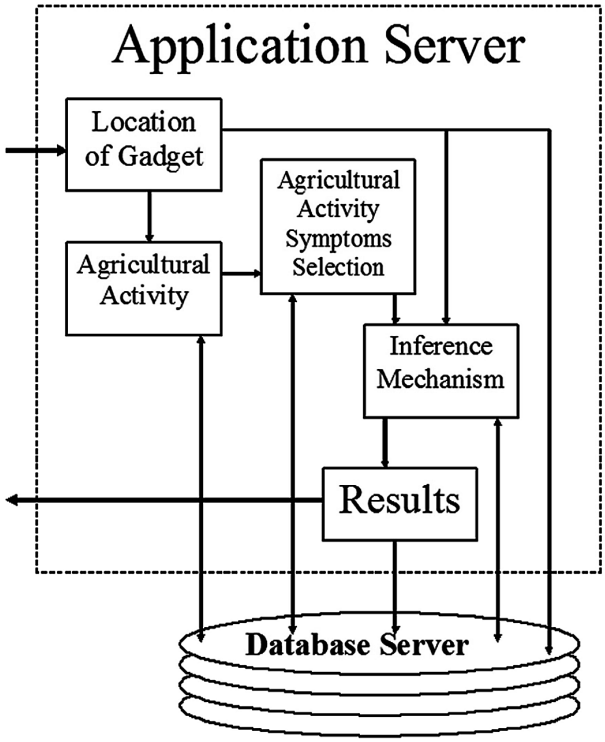
Application Server

Application server interacts with both web and database server for different activities. The web server sends a request to the application server with location parameters of the mobile device which in turns finds the exact smallest location unit name from the database using the predefined instructions employing the location API (Jain, Kumar, & Singla, 2013). Then the web server sends other parameters related with agricultural activity under consideration to the application server for selecting symptoms of agricultural activity, which interacts with the database containing set of various activities, symptoms and rule-base of agricultural processes (Figure 3).

Localization of Information

Technological advances are opening up huge opportunities. With new technologies, unmatched developments, and booming economies, the face of the world of telecommunication and IT is changing rapidly. Integrating the locale into this change and adopting the technologies for maximizing the impact in rural areas is a challenging task (Nanda & Arunachalam, 2010). Mainly mobile technologies have created new channels to communicate with others through a well-located manner. The penetration of mobile applications in the rural market is increasing day-by-day due to reducing cost of smart phones, PDA, tablets *etc.* The mobile application developer can use the manufacture provided API of these phones/technologies to develop various applications for providing localized services to the farmers. For getting the location information at the micro-macro level (administrative block level), two techniques have been employed:

Figure 3. Application server architecture



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- Selection based techniques,
- Automatic location information.

There are 29 states and 7 union territories in India with overall 640 districts and 6451 administrative blocks (Census of India, 2011). Thus, the whole nation is divided into smaller units called administrative blocks. These blocks have diverse information related to geography, geology, administration, ecology *etc.* Thus localized information can be obtained if stored in the digital format. In the selection based techniques, a database is populated with the information of the state, district and blocks of the country, for example, in MNREGA (Mahatma Gandhi National Rural Employment Guarantee Act) database, desired information can be obtained by selecting the state, district and administrative blocks under observation.

In automatic location information technique, Global Positioning System (GPS) of a mobile device can pass information related to longitude and latitude to the server. Location API on server can process this information to get the geographical data of administrative blocks in which this device is located. Then based on this, geographic agricultural data can be extracted and disseminated to this device. The server Location API can access the Geographical Information System (GIS) maps, which is imported in the database server supporting spatial information. This information is used further for processing of the other parameters. Both techniques have been described in Figure 4.

Figure 5 describes the way an electronic device, whether GPS enabled or not, accesses the Location API and uses the other APIs to process the location information. This information is used in the ISs for

Figure 4. Flow chart for implementation of location based search

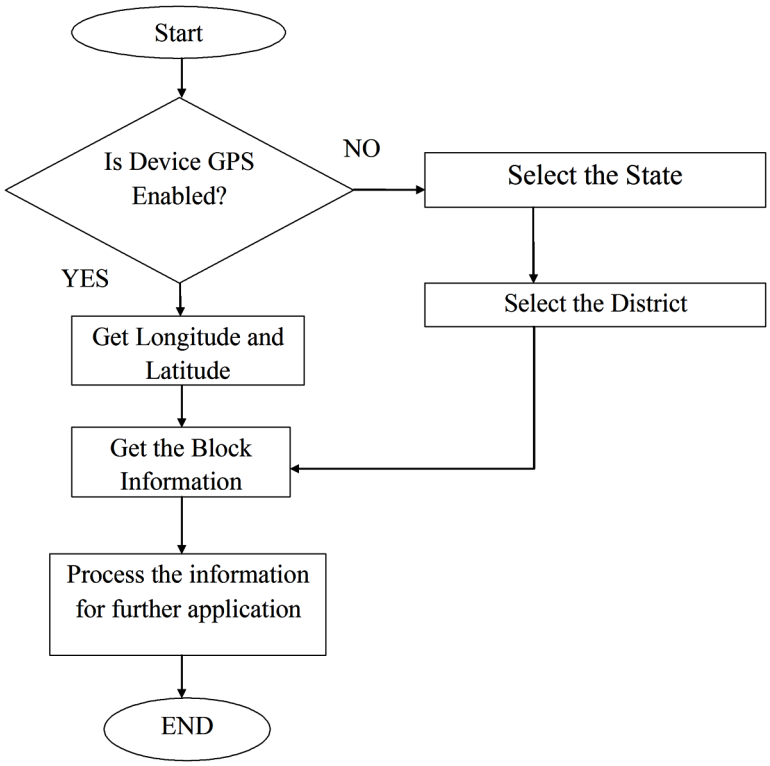

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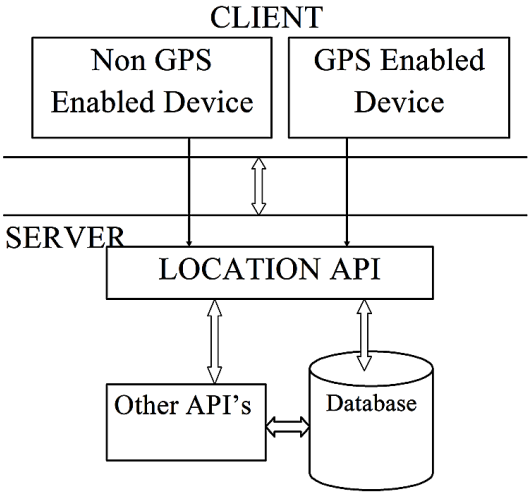
Figure 5. Client-server architecture using the location API



getting localized knowledge. Storing the information about the local spoken language can further localize it. Based on this input, data can be disseminated in the localized format.

Inference Mechanism for an AgIS

Various techniques of Soft computing like fuzzy logic, artificial neural networks, Genetic algorithm, support vector machines, Bayesians approaches etc. are being used for making the inferences. These techniques give precise result which can be used for delivering the precise agricultural information.

Mobile Based AgIS (mAgIDS)

Various initiatives have been taken to disseminate the agricultural information to farmers. An initiative name 'mAgIDS' has been taken to provide the agricultural information precisely and round the clock. This Android-based mobile phone application 'mAgIDS', using the improved dynamic fuzzy rule promotion (Jain, Kumar, Singla, Singh, & Singh, 2014) based technique to infer the advice to farmers, has been developed.

A dynamic fuzzy rule promotion approach (Kolhe, Kamal, Saini, & Gupta, 2011) for the promotion of confidence factor of a rule for every successful session for diagnosis of activity by using the specific rules have already been proposed in the literature. This technique has the limitation that error in the initial estimation of weights reduces linearly after every session the rule is being used. An improved approach has been proposed using square root of sum of squares of frequencies, which are spread around mean true value to reduce error around mean value. The improved approach decreases error in uncertainty of estimation of weight for rules after every successful session. This approach has been used in the 'mAgIDS' application.

The application uses Global Positioning System (GPS) for localized inference, and local language selected by the user. The required information is collected and transferred to the application server over

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the mobile networks. This information is processed incorporating the improved dynamic rule promotion technique. Application has been tested on the dataset of various symptoms (rules) for disease diagnosis (activity) of paddy crop. Chi-Square ($\chi 2$) test has been used to match the result of the mAgIDS system with the expert's inferences. It has been found that the results of the system and experts match with accuracy of 95.84% at 5% level of significance. Twenty two scientists working at various locations within Punjab state in India were contacted for validation of the system with fifteen relevant parameters. It has been found that the proposed system is statistically valid. The real time application of this system is in process and implementation of the system can provide immense and timely help to the farmers for taking appropriate decisions for their crop production.

CONCLUSION

Generic Information and knowledge furnished to farmers may not be relevant to them at their respective geographical locations. Dissemination of local level information through mobile networks can help them to improve their productivity and hence socioeconomic aspects. The experts can get the information about the location unit where a particular agricultural activity is more prevalent and it can help them to research that location unit. The information being requested can be processed for use in further sessions to get improvement in decision level and this can make the decisions dynamic based on previous experiences. Information dissemination in local language is one of the main requirements for proper transfer of agricultural information to the user and has to be explored.

REFERENCES

Agropedia. (2014, Feb 10). Retrieved Agropedia site from: http://agropedia.iitk.ac.in/

Alibaygi, A., Karamidehkordi, M., & Karamidehkordi, E. (2011). Effectiveness of rural ICT centers: A perspective from west of Iran. *Procedia Computer Science, 3*, 1184–1188. Retrieved from http://www.sciencedirect.com/science/article/pii/S1877050910005661

Anastasios, M., Koutsouris, A., & Konstadinos, M. (2010). Information and Communication Technologies as Agricultural Extension Tools: A Survey among Farmers in West Macedonia, Greece. *Journal of Agricultural Education and Extension*, *16*(3), 249–263. doi:10.1080/1389224X.2010.489767

Angell, I. O., & Smithson, S. (1991). *Information Systems Management: Opportunity and Risk*. London: Palgrave Macmillan. doi:10.1007/978-1-349-21555-3

Annonymous. (2014). *Data Tables: Planning Commission, Government of India.* Planning Commission of India. Retrieved from http://planningcommission.nic.in/data/datatable/

Armenta, A., Serrano, A., Cabrera, M., & Conte, R. (2012). The new digital divide: The confluence of broadband penetration, sustainable development, technology adoption and community participation. *Information Technology for Development*, *18*(4), 345–353. doi:10.1080/02681102.2011.625925

Chauhan, N. M. (2010). *Expectations of the Farmers from ICT in Agriculture*. Academic Press.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Confalonieri, R., Foi, M., Casa, R., Aquaro, S., Tona, E., Peterle, M., ... Acutis, M. (2013). Development of an app for estimating leaf area index using a smartphone. Trueness and precision determination and comparison with other indirect methods. *Computers and Electronics in Agriculture*, *96*, 67–74. doi:10.1016/j.compag.2013.04.019

Delgado, J. A., Kowalski, K., & Tebbe, C. (2013). The first Nitrogen Index app for mobile devices: Using portable technology for smart agricultural management. *Computers and Electronics in Agriculture*, *91*, 121–123. doi:10.1016/j.compag.2012.12.008

Demiryürek. (2010). Information systems and communication networks for agriculture and rural people. *Agricltural Economics – Czech, 56*(5), 209–214.

Gandhi, R., Veeraraghavan, R., Toyama, K., & Ramprasad, V. (2007). Digital Green: Participatory video for agricultural extension. In *Information and Communication Technologies and Development, 2007. ICTD 2007. International Conference on* (pp. 1–10). IEEE. doi:10.1109/ICTD.2007.4937388

Garbacz, C., & Jr, H. T. (2007). Demand for telecommunication services in developing countries. *Telecommunications Policy*, *31*(5), 276–289. doi:10.1016/j.telpol.2007.03.007

García, A., Erenas, M. M., Marinetto, E. D., Abad, C. A., de Orbe-Paya, I., Palma, A. J., & Capitán-Vallvey, L. F. (2011). Mobile phone platform as portable chemical analyzer. *Sensors and Actuators. B, Chemical*, *156*(1), 350–359. doi:10.1016/j.snb.2011.04.045

Gichamba, A., & Lukandu, I. (2012). A Model for designing M-Agriculture Applications for Dairy Farming. *The African Journal of Information Systems*, *4*(4). Retrieved from http://digitalcommons.kennesaw.edu/ajis/vol4/iss4/1

Government of India. (2013). State of Indian Agriculture. Ministry of Indian Agriculture, Department of Agriculture & Cooperation, New Delhi.

Information and Communication Technology. (2011). In *Wikipedia*. Retrieved June 15, 2011, from http://en.wikipedia.org/wiki/Information_and_communication_technologies

Information System. (2011). In *Wikipedia*. Retrieved June 15, 2011, from http://en.wikipedia.org/wiki/Information_system

International Telecommunication Union (ITU). (2011a, Jan 6). *ICT services getting more affordable worldwide.* Retrieved from International Telecommunication Union website: http://www.itu.int/net/pressoffice/press_releases/2011/15.aspx#.Ulf2LdJkPE0

International Telecommunication Union (ITU). (2011b, Nov 12). *World Telecommunication /ICT Indicators Database.* Retrieved from International Telecommunication Union website: http://www.itu.int/ITUD/ict/statistics/#.Ulf2LdJkPE0

Iqbal, Z., & Bjorklund, R. B. (2011). Colorimetric analysis of water and sand samples performed on a mobile phone. *Talanta*, *84*(4), 1118–1123. doi:10.1016/j.talanta.2011.03.016 PMID:21530787

Jain, L., Kumar, H., & Singla, R. K. (2011). A Review of Fuzzy Rule Promotion Techniques in Agriculture Information System. *International Journal of Computer Applications*, 55–60.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Jain, L., Kumar, H., & Singla, R. K. (2013). *Localization of Information Dissemination in Agriculture using Mobile Networks Changing Agricultural Scenario and Information Needs Use Multimedia in Agriculture Web and Mobile Applications Need for Mobile Phone based Communication in Agriculture Lack of*. Academic Press.

Jain, L., Kumar, H., & Singla, R. K. (2014). Assessing Mobile Technology Usage for Knowledge Dissemination among Farmers in Punjab. *Information Technology for Development*, 1–9. doi:10.1080/02681102.2013.874325

Jain, L., Kumar, H., Singla, R. K., Singh, P., & Singh, L. J. (2014). Error Reduction in Promoted Confidence Factor of a Rule Using Improved Fuzzy Rule Promotion Technique. *Cybernetics and Information Technologies*, *14*(1), 72–83. doi:10.2478/cait-2014-0006

Kirk, M., Steele, J., Delbe, C., Crow, L., Keeble, J., Fricke, C., … Bulloch, G. (2011). *Connected Agriculture: The role of mobile in driving efficiency and sustainability in the food and agriculture value chain*. Retrieved from http://www.accenture.com/SiteCollectionDocuments/PDF/Accenture-Connected-Agriculture.pdf

Kolhe, S., Kamal, R., Saini, H. S., & Gupta, G. K. (2011). A web-based intelligent disease-diagnosis system using a new fuzzy-logic based approach for drawing the inferences in crops. *Computers and Electronics in Agriculture*, *76*(1), 16–27. doi:10.1016/j.compag.2011.01.002

Lee, D., Chou, W. P., Yeh, S. H., Chen, P. J., & Chen, P. H. (2011). DNA detection using commercial mobile phones. *Biosensors & Bioelectronics*, *26*(11), 4349–4354. doi:10.1016/j.bios.2011.04.036 PMID:21621401

Mehta, P. (2003). Information Technology in Agriculture: Reaching the Unreached. *National Workshop on ICT for Agriculture and Rural Development*, Ahmedabad.

Nanda, S., & Arunachalam, S. (2010). Reaching the unreached (Vol. 7). Chennai: Jamsetji Tata National Virtual Academy (NVA), M S Swaminathan Research Foundation.

Nokia Life Tools. (n.d.). In *Wikipedia.* Retrieved February 10, 2014, from http://en.wikipedia.org/wiki/Nokia_Life_Tools

Philip, H., Vennila, M. A., & Gomathy, M. (2003). Multimedia: an effective communication technology for extension | OpenAgri: An Open Access Agriculture Research Repository. In B. Jirli (Ed.), *International Conference on Communication for Development in the Information Age: Extending the Benefits of Technology for All., Varanasi, India*. Varanasi, India: Department of Extension Education, Institute of Agricultural Sciences, Banaras Hindu University. Retrieved from http://agropedia.iitk.ac.in/openaccess/?q=content/multimedia-effective-communication-technology-extension

Raj, S. (2013). e-Agriculture Prototype for Knowledge Facilitation among Tribal Farmers of North-East India: Innovations, Impact and Lessons. *Journal of Agricultural Education and Extension*, *19*(2), 113–131. doi:10.1080/1389224X.2012.718247

Ramamritham, K. (2004). aAqua : A Database-backended Multilingual. *Multimedia Community Forum*, 1–4.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Ramamritham, K., Bahuman, A., Duttagupta, S., Bahuman, C., & Balasundaram, S. (2005). *Innovative ICT Tools for Information Provision in Agricultural Extension (December 2005)*. Retrieved from http://www.cse.iitb.ac.in/~krithi/papers/ ICTD2006.pdf

Reddy, P. K., & Ankaiah, R. (n.d.). A framework of information technology-based agriculture information dissemination system to improve crop productivity. *Current Science, 88*(12), 1905–1913. Retrieved from http://tejas.serc.iisc.ernet.in/~currsci/ jun252005/1905.pdf

Saravanan, R. (2008). *Agricultural extension: worldwide innovations*. New Delhi: New India Publishing Agency.

Saravanan, R. (2010). *Icts for@ Agricultural Extension: Global Experiments, Innovations and Expereience*. New Delhi: New India Publishing Agency.

Silver, M. S., Markus, M. L., & Beath, C. M. (1995). The Information Technology Interaction Model: A Foundation for the MBA Core Course. *Management Information Systems Quarterly*, *19*(3), 361–390. doi:10.2307/249600

Singh, P. (2004). Indian Agricultural Development in Changing Scenario Past, Present and Future. *Journal of the Indian Society of Agricultural Statistics*, *58*, 37–49. Retrieved from http://isas.org.in/jsp/volume/vol58/panjabsingh.pdf

Singh, S. K. (2008). The diffusion of mobile phones in India. *Telecommunications Policy*, *32*(9-10), 642–651. doi:10.1016/j.telpol.2008.07.005

Sumriddetchkajorn, S., Chaitavon, K., & Intaravanne, Y. (2013). Mobile device-based self-referencing colorimeter for monitoring chlorine concentration in water. *Sensors and Actuators. B, Chemical*, *182*, 592–597. doi:10.1016/j.snb.2013.03.080

The Economist. (2011). Beyond the PC. *The Economist*. Retrieved November 12, 2012, from http://www.economist.com/node/21531109

TRAI. (2014). *Telecom Subscription Data as on 31st January, 2014*. Retrieved from http://trai.gov.in/Content/PressDetails/2135_0.aspx

UNESCAP. (2011). *Statistical Yearbook for Asia and the Pacific 2011*. Retrieved from http://www.unescap.org/stat/data/syb2011/

Vu, K. M. (2011). ICT as a Source of Economic Growth in the Information Age: Empirical Evidence from the 19962005 Period. *Telecommunications Policy*, *35*(4), 357–372. doi:10.1016/j.telpol.2011.02.008

World Bank. (2011). *ICT in Agriculture: Connecting Smallholders to Knowledge, Networks, and Institutions*. World Bank.

Yadav, K. (2011, April 4). *Impact Assessment of ICT – enabled Knowledge Sharing Agri-portals in Uttarakhand*. Govind Ballabh Pant University of Agriculture & Technology, Pant Nagar, Uttrakhand. Retrieved from http://oar.icrisat.org/id/eprint/5845

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Chapter 25
Sustainability Assessment in a Geographical Region and of the Activities Performed

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ABSTRACT

The applicability of emergy analysis (EA), a nature oriented thermodynamic analysis technique, as a regional sustainability assessment tool is explored in the context of an Indian village (Rampura). EA provides information about how much environmental support is required, system renewability, system efficiency, load of system to environment and dependency of system on external resources (self-sufficiency). The results of Rampura analysis reveal that sustainability is achieved neither at village level nor at subsystem levels. The chapter shows that the effective use of the renewable local resources can reduce the dependence on external resources and increase self-sufficiency and sustainability

INTRODUCTION

Sustainability is a complex concept since social, economic, technical and complex dynamic factors are decisive in a simultaneously interacting manner (Bakshi, Ziv, & Lepech, 2015). Hence, considering only one dimension of events does not create success in assessing a multi-dimensional phenomenon like sustainability. In today's world where many of thresholds of Earth's carrying capacity in life support mechanisms have been crossed (Steffen *et al.*, 2015), analyzing the interaction of natural and anthropogenic systems is crucial in order to cease the further deterioration and start the restoration of natural capital (Mellino *et al.*, 2015). In that regard, emergy analysis (EA) can be an effective tool to evaluate the interaction between natural and anthropogenic systems because of the insights it can provide.

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EA is a nature oriented, thermodynamic analysis technique. Odum (1996) expresses emergy as "the total amount of available energy of one kind that is directly or indirectly required to make a given product or to support a given flow." EA quantifies total available energy (emergy) input flows to a system and classifies these flows as renewable, non-renewable and purchased. Classification of emergy input flows enables calculation of emergy metrics providing information about how much environmental support is required for the area or process in question, system renewability, system efficiency, load of system to environment and dependency of system on external resources. Detailed information about emergy analysis and its application are given in *Emergy Analysis Technique* section which follows *Background*.

The aim of this chapter is to validate the applicability of EA as a regional sustainability assessment tool and to evaluate sustainability of human activities and their interaction with nature. With this purpose, The Ohio State University research team chose Rampura Village in Jhansi district of Uttar Pradesh, India as the project site. Rampura village is chosen as the project site because of successful implementation of capacity building applications as well as availability of wide range of data which improves analysis quality. Moreover, Bundelkhand is a semiarid region suffering from lack of water and vulnerable to climate change. The area went through a 4-year-long drought, which caused greater suffering for the village residents who are already bearing some effects of climate change problems (Development Alternatives, 2011). Hence, the area needs a quick shift towards sustainability and assessment of the activities performed. Here, the research team worked in collaboration with a non-governmental organization (NGO), Development Alternatives, uniting NGO's field experience with their holistic analysis experience. Development Alternatives works in the area of sustainable development, and capacity building of rural people to improve their income generation capabilities (DevAlt, 2013). Its technology disseminating branch TARA (Technology and Action for Rural Advancement) has been working in the Bundelkhand region (region including Rampura village) of Central India for over 10 years (TARA, 2013). More detailed information about Rampura, Development Alternatives and emergy analysis study carried out can be found in *Rampura Village Case Study* section.

BACKGROUND

Prior to performing a regional sustainability assessment study, one should define what sustainability or sustainable development means. One definition for sustainable development given by World Commission on Environment and Development (WCED) in 1987 is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). This definition is vague in terms of foreseeing what the needs of future generations will be and how the current needs will be met without compromising an unknown future (Marshall & Toffel, 2005). The vagueness in this definition of sustainability is also due to lack of unanimity in defining what is regarded as sustainable. To Costanza and Patten (1995), sustainability is not a "definition", but a "prediction" problem. One can only determine a system as sustainable after seeing the results for certain. In that regard, to better objectify the sustainability concept, the "time and space scales" should be specified regarding what is considered as sustainable and unsustainable (Costanza & Patten, 1995). In nature, systems are interconnected within a hierarchical order through energy and material exchanges (Odum, 1996).

Entities which are higher in the hierarchy encompass broader time and space scales. For instance, ecosystems have longer lifetimes than the species they contain or species survive longer than an individual of the species. Hence, each entity has an expected life span increasing as the entity ascends higher in the

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hierarchy. Based on this fact, Costanza and Patten define a sustainable system as "one attains its full expected lifespan within the nested hierarchy of systems within which it is embedded" (Costanza & Patten, 1995). Hence, actions which cause a system survive shorter than its expected life span diminishes that system`s sustainability. Pollutants shortening human life or excessive nitrogen and phosphorous flows released into water resources causing algal blooms affect the functionality of these systems negatively, thus reducing their sustainability (Costanza & Patten, 1995; Marshall & Toffel, 2005). To achieve or improve sustainability, actions supporting and enhancing the harmony of a system with its life support mechanisms should be adopted (Costanza & Patten, 1995). Resources utilized in a system should not be consumed faster than their renewal rate. Pollutant and toxic material emission rates should not be greater than their assimilation rate in an ecosystem (Marshall & Toffel, 2005).

Past development pathways, the developed countries pursued (generally fossil energy and external input (mostly non-renewable) dependent) induce many of the environmental problems humanity fight against today (Steffen, Persson, & Deutsch, 2011). Energy generation, transportation and agriculture are the main human activities affecting Earth and its support mechanisms (Steffen *et al*., 2011; Rockstrom et al., 2009) because the rate of resource utilization and waste creation by these processes exceed the resource formation and waste elimination rates of Earth's life support system (Steffen *et al.*, 2015). For the last 10,000 years (Holocene), Earth has had a considerably benign climate which enabled the development of human civilization (agriculture, towns and cities) (Griggs *et al*., 2013). And, this support system can continue to function in this human-friendly way only below certain thresholds above which catastrophic results may arise for humanity (Steffen *et al.*, 2015).

In that regard, there are increasing efforts toward a paradigm shift in how humanity needs to function while sustaining Earth`s life support system. This came with the recognition of fundamental importance of natural capital in supporting humanity (Griggs *et al.*, 2013). The earlier three pillars (economic, social and environmental) of sustainable development are integrated within a hierarchical model taking Earth`s support function as a basis on which society and economy thrive (Griggs *et al*., 2013; Rokstrom *et al.*, 2009). However, most of earlier engineering efforts to achieve or improve sustainability generally focused on increasing resource or energy use efficiency (Bakshi, 2011). However, this reductionist approach does not lead to sustainability. Thus, sustainability assessment of a system should be performed within a systems thinking paradigm.

Likewise, classical economics considers only human labor and money as limiting factors for a production activity and perceives nature as a free resource that supplies raw materials and eliminates waste (Mellino, Bounocore, & Ulgiati, 2015). However, the role of ecosystem services in supporting the systems analyzed should be accounted for (Ulgiati *et al*., 2010). And, ecosystem services should be perceived as the third limiting factor for production activities. All systems need external energy or material inputs to sustain themselves. What matters in terms of sustainability is how renewable these inputs are and if their utilization rate is within the carrying capacity of the surroundings. If resource use is within the carrying capacity of the relevant surroundings, then the system is likely to become sustainable (Bakshi, 2011), since such a system would satisfy a necessary but not sufficient condition for sustainability (Bakshi *et al.*, 2015). Therefore, reducing reliance on nonrenewable sources is a common goal of many efforts toward sustainable development. If developing countries follow the same paths that the developed countries did for their development, it is highly unlikely that a sustainable future awaits humanity given the huge populations of these countries (China, India) and possible impacts of such a development path.

In the literature, there are numerous applications of emergy analysis that evaluate human created systems and their interactions with their surroundings. For instance, Coscime *et al.* evaluated natural

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capital of many nations and how the characteristics of the natural capital translate into their economic systems (Coscime *et al.*, 2014). They classified nations based on their findings. *A striking outcome of the study is the superiority of ecosystems in creating useful outputs over economic activities*. Emergy analysis can also be utilized for regional planning purposes and recommendations for decision makers. Vega-Azamar *et al.* analyze island of Montreal and quantify resource consumption, waste generation and their relation with population density. This analysis points out importance of recovery of degraded areas to improve sustainability of the region (Vega-Azamar *et al.*, 2013). A similar assessment for Canada and its provinces has been done for emergy mapping and regional evaluation (Hossaini & Hewage, 2013). Geographical information systems (GIS) can be aided to quantify different emergy flows to and from regional boundaries considered (Mellino *et al.*, 2015; Mellino *et al.*, 2014). Furthermore, emergy analysis can be utilized to evaluate self-sufficiency and dependence of a region on external inputs (Zhang, Yang, & Chen, 2007). Several agricultural systems, economic patterns and relative sustainability of these actions can also be assessed by means of emergy analysis (Jiang *et al.*, 2009; Lin, Huang, & Budd, 2013; Nakajima & Ortega, 2014).

Several other methods are available to assess regional sustainability such as human and environmental risk assessment, ecological footprint, material and energy flow analysis, ecological network analysis etc. A detailed discussion of these techniques, their pros and cons can be found in Loiseau *et al.* (2012). Comparison and discussion of these methods are beyond the scope of the present chapter. However, utilizing emergy analysis in evaluation of sustainability in a region enables quantification of environmental work invested in activities taking place, interaction and dependence of these activities to each other as we show in emergy analysis case study of Rampura and its subsectors. Utilizing solar emergy as a common denominator to represent emergy of all inputs enables accounting for quality differences among the resources (Odum, 1996 and Ulgiati *et al*., 2010). Energy sources like tidal energy or crustal heat not having a solar origin are transformed solar equivalents by certain conversion factors. Emergy accounts for all the environmental work spent back in time for formation of natural resources, creating an "energy memory". In short, emergy represents the environmental support invested by nature for the activities taking place in a region (Odum, 1996).

In the rest of this chapter, emergy analysis fundamentals and framework are introduced followed by a section about Rampura village emergy analysis case study to express the applicability of emergy analysis as a regional sustainability assessment tool. Chapter ends with a section that discusses future research areas and a conclusion section expressing the inferences and recommendations based on the case study results.

EMERGY ANALYSIS TECHNIQUE

Fundamentals of Emergy Analysis

Emergy is defined as the total amount of available energy of one kind that is directly or indirectly required to make a given product or to support a given flow" (Odum, 96). Hence, emergy types such as coal emergy, oil emergy or solar emergy can be employed (Ulgiati *et al.*, 2010). Solar equivalent joule (sej) is generally chosen to be the emergy unit because of sun being the motor that drives all transformations in nature and human activities. Odum (1996) suggests that solar energy is transferred among living things (producers, primary consumers, predators) or in formation of energy sources. All natural or human

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dominated systems forms a network of energy transformations by concentrating and increasing the quality of lower quality energy into higher quality energy and waste heat (Hau & Bakshi, 2004a; 2004b). Solar energy is converted by green plants into chemical energy via photosynthesis or electricity is produced in coal power plants in a way to use a dilute energy form and create higher quality one. Hence, biological and economic systems sustain themselves and support each other by creating an "energy hierarchy" (Brown & Ulgiati, 2004; Hau & Bakshi, 2004b).

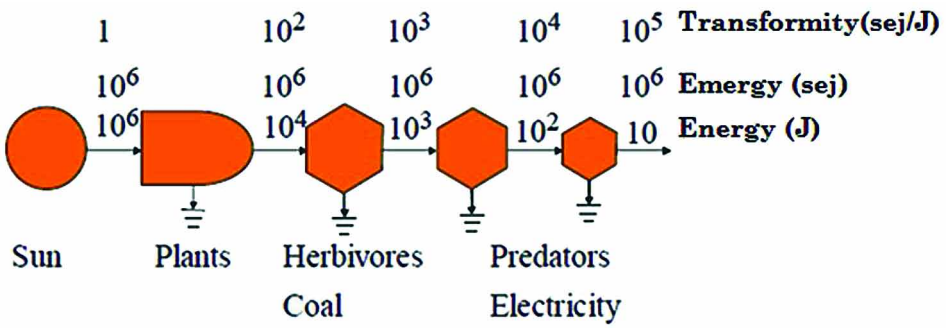
Solar energy that is needed to produce one gram, one joule or one dollar of a resource or product is called transformity or specific emergy (Brown & Ulgiati, 2004). Hence, transformity can be in units of sej/J, sej/g or sej/$. It is accepted as an indicator of energy quality since in energy transformations, energy is concentrated and its quality is increased. As a result, transfromity of a resource becomes higher as it ascends higher in the energy hierarchy (Hau & Bakshi, 2004a; 2004b). In other words, it takes more solar equivalent joules of energy or environmental work to make a higher quality product. Figure 1 elaborates these energy transformations within ecosystems and economy related systems as explained above.

To calculate emergy of an input to a system, transformity of the input is multiplied by its quantity (energetic or material quantity). Then, total emergy input to the system can be calculated simply by adding emergy of all input flows (Odum, 1996; Pizzigallo, Granai, & Borsa, 2008). Emergy classifies input flows as locally available renewable (R) and non-renewable (N) inputs and external purchased (F) inputs. By this way, emergy indicators are calculated as indicators of environmental performance for the system or region evaluated. The calculated ratios are indicators of system renewability, system efficiency, load of system to environment and dependency of system on external resources (or self-sufficiency) (Odum, 1996 and Ulgiati et al, 2010). In the following subsection, emergy analysis procedure will be introduced followed by a subsection regarding emergy algebra.

Emergy Analysis Procedure

Emergy analysis procedure includes energy systems diagram drawing, emergy evaluation table construction and calculation of emergy ratios. In energy systems diagramming, emergy flows entering and leaving the defined system boundary and emergy flows among system components are defined. In construction of emergy table, all input quantities, related transformity values and calculated emergy values for each input are listed. Emergy tables can be used to graph the emergy flows calculated for each input to show

Figure 1. Hierarchical transformation of sun energy in nature
Adapted from Odum, 1996 and Hau & Bakshi, 2004b.



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the distribution of the emergy input flows to the system assessed. Based on different classification of emergy inputs (local renewable (R), non-renewable (N) and external purchased (F)), emergy ratios are calculated at the last stage (Odum, 1996; Brown, Rugei, & Ulgiati, 2012).

Energy Systems Diagrams

In energy systems diagramming, a pictorial model of the system to be studied is formed. Here, the purpose is to understand and determine the external energy and material flows, to identify material and energy exchanges and interactions among system components and to identify the patters of interaction between the system analyzed and its surroundings (Brown, 2004; Odum, 1996).

Figure 2 presents fundamental symbols used to draw energy systems diagrams. Of these symbols, circles represent either natural forcing functions such as sun, rain and rain or purchased forcing functions such as diesel and gasoline. Arrows represent material or energy flows among system components and flows from or to the analysis boundary. Green plants or algae are represented by producer symbol. For example, producer symbol is used to represent agriculture in emergy analysis of Rampura village. Storage represents any entity that accumulates within the analysis boundary and has a potential of creating flows. Topsoil and underground water are the storages for Rampura energy systems diagrams. Consumer symbol hexagon is used to represent livestock and domestic sector in Rampura. Interaction symbol is utilized to identify interactions and transformations among system components (Odum, 1996; Brown, 2004).

Emergy Evaluation Table

Emergy evaluation table is constructed based on the energy systems diagram drawn for the considered system. This table forms the inventory data for emergy analysis and the following emergy ratios calculation. All inputs, outputs, their quantities for a specific time interval, transformity values for each input and calculated emergy values are all listed in the table (Odum, 1996). Table 1 presents a generic emergy evaluation table. Addition of all emergy inputs gives total emergy input to the system. Division of dedicated emergy yield by the quantity of the system outputs gives the transformity value of outputs (Odum, 1996).

Figure 2. Energy systems diagramming symbols
Source: UFCEP, 2013.

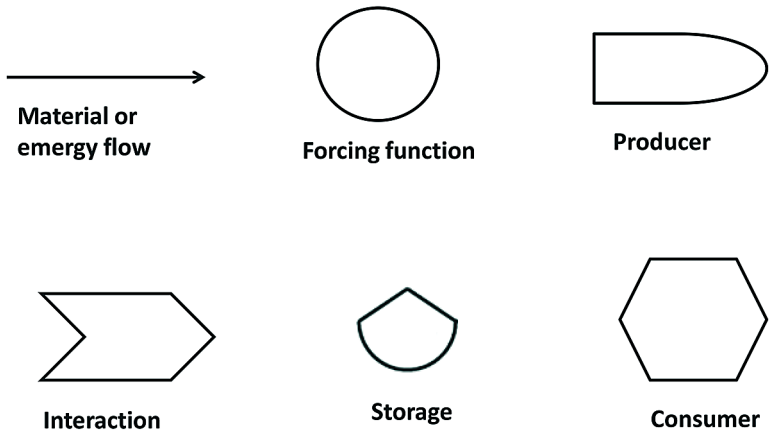

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Table 1. A generic emergy evaluation table

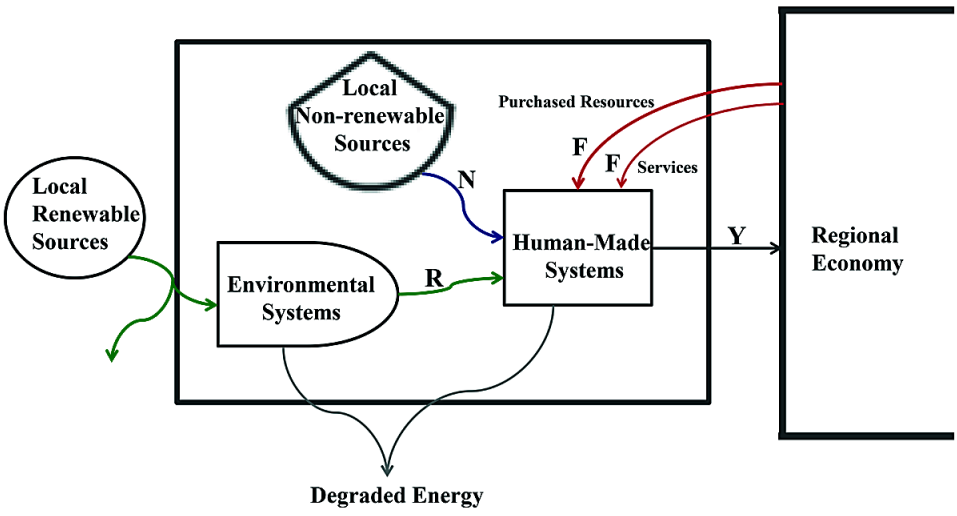
Item	Item (Name)	Data (Flow/Time)	Units	Transformity (sej/Unit)	Solar Emergy (sej/Time)
1	First item	xxxx	J/year	Xxxx	Em_1
2	Second item	xxxx	g/year	Xxxx	Em_2
…	…	…	…	…	…
n..	nth item	xxxx	J/year	Xxxx	Em_n
O	Output	xxxx	J/year or g/year	Xxxx	$\sum_{1}^{n} Emi$

Calculation of Emergy Ratios

Emergy inputs which are free and provided by nature locally are classified as renewable. Examples of renewable emergy inputs are solar radiation, wind and rain. Amounts of these renewable inputs are flow-limited and their amount cannot be increased or decreased by human intervention. Non-renewable inputs are also local resources but not necessarily free. Examples of non-renewable emergy inputs can be topsoil, ground water or minerals such as quartz. For these inputs to be non-renewable, their regeneration rate by nature should be slower than their withdrawal rate else they are classified as renewable. And, purchased or feedback emergy flows are external inputs which are neither free nor locally (within the analysis boundary) available (Ulgiati & Brown, 1998).

Emergy can connect natural systems to human created economic systems. Figure 3 summarizes classification of emergy inputs and how this translates into the interaction of natural systems with economic systems. Classification of emergy inputs enables calculation of emergy ratios. By this way, inferences about environmental performance of a human created system can be made (Ulgiati *et al.*, 2010).

Figure 3. Classification of emergy flows to a system which is the basis for calculation of emergy ratios



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Of the emergy indicators yield (Y) or total emergy input quantifies the environmental work or available energy (including the ones accumulated back in time) invested by nature to the system analyzed. The quantity of yield equals the sum of all emergy inputs to the system. Renewability (Re) represents the ratio of renewable emergy inputs in the yield. Renewable emergy is provided by natural Earth processes and is related to the carrying capacity of the surroundings within which the analyzed system exists in. For that reason, high renewability is and indicator of long term sustainability for a system (Odum, 1996). As a result, the higher the Re of a system, the more sustainable it can be. Emergy yield ratio (EYR) is an indicator of a system's ability to contribute to the economy by exploiting local resources (Ulgiati *et al.*, 2010). EYR is the ratio of yield (Y) to purchased emergy (F). In essence, it is reciprocal of economic efficiency and represents the reciprocal fraction of external (purchased) emergy within the yield. Hence, a process with higher EYR is preferred over the one with a lower EYR. Environmental loading ratio (ELR) is an indicator of stress exerted on the surroundings by the studied system due the activities performed. ELR represents the non-renewable portion of emergy input and equals the ratio of non-renewable and purchased emergy inputs to renewable inputs. A high ELR translates into a stress beyond the carrying capacity of surroundings (Odum, 1996; Paoli, Vassallo, & Fabiano, 2008; Pizzigallo *et al.*, 2008 and Ulgiati *et al.*, 2010). Hence, a system with a lower ELR is preferred over the one with a higher ELR. Ratio of ELR to EYR results in a new ratio called environmental sustainability index (ESI) which is an indicator of a high output with low environmental loading. Environmental investment ratio (EIR) expresses the ratio between local versus imported resources and is the ratio of purchased inputs (F) to renewable (R) and non-renewable (N) local inputs. Due to high dependence on external resources, a high EIR value usually indicates a fragile system (Odum, 1996, Paoli *et al.*, 2008, Ulgiati *et al*., 2010). Calculation of emergy ratios based on the classification of emergy inputs is presented mathematically in equations 1-6.

$$\text{Emergy Yield } (Y) = R + N + F \tag{1}$$

$$\text{Renewabiliy} = \frac{R}{Y} \tag{2}$$

$$\text{Emergy Yield Ratio } (EYR) = \frac{Y}{F} \tag{3}$$

$$\text{Environmental Loading Ratio } (ELR) = \frac{(N+F)}{R} \tag{4}$$

$$\text{Environmental Sustainability Index} = \frac{EYR}{ELR} \tag{5}$$

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$$\text{Environmental Investment Ratio} = \frac{F}{(R+N)} \tag{6}$$

Emergy Algebra

Co-Products and Splits

"Emergy algebra" is a set of rules governing the allocation of total emergy yield to multiple outputs of a system (Brown & Herendeen, 1996). In general, allocation is avoided in emergy analysis and emergy yield is allocated to each of the co-products. Allocation in splits is performed based on the available energy contents of the splits (Hau & Bakshi, 2004a). Hence, it is necessary to define what co-products and splits are to allocate total emergy yield correctly in related analyzes.

Co-products can be defined as products that can only be produced jointly and have different properties and purposes of use (Bastionani *et al.*, 2009). Animal draft, milk and cow dung which are the outputs of husbandry sector in Rampura can be classified as co-products because these outputs cannot be produced separately and they have different functionality (purposes of use).On the other hand, splits are products of similar characteristics with similar functionality and they can be produced separately (Odum, 1996 and Bastionani *et al.*, 2009). For instance, outputs of an agricultural activity can be classified as splits since different crops can be grown independently from each other and they have similar functionality (food). Emergy yield is allocated according to the available energy content in splits.

The co-products of earth processes such as rain, wind, earth cycle are assigned all emergy yield available to earth in a year. And their transformity equals the ratio of this total emergy to their available energy content (Odum, 2000). To calculate available energy contents of some co-products of earth processes, the fundamental equations utilized are given in equations 7-9.

$$\text{Available Energy of Sun in a Year} = \text{Land Area} \times \text{Solar Irradiation} \times (1 - \text{Albedo}) \tag{7}$$

Here, albedo is the fraction of sun energy reflected back by the analyzed land area.

$$\text{Available Energy of Rain} = \text{Land Area} \times \text{Precipitation} \times \text{Density of Water} \times \text{Gibb's Free Energy of Water} \tag{8}$$

$$\text{Available Energy of Top Soil Loss} = \text{Land Area} \times \text{Energy Content of Organic Matter} \times \text{Organic Matter Percentage} \tag{9}$$

Additionally, wind energy in Rampura is 491 J/m^2 and earth cycle available energy is 1.00x 10^6 J/m^2 (DevAlt, 2011; Odum, 1996).

Rules of Emergy Algebra

Emergy algebra includes three basic rules. First rule governs the allocation of emergy yield for co-products. It is stated as follows: "All source emergy is assigned to the process outputs." This means that allocation

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is avoided for co-products of a system (Brown & Herendeen, 1996). The second rule is about allocation of emergy yield in splits. It states that "When a pathway (co-product) splits, emergy is assigned into each leg based on its percentage of the total energy flow on the pathway." This means that allocation of emergy yield is based on the available energy content ratio of each split (Brown & Herendeen, 1996).

Figure 4 elaborates partitioning of total emergy yield among co-products and splits according to the rules of emergy algebra. Here a total emergy yield of 5000 sej is assigned to each of the co-products in a. Then, in b, 5000 sej is assigned to two co-products first. Afterwards, 5000 sej is allocated between the two splits of first co-product in a way that is directly proportional to their available energy content.

The third rule of emergy algebra is to prevent double counting and states that "Emergy cannot be counted twice within a system. Co-products, when they are reunited, cannot be added to equal to a sum greater than the source emergy from which they are derived." (Brown & Herendeen, 1996; Bastionani *et al.*, 2009). Hence emergy of splits are additive whereas emergy of co-products are not. In case of co-products the emergy of co-product with maximum magnitude is chosen to avoid double counting (Odum, 2000).

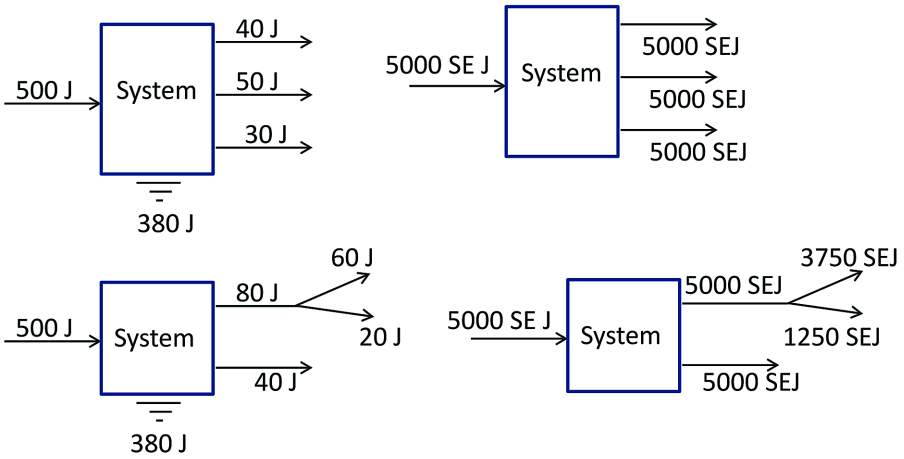
RAMPURA VILLAGE CASE STUDY

Rampura Village, Development Alternatives, and Project Preparation Process

Project Site

This case study is realized in a village named Rampura founded in Jhansi district of Uttar Pradesh, India. The reason of choosing Rampura village as project site is the successful implementation of capacity building applications as well as availability of wide range of data which improves analysis quality. Bundelkhand which also includes Rampura village is a semiarid region suffering from lack of water and prone to climate change. The area went through a 4-year-long draught making village suffer from the existing climate change problems more severely (Development Alternatives, 2011).

Figure 4. Partitioning of total emergy yield among co-products and splits



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In Rampura village, there are 436 individuals of which 179 are males, 149 are females and the rest is children. The literacy in the village is 70% (DevAlt, 2013). Of the 69 households in the village, 44 are connected to the 8.7 kWp multi-crystalline silicon solar grid implemented by Development Alternatives (project partner) in collaboration with Scatec Solar (Scatec Solar, 2013). The houses which are connected to the solar grid utilize solar electricity for lighting and those which are not connected utilize kerosene for the same purpose. Cooking needs are supplied from wood, agricultural residues and cow dung cake. Table 2 summarizes the amount of each energy source utilized in the village annually. Of the 133.6 hectares total village area, 89 hectares are cultivable land and 68 hectares of cultivable land is irrigated. In the village there is no dedicated grazing land or reserve forest. According to the season, non-irrigated land is utilized as grazing land.

The main income generating activities in the village are agriculture and animal husbandry. The main crops grown are wheat, pulses, groundnut, mustard and different vegetables. The annual amounts of each product grown are given in table 3[1]. There are 117 buffalos, 45 bullocks, 55 cows, 36 calves and 155 goats in the village totally. Bullocks and sometimes buffalos are utilized as draft animals. Cows, goats and buffalos produce milk. While goats open graze and are not fed fodder, other animals are fed fodder consisting mainly of wheat straw. Vegetables and milk are the items for liquid cash flow within the year.

Table 2. Annual energy use in Rampura Village

Energy Use in Rampura	Amount/Year
Electricity (kWh)	6935
Kerosene (liter)	1278
Wood (kg)	355875
Agricultural Residues (kg)	100375
Dung Cake (kg)	189800

Source: DevAlt, 2011.

Table 3. Agricultural products grown in Rampura and their annual quantity

Agricultural Products	Amount(kg/Year)
Wheat	1.38E+08
Gram	1.28E+07
Mustard	1.61E+07
Maize	2.12E+07
Urad Dal	1.41E+07
Soya	3.53E+07
Groundnut	1.25E+07
Vegetables	8.25E+07
Agricultural Residues	2.95E+08

Source: DevAlt, 2011.

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Project Partner

The project partner for Rampura Case study is Development Alternatives (DA), a local non- governmental organization (NGO). Development Alternatives works in the area of sustainable development, and capacity building of rural people to improve their income generation capabilities (DevAlt, 2013). Its technology disseminating branch TARA (Technology and Action for Rural Advancement) has been working in the Bundelkhand region of Central India for over 10 years (TARA, 2013). In Rampura study, the role of DA is to participate in preparation of village surveys to have household level data and provide cumulative village level data.

DA has a campus (Orchha) in Tikamgarh district of Madhya Pradesh where they empower local communities by increasing their capabilities in value creation activities. For instance, local women produce paper souvenirs from waste fabric or peanuts grown in the region are peeled off and packed to be sold at a higher price in the market. People are trained by DA for these activities first and machinery needed is rented also by DA to the locals. The Pahuj campus of DA in Uttar Pradesh offers agricultural and societal networking solutions for sustainable development. Agrarian communities are trained for effective water use and innovative agricultural practices. Trainings on roof-top rain water, underground water harvesting, seed germination in trays to obtain seedlings and to increase yield takes place on this campus. Shri Ram Raja Gaushala is a cowshed founded near Orchha campus of DA. Here, biogas electricity generated from cow dung is utilized for value creation activities and cowshed is mainly operated by local women with minor support from DA (DevAlt, 2011).

Preparation Process

The first step of preparation was to prepare a survey to be applied to the villagers in Rampura. Questions related to social status, amount of land area owned, types of crops they grow, irrigation, pesticide and fertilizer usage, number and types of livestock owned, what fraction of the crops and animal products they sell at the market, how they transport their products to the market and means of transportation were asked in the survey. Following survey preparation, these questions are asked to households from different economic status. Surveys provided the household level data. Additional data such as irrigation patterns for different crops, crop to residue information, available local resource information were provided by DA. Raw data obtained from surveys and DA were then processed to define village system and subsystems and form the energy systems diagrams.

Characteristics of Village System and Energy Systems Diagramming

In Rampura village, there are three subsystems interacting, systems that exchange materials and energy among themselves. These subsystems are animal husbandry, agriculture sectors and human ecosystem or domestic sector. Human ecosystem provides the labor needed in husbandry for the animals to be fed, barns to be cleaned etc. In agriculture, labor is needed to manage animals or tractors for fields to be ploughed, to apply fertilizers and pesticides and to harvest the crops. Husbandry sector provides the animal draft for the fields to be ploughed and manure as fertilizer. Milk produced by cows, buffalos and goats is an important nutrition source for the people in the village. Furthermore, cow dung dried under the sun is an important energy source for cooking activities. Around 40% of the agricultural residues are fed to cows as fodder and around 34 % of agricultural residues are used for cooking purposes by people

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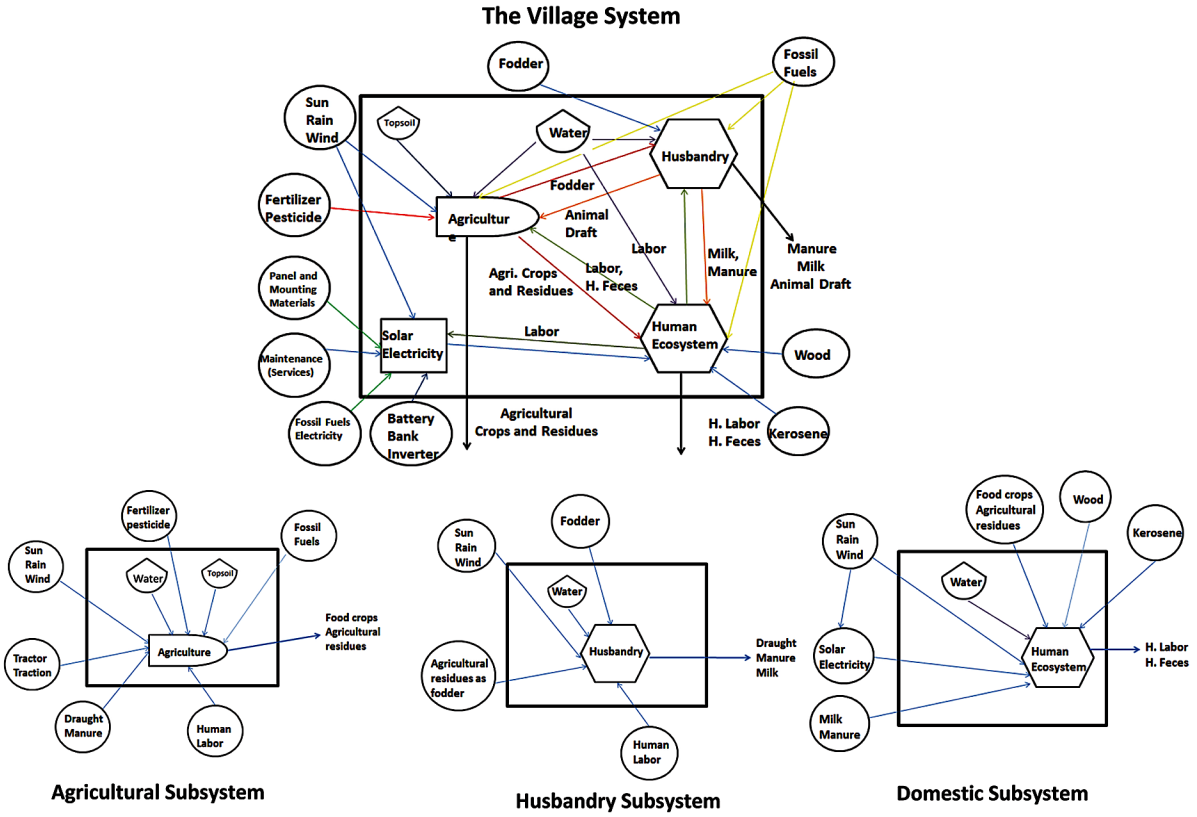
in the village. Since emergy analysis is an input-output analysis method, only external inputs to the village and outputs from the village are taken into account for village level emergy analysis (Odum, 1996; Ulgiati & Brown, 1998). Interactions among three subsystems within the village boundary have not been considered at this level. However, the interactions among subsystems determine the need for external inputs. If agricultural residues were not used as fodder, more fodder would be purchased from the market for animals; or if cow dung was not used for cooking, another energy source would be needed. Figure 5 presents village level and subsystem level energy systems diagrams drawn for the systems analyzed. Given the influence of internal interactions (among subsystems) within the village on overall village system, the three subsystems are also analyzed separately to understand their relative sustainability and their individual effects on the overall village system.

Classification of Emergy Inputs and Emergy Evaluation Tables

At the village level, inputs provided locally and freely by nature such as sun, rain and wind are classified as renewable. The external inputs, fossil fuels, fertilizer, pesticide, inputs related to the solar panel in the village, purchased fodder for animals, kerosene used for lighting, which are neither free nor locally available, are the purchased external inputs contributing to the overall village system. Wood, ground water and soil erosion (topsoil loss), which are utilized faster than their renewal rate by nature, are the local non-renewable emergy inputs contributing to this system.

Figure 5. Energy systems diagram for Rampura village and village subsystems



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Of the three interacting subsystems of Rampura, husbandry sector provides animal draft, manure and milk outputs. Agricultural crops and residues are the outputs from agriculture. Human ecosystem outputs are human labor and feces. There is an important point to be emphasized for the village level analysis. The output quantities stated are the net amounts coming out of the village analysis boundary. For example, the value given for agricultural residues is equal to total residues minus the residues utilized in domestic and husbandry sectors.

Table 4 presents the emergy evaluation for village level emergy analysis of Rampura. In the last column of this table, references for transformity values utilized are given. As can be seen from the table, the largest emergy input to the village is fodder input for animals followed by ground water. There is an upper and lower limit for total yield calculated originating from topsoil loss and tractor traction. Topsoil loss for this area is taken as 5-10 tonnes/ha/year (Yedla & Peddi, 2003) and there is a range for diesel use per season utilized by farmers of Rampura to plough their fields and transport their crops to the market.

Table 4. Emergy evaluation table for village level emergy analysis of Rampura

Inputs	Amount	Unit	Transformity (Sej/Unit)	Emergy (Sej/ Year)	Reference
Sun(land)(100% R)	1.86E+15	J	1	1.86E+15	Odum,2000
Sun(field)(100% R)	4.64E+15	J	1	4.64E+15	Odum,2000
Rain(100% R)	5.61E+12	J	3.06E+04	1.71E+17	Odum,2000
Wind (100% R)	6.56E+08	J	2.52E+03	1.65E+12	Odum,2000
Earth Cycle(100% R)	1.34E+12	J	4.28E+04	5.71E+16	Odum,2000
Topsoil loss (low) (100% N)	3.01E+11	J	1.25E+05	3.76E+16	Pizzigallo,2008
Topsoil loss(Up) (100% N)	6.03E+11	J	1.25E+05	7.54E+16	Pizzigallo,2008
Ground water (100% N)	6.62E+11	g	3.98E+05	2.63E+17	Zhang, 2012
Diesel(Irrigation)(100% F)	4.36E+06	g	2.89E+09	1.26E+16	Bastianoni,2009
Pesticide(100% F)	2.41E+04	g	1.48E+10	3.56E+14	Odum, Brown, Brandt-Williams, 2002
Fertilizer(100% F)	6.92E+06	g	2.22E+10	1.54E+17	Odum, 2002
Tractor Traction(Up)(100% F)	2.53E+07	g	2.89E+09	4.43E+16	Bastianoni, 2009
Tractor Traction(Low)(100% F)	1.15E+07	g	2.89E+09	3.32E+16	Bastianoni, 2009
Solar Electricity(100%F)(Total)	3.01E+10	J	1.81E+05	5.46E+15	Self-calculation
Sun	4.59E+11	J	1.00E+00	4.59E+11	Odum, 2000
Fossil Fuels and electricity		g		5.16E+14	
Mounting and Panel Materials		g		1.39E+15	
Maintenance	261.10	€	2.22E+12	5.80E+14	Paoli, 2008
Maintenance Labor(20%R,80%F)	3.17E+06	J	1.37E+06	4.34E+12	Self-Calculation
Batter Bank(100%F)	761	€	2.22E+12	1.69E+15	Paoli, 2008
Inverter(100%F)	596	€	2.22E+12	1.32E+15	Paoli, 2008
Kerosene(100%F)	1.02E+06	g	2.88E+09	2.94E+15	Bastionani,2009
Wood(100%N)	3.56E+08	g	6.79E+08	2.42E+17	Pizzigallo, 2008
Ground water(100%N)	3.15E+09	g	3.98E+05	1.25E+15	Zhang, 2012

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Table 4. Continued

Inputs	Amount	Unit	Transformity (Sej/Unit)	Emergy (Sej/ Year)	Reference
Fodder(100%F)	1.07E+09	g	2.07E+09	2.21E+18	Zhang, 2007
Ground water(100%N)	3.99E+09	g	3.98E+05	1.59E+15	Zhang, 2012
Gasoline(100%F)	4.34E+06	g	2.92E+09	1.27E+16	Bastionani, 2009
			Yield (Up)	3.20E+18	
			Yield(low)	3.14E+18	
Outputs					
1. Agriculture		**Amount(g)**		**Exergy (J)**	
Wheat		1.03E+08		1.63E+12	
Gram		1.02E+07		1.74E+11	
Mustard		1.61E+07		3.06E+11	
Maize		2.01E+06		3.40E+10	
Urad Dal		1.24E+07		1.82E+11	
Soya		3.09E+07		5.25E+11	
Groundnut		1.19E+07		2.83E+11	
Vegetables		5.78E+07		8.60E+11	
Agricultural Residues		7.60E+07		1.29E+12	
2. Domestic					
Human Labor		-		5.60E+11	
Human Feces		3.91E+07		3.13E+11	
3. Husbandry					
Milk		1.45E+08		2.34E+12	
Animal Draft		-		6.63E+11	
Manure		1.34E+09		7.08E+12	

The first subsystem analyzed is the husbandry sector. In this subsystem sun, rain and wind are the locally available renewable emergy inputs. Groundwater is the local non-renewable input since underground water level in Rampura has been declining. Human labor is categorized as 20 % renewable and 80 % purchased of which calculation is presented in human ecosystem emergy analysis. Likewise, agricultural residues are 20 % renewable and 80% purchased inputs of which calculation is presented in agricultural sector emergy analysis. As in case of village level emergy analysis, fodder purchased and gasoline used for the transportation of milk to market are classified as purchased inputs contributing to husbandry sector.

Animal draft, manure and milk are the products (outputs) obtained from the husbandry sector. These outputs are co-products which cannot be produced independently. For that reason, the total emergy yield is assigned to all products without allocation according to the emergy algebra rules (Odum, 1996 and Bastianoni *et al.*, 2009). And, product transformities are calculated by division of total emergy yield by product's available energy (exergy) or product's mass. Emergy evaluation table for husbandry sector that is presented in Table 5 shows the emergy flows calculated for all these inputs. References from which

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Table 5. Emergy evaluation table for husbandry sector in Rampura village

Inputs	Amount	Unit	Transformity (Sej/Unit)	Emergy (Sej/year)	Reference
Sun(land)(100%R)	1.86E+15	J	1	1.86E+15	Odum, 2000
Sun(field)(100%R)	4.64E+15	J	1	4.64E+15	Odum, 2000
Rain(100%R)	5.61E+12	J	3.06E+04	1.71E+17	Odum, 2000
Wind(100%R)	6.56E+08	J	2.52E+03	1.65E+12	Odum, 2000
Earth Cycle(100%R)	1.34E+12	J	4.28E+04	5.71E+16	Odum, 2000
Fodder(100%F)	1.07E+09	g	2.07E+09	2.21E+18	Zhang, 2007
Human Labor(20%R,80%F)	1.72E+11	J	1.37E+06	2.36E+17	Self-Calculation
Ground water(100%F)	3.99E+09	g	3.98E+05	1.59E+15	Zhang, 2012
Ag. Residue Fodder(20%R,80%F)	1.19E+08	g	2.37E+09	2.81E+17	Self-Calculation
Milk Transportation to Market					
Gasoline(100%F)	4.34E+06	g	2.92E+09	1.27E+16	Bastionani,2009
			Total	**2.92E+18**	
Outputs					
Milk	2.08E+08	g	1.40E+10	2.92E+18	
Animal Draft	8.60E+11	J	3.38E+06	2.92E+18	
Manure	1.85E+09	g	1.58E+09	2.92E+18	

transformity values for each input obtained are listed in the last column of the table. Fodder is the largest emergy input to the husbandry sector followed by agricultural residues used as fodder.

The second subsystem, agricultural sector, provides food, agricultural residue to be used as fuel for cooking to the people of Rampura and provides around 10% of the fodder that animals consume. Some of the agricultural products are consumed by villagers and the remaining are sold at the market in Jhansi. At this subsystem, ground water and topsoil are non-renewable inputs to agriculture since they are utilized faster than they are replenished by nature. Sun, wind and rain are renewable inputs. Fertilizer, pesticide, fossil fuel (diesel) used for irrigation and tractor traction (diesel) are imported purchased inputs contributing to the subsystem. As in husbandry sector, human labor is 20% renewable and 80 % purchased. Animal draft from husbandry sector is 10 % renewable and 90 % purchased. For emergy analysis, emergy flow related to each input is calculated.

Table 6 is the emergy evaluation table for agricultural sector of Rampura. Human labor and animal draft are the largest emergy inputs to the agricultural system. Groundwater and rain are also important emergy inputs. In Rampura, agriculture is not highly mechanized as can be inferred from the contribution of tractor traction to the total emergy yield. Outputs of agricultural sector (food crops and agricultural residues) are classified as splits since they can be produced independently and serve to meet similar purposes (Bastionani et al., 2009). According to the emergy algebra rules, the total emergy of a system is allocated among splits according to their available energy (exergy) content. Based on the ranges for tractor traction diesel use and topsoil loss, there is an upper and lower range for total emergy yield calculated. Consequently, upper and lower transformity values for outputs are calculated.

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Table 6. Emergy evaluation for agricultural sector in Rampura

Inputs	Amount	Unit	Transformity (Sej/Unit)	Emergy (Sej/year)	Reference	
Sun(field)(100% R)	4.64E+15	J	1	4.64E+15		
Rain(100% R)	5.61E+12	J	3.06E+04	1.71E+17	Odum, 2000	
Wind(100% R)	6.56E+08	J	2.52E+03	1.65E+12	Odum, 2000	
Earth Cycle(100% R)	1.34E+12	J	4.28E+04	5.71E+16	Odum, 2000	
Topsoil loss(Up)(100%N)	3.01E+11	J	1.25E+05	3.76E+16	Odum, 2000	
Topsoil loss(low)(100%N)	6.03E+11	J	1.25E+05	7.54E+16	Pizzigallo, 2008	
Ground water(100%N)	6.62E+11	g	3.98E+05	2.63E+17	Pizzigallo,2008	
Diesel(Irrigation)(100%F)	4.36E+06	g	2.89E+09	1.26E+16		
Pesticide(100%F)	2.41E+04	g	1.48E+10	3.56E+14	Zhang, 2012	
Fertilizer(100%F)	6.92E+06	g	2.22E+10	1.54E+17	Odum, 2002	
Human Labor(20%R,80%F)	6.88E+11	J	1.37E+06	9.43E+17	Odum, 2002	
Animal Draft(10%R,90%F)	1.98E+11	J	3.38E+06	6.69E+17	Self-Calculation	
Tractor Traction(up)(100%F)	1.53E+07	g	2.89E+09	4.43E+16	Self-Calculation	
Tractor Traction(Low)(100%F)	1.15E+07	g	2.89E+09	3.32E+16	Bastianoni, 2009	
			Y Lower	**2.28E+18**	Bastianoni, 2009	
			Yupper	**2.33E+18**		
Outputs	**Amount(g)**	**Exergy (J)**	**Trans. Low**	**Trans Up**	**Emergy Low**	**Emergy Up**
Wheat	1.38E+08	2.18E+12	2.37E+05	2.42E+05	5.16E+17	5.27E+17
Gram	1.28E+07	2.18E+11	2.37E+05	2.42E+05	5.16E+16	5.27E+16
Mustard	1.61E+07	3.06E+11	2.37E+05	2.42E+05	7.25E+16	7.41E+16
Maize	2.12E+07	3.58E+11	2.37E+05	2.42E+05	8.48E+16	8.66E+16
Urad Dal	1.41E+07	2.09E+11	2.37E+05	2.42E+05	4.94E+16	5.05E+16
Soya	3.53E+07	6.00E+11	2.37E+05	2.42E+05	1.42E+17	1.45E+17
Groundnut	1.25E+07	2.98E+11	2.37E+05	2.42E+05	7.05E+16	7.20E+16
Vegetables	8.25E+07	1.23E+12	2.37E+05	2.42E+05	2.91E+17	2.97E+17
Agricultural Residues	2.95E+08	4.25E+12	2.37E+05	2.42E+05	1.01E+18	1.03E+18

The last subsystem, domestic sector, provides the human labor required in husbandry and agricultural sectors. Human feces can also be a source of organic fertilizer despite not being utilized in the village currently. Food crops and agricultural residues are 20% renewable, 80 % purchased emergy inputs to domestic sector classified according to the analysis results of agricultural sector. Milk and manure are 10% renewable, 90% purchased inputs classified similarly according to the analysis results of husbandry sector. Wood and groundwater are non-renewable local inputs which are utilized faster than their replenishment rate by nature. Sun, rain and wind are local renewable inputs. Lastly, kerosene and inputs for solar electricity are purchased emergy inputs contributing to domestic sector.

As in the other subsystems of Rampura village, emergy flow belonging to each emergy input is calculated. Table 7 is the emergy evaluation table for domestic sector presenting the values for each emergy flow related to each input and the references for related transformity values. Here, emergy flow

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Table 7. Emergy evaluation table for domestic sector in Rampura

Inputs	Amount	Unit	Transformity (Sej/ Unit)	Emergy (Sej/year)	Reference
Sun(land)(100%R)	1.86E+15	J	1	1.86E+15	Odum, 2000
Sun(field)(100%R)	4.64E+15	J	1	4.64E+15	Odum, 2000
Rain(100%R)	5.61E+12	J	3.06E+04	1.71E+17	Odum, 2000
Wind(100%R)	6.56E+08	J	2.52E+03	1.65E+12	Odum, 2000
Earth Cycle(100%R)	1.34E+12	J	4.28E+04	5.71E+16	Odum, 2000
1.Lighting					
Solar Electricity(100%F)	3.01E+10	j	1.81E+05	5.46E+15	Self-Calculation
Kerosene(100%F)	1.02E+06	g	2.88E+09	2.94E+15	Bastionani,2009
2.Cooking					
Cow Dung(10%R,90%F)	2.67E+12	J	2.98E+05	7.97E+17	Self-Calculation
Agricultural Residues (20%R,80%F)	1.00E+08	g	2.37E+09	2.38E+17	Self-Calculation
Wood(100%N)	3.56E+08	g	6.79E+08	2.42E+17	Pizzigallo, 2008
Ground Water(100%N)	3.15E+09	g	3.98E+05	1.25E+15	Zhang, 2012
Food (20%R,80%F)	6.96E+07	g	2.57E+09	1.79E+17	Self-Calculation
Milk(10%R,90%F)	6.20E+07	g	1.40E+10	8.74E+17	Self-Calculation
			Total	**1.71E+18**	
Outputs					
Human Labor	1.25E+12	J	1.37E+06	1.71E+18	
Human Feces	3.13E+11	J	5.46E+06	1.71E+18	

belonging to each emergy input is calculated. Cow dung and milk are two co-products of husbandry sector contributing to domestic sector. According to the emergy algebra rules, emergy flows for co-products cannot be added but the emergy flow having the maximum value is picked (Odum, 1996; Basianoni *et al*., 2009). For that reason, emergy flow of milk is accounted for in emergy evaluation. On the other hand, food crops and agricultural residues are the products of agricultural sector. However, their emergy flows can be added up since they are splits not co-products (Bastianoni *et al*., 2009). The largest emergy input to domestic sector is milk, almost containing 50% of total emergy inputs followed by wood and agricultural residues utilized for cooking purposes. Rain and food crops are other significant emergy inputs to domestic sector.

Emergy Indicators

After quantification emergy flows at the village and subsystem levels; renewable, non-renewable and purchased emergy flows are calculated for each system. Then, emergy ratios (renewability, EYR, ESI, ELR and EIR) for each system are calculated to evaluate individual and relative sustainability of these systems.

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Fodder is the main driver affecting emergy ratios in all systems directly or indirectly. In overall village system and husbandry sector, fodder constitutes 70% and 75% of all emergy inputs as a direct input. Although fodder is not a direct input to the agricultural system, renewability of fodder affects the renewability of animal draft. When fodder is 20% renewable, animal draft becomes 25% renewable. When fodder is 40% renewable, animal draft becomes 40% renewable. Fodder is not a direct input to domestic sector, however renewability of fodder affects the renewability of milk directly and the renewability of the agricultural residues indirectly. When fodder is 20% renewable, milk becomes 25% renewable and agricultural residues become 26% renewable. When fodder is 40% renewable, milk is 40 % renewable and agricultural residues are 30% renewable. Characteristically, fodder purchased from the market in Rampura is mainly wheat straw which is also an agricultural residue. As it can also be seen from agricultural sector emergy analysis, there are renewable (rain, sun, wind) or partially renewable (human labor, animal draft) inputs for production of agricultural outputs. For that reason, fodder cannot be classified as 100% purchased despite being an imported input. A sensitivity analysis is performed to detect the effects of changes in renewability of fodder on the overall village system and subsystem emergy ratios considering fodder as 100% F, 20% Re-80 % F and 40 % Re-60 % F.

Figure 6 shows the renewability, EYR and ESI values for the village and subsystems analyzed. For these indicators, the higher the value of the indicator the better sustainability becomes. Bar graphs show the case where fodder is 20 % Re-80 % F. Top of error bars represent the values of emergy ratios for the case where fodder is 40 % Re-60 % F whereas the bottom of bar graphs represents the case that fodder is 100 % F. Figure 7 shows ELR and EIR values for the village and subsystems. For these indicators, the lower the value of indicator the better sustainability becomes. In figure 7, bar graphs also show the case where fodder is 20 % Re-80 % F. However, top of error bars represents the values of emergy ratios for the case where fodder is 100 % F whereas the bottom of bar graphs represents the case that fodder is 40 % Re-60 % F.

Based on these considerations, the village has low renewability (0.05), an EYR a little higher than 1 due to the dominance of purchased inputs (mainly fodder) contributing to the system at the base case (fodder 100% F). Similarly, village system has high environmental loading ratio (ELR) and environmental investment ratio (EIR) again due to the high fraction of purchased external inputs in the total emergy yield. Environmental sustainability index (ESI) which is the ratio of EYR to ELR is much lower than 1 because of low EYR and high ELR values at the base case (fodder 100 % F). As renewable fraction of fodder emergy increases, system renewability (0.2) and EYR increases significantly. Accordingly, ELR and EIR ratios decrease. With increasing EYR and declining ELR, ESI increases considerably. From these results it can be concluded that fodder purchase should be limited and fodder should be grown in more renewable ways in the village as a local resource to improve the overall sustainability.

In husbandry sector, renewability and EYR of the husbandry subsystem also increase as the renewable fraction of fodder increases. In other words, as the fraction of purchased input flows decrease Re and EYR increase. Despite being lower than village level, husbandry sector has also high ELR value decreasing with increasing fodder renewability. Husbandry EIR is higher than village level EIR mainly due to the higher fraction of purchased fodder and lower fraction of local non-renewable inputs in the total emergy yield. As ELR, EIR also reduces with increasing fodder renewability. ESI increases due to increasing EYR and decreasing ELR values. These results also support the conclusion that fodder should be grown in more renewable ways in the village as a local resource.

At the base case (fodder 100 % F), agriculture in Rampura is more renewable than the village and the husbandry sector. This situation is due to higher portion of renewable emergy flows contributing

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to the agricultural system. Based on the same reason, agricultural system has higher EYR and lower ELR than the other two systems. Furthermore, agricultural system EIR is lower than husbandry and village level EIR values. Consequently, the agricultural sector is more sustainable (higher ESI) than the husbandry sector and the overall village system when fodder is considered 100 % F. As in husbandry sector, increase in renewability of fodder increases agricultural system renewability and EYR. System ELR and EIR reduces. As a consequence of increased EYR and reduced ELR, system ESI increases indicating an improvement in overall system sustainability for agriculture. Furthermore, decreasing fertilizer and pesticide and fossil fuel usage can improve agricultural sector self-sufficiency consequently sustainability further.

Domestic sector obtains inputs from both husbandry and agricultural sectors. Many of the emergy indicators have values between husbandry and agricultural sectors at the base case. As in husbandry and agricultural sectors, increase in renewability of fodder increases domestic sector renewability and EYR. System ELR and EIR reduces as a result of reduced fraction of purchased and increased fraction of renewable emergy inputs. As a consequence of increased EYR and reduced ELR, system ESI increases indicating an improvement in domestic sector sustainability. Due to dual dependence of domestic sector, interventions increasing sustainability of husbandry and agricultural sectors can also improve domestic sector sustainability.

A sustainability assessment study is performed on three Chinese villages by Yong, Andreas and Guojie (2009). This study also yields similar results (low renewability, EYR and high ELR) for the analyzed Chinese villages as found for Rampura village indicating high reliance on non-renewable external inputs. Even at village level, sustainability is not achieved in these developing countries. However, if the renew-

Figure 6. Renewability, EYR, and ESI results for the overall village system and the three subsystems analyzed

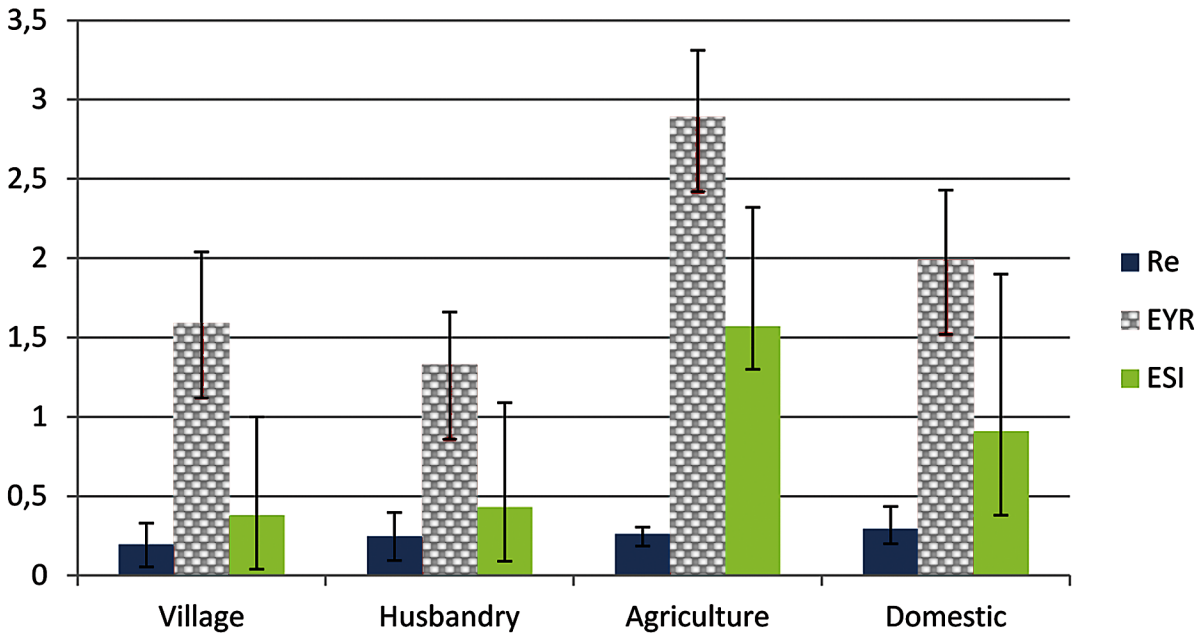

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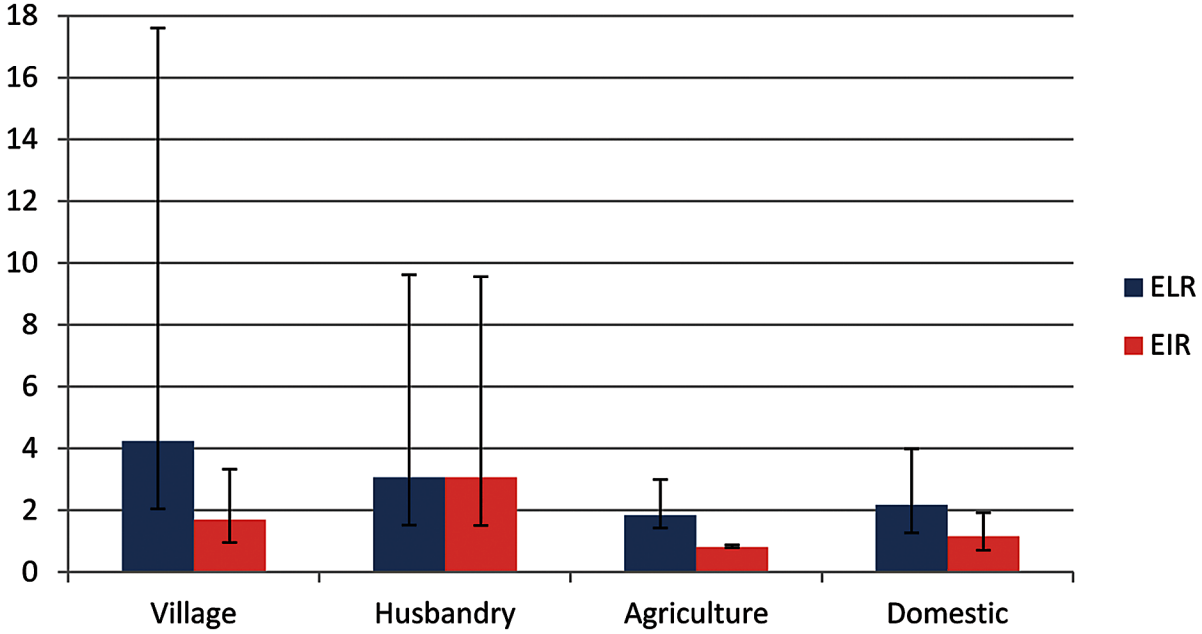
Figure 7. ELR and EIR results for the overall village system and the three subsystems analyzed



able local resources are utilized effectively within the carrying capacity of these regions, dependence on external resources can be reduced also increasing the self-sufficiency and sustainability. Ways of improving sustainability by relying on local resources and less consumptive life styles are well presented in a study by Levine, Hughes, Mather and Yanarella (2008). In their study, Levine *et al.* (2008) interpret how life styles in traditional Chinese villages can be adapted to modern life and they point out how this low consumptive, high productive life style can lead to development of sustainable towns.

FUTURE RESEARCH DIRECTIONS

Emergy analysis is a nature oriented or donor-side thermodynamic analysis technique. It can evaluate natural capital which includes sources whose role is not captured in market prices. Like other methods for analyzing large systems, emergy analysis also faces problems of reproducibility. To improve emergy analysis in terms of accuracy and reproducibility of results, there are attempts to integrate emergy analysis within life cycle assessment (LCA) framework and harmonize their calculation techniques (Marvuglia *et al.*, 2013; Rugani & Benetto, 2012). In our opinion, standardization of emergy analysis through a robust framework construction will be the trend for methodological research related to emergy in the future. Additionally, emergy analysis does not evaluate carrying capacity of a region despite evaluating natural value of resources. Developing analysis techniques which can account for the carrying capacity of a region and integrating them with emergy are important steps to be taken in the future.

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CONCLUSION

Today, Earth is in a transitional state in which the resources that can be provided by the planet become the limiting factor for human activities rather than money or work force. This can transform planetary support mechanisms irreversibly and reduce their ability to support human activities. In that regard, analyzing the interaction of natural and anthropogenic systems is crucial in order to cease further deterioration and start restoration of natural capital. In analyzing the interaction between natural and human-dominated systems, emergy analysis can be an effective tool. While emergy can be used to evaluate many forms of human-nature interactions, utilizing emergy analysis in evaluation of sustainability of a region enables quantification of environmental work invested in activities taking place in the area and also the interaction and dependence of these activities to each other. In this work, Rampura Village case study is presented to demonstrate applicability of emergy analysis in regional sustainability assessment.

At the overall village level, emergy analysis results show that the village is not self-sufficient and is highly dependent on non-renewable external material and energy inputs. Of the three subsystems interacting in Rampura, husbandry sector has the lowest renewability, EYR, ESI and the highest ELR, EIR values while agricultural sector has highest renewability, EYR, ESI and lowest ELR and EIR. This reveals that the husbandry sector is the subsystem that contributes most to the detected unsustainability in Rampura.

When the subsystem level emergy results are examined in detail, it is seen that the largest emergy input is purchased fodder for feeding animals in husbandry sector followed by agricultural residues of crops grown in the village and fed as fodder to animals. In emergy analysis of agricultural sector, renewability of agricultural residues is found to be around 20%. If renewability of fodder is considered as 20%, renewability of animal power and husbandry products becomes 25%. 75 % of emergy inputs to the sector come from purchased external and non-renewable inputs. Even when fodder is considered as 20% renewable, husbandry sector has high ELR (3.06) and low EYR (1.33) and ESI (0.43) values. If fodder were considered 100% purchased, these indicators would be worse.

In agricultural sector, human labor and animal draft are the largest emergy inputs; renewability of animal draft input depends on fodder renewability. As a result, agricultural products and residues have a renewability of 26% when fodder is accounted as 20% renewable. Agricultural system has better emergy indicators (higher %Re, EYR, and ESI, lower ELR) than the husbandry sector due to higher share of renewable inputs. However, agricultural system in Rampura is also not a self-sufficient system which is dependent on non- renewable external inputs such as fertilizer, pesticide and fossil fuels.

Domestic sector in Rampura benefits both from agricultural and husbandry sectors by providing human labor in exchange. Agricultural sector provides food and energy resources (agricultural residues) to this subsystem and husbandry sector provides cow dung and milk. Renewability of fodder indirectly affects the renewability of products of the domestic sector. When fodder is considered as 20% renewable, the renewability of human labor in Rampura becomes 30%. Domestic sector has more favorable emergy indicators than the husbandry sector, however, this subsystem is also not self-sufficient or sustainable.

Overall, these results indicate that Rampura village is not a self-sufficient, sustainable system. To improve the sustainability in Rampura, dependency on purchased inputs fodder, fertilizer and diesel and non-renewable cooking fuel wood should be reduced. But, mainly fodder should be grown in more renewable ways in the village as a local resource. This assessment also demonstrates the applicability of emergy analysis as a successful regional sustainability assessment tool.

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Furthermore, study results about the state of sustainability in Rampura are compatible with the results found for Chinese villages. Even at village level, sustainability is not achieved in these developing countries. However, if the renewable local resources are utilized effectively within the carrying capacity of these regions, dependence on external resources can be reduced also increasing the self-sufficiency and sustainability. Designing sustainable human systems necessitates consideration of social, economic and environmental aspects simultaneously. Besides, these systems must be in harmony with biosphere they exist in (Griggs *et al.*, 2013; Martin *et al.*, 2010). Hence, conscious consumption patterns relying on renewable resources within the carrying capacity of the planet can lead to the achievement of global sustainability (Kurşun *et al.*, 2015).

REFERENCES

Bakshi, B. R. (2011). The path to a sustainable chemical industry: Progress and problems. *Current Opinion in Chemical Engineering*, *1*(1), 64–68. doi:10.1016/j.coche.2011.07.004

Bakshi, B. R., Ziv, G., & Lepech, M. D. (2015). Tecno-ecological synergy: A framework for sustainable engineering. *Environmental Science & Technology*, *49*(3), 1752–1760. doi:10.1021/es5041442 PMID:25560912

Bastianoni, S., Chambell, D. E., Rudolfi, R., & Pulselli, F. M. (2009). The solar transformity of petroleum fuels. *Ecological Modelling*, *220*(1), 40–50. doi:10.1016/j.ecolmodel.2008.09.003

Brown, M. T. (2004). A picture is worth thousand words: Energy systems language and simulation. *Ecological Modelling*, *178*(1-2), 83–100. doi:10.1016/j.ecolmodel.2003.12.008

Brown, M. T., & Herendeen, R. A. (1996). Embodied energy analysis and emergy analysis: A comperative view. *Ecological Economics*, *19*(3), 219–235. doi:10.1016/S0921-8009(96)00046-8

Brown, M. T., Raugei, M., & Ulgiati, S. (2012). On boundaries and investments in emergy synthesis and LCA: A case study on thermal versus electricity. *Ecological Indicators*, *15*(1), 227–235. doi:10.1016/j.ecolind.2011.09.021

Brown, M. T., & Ulgiati, S. (2004). Energy quality, emergy and transformity: H.T Odum`s contributions to quantifying and understanding systems. *Ecological Modelling*, *178*(1-2), 201–213. doi:10.1016/j.ecolmodel.2004.03.002

Coscime, L., Pulselli, F. M., Marchettini, N., Sutton, P. C., Anderson, S., & Sweeney, S. (2014). Emergy and ecosystem services: A national biogeographical assessment. *Ecosystem Services*, *7*, 152–159. doi:10.1016/j.ecoser.2013.11.003

Costanza, R., & Patten, B. C. (1995). Defining and predicting sustainability. *Ecological Economics*, *15*(3), 193–196. doi:10.1016/0921-8009(95)00048-8

DevAlt. (2011). *Personal Communication, Survey, Organizational Data*.

Development Alternatives. (n.d.). Retrieved from March, 2013, www.devalt.org

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Griggs, D., Stafford-Smith, M., Gaffney, O., Rockstrom, J., Ohman, M. C., Shyamsundar, P., ... Noble, I. (2013). Sustainable development goal for people and planet. *Nature*, *495*(7441), 305–307. doi:10.1038/495305a PMID:23518546

Hau, J. L., & Bakshi, B. R. (2004a). Promise and problems of emergy analysis. *Ecological Modelling*, *178*(1-2), 215–225. doi:10.1016/j.ecolmodel.2003.12.016

Hau, J. L., & Bakshi, B. R. (2004b). Expanding exergy analysis to account for ecosystem products and services. *Environmental Science & Technology*, *38*(13), 3768–3777. doi:10.1021/es034513s PMID:15296331

Hossaini, N., & Hewage, K. (2013). Emergy accounting for regional studies: Case study of Canada and its provinces. *Journal of Environmental Management*, *118*, 177–185. doi:10.1016/j.jenvman.2012.12.034 PMID:23435155

Jiang, M. M., Zhou, J. B., Chen, B., Yan, Z. F., Ji, X., Zhang, L. X., & Chen, G. Q. (2009). Ecological evaluation of Beijing economy based on emergy indices. *Communications in Nonlinear Science and Numerical Simulation*, *14*(5), 2482–2494. doi:10.1016/j.cnsns.2008.03.021

Kurşun, B., Bakshi, B. R., Mahata, M., & Martin, J. F. (2015). Life cycle and emergy based design energy systems in developing countries: Centralized and localized options. *Ecological Modelling*, *305*, 40–53. doi:10.1016/j.ecolmodel.2015.03.006

Levine, R. S., Hughes, M. T., Mather, C. R., & Yanarella, E. J. (2008). Generating sustainable towns from Chinese villages: A system modeling approach. *Journal of Environmental Management*, *87*(2), 305–316. doi:10.1016/j.jenvman.2006.10.026 PMID:17854975

Lin, Y. C., Huang, S. L., & Budd, W. W. (2013). Assessing environmental impacts of high-altitude agriculture in Taiwan: A driver-pressure-state-impact-response (DPSIR) framework and spatial emergy synthesis. *Ecological Indicators*, *32*, 42–50. doi:10.1016/j.ecolind.2013.03.009

Loiseau, E., Junqua, G., Roux, P., & Bellon-Maurel, V. (2012). Environmental assessment of a territory: An overview of existing tool and methods. *Journal of Environmental Management*, *112*, 213–225. doi:10.1016/j.jenvman.2012.07.024 PMID:22929644

Marshall, J. D., & Toffel, M. W. (2005). Framing the elusive concept of sustainability: A sustainability hierarchy. *Environmental Science & Technology*, *39*(3), 673–682. doi:10.1021/es040394k PMID:15757326

Martin, J. F., Roy, E. D., Diemont, S. A., & Ferguson, B. G. (2010). Traditional ecological knowledge (TEK): Ideas, inspiration and designs for ecological engineering. *Ecological Engineering*, *36*(7), 839–849. doi:10.1016/j.ecoleng.2010.04.001

Marvuglia, A., Benetto, E., Rios, G., & Rugani, B. (2013). Scale: Software for calculating emergy based on life cycle inventories. *Ecological Modelling*, *248*, 80–91. doi:10.1016/j.ecolmodel.2012.09.013

Mellino, S., Bounocore, E., & Ulgiati, S. (2015). The worth of land use: A GIS-emergy evaluation of natural and human-made capital. *The Science of the Total Environment*, *506-507*, 137–148. doi:10.1016/j.scitotenv.2014.10.085 PMID:25460948

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Mellino, S., Ripa, M., Zucaro, A., & Ulgiati, S. (2014). An emergy-GIS approach to the evaluation of renewable resource flows: A case study of Campania Region, Italy. *Ecological Modelling*, *271*, 103–112. doi:10.1016/j.ecolmodel.2012.12.023

Nakajima, E. S., & Ortega, E. (2014). Exploring the sustainable horticulture production systems using the emergy assessment to restore the regional sustainability. *Journal of Cleaner Production*, *96*, 531–538. doi:10.1016/j.jclepro.2014.07.030

Odum, H. T. (1996). *Environmental accounting: emergy and environmental decision making*. New York, NY: Wiley.

Odum, H. T. (2000). Handbook of emergy evaluation: a compendium of data for emergy computation issued in a series of folios. Emergy of global processes. Folio No. 2. Center for Environmental Policy, University of Florida.

Odum, H. T., Brown, M. T., & Brandt-Williams, S. (2002). Handbook of Emergy Evaluation: A compendium of data for emergy computation issued in a series of folios. Emergy of Florida Agriculture. Folio No. 4. Center for Environmental Policy, University of Florida.

Paoli, C., Vassallo, P., & Fabiano, M. (2008). Solar power: An approach to transformity evaluation. *Ecological Engineering*, *34*(3), 191–206. doi:10.1016/j.ecoleng.2008.08.005

Pizzigallo, A. C. I., Granai, C., & Borsa, S. (2008). The joint use of LCA and emergy evaluation for the analysis of two Italian wine farms. *Journal of Environmental Management*, *86*(2), 397–406. doi:10.1016/j.jenvman.2006.04.020 PMID:17097798

Rockström, J., Steffen, W., Noone, K., Persson, A., Chapin, F. S., Lambin, E. F., ... Foley, J. A. (2009). A safe operating space for humanity. *Nature*, *461*(7263), 472–475. doi:10.1038/461472a PMID:19779433

Rugani, B., & Benetto, E. (2012). Improvements to emergy evaluations by using life cycle assessment. *Environmental Science & Technology*, *46*(9), 4701–4712. doi:10.1021/es203440n PMID:22489863

Scatec Solar. (n.d.). Retrieved March, 2013, http://www.scatecsolar.com/

Steffen, W., Persson, A., Deutsch, L., Zalasiewicz, J., Williams, M., Richardson, K., ... Svedin, U. (2011). The Anthropocene: From global change to planetary stewardship. *Ambio*, *40*(7), 739–761. doi:10.100713280-011-0185-x PMID:22338713

Steffen, W., Richardso, K., Rockstrom, J., Cornell, S., Fetzer, I., Bennet, E. M., ... Sorlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science*, *347*(6223), 1259855. doi:10.1126cience.1259855 PMID:25592418

Technology and Action for Rural Advancement (TARA). (n.d.). Retrieved January, 2013, http://tara.in

UFCEP. (n.d.). *University of Florida Center for Environmental Policy*. Retrieved May, 2013, http://www.cep.ees.ufl.edu/emergy/resources/symbols_diagrams.shtml

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Ulgiati, S., Ascione, M., Bargigli, S., Cherubini, F., Federici, M., Franzese, P. P., . . . Zucaro, A. (2010). Multi-method and multi-scale analysis of energy and resource conversion and use. *NATO Science for Peace and Security Series C: Environmental Security*. University of Florida Center for Environmental Policy (UFCEP). Retrieved May, 2013, http://www.cep.ees.ufl.edu/emergy/resources/symbols_diagrams.shtml

Ulgiati, S., & Brown, M. T. (1998). Monitoring patterns of sustainability in natural and man-made ecosystems. *Ecological Modelling*, *108*(1-3), 23–36. doi:10.1016/S0304-3800(98)00016-7

Vega-Azamar, R. E., Glaus, M., Hausler, R., Opeza-Garcia, N. A., & Romera-Lopez, R. (2013). An emergy analysis for urban environmental sustainability assessment, the Island of Montreal, Canada. *Landscape and Urban Planning*, *118*, 18–28. doi:10.1016/j.landurbplan.2013.06.001

World Commission on Environment and Development (WCED). (1987). *Our Common Future*. Oxford, UK: Oxford University Press.

Yedla, S., & Peddi, S. (2003). *India Environmental Assessment. Roles of Agriculture*. Retrieved from: ftp://ftp.fao.org/es/ESa/roa/pdf/2_Environment/Environment_IndiaNA.pdf

Yong, C., Andreas, K., & Guojie, C. (2009). Emergy analysis of a village ecosystem in Wolong Nature Reserve in China. *Chinese Journal of Population*. *Resources and Environment*, *7*, 59–66. doi:10.1080/10042857.2009.10684925

Zhang, L. X., Song, B., & Chen, B. (2012). Emergy Based Analysis of Four Farming Systems: Insight into diversification in rural China. *Journal of Cleaner Production*, *28*, 33–44. doi:10.1016/j.jclepro.2011.10.042

Zhang, L. X., Yand, Z. F., & Chen, G. Q. (2007). Emergy analysis of cropping grazing system in Inner Mongolia Autonomous Region, China. *Energy Policy*, *35*(7), 3843–3855. doi:10.1016/j.enpol.2007.01.022

ENDNOTE

[1] Informatıon related to crop yields, crop residue quantities separately for each crop, irrigation, fertilizer and pesticide usage data and fodder consumption data for different animal types are available upon request at berrin.kursun@marmara.edu.tr.

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Chapter 26
Environmental Audit in Integrated Audit System

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ABSTRACT

The niche of a narrow literature in the field inspires the core objective of this chapter which is to develop a coherent and eco-efficient outline for environmental audit in an integrated audit management system. The research paradigm is based on the stakeholder theory refined with Hart's vision of the entity based on natural resources in order to recognize the natural environment as the main stakeholder of any entity. The revision of the literature enables ascertaining the determining factors for an environmental audit integrated in the audit management system. The result is built on the management component of the continuous improvement and creates knowledge for a way of action to implement an environmental management system and environmental auditing and implicitly, to react to social corporate responsibility. Future researches regard the increase the auditor's role in integrating various areas of the sustainability reports.

INTRODUCTION

Placed in the context of stakeholder theory, the main objective of this chapter is to develop a coherent and eco-efficient framework for environmental audit in an integrated audit management system. The starting point is the normative-managerial approach of the theory, offered and argued by Donaldson and Preston (1995). The normative approach involves using of accepted concepts and theories in the

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field, to substantiate the structures, attitudes and management practices designed to equally consider and meet the interests of all stakeholder groups. Gomes and Gomes (2007) believe that stakeholder theory is opposable to the understanding of the influences that an entity has and perceives, as a member of the community and environment in which it operates. In this context, the authors consider stakeholder theory to be the theoretical alternative to the junction between the resource dependence theory and the institutional theory, with the entity's social and cultural compliance under the environmental pressures as a central point (Scott, 1998). The foundation of resource dependence theory is the existence of relationships between the entity and the specialized environment in which it operates (Orrù, Biggart, & Hamilton, 1991). Like Jacobs (1997), Phillips and Reichart (2000) or Haigh and Griffiths (2009), this discourse recognizes the natural environment as the main stakeholder of any entity. The environment influences the entity performance and is directly affected by the entity activities. From this perspective, the vision of the entity based on natural resources developed by Hart (1995) is the theoretical paradigm complementary to stakeholder theory, which offers the same challenge for environmental audit as part of an integrated audit management system.

The sovereign opinion on the entity activities is assumed by the auditing process used to improve its functionality in a large variety of fields (Jasch, 2000) and to transfer information between non competing entities (Ammenberg & Sundin, 2005). The audit process is influenced by the attitudes and beliefs of each individual/group, which are parts of the ethical environment organization (Meyers, 2004; Martinov-Bennie & Pflugrath, 2009), and it is a tool of management control (Verschoor & Reijnders, 2001, cited in Mironeasa & Codina, 2013). Improving functionality in miscellaneous turfs, audits generate benefits in a variety of the environmental aspects dimensions. First, audits should decrease costs, especially, the costs of compliance with any effluent limit imposed by the relevant environmental protection agency. For instance, audits should offer information relating to the most cost-effectively set up to better control the pollution. Second, audits should increase the social responsibility promoting a "green" image. Third, audits may generate other regulatory and non-regulatory benefits; for instance, if the regulator body knows the audit engagements then, these engagements may generate goodwill that might increase the awareness of the authorities on the future potential issues (Earnhart & Leonard, 2013).

The current chapter aims to contribute to the literature from the perspective of the effects and actions need to adapt to the climate change, as a substantiation to assess the current level of environmental management and to identify environmental and social elements that are relevant for entities to include in their corporative management. Achieving the objective, has determined, in the first section of the research work, the description of the scientific context by developing the concept of adaptation to global climate change and multiple perspectives identified in approaching the concept, both in the literature and international regulators. Next section discusses the environmental audits in the context of an integrated audit system as the European Union Eco-Management and Audit Scheme (EMAS), which requires assessing the current degree of environmental management implementation. The following section completes this picture with a managerial approach on environmental audit to create a coherent framework for an eco-efficient corporative management. Finally, there are presented the future research directions and conclusions of the debate conducted along the chapter.

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DETERMINANTS AND THEORETICAL GROUNDWORK

The context of sustainable development is strongly influenced by current global climate changes. The extent and intensity of environmental impacts caused international, national, regional, local, and individual positions and actions (in terms of individuals and economic entities). In a broader sense, climate change is understood as any form of climate deviation that has no physical cause and is not statistical in nature. The causes of this complex phenomenon are *natural* (changes in solar activity, long-term alterations of the Earth's orbit, internal natural processes of the climate system) and *anthropological* (the increase in carbon dioxide and other greenhouse gases atmospheric concentration). In a narrow sense, climate change indicates significant alterations of climatological elements during a given period, entailing economic, social and environmental consequences. Climate change is an environmental problem leading to risks in the development process (European Commission [EC], 2009). Food crisis, water shortage, spread of diseases in new areas, damage caused by floods, the labor migration forced by the desertification of farmlands and the rising sea and ocean levels are only few effects of climate change that all countries must recognize.

The perspective of the planetary history explains and refines the understanding of the problem. Effects such as global warming have been offset by stimulating the development of new species that have found favorable conditions for life and multiplied explosively in the absence of competition, recreating an atmosphere with less carbon. Therefore, the answer is primarily provided by nature instead of technology or policy, and has as a result the disappearance of some species and the emergence of others. This is already perceived as a risk: dozens of species disappear each day, and biotechnologies based on cultures of microorganisms having a versatile enough behavior to meet technological needs/purposes are able, at least in theory, to generate global epidemics, leaving the nature as the sole regulating factor of the climate change. Nowadays, the danger of climate change must be approached not only from an ecological, but as well as from social and economic perspectives.

Adaptation to Climate Change: Concepts and Perspectives

In the Fifth Assessment Report (AR5) released by the Intergovernmental Panel on Climate Change [IPCC], (2014), strategies to reduce the risks of climate change impacts over different periods are mitigation and adaptation. If mitigation addresses the latter decades of the 21st century and beyond, adaptation ensures the ways to deal with current risks inferring to the emerging ones. The two fundamental choices in response to risks caused by anthropogenic climate change were earlier discussed in Füssel and Klein (2005). In *Table 1* the authors of this chapter present an adapted view of the two strategies addressing climate change.

Currently, adaptation to climate change has become a pervasive topic in public debates on environmental policies. Detailed and regionalized cost estimates, as a basis for cost-benefit analyses, are rare (Osberghaus & Reif, 2010). Accounting, as a communication and managerial tool, is expected to provide a comprehensive account of resource consumption and its effects; audit has to provide an independent opinion on those aspects. However, in terms of *natural* resources and regeneration of natural resources, the following question arises: Can one speak-on the correct application of the comprehensiveness principle? Gray and Bebbington (2000) raise the problem of a fundamental conflict between the main objective of a business (profit) and environmental protection, especially from the perspective of sustainable

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Table 1. Mitigation vs. adaptation to climate change

	Mitigation of climate change	Adaptation to climate change
Benefited systems	All systems	Selected systems
Scale of effect	Global	Local to regional
Life time	Centuries	Years to centuries
Lead time Decades	Decades	Immediate to decades
Effectiveness	Certain	Generally less certain
Ancillary benefits	Sometimes	Mostly
Polluter pays	Typically yes	Not necessarily
Payer benefits	Only little	Almost fully
Monitoring	Relatively easy	More difficult
Responsibility	Unidentified	Specialized organizations (e.g., IPCC) and entities
Research	Exact sciences	Post-normal sciences

development goals. In addition, Ngwakwe (2012) highlights, the lack of a current accounting alternative to communicate corporate sustainability information.

Adapting to climate change is an intensely debated issue in the literature. This assessment is based on the conceptual approach provided in *Table 2*.

Academia was the first in addressing this issue and leading the way towards institutional efforts and specialized regulations. *Table 3* presents the concept of adaptation to climate change, as defined by specialized organizations.

The negative impact of climate change, including climate variability and extreme weather events on natural and anthropic systems determines the degree of system vulnerability. Watson et al., (1996) believe that vulnerability depends not only on the system sensitivity, but also on its adaptive capacity when confronted with new climate conditions. The instruments, resources and institutional structures needed to effectively implement the measures for adaptation constitute the *adaptive capacity*, which is enhanced by an adaptive management system oriented towards the sustainable performance: economic, social and environmental performance. A successful adaptation depends on technological advancements, institutional commitments, financing availability, and the willingness to communicate (Watson et al., 1996). The disastrous effects, the greater risks and the difficulties in coping with climate change impacts convince Wise, Fazey, Stafford Smith, Park, Eakin, Archer Van Garderen and Campbell (2014, p. 332) to assert the *adaptation science,* designed to be more effective and influential for decision-making process and for managing the existing complex socio-ecological systems.

Stakeholders and Externalities and Environmental Audit

Stakeholders can be defined as "any group or individual who can affect or is affected by the achievement of the firm's objectives" (Freeman, 1984, p. 46). In support of this concept, Freeman (1984) refines the idea that entities produce externalities that affect several internal or external sectors of an organization.

Externalities often motivate stakeholders to increase their influence over the organizations, in order to reduce the negative impacts in favor of positive ones. The stakeholder theory, initially formulated by

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Table 2. Adaptation to climate change – conceptual approach

Source	Concepts
Burton, 1992, cited in Smit, Burton, Klein and Street, (1999, p. 203)	*Societal adaptation to climate* is "the process through which people reduce the adverse effects of climate on their health and well-being, and take advantage of the opportunities that their climatic environment provides".
Smit, 1993, cited in Smit et al., 1999, p. 203	*Adaptation* involves "adjustments to enhance the viability of social and economic activities and reduce their vulnerability climate, including its current variability and extreme events as well as longer term climate change".
Stakhiv, 1993 cited in Smit et al., 1999, p. 203	*Adaptation* means "any adjustment, whether passive, reactive or anticipatory, that is proposed as a means for ameliorating the anticipated adverse consequences associated with climate change".
Smith, Ragland, & Pitts, 1996 cited in Smit et al., 1999, p. 203	*Adaptation to climate change* includes all adjustments in behaviour or economic structure that reduce the vulnerability of society to changes in the climate system.
Watson, Zinyowera, & Moss, 1996 cited in Smit et al., 1999, p. 203	*Adaptability* refers to "the degree to which adjustments are possible in practices, processes, or structures of systems to projected or actual changes of climate".
Tol, Fankhauser, and Smith, 1998	Adaptation is considered in a balanced context, seen as a change not static but a dynamic response to continuous climate change. This will in turn help to determine the optimal control level of greenhouse gas emissions, and optimal government policies to adapt to climate change.
Smit, Burton, Klein and Wandel 2000	Adaptation to climate stimuli includes the ability to adapt through feedback to extreme events, to yearly climate variability and long-term changes in the mean conditions, both individually and in interdependence.
Füssel and Klein, 2005	Adaptation primarily aims at moderating the adverse effects of unavoided climate change through a wide range of actions that are targeted at the vulnerable system. (It may also include taking action to seize new opportunities brought about by climate change.)
Blanco, Alberti, Forsyth, Krizek, Rodriguez, Talen and Ellis., 2009	Adapting to climate change is somewhat similar to mitigating natural hazards, through climate change results in spatially dispersed and systemic impacts, while natural hazards are generally localized, episodic events.
Hallegatte, Lecocq and de Perthuis, 2011	Adaptation to climate change is defined as the set of organization, localization and technical changes that societies will have to implement to limit the negative effects of climate change and to maximize the beneficial ones.

Table 3. Adaptation to climate change – regulatory approach

Source	Concepts
IPCC, 2001	Adaptation refers to actions that people take in response to or in anticipation of projected or actual changes in climate, either to reduce the adverse impacts or to take advantage of opportunities offered by such changes.
EC, 2007	Adaptation aims at reducing the risk and damage from current and future harmful impacts cost-effectively or exploiting potential benefits.
IPCC, 2007	Adaptation means the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.

Freeman (1984), represents a corporate management and business ethics tool that allows the harmonization of an entity's interests with those of its stakeholders. Generally, there are two groups of stakeholders affecting organizations: internal and external stakeholders. The pragmatic approaches of stakeholder theory analyze what are the groups of individuals that management pays attention to (Mitchell, Agle, & Wood, 1997). According to the stakeholder theory, stakeholders are receivers and senders in rela-

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tion with an entity's actions, requiring a legitimate confidence in the organization. In relation with the environment, legitimacy takes the form of environmental audit, for the moment, a voluntary area for most entities. The environmental standards ISO 14000 stipulates environmental audit principles and standards for auditing environmental management systems. Compared with the entities that do not resort to environmental audit, the environmental audited organizations are associated with various degrees of stakeholders' influence perception. The environmental audit provides an entity with a better investment protection due to the auditing process that imposes compliance with procedures and systems able to support sustainable activities from the environmental management perspective (de Moor & de Beelde, 2005). Environmental audit identifies environmental problems before these escalate, diminishing the negative environmental impact, risks and remediation costs for improving external image of the entity. Therefore, organizations who use environmental audit communicate complete and reliable information to stakeholders, regarding their environmental concerns.

Internal stakeholders include management and non-management employees (Waddock & Graves, 1997) and they have a direct economic role within the organization, being typically located inside the organization (Freeman, 1984). Internal stakeholders are relevant for environmental audit because employees are the initiators of proactive activities within the entity (Daily & Huang, 2001; Hanna Newman, & Johnson, 2000; Ramus & Steger, 2000). Such initiatives are deeply rooted in the employees' specialized knowledge, organizational abilities and the way they connect with the natural environment. In this context, environmental audit used by organizations is definitely associated with the acknowledged influence of internal stakeholders.

External stakeholders have a more limited influence and control over the entity's resources (Mitchell et al., 1997; Sharma & Henriques, 2005). Nevertheless, there are certain situations where external stakeholders have the ability to regulate the entity's operation and organization (Fineman & Clarke, 1996; Freeman, 1984). Their influence and authority vary, depending on their affiliation to different interest groups:

- Stakeholders having regulatory powers (for example, syndicates or trade unions that can initiate public campaigns and protests that increase internal pressure on entities to improve sustainable performances) influence entities to apply the current environmental regulations, or threat to take legal action pursuing their own agenda (Henriques & Sadorsky, 1996). Environmental audit used by organizations is associated with the perception of the influence exercised by rules-promoting stakeholders;
- Social stakeholders are represented by interest groups in the area of environmental, community and professional organizations. They all have the capacity to influence the public opinion in favor or against an entity, influencing indirectly organizational behavior. Social stakeholders grant an entity's "social certificate" (Gunninghamn & Thornton, 2004), and can be decisive factors in its decision to resort to environmental audit;
- Stakeholders being directly or indirectly involved in satisfying customer demands (suppliers, transporters, retailers, clients themselves) ensure a positive qualitative impact on the environment by reducing the possibilities to use products that are presented as environmental-friendly, but do not meet such requirements (Green, Morton, & New, 2000).

Exploring a broader area of decision-making situations in public and private organizations in developed countries involves special attention to the information needs of stakeholders, including consumers

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(Bebbington, Brown, & Frame, 2007). Stakeholder engagement to sustainable development issues is crucial to the legitimacy and quality of decisions. In order to accept the complexity of value judgments in decision-making and accountability processes, stakeholders need new experiences to interact with traditional ones in their cooperation to generate knowledge on sustainability. Ideological pluralism and value diversity are also essential to conceptualization of the sustainability and implementation of the Post-normal Sustainable Technologies (PNSTs). The value-based nature of the issues involved is expressed in a way that seeks multidimensional support offered by accounting and auditing procedures.

To conclude, one has to state that the influence exercised by internal or external stakeholders' is correlated with their interests and power over the environmental audit types. Environmental audit provides stakeholders with assurance that the audited entity complies with sustainability objectives, by minimizing negative external effects and optimizing positive effects on the natural environment (Darnall, Seol, & Sarkis, 2009).

ENVIRONMENTAL AUDIT FROM INTEGRATED AUDIT PERSPECTIVE

Globally, the concerns about sustainable development have resulted in the last decade as an exponentially increased confidence in the companies' systems for auditing environmental impact and environmental performance, creating the competitive advantage in strategic positioning. Sustainable actions involving entities give high importance to the economic, social and environmental factors in providing benefits and information to stakeholders and reflect sustainable performance. The management of sustainable performance requires a sound management framework, which links environmental and social management to the business and competitive strategy management. Furthermore, it is necessary to integrate environmental and social information with business information, reporting and auditing in order to provide a comprehensive image about the entity (Caraiani, Lungu, Dascălu, Cimpoeru, & Dinu, 2012).

An institution acknowledgement that guarantees the trusted environment responsibility effectively performed is recognized as environmental auditing. Environmental audit should diminish irregularity of information and drives to dutifully environmental responsibilities performance. This target is achieved through auditors' independent examination and evaluation of the performing status of the entrusted environment responsibility (Stafford, 2005, cited in Huang, 2011).

Issues and Controversies in Relation to the Integrated Environmental Audit

The main topic of this chapter is the audit. In order to avoid misconstructions some essential concepts are defined in *Table 4*, from the perspective of the international standards. The worldwide major designer of voluntary International Standards is the International Organization for Standardization [ISO]. For business environment, ISO International Standards are strategic gears that reduce costs by diminishing waste and errors, increase productivity, provide access to new markets, offer the same opportunities for developing countries and empower free and fair global trade. Nevertheless, literature on the integration auditing subsystems is much meager.

Bernardo, Casadesus, Stanislav Karapetrovic and Heras (2010) itemize the existence of some guidance on integrated auditing that are stated in different documents on management systems integration, such as the related ISO handbook (ISO, 2008), as well as national standards, for instance the Australian/New Zealand AS/NZS 4581: 1999 (SAI Global, 1999), the Danish DS 8001: 2005 (Dansk Standard,

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Table 4. Concepts about audit as of ISO standpoint

Concepts	Definitions	ISO Source
Audit	A systematic, independent and documented process for obtaining audit evidence and evaluating it objectively to determine the extent to which audit criteria are fulfilled	**ISO 19011:2002 ISO 9000:2005**
Internal (first party) Audit	Audit is conducted by, or on behalf of, the organization itself for management review and other internal purposes, and may form the basis for an organization's declaration of conformity	
External Audit	Audit is conducted parties outside of the entity: • Second-party audit is conducted by parties having an interest in the organization, such as customers, or by other persons on their behalf; • Third-party audit is conducted by external, independent auditing organizations, such as those providing certification/registration of conformity.	
Combined Audit	Simultaneous audits of quality and environmental management systems, which are separate systems, conducted by separate audit teams, under separate management.	**ISO 19011:2002**
Joint Audit	Audit conduct by two or more auditing organizations cooperate to audit a single auditee	
Integrated Audit System	Full audit integration necessitates the establishment of a single audit system across all functions and hence a complete amalgamation of all cross-functional goals, processes and resources.	Karapetrovic and Willborn, 1998; Karapetrovic, 2002, 2003. **No ISO source**

2005), the Spanish UNE 66177: 2005 (AENOR, 2005), and the British PAS 99: 2006 (British Standards Institution, 2006).

Integrated audit system needs the involving of all the components amid cross-functional audits, like quality, environmental and safety management system audits. However, practically, the integration of quality, environmental, safety and other kinds of management systems audits can be reduced to involve the sharing of a selected number of the aforementioned components among cross-functional audits (Karapetrovic, Casadesus, & Heras, 2006).

Literature on the integration auditing subsystems is much meager and unfortunately, empirical researches on the integration of audits or integration of management systems are few. In order to be concise the authors of this chapter have summarized some of empirical investigation and their main topics in the *Table 5*.

The worldwide major designer of voluntary International Standards is the International Organization for Standardization [ISO]. For business environment, ISO International Standards are strategic gears that reduce costs by diminishing waste and errors, increase productivity, provide access to new markets, offer the same opportunities for developing countries and empower free and fair global trade. ISO 14001:2004 stretches the recommendations for environmental management systems and recalls its global relevance for entities asking to trigger in an environmentally sustainable manner. According to the ISO statistics the state of ISO 14001 certifications and their trend in 2011-2012 period are presented in *Table 6*. The greatest reported number of certifications is in China followed by Japan and Italy, whilst regarding the growth in number of certificates the top three are China, Spain and Italy.

These statistics reveals that organizations worldwide have aligned their management systems with ISO 14001, to accomplish external environmental audit as a condition of the activity's certification.

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Table 5. Empirical studies on integration of auditing subsystems

Empirical studies	Main topic/findings
Karapetrovic et al., 2006; Salomone, 2008; Kraus and Grosskopf, 2008; Bernardo et al., 2010	The integration of management system audits
Baldi, 1999; Douglas and Glen 2000; Beckmerhagen, Berg, Karapetrovic and Willborn, 2003; Bamber, Sharp and Castka, 2004; Rajendran and Devadasan, 2005; Bernardo et al., 2010	The integration of internal auditing subsystems or external function-specific audits, like the ones performed against a Quality or an Environmental Management system.
Zeng, Tam, Tam and Deng, 2005; Zeng, Shi and Lou, 2007; Zutshi and Sohal, 2005; Asif, Fisscher, Joost de Bruijn and Pagell, 2010; Bernardo et al., 2010; Khanna, Laroiya and Sharma, 2010; López-Fresno, 2010.	The integration of management systems
Baldi, 1999	Classification of integrated audits: • *fully integrated audit* when a multidisciplinary audit team conducts the audit at a certain moment; • *simultaneous audit* involve auditing distinctly but at the same time the elements of the management system; • *overlapping audits* cover distinct aspects of the integrated management system, but may join in terms of preparation and areas audited; • *sequential audits* entail auditing one management system first, followed by the next one at another point in time.
Berbardo et al., 2010	Levels of integration: • *Not Integrated*, indicating different audit teams; different times when audits are conducted; audits of independent management system; as well as different plans and reports, • *Partially Integrated*, meaning single audit teams and/or simultaneous audits, but only for the selected standardized management systems or against certain management system standards; audits of interrelated management systems; as well as single audit plans, but different audit reports • *Fully Integrated* referring to a single audit teams and/or simultaneous audits for all management systems or standards, audits of integrated management systems, and single audit plans and reports.

Table 6. ISO 14001:2004 certificates

	Certificates in 2012	Certificates in 2011	Dynamics	Dynamics in %
Number of certificates	285 844	261 957	+23 887	109%
Number of countries	167	158	+9	106%

Source: adaptation from ISO, 2012

Extending these requirements, many entities have implemented internal environmental audit and currently use both auditing systems (Darnall et al., 2009).

The European model for promoting corporate social and environmental responsibility is known as Eco-Management and Audit Scheme (EMAS), being voluntarily accepted and experienced in line with stakeholders' expectations and interests. Voluntary adoption of EMAS involves recognition and complying with all the provisions, as the guarantee of reliable and accurate approach to environmental management. EMAS is a European regulation with specific requirements, compulsory external audit, and publication of the audit report.

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This subsection evaluate the current knowledge in the field of environmental audit, aiming integration of the environmental issues within the accounting profession, and it proposes an action plan for the implementation of Environmental Management System (EMS) and consequently of environmental audits, towards corporate social responsibility. The environmental audit is a voluntary activity, standardized by independent professional bodies with no regulatory power. This standpoint allows identifying the central features of the topic: (1) establishing the need for regulation in the field of environmental audit; (2) reviewing of the specialized literature; and (3) the development of a framework for environmental audit missions in the context of integrated management systems audits.

Concept and Necessity: Consideration for Environmental Audit

In the '70s, in the United States were first attempts to audit the environment, as support, supplier and beneficiary of the industrial business entities. Environmental audit has developed based on remediation and penalties cost-cutting reasons, recognized in industrial accidents having human and environmental impact, and on the requirement to manage the environmental impact and performance.

Environmental audit has been promoted by multinational companies which have applied specific procedures both at the corporate and the horizontal level of the subsidiaries in other countries, facing different rules depending on the policies implemented by the states where have been created operational and functional structures. With the development of the audit procedures and the emergence of the obvious environmental and socio-economic crisis, the vertically scope enlarged, by requesting "green" certificates for all business partners involved in the provision of goods and services of multinational companies. Worldwide, environmental auditing has become an important tool for creating competitive advantages to the interested entities that are revealed by identifying potential markets, internal and external stakeholders benefit sustainable earnings, financial savings, and improved public image of the entity.

The audit is performed in the context of a philosophy of auditing, in compliance with ethical rules and using the construction, acceptance and implementation of specific procedures to provide, to the stakeholders, a competent opinion on the audited subject. Reasons of accountability, of individuals or communities, society have an increasingly evident tendency to evaluate the various practices of audit (Power, 1997). From the natural environment perspective, the audit has been developed as a means of guaranteeing entity's compliance with environmental standards in terms of assessment and information, and creation competitive advantage in the current global environmental crisis.

Various practices, procedures, objectives and targets have been applied since the first environmental audits performed at national, European and international level. These are now found under the concept of environmental auditing, an independent concept, and part of the most new approach to audit, an integrated audit system. The Confederation of British Industry [CBI] presented a representative definition in 1990: environmental audit is the systematic examination of the relationship between the processes, procedures and activities of the entity with the environment. In a broad approach, this relationship includes the emissions, the legal restrictions on land and water use, the effects on neighboring community, the conservation and protection of natural landscapes, complying with the principles of ecology, public perception of the entity in the local context etc. Formally, a management tool that provides systematic documentation and evaluation of how the entity, equipment and technologies, involved in its activity, protect the natural environment is identified with the concept of environmental audit (International Chamber of Commerce [ICC], 1991). Complementing this concept, the European Communities Council [ECC], (1993) defines the environmental audit as a management tool consisting of systemic, documented, periodic and objective

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evaluation of the entity's performance, of the management system and the processes designed to protect the environment. The aim is to control the practices having an environmental impact and to assess their conformity with the entity's policies of the entity.

Types of partial environmental audits carried out by the international practice have been shared by the academic environment (Thompson & Thervie, 1991; Welford & Gouldson, 1993) and by professional organisms in the field (Environmental Resources Management [ERM], 1996). These are:

- *Compliance Audit*, the most common type of audit consisting of checks against environmental legislation and company policy;
- *Issues Audit* is described as an evaluation of how a company's activities relate to an environmental issue or (e.g. global pollution, energy use) or an evaluation of a specific issue (e.g. buildings, supplies);
- *Health and Safety Audit*, an assessment of risks and contingency planning (sometimes merged with environmental auditing because of the interconnected impacts of industrial processes and hazards);
- *Site Audit,* an audit of a particular site to examine actual or potential environmental problems;
- *Corporate Audit,* an audit of the whole company and its polices, structures, procedures and practices;
- *Due Diligence Audit*, an assessment of potential environmental and financial risks and liabilities carried out before a company merger or site acquisition or divestiture (e.g. contaminated land remediation costs);
- *Activity or Operational Audit*, an assessment of activities that may cross company departments or units (e.g. energy or waste management) and
- *Product or Life Cycle Audit*, an analysis of environmental impacts of a product throughout all stages of its design, production, use and disposal, including its reuse and recycling (cradle to grave).

The principle of audit integration address all forms of audit described in the literature to apply the environmental perspective. *External environmental audit* aims to evaluate environmental conditions at local, regional, and national level and express the opinions in a report on the environment status. *Internal environmental audit* focuses mainly on two directions:

- The impact assessment of the entity's policies, through a systematic study of the activities, objectives, services, practices affecting the environment; and
- The audit management system, through a review of procedures and structures that drives the environmental policy by entity.

In the last twenty years, the companies' management has reacted to the stakeholders' influence, demonstrating environmental responsibility. Some of them began to publish environmental information using corporate reporting, either as a part of their annual report, or as standalone voluntary environmental reports. Financial reporting requirements allow full recognition and disclosure of current and/or potential environmental issues. In countries concerned about current environmental issues, corporate reports including the environmental component have been originally adopted by public companies, and then by the private entities wishing to release consistent environmental reporting, the requirement for

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acceptance and participation in a sustainable business (Darnall, Gallagher, & Andrews 2001). Moreover, environmental reporting has become a characteristic of any activity (Gray & Bebbington, 2001). Some entities have advanced the integration of environmental information in decision-making processes through voluntary certification under the requirements of ISO 14001, but also, by implementing comprehensive environmental management systems. As part of this complex integration operation, the entities are using environmental audit (Darnall et al., 2009).

Alternatives and Perspectives of Environmental Audit Approach

In the current regulatory global context, the environmental audit is a voluntarily activity. Entities carrying out an environmental audit face the management of the pros and cons identified in connection with performing of this audit. Arguments *in favor* of environmental audit emerge from sustainable development and the position of the entity into the relevant market. One category of arguments refers to the early detection of environmental problems over which the entity can act before they become significant (Stanwick & Stanwick, 2001) by avoiding major damage, risks and costs of environmental remediation, with substantial improvement of the public image of the entity. The second category of arguments refers to the protection of entity's investments through the procedures and systems created in the audit process in order to improve continuously the environmental performance (de Moor & de Beelde, 2005; O'Dwyer, 2001; Pfaff & Sanchirico, 2000). The third one that refers to the investments of entities' own resources in environmental friendly technologies are significant and must be managed responsibly to achieve sustainable governance (Portney & Stavins, 2000). Arguments *against* environmental audit arise when nonconformities or flagrant violations of environmental regulations are identified. In such cases, the entity is legally obliged to report discrepancies to the rules, leading to sanctions, financial penalties or even their closing (Watson & Emery, 2004). However, implementation of the environmental audit involves a series of training costs, motivating the management to conduct an internal audit, or to budget substantial fees for an external audit.

The research field of environmental auditing is relatively narrow. Research to date refers to the general concept of audit rather than its environmental side. The authors of the researches addressing this subject perceive environmental audit as a standardized category of environmental management practice (Hillary, 1998; Tilt, 2001; Khanna & Anton, 2002), without discussing the factors associated with using of different types of environmental audits (Darnall et al., 2009). Specialized environmental audit engages the collection, the confrontation, the analysis, the interpretation and the presentation of information necessary for: (1) assessing performance in the context of the requirements and objectives for a particular aspect; (2) complying with the environmental legislation and the entity's policy; (3) measuring performance in accordance to the requirements of environmental management standards.

To this end, the environmental audit is organized in terms of well-identified circumstances, adapted to the entity size, to the appropriate activities and the corporate culture. The auditing purpose and its techniques may differ, but generally, available steps and activities may be identified, as presented in *Table* 7.

Under the impact of global and, consequently, the environmental crisis, there is a growing requirement to present audit reports. Thus, the first request was expressed by the ECC in 1990 and this was supported by the EMAS, requiring participants to publish the environmental reports, adopted by the ECC in 1993. Given the pros and cons of environmental audits and environmental management systems, standardized and convergent to the sustainable development principles, four alternatives for environmental audits have been outlined in the literature. These are provided in *Table 8*.

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Table 7. The general framework of an environmental audit mission

Steps	Activities
Audit preparation	• Full commitment to the management entity; • Setting the objectives, general goals and environmental priorities to be audited; • Choosing a team to ensure objectivity and professional competence of the mission.
Audit mission	• Audits on the spot, with the correct and systematic protocols and priorities; • Verification of the documents, registers, accounts etc.; • Examination of applied policies; • Discussions, interviews, questionnaires; • Inspections.
Post-auditing	• Evaluation of findings and results; • Reporting the recommendations; • Preparation of action plan; • Tracking implementation of mitigation or enhancement measures.

Table 8. Alternatives for organizing environmental audit

Alternatives	Characteristics	Limits	References
No environmental audit organized	The entity may adopt positive measures relating to the environment	Does not systematically check and periodically evaluate the environmental impact	Darnall et al., 2009
Organizes internal environmental audit	Determines the compliance with regulations and make recommendations for reducing negative environmental impact; Examines the provisions for uncertain events and validates the quality of environmental accounting	Only satisfies internal stakeholders, either managers or employees; Does not meet the requirements for implementing EMAS (mandates for the external environmental audit)	Dittenhofer, 1995; Power, 1997
Organizes external environmental audit	Determines compliance with environmental regulations; Examines the impact of environmental issues on the financial statements; Expresses an opinion on overall performance; Is objective and independent, as executed by an person outside the entity; Provides assurance on the legality of the activity, by presenting an environmental statement that meets the requirements of external stakeholders	Incurs high fees as provided for the independent external auditors' team Does not refer to the negative aspects of environmental impacts, existing in the deepest structures of the entity	Dittenhofer, 1995; Power, 1997; Solomon, 2000; Karapetrovic and Willborn, 2001; Kollman and Prakash, 2001
Organizes internal and external environmental audit	The most effective alternative; Combines the thorough knowledge coming from the entity's experiences ⇒ maximizes the external auditors beneficial environmental effects and increases the external credibility; Serves the interest of all stakeholders (internal and external)	It is the most costly alternative of organizing environmental audits, but also the most efficient in terms of benefits and credibility	Stanwick and Stanwick, 2001; Watson and Emery, 2004

From a cultural and traditional perspective, the auditors and the accountants are dissociated from the environmental aspects and environment conservation. They are increasingly involved in the environmental issues, as information and reports providers and as guarantors of the accuracy of the financial and accounting outputs used into decision process. The influence of accountants and auditors comes from their access to financial and performance information, their studies, reports and communications for decision-making process. They also encourage transparency, the right decision on purchasing and resource consumption and the recognition of environmental impact without breaching existing account-

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ing standards and regulations. International Organization of Superior Audit Institutions [INTOSAI], through its Working Group on issues of environmental audit [WGEA] identified three perspectives of the audit focused on environmental issues: financial statement audit, compliance audit and performance audit (INTOSAI WGEA, 2000).

Financial statement audit focuses on relevant issues related to the environment, the impact on their specific components, such as: measures to prevent, stop or remedy environmental damage; conservation of renewable and non-renewable resources; consequences of violating environmental laws and obligations imposed by governments (ecological charges, liability for damages caused by previous owners etc.). *Compliance audit* relating to the environment is able to provide guarantees that the audited activities are consistent with environmental laws, standards, and policies. *Environmental performance audits* include certifications regarding: the eco-performance indicators, correctly retrieved in the entity's overall performance and environmental programs conducted economically, efficiently and effectively.

Discussions on Environmental Audit Managerial Approach

An EMS is "that part of an organization's management system used to develop and implement its environmental policy and manage its environmental aspects" (ISO 14001, 2004). Figure 1 shows a schematic of the key elements of an EMS. The EMS process can be expressed in terms of environmental management techniques set out below.

The normative view offers opportunities for the debate, design, and implementation of an environmental management system, in the context of area-specific and voluntary regulations. The choices depend on the degree of responsibility, culture and respect for the environment. Table 9 provides a synthetic view of the main normative options in the field of environmental management systems.

The voluntary adoption of EMAS involves the recognition of and the compliance with the entire set of provisions, as a sole guarantee of a reliable and rigorous approach of the environmental management. The main characteristics of EMAS are summarized below:

- is an European regulation with precise requirements;
- involves the binding obligation of an external audit;

Figure 1. Key elements of an EMS

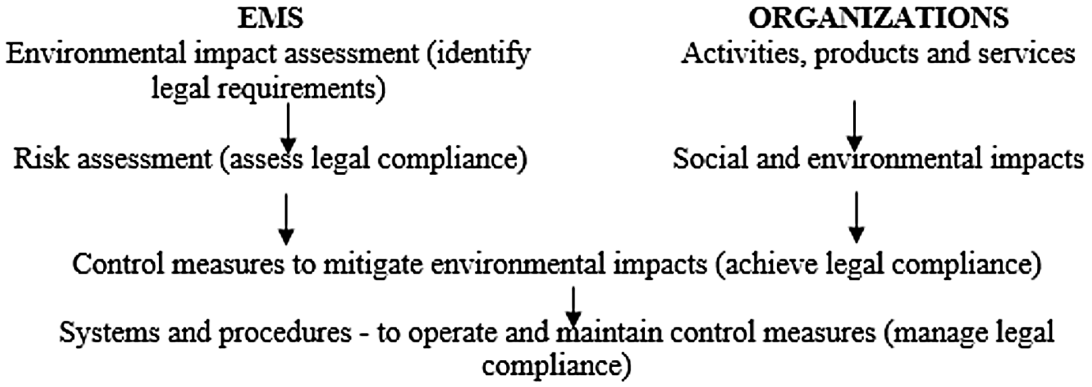

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Table 9. EMS – Normative choices

	Description	Applicability	Standard/ Regulation
In-house EMS	Many companies choose to design and implement an EMS to their own specification. An in-house EMS may be as effective as any other, but the main drawback for regulators is that it is more difficult to assess the effectiveness of such an EMS in the absence of a standard approach, including assessment criteria.	International	**-**
EMS: Requirements with Guidance for Use	The standard specifies the different elements of an EMS and how they relate to one another based on a methodology known as plan-do-check-act. The overall aim of the standard is to support environmental protection and prevention of pollution in balance with socio-economic needs. In common with all management systems, the standard provides a means for continual improvement of performance. Conformity against the requirements of ISO 14001:2004 can be demonstrated through self-declaration, accredited certification or by other independent means. Organization are also required "to establish, implement and maintain a procedure(s) to identify and have access to applicable legal requirements and other requirements to which the organization subscribes related to its environmental aspects" and "to determine how these requirements apply to its environmental aspects". This requirement is intended to promote knowledge and understand legal responsibilities. This standard does not require an organization to establish libraries of legal or other documents that will rarely be referenced or used, but to develop information that will help the organization to know what is legally required and how it relates to their organization.	International	**ISO 14001/ 2004**
EMS: Guide to the phased Implementation of an EMS including the use of Environmental Performance Evaluation	The standard: • provides guidance to organizations on environmental management and the use of environmental performance indicators; • describes a six-phase, incremental approach to implementing an EMS using environmental performance evaluation; • is suitable for any organization, particularly small and medium-sized enterprises, to implement an EMS – for example to ISO 14001 standard; • may be used to demonstrate improved environmental performance to customers and stakeholders.	British entities	**British Standard (BS) 8555/ 2003**
Eco-Management and Audit Scheme (EMAS)	It is a registration scheme, not simply a standard. It is a voluntary initiative designed to improve organizations' environmental performance. Its EMS specification is the same as that of ISO 14001:2004 but it places additional emphasis on legal compliance and environmental performance.	European	**European Council, Directive 1836/1993**

- requires the mandatory disclosure of the audit report and the disclosure of results arising from the implementation of measures resulting from the audit, to inform stakeholders;
- operates under the specific requirement of compliance with legal provisions;
- the focus is the continuous improvement of environmental performance/impact.

The main EMAS objective is the continuous improvement of environmental performance through the implementation of adequate measurement, evaluation and reporting tools. The main results consist of the continuous improvement of environmental issues management, as well as providing reliable information in the field. This voluntary environmental management tool is operational since 1995. The development of EMAS has undergone three major qualitative stages:

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- EMAS I – 1993-1995 – EMAS is adopted by the European Council and opens for participation by industrial companies;
- EMAS II – 2001 Regulation *No. 761/2001*adopted by the European Council open to all economic sectors including public and private services;
- EMAS III – 2009 – 2010 New Regulation *No. 1221/2009* adopted by the Council and entered into force on 11 January 2010. This new regulation aims voluntary participation in EMAS of all entities inside and outside the European Community. EMAS III has bought some new elements regarding (1) the improvement of the applicability and credibility of the scheme and (2) consolidation EMAS' visibility and outreach.

  The application of environmental auditing activities is performed by the entities that use the audit function at the highest-level performance. Having the desire to assume the continuous improvement process, entities that rely on quality audit have the guarantee that a proficient assessment is done consistently. When product defects or activity deficiencies are reported appropriate corrective measures are taken (Corbett, Montes-Sancho, & Kirsch 2005). They also use long-term planning and monitoring progress to achieve the expected results. Similarly, entities that use environmental audit seek to assure themselves that the environmental impact is continuously measured, the environmental objectives are met and the improvement actions are taken when problems occur (Darnall et al., 2009).

Management proceeds through two major components: maintenance and continuous improvement of the activity. The current global circumstances impose the complying with the principles of sustainable development, which means treatment with responsibility and competence in the environmental matters. In Europe, concerns about the natural environment are very serious and they are supported by a General Directorate for Environment (DGEnvironment) of EC, to promote, implement and certify the EMAS. In a quantitative evaluation released by the EC, dominated by numbers and unilateral elliptic reasoning with qualitative connotations, EU countries have implemented EMAS in 2.956 organizations with 9.836 sites certificated in 2015. The top three EU countries who had implemented EMAS starts with Italy, 1.047 organizations, España, with 906 organizations and Deutschland with 330 organizations. According to the same source, 18% are large organizations, 30% medium, 32% small and the rest micro entities (EC-EMAS, 2015).

This chapter viewpoint might be resume as a need for a mindful environmental management, both at micro and macroeconomic levels, in order to friendly cohabit with natural environment, in a sustainable development principles context-dependent. It is the example of the EMS that allows entities to target, to achieve and demonstrate continuous improvement in their environmental performance (Caraiani, Lungu, & Dascălu, 2007). EMS is part of an integrated environmental management, characterized by a series of phases that include environmental audits, which are standardized at international, national and European level. These phases are:

- Adopting an environmental policy to confirm and promote the continuous improvement of environmental performance;
- Acceptance of systematic checks to identify significant environmental issues and their effects;
- Development of environmental programs with clear and precise objectives, goals and actions;
- Adoption of an EMS to implement actions necessary to achieve the objectives;

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- Organizing standard environmental audits to measure the performance and the environmental impact;
- Preparing an environmental statement on eco-performance;
- Obtaining independent certification of the environmental report, based on the external audit.

Standing on the management component of continuous improvement the authors of this chapter bring into discussion the Deming's diagram, commonly known as the *PDCA* cycle for *Plan – Do – Check – Act*:

- *Plan*: design or revise business process components to improve results;
- *Do*: implement the plan and measure its performance;
- *Check*: assess the measurements and report the results to decision makers;
- *Act*: decide on changes needed to improve the process.

In its essence, the PDCA cycle is the feedback loop performed after each closing of the circle, so that managers could identify and improve processes and procedures, which are not sufficiently consistent with objectives (Dascălu, Caraiani & Lungu, 2008). The continuous development model led to the construction of quality management standards (ISO 9000:2000, ISO 9001:2008) and was taken in environmental management standard (ISO 14001, 2004), which is EMAS European correspondent. Although the international standard and European management and audit scheme are convergent, there are aspects of approach and details that distinguish them (Table 10).

To implement an effective EMS, the four phases of the diagram are taken up in a cyclical process, with the activities fulfillment during each phase. In Figure 2 the structure of the PDCA cycle with some appropriate activities are presented. This research assesses the knowledge in the environmental audit, promotes environmental issues within the accounting profession and proposes an action for implementing EMS and environmental auditing implicitly, to respond to social corporate responsibility. The scientific approach has shown that environmental audits are interesting both for the internal stakeholders (shareholders, partners, managers and ordinary employees) and for the external ones (potential investors, suppliers, current and potential customers, etc.) (Dascălu, Caraiani, Guşe, & Lungu, 2009).

This approach was encouraged by the narrow literature comparing the current frameworks of EMS. Converging with this chapter proposal were Testa, Rizzi, Daddi, Gusmerotti, Frey and Iraldo (2014), in their attempt to dispute the effectiveness of improvement environmental performance under an EMS framework, either EMAS, or ISO 14001. They empirically tested the environmental performance and found that, under ISO 14001 entities show improvements of their short-run environmental performance.

Table 10. EMAS vs. ISO 14001

EMAS	ISO 14001
Regulation operable in EU	International Standard
Requires initial analysis of the environmental impact	Does not require original analysis of the environmental impact
Aims to improve performance through best available techniques	EMS continuous improvement reflected in increased eco-performance
Requires public environmental statement, directly targeting the environmental policy and programs	Suggests external communication without formal requirements, but requires access to environmental policy

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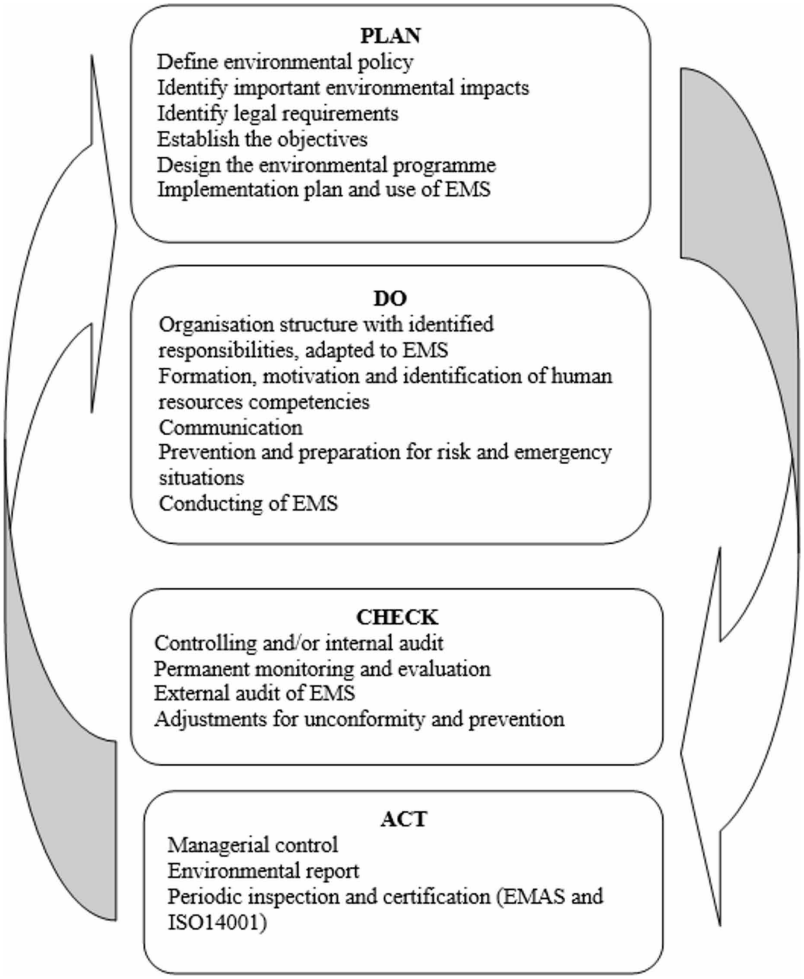
Figure 2. PDCA cycle for Environmental Management System



The EMAS framework much involves the authorities and promotes transparency and collaboration. These values are warranties on long-term, and as such are the improvements in environmental performance.

FUTURE TRENDS

Environmental impact is a major problem for the sustainable development of companies. The economic quantitative statements are based on the erroneous assumption of a steady natural environment. When the environment becomes unstable and resources become exhaustible, more complex situations arise. These complex situations can no longer be assessed by classical mechanisms but through instruments developed by complexity sciences. The sustainability mechanisms are no longer linear but complex and are based on the link method of the information flow and data or material accumulation described in this

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chapter. This aspect requires a holistic approach on reporting and auditing procedures which should be achieved through integration. In this respect, worldwide accounting and audit professional organizations, for instance Public Company Accounting Oversight Board [PCAOB] and Sustainability Accounting Standards Board [SASB] become more preoccupied about the environmental crisis and sustainability that may be the starting point to transcend the crisis.

Established by US Congress through the Sarbanes-Oxley Act of 2002, the PCAOB oversees the audits of public companies in order to protect investors and the public interest by promoting informative, accurate, and independent audit reports (PCAOB, 2013). PCAOB has been working with the SASB "to come up with standards for the external assurance of sustainability reporting" using the already-established assurance standards of the PCAOB (Bogoslaw, 2013).

The contemporary business-model of Corporate Social Responsibility (CSR) involves sustainable development because of its corporate self-regulation dimension. In order to comprise this component into their reports, companies have to convey sustainability-related information in a comparable manner with financial reporting. A sustainability report is a report published by a company or organization about the economic, environmental and social impacts caused by its everyday activities (Global Reporting Initiative [GRI], 2013), organization's values and governance model. This kind of reporting should highlight the connection between organizational strategy and its commitment to a sustainable global economy.

Regarding the role that audit has to play in the new age of sustainability reporting it is obvious that focusing only on financial data is not enough anymore (Du Toit, 2008). Additionally, due to the audiences of company reports that entail more than simply financial data accounting certainly have to be changed. As Puaschunder (2011) suggests the current requests for changing in accounting have been catalyzed by the recent financial crisis. Whether or not one agrees with such a conclusion, the shift towards non-financial information reporting is clear and evident when considering a recent report found that 95% of the Global 250 issue sustainability reports (Ernst & Young, 2013).

Johnson (2010) suggests an interesting approach to the future of audit. He adapts the "physician paradigm" to the auditing procedures. In his view, the auditing profession employs a holistic approach of disclosure and suggests going beyond financial performance numbers as in medicine the blood test results only are not enough anymore. Then, he proposes consideration of organizational design, environmental issues, implementation procedures and company culture (which in medicine may be referred as behavioral and genetic risk factors). This forward-looking perspective concerned with ongoing health and sustainability (Eccles, Cheng, & Saltzman, 2010) awake the awareness of accounting consultancy companies that must consider the rapid development of sustainability reporting as a signal to train and prepare their current and future employed audit professionals for comprehensive auditing procedures.

Complex approach to global environmental crisis, especially to climate change provides a solution to create projections of reality that can be studied by integrated analysis. It validates the need to create an integrated framework to "reduce complexity" so that it becomes predictable, controllable and responsive to the actions of correcting the destructive effects caused by natural or human forces. Future researches have to generate auditing procedures that should allow integrating a variety of areas relevant to sustainability, including both natural and social sciences and using a system of values that are recognized, identifiable and quantifiable. They should be accessible to decision-makers, combining different effects of options in various areas, and that call for the development of human abilities, which are now limited to monitoring a small number of dimensions of reality (Huppes & Ishikawa, 2009).

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CONCLUSION

Improving the performance requires action oriented towards the reduction of complexity and the clarification roles and obligations of each individual in the group. Resources must be targeted where they are actually needed. It is necessary to plan expertise activities for skill development of the employees, the managers and the directors, but also to create opportunities for inclusion of auditors and lawyers specialized in the requirements of social and environmental reporting. All these measures are designed to ensure reduced business risks through a systematic process that prioritizes actions to eliminate discrepancies. The results will be seen in the social and environmental audit reports, in the proposals for corrective actions intended, for example, to reduce accommodation risks arising from the relocation of employees (Caraiani, Guşe, Lungu, & Colceag, 2009).

The content of sustainability reports tend to appear in forms and measuring units that are not easily convertible into monetary terms. In this chapter, the idea of intensifying the pressures to increase corporate responsibility in all its dimensions is supported. The overlap and the convergence of reporting financial and sustainability performance seem more obvious and possible. Full integration in the form of a single report, describing the global performance (traditional financial, but also economic, environmental and social) is already practiced by some leading companies. The improved analytical methods and the increasing demands of interested stakeholders will continue to support the move towards a new generation of reporting performance.

REFERENCES

Ammenberg, J., & Sundin, E. (2005). Products in environmental management systems: The role of auditors. *Journal of Cleaner Production*, *13*(4), 417–431. doi:10.1016/j.jclepro.2003.12.006

Asif, M., Fisscher, O. A. M., Joost de Bruijn, E., & Pagell, M. (2010). An examination of strategies employed for the integration of management systems. *The TQM Journal*, *22*(6), 648–669. doi:10.1108/17542731011085320

Asociación Españiola de Normalización y Certificación. (2005). *UNE 66177: Sistemas de gestion. Guıa para la integracion de los sistemas de gestion*. Madrid, Spain: AENOR.

Baldi, D. (1999). Management System Mergers. *Environmental Protection*. Retrieved October 15, 2011, from http://www.eponline.com/

Bamber, C., Sharp, J., & Castka, P. (2004). Third party assessment: The role of the maintenance function in an integrated management system. *Journal of Quality in Maintenance Engineering*, *10*(1), 26–36. doi:10.1108/13552510410526848

Bebbington, J., Brown, J., & Frame, B. (2007). Accounting technologies and sustainability assessment models. *Ecological Economics*, *61*(2-3), 224–236. doi:10.1016/j.ecolecon.2006.10.021

Bebbington, J., & Thomson, I. (1996). *Business Conceptions of Sustainability and the Implications for Accountancy*. London: ACCA.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Beckmerhagen, I., Berg, H., Karapetrovic, S., & Willborn, W. (2003). Integration of management systems: Focus on safety in the nuclear industry. *International Journal of Quality & Reliability Management*, *20*(2), 209–227. doi:10.1108/02656710310456626

Bernardo, M., Casadesus, M., Stanislav Karapetrovic, S., & Heras, I. (2010). An empirical study on the integration of management system audits. *Journal of Cleaner Production*, *18*(5), 486–495. doi:10.1016/j.jclepro.2009.12.001

Blanco, H., Alberti, M., Forsyth, A., Krizek, K. J., Rodriguez, D. A., Talen, A., & Ellis, C. (2009). Hot, congested, crowded and diverse: Emerging research agendas in planning. *Progress in Planning*, *71*(4), 153–205. doi:10.1016/j.progress.2009.03.001

Bogoslaw, D. (2013). *SASB previews sustainability standards for financials.* Retrieved November 25, 2013, from Corporate Secretary: http://www.sasb.org/wp-content/uploads/2013/04/Corporate-Secretaries.pdf

British Standards Institution. (2006). [*Specification of Common Management System Requirements as a Framework for Integration*. London, UK.]. *PAS*, *99*, 2006.

Canadian Institute of Chartered Accountants. (1993). *Environmental Stewardship: Management, Accountability and the Role of Chartered Accountants*. Toronto: CICA.

Caraiani, C., Guse, R.G., Lungu C.I., & Colceag, F (2009). Triple Bottom Line (TBL) reporting – New performance reporting tools in a knowledge based management approach. *Annals of Oradea University, Economic Science Section*, tom XVIII, 3, 838-843.

Caraiani, C., Lungu, C. I., & Dascalu, C. (2007). Green Accounting – a Helping Instrument in European Harmonization of Environmental Standards, Database Social Science Research Network (SSRN), Retrieved October 17, 2013 from http://ssrn.com/abstract=1014012

Caraiani, C., Lungu, C. I., Dascălu, C., Cimpoeru, M. V., & Dinu, M. (2012). Social and environmental performance indicators: Dimensions of integrated reporting and benefits for responsible management and sustainability. *African Journal of Business Management*, *6*(14), 4990–4997.

Corbett, C., Montes-Sancho, M., & Kirsch, D. (2005). The financial impact of ISO 9000 certification in the United States: An empirical analysis. *Management Science*, *51*(7), 1046–1059. doi:10.1287/mnsc.1040.0358

Daily, B. F., & Huang, S. C. (2001). Achieving sustainability through attention to human resource factors in environmental management. *International Journal of Operations & Production Management*, *21*(12), 1539–1552. doi:10.1108/01443570110410892

Darnall, N., Gallagher, D. R., & Andrews, R. N. L. (2001). ISO 14001: Greening management systems, in Sarkis, J. Greener manufacturing and operations: From design to delivery and back, 178–190, Sheffield, UK: Greenleaf Publishing.

Darnall, N., Seol, I., & Sarkis, J. (2009). Perceived stakeholder influences and organizations' use of environmental audits. *Accounting, Organizations and Society*, *34*(1), 170–187. doi:10.1016/j.aos.2008.07.002

Dascălu, C., Caraiani, C., Guşe, G. R., & Lungu, C. I. (2009). Corporate social accountability through eco-environmental audit. *Financial Audit Review*, *11*, 34–43.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Dascălu, C., Caraiani, C., & Lungu, C. I. (2008). Eco – cost challenges for environmental protection. *Journal of Environmental Protection and Ecology*, *9*(4), 924–939.

de Moor, P., & de Beelde, I. (2005). Environmental auditing and the role of the accountancy profession: A literature review. *Environmental Management*, *36*(2), 205–218. doi:10.100700267-004-0142-6 PMID:15995890

Dittenhofer, M. (1995). Environmental accounting and auditing. *Managerial Auditing Journal*, *10*(8), 40–51. doi:10.1108/02686909510093615

Donaldson, T., & Preston, L. (1995). The stakeholder theory of the corporation: Concepts, evidence, & implications. *Academy of Management Review*, *20*(1), 65–91.

Douglas, A., & Glen, D. (2000). Integrated management systems in small and medium enterprises. *Total Quality Management*, *11*(4–6), 686–690. doi:10.1080/09544120050008075

Du Toit, A. (2008). *Sustainability assurance as a driver of change for the auditing profession.* British Accounting Association (BAA) annual conference, Blackpool, England.

Earnhart, D., & Leonard, J. M. (2013). Determinants of environmental audit frequency: The role of firm organizational structure. *Journal of Environmental Management*, *128*, 497–513. doi:10.1016/j.jenvman.2013.05.042 PMID:23827510

Eccles, R. G., Cheng, B., & Saltzman, D. (2010). *The Landscape of Integrated Reporting*. Cambridge, MA, USA: Harvard Business School.

Ernst & Young. (2013). *The Value of Sustainability Reporting*. Retrieved November 25, 2013, from Ernst & Young: http://www.ey.com/US/en/Services/Specialty-Services/Climate-Change-and-Sustainability-Services/Value-of-sustainability-reporting

Esty, D. C., & Winston, A. S. (2006). *Green to Gold*. New Haven, London: Yale University Press.

European Commission. (2007) "Adapting to climate change in Europe – options for EU action", Green paper from the commission to the council, the European parliament, the European economic and social committee and the committee of the regions, Brussels, 3.

European Commission. (2009). Supporting a climate for change. Retrieved November 10, 2011 from ec.europa.eu/clima/publications/docs/ea_climatechange_br_final.pdf

European Commission – Eco-Management and Audit Scheme. (2015). EMAS reports&Statistics. Retrieved March 23, 2015, from http://ec.europa.eu/environment/emas/register/reports/reports.do;jsessionid=8bDZSVgKs5rl9VjFyGHw2nByvZ4g9N215DFL7wHvy3v0J1P1nhRD!-20310670

European Communities Council. (1993). Council Regulation (EEC) No 1836/93 of 29th June 1993. *Official Journal*, L168.

Fineman, S., & Clarke, K. (1996). Green stakeholders: Industry interpretations and response. *Journal of Management Studies*, *33*(6), 715–730. doi:10.1111/j.1467-6486.1996.tb00169.x

Freeman, R. E. (1984). *Management: A stakeholder approach*. Boston, MA: Pitman.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Füssel, H. M., & Klein, R. J. T. (2005). Climate Change Vulnerability Assessments: An Evolution of Conceptual Thinking. *Climatic Change*, *75*(3), 301–329. doi:10.100710584-006-0329-3

Global, S. A. I. (1999). *AS/NZS 4581:1999. Management System Integration – Guidance to Business*. Sydney, Australia: Government and Community Organizations.

Global Reporting Initiative. (2013). *Sustainability reporting guidelines.* Retrieved November 25, 2013 from https://www.globalreporting.org

Gomes, R. C., & Gomes, L. M. (2007). Proposing a Theoretical Framework to Investigate the Relationships between an Organization and its Environment. *Revista de Administração Contemporânea*, *11*(1), 75–95. doi:10.1590/S1415-65552007000100005

Gray, R., & Bebbington, J. (2000). Environmental accounting, managerialism and sustainability: Is the planet safe in the hands of business and accounting? Advances in Environmental Accounting & Management, 1, Emerald Group Publishing Limited, 1-44.

Gray, R., & Bebbington, J. (2001). *Accounting for the environment*. Thousand Oaks, CA: Sage Publications.

Green, K., Morton, B., & New, S. (2000). Greening organizations: Purchasing, consumption, and innovation. *Organization & Environment*, *13*(2), 206–225. doi:10.1177/1086026600132003

Gunningham, N. A., Robert, A. K., & Thornton, D. (2004). Social license and environment protection: Why businesses go beyond compliance. *Law & Social Inquiry*, *29*(2), 307–341. doi:10.1111/j.1747-4469.2004.tb00338.x

Haigh, N., & Griffiths, A. (2009). The natural environment as a primary stakeholder: The case of climate change. *Business Strategy and the Environment*, *18*(6), 347–359. doi:10.1002/bse.602

Hallegatte, S., Lecocq, F., & de Perthuis, C. (2011). Designing Climate Change Adaptation Policies: An Economic Framework. *Policy Research Working Paper,* 5568, 1-39. Retrieved November 22, 2013, from http://basepub.dauphine.fr/xmlui/bitstream/handle/123456789/7780/11-02-WB-Adaptation-to-Climate-change-an-Economic-Framework.pdf?sequence=1

Hanna, M. D., Newman, W. R., & Johnson, P. (2000). Linking operational and environmental improvement through employee involvement. *International Journal of Operations & Production Management*, *20*(2), 148–165. doi:10.1108/01443570010304233

Hart, S. L. (1995). A Natural-Resource-Based View of the Firm. *Academy of Management Review*, *20*, 986–1014.

Henriques, I., & Sadorsky, P. (1996). The determinants of an environmentally responsive firm: An empirical approach. *Journal of Environmental Economics and Management*, *30*(3), 381–395. doi:10.1006/jeem.1996.0026

Hillary, R. (1998). Environmental auditing: Concepts, methods and developments. *International Journal of Auditing*, *2*, 71–85.

Huang, R. (2011). Environmental Auditing: An Informationized Regulatory Tool of Carbon Emission Reduction. *Energy Procedia*, *5*, 6–14. doi:10.1016/j.egypro.2011.03.002

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Huppes, G., & Ishikawa, M. (2009). Eco-Efficiency Guiding Micro-Level Actions towards Sustainability: Ten Basic Steps For Analysis. *Ecological Economics*, *68*(6), 1687–1700. doi:10.1016/j.ecolecon.2009.01.007

Intergovernmental Panel on Climate Change. (2001). Climate Change: Impacts, Adaptation and Vulnerability. Contributions of Working Group II to *the 3rd Assessment Report of the IPCC.*

Intergovernmental Panel on Climate Change. (2007). *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds.]. Cambridge, UK: Cambridge University Press.

Intergovernmental Panel on Climate Change. (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland.

International Chamber of Commerce. (1991). *ICC guide to effective environmental auditing*. Paris: ICC Publishing.

International Organization for Standardization. (2002). *ISO 19011. International Standard: Guidelines for Quality and/or Environmental Management Systems Auditing*. Geneva, Switzerland: International Organization for Standardization.

International Organization for Standardization. (2005). *ISO 9000. International Standard: Quality Management Systems –Fundamentals and Vocabulary*. Geneva, Switzerland: International Organization for Standardization.

International Organization for Standardization. (2008). *The Integrated Use of Management System Standards*. Geneva, Switzerland: International Organization for Standardization.

International Organization for Standardization. (2008). *ISO 14001 Environmental management systems — Requirements with guidance for use*. Geneva, Switzerland: International Organization for Standardization.

International Organization for Standardization. (2012). *The ISO Survey of Certifications - 2012.* International Organization for Standardization, Geneva, Switzerland. Retrieved November 15, 2013 from http://www.iso.org/iso/iso_survey_executive-summary.pdf

International Organization of Superior Audit Institutions - Working Group of Environmental Audit. (2000). *Guidance on Conducting Audits of Activities with an Environmental Perspective*. Retrieved September 10, 2010 from http://www.issai.org/media%28416,1033%29/ISSAI_5110E.pdf

Jacobs, M. (1997). The Environment as Stakeholder. *Business Strategy Review*, *8*(2), 25–28. doi:10.1111/1467-8616.00017

Jasch, C. (2000). Environmental performance evaluation and indicators. *Journal of Cleaner Production*, *8*(1), 79–88. doi:10.1016/S0959-6526(99)00235-8

Johnson, K. L. (2010). *Auditors at the Crossroads in Eccles, R. G., Cheng, B., & Saltzman, D. (2010). The Landscape of Integrated Reporting*. Cambridge, MA, USA: Harvard Business School.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Karapetrovic, S. (2002). Strategies for the integration of management systems and standards. *The TQM Magazine*, *14*(1), 61–67. doi:10.1108/09544780210414254

Karapetrovic, S. (2003). Musings on integrated management systems. *Measuring Business Excellence*, *7*(1), 4–13. doi:10.1108/13683040310466681

Karapetrovic, S., Casadesus, M., & Heras, I. (2006). *Dynamics and Integration of Standardized Management Systems: An Empirical Study*. Girona, Spain: Documenta Universitaria.

Karapetrovic, S., & Willborn, W. (1998). The system's view for clarification of quality vocabulary. *International Journal of Quality & Reliability Management*, *15*(1), 99–120. doi:10.1108/02656719810198601

Karapetrovic, S., & Willborn, W. (2001). Audit System: Concepts and Practices. *Total Quality Management*, *12*(1), 13–28. doi:10.1080/09544120020010066

Khanna, K. H., Laroiya, S. C., & Sharma, D. D. (2010). Integrated management systems in Indian manufacturing organizations: Some key findings from an empirical study. *The TQM Journal*, *22*(6), 670–686. doi:10.1108/17542731011085339

Khanna, M., & Anton, W. R. Q. (2002). Corporate environmental management: Regulatory and market-based Incentives. *Land Economics*, *78*(4), 539–558. doi:10.2307/3146852

Kollman, K., & Prakash, A. (2001). Green by Choice? Cross-National Variations in Firms' Responses to EMS-based Environmental Regimes. *World Politics*, *53*(03), 399–430. doi:10.1353/wp.2001.0010

Kraus, J., & Grosskopf, J. (2008). Auditing integrated management systems: Considerations and practice tips. *Environmental Quality Management*, *18*(2), 7–16. doi:10.1002/tqem.20202

López-Fresno, P. (2010). Implementation of an integrated management system in an airline: A case study. *The TQM Journal*, *22*(6), 629–647. doi:10.1108/17542731011085311

Management, E. R. (1996). Environmental Audit and Assessment concepts, measures, practices and initiatives. S*cottish Natural* [SNH, Battleby.]. *Heritage Review (Bismarck, N.D.)*, 46.

Martinov-Bennie, N., & Pflugrath, G. (2009). The strength of an accounting firm's ethical environment and the quality of auditors' judgments. *Journal of Business Ethics*, *87*(2), 237–253. doi:10.100710551-008-9882-1

Meyers, C. (2004). Institutional culture and individual behavior: Creating an ethical environment. *Science and Engineering Ethics*, *10*(2), 269–276. doi:10.100711948-004-0022-8 PMID:15152852

Mironeasa, C., & Codina, G. G. (2013). A new approach of audit functions and principles. *Journal of Cleaner Production*, *43*, 27–36. doi:10.1016/j.jclepro.2012.12.018

Mitchell, R. K., Agle, B. R., & Wood, D. J. (1997). Toward a theory of stakeholder identification and salience: Defining the principle of who and what really counts. *Academy of Management Review*, *22*, 853–886.

Ngwakwe, C. C. (2012). Rethinking the accounting stance on sustainable development. *Sustainable Development*, *20*(1), 28–41. doi:10.1002d.462

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

O'Dwyer, B. (2001). The legitimacy of accountants' participation in social and ethical accounting, auditing and reporting. *Business Ethics (Oxford, England)*, *10*(1), 27–39. doi:10.1111/1467-8608.00209

Orrù, M., Biggart, N. W., & Hamilton, G. G. (1991). Organizational isomorphism in East Asia. In W. S. Powell & P. J. DiMaggio (Eds.), *The new institutionalism in organizational analysis*. Chicago: The University of Chicago Press.

Osberghaus, D., & Reif, C. (2010). Total Costs and Budgetary Effects of Adaptation to Climate Change: An Assessment for the European Union. *CESifo Working Paper Series No. 3143*. Retrieved November 10, 2011 from http://ssrn.com/abstract=1655647

Pfaff, A. S. P., & Sanchirico, C. W. (2000). Environmental self-auditing: Setting the proper incentives for discovery and correction of environmental harm. *Journal of Law Economics and Organization*, *16*(1), 189–208. doi:10.1093/jleo/16.1.189

Phillips, R. A., & Reichart, J. (2000). The Environment as a Stakeholder? A Fairness-Based Approach. *Journal of Business Ethics*, *23*(2), 185–197. doi:10.1023/A:1006041929249

Portney, P. R., & Stavins, R. N. (2000). Public policies for environmental protection. In *Resources for the Future*. Washington, DC: Resources for the Future.

Power, M. (1997). *The Audit Society. Rituals of verification*. London: Oxford University Press.

Puaschunder, J. M. (2011). *On the emergence, current state and future perspectives of Socially Responsible Investment*. Cambridge, MA, USA: SRI.

Public Company Accounting Oversight Board. (2013). *About The PCAOB*. Retrieved November 25, 2013, from http://pcaobus.org/about/pages/default.aspx

Rajendran, M., & Devadasan, S. R. (2005). Quality audits: Their status, prowess and future focus. *Managerial Auditing Journal*, *20*(4), 364–382. doi:10.1108/02686900510592052

Ramus, C. A., & Steger, U. (2000). The roles of supervisory support behaviours and environmental policy in employee 'ecoinitiatives' at leading-edge European companies. *Academy of Management Journal*, *43*(4), 605–626. doi:10.2307/1556357

Salomone, R. (2008). Integrated management systems: Experiences in Italian organizations. *Journal of Cleaner Production*, *16*(16), 1786–1806. doi:10.1016/j.jclepro.2007.12.003

Scott, W. R. (1998). *Organizations rational, natural, and open systems*. New Jersey: Prentice-Hall Inc.

Sharma, S., & Henriques, I. (2005). Stakeholder influences on sustainability practices in the Canadian forest products industry. *Strategic Management Journal*, *26*(2), 159–180. doi:10.1002mj.439

Smit, B., Burton, I., Klein, R. J. T., & Street, R. (1999). The Science of Adaptation: A Framework for Assessment. *Mitigation and Adaptation Strategies for Global Change*, *4*(3-4), 199–213. doi:10.1023/A:1009652531101

Smit, B., Burton, I., Klein, R. J. T., & Wandel, J. (2000). An anatomy of adaptation to climate change and variability. *Climatic Change*, *45*(1), 223–251. doi:10.1023/A:1005661622966

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Smith, J. B., Ragland, S. E., & Pitts, G. J. (1996). A process for evaluating anticipatory adaptation measures for climate change. *Water, Air, and Soil Pollution*, *92*, 229–238.

Solomon, A. (2000). Could corporate environmental reporting shadow. *Accounting Forum*, *24*(1), 35–61. doi:10.1111/1467-6303.00028

Standard, D. (2005). DS 8001:2005. Ledelsessystemer - Vejledning i opbygning af et integreret ledelsessystem. Copenhagen, Denmark.

Stanwick, P., & Stanwick, D. (2001). Cut your risks with environmental auditing. *Journal of Corporate Accounting & Finance*, *12*(4), 11–14. doi:10.1002/jcaf.2403

Stone, D. (1995). No longer at the end of the pipe, but still a long way from sustainability: A look at management accounting for the environment and sustainable development in the United States. *Accounting Forum*, *19*, 95–110.

Testa, F., Rizzi, F., Daddi, T., Gusmerotti, N. M., Frey, M., & Iraldo, F. (2014). EMAS and ISO 14001: The differences in effectively improving environmental performance. *Journal of Cleaner Production*, *68*, 165–173. doi:10.1016/j.jclepro.2013.12.061

Thompson, S., & Therivel, R. (1991). *Environmental auditing*, Working Paper No. 130, Oxford Brookes University, Schools of Biological and Molecular Sciences and Planning, Oxford.

Tilt, C. A. (2001). The content and disclosure of Australian corporate environmental policies. *Accounting, Auditing & Accountability Journal*, *14*(2), 190–212. doi:10.1108/09513570110389314

Tol, R. S. J., Fankhauser, S., & Smith, J. B. (1998). The scope for adaptation to climate change: What can we learn from the impact literature? *Global Environmental Change*, *8*(2), 109–123. doi:10.1016/S0959-3780(98)00004-1

Verschoor, A. H., & Reijnders, L. (2001). The environmental monitoring of large international companies. How and what is monitored and why. *Journal of Cleaner Production*, *9*(1), 43–55. doi:10.1016/S0959-6526(00)00030-5

Waddock, S. A., & Graves, S. B. (1997). Finding the link between stakeholder relations and quality of management. *Journal of Investing*, *6*(4), 20–24. doi:10.3905/joi.1997.408435

Watson, M., & Emery, A. R. T. (2004). Environmental management and auditing systems: The reality of environmental self-regulation. *Managerial Auditing Journal*, *19*(7), 916–928. doi:10.1108/02686900410549439

Watson, R. T., Zinyowera, M. C., & Moss, R. H. (1996). *Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses. Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.

Welford, R., & Gouldson, A. (1993). *Environmental management and business strategy*. London: Ryman Publishing.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Wise, R. M., Fazey, I., Stafford Smith, M., Park, S. E., Eakin, H. C., Archer Van Garderen, E. R. M., & Campbell, B. (2014). Reconceptualising adaptation to climate change as part of pathways of change and response. *Global Environmental Change*, *28*, 325–336. doi:10.1016/j.gloenvcha.2013.12.002

Zeng, S., Shi, J., & Lou, G. (2007). A synergetic model for implementing an integrated management system: An empirical study in China. *Journal of Cleaner Production*, *15*(18), 1760–1767. doi:10.1016/j.jclepro.2006.03.007

Zeng, S. X., Tam, C. M., Tam, V. W. Y., & Deng, Z. M. (2005). Towards implementation of ISO 14001 environmental management systems in selected industries in China. *Journal of Cleaner Production*, *13*(7), 645–656. doi:10.1016/j.jclepro.2003.12.009

Zutshi, A., & Sohal, A. S. (2005). Integrated management system. The experience of three Australian organisations. *International Journal of Quality & Reliability Management*, *16*(2), 211–232.

KEY TERMS AND DEFINITIONS

Adaptation to Climate Change: Set of organization, localization and technical changes that societies have to implement to limit the negative effects of climate change and to maximize the beneficial ones.

Climate Change: An environmental problem leading to risks in the development process.

Eco-Management and Audit Scheme: A voluntary initiative designed to continuous improvement of organizations' environmental performance through the implementation of adequate measurement, evaluation and reporting tools.

Environmental Audit: An institution agreement that guarantees the trusted environment responsibility to be fulfilled effectively.

Environmental Management System: Part of an organization's management system used to develop and implement its environmental policy and manage its environmental aspects.

Integrated Audit: Involves of all the components amid cross-functional audits, like quality, environmental and safety management systems audits.

Plan-Do-Check-Act Cycle: The feedback loop performed after each closing of the circle that allows managers and auditors to identify and improve processes and procedures, which are not sufficiently consistent with objectives.

Stakeholder: Any group or individual who can affect or is affected by the achievement of the entity's objectives.

Sustainability Report: A report published by a company or organization about the economic, environmental and social impacts caused by its everyday activities.

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Chapter 27
Spatio-Temporal Variability of Seasonal Drought Over the Dobrogea Region

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ABSTRACT

In this study we have examined the spatial and temporal variability of seasonal short-term drought over Dobrogea region over the period 1965 -2005. The dominant mode of spatial variability captures an in-phase relationship of drought conditions over the entire analyzed region, for all the seasons. We show that the Arctic/North Atlantic Oscillation patterns control a significant part of the interannual drought variability over the Dobrogea region in all seasons. Dry (wet) periods in Dobrogea region are associated with geopotential height anomalies at 850mb that project onto the negative (positive) phase of Arctic/North Atlantic Oscillation. Moreover, the SST anomalies from the Atlantic Ocean realm and potential evapotranspiration anomalies over the south eastern part of Romania play also a significant role on the variability of drought conditions over Dobrogea region.

INTRODUCTION

Drought is one of the most complex phenomena which may have a strong impact on agriculture, society, water resources and ecosystems. Drought affects many regions of the world and is the costliest climatic hazard globally (Wilhite, 2000). One of the reasons for this is the usually large spatial extent of droughts and their lengthy duration, sometimes reaching continental scales and lasting for many years. Generally, drought originates from a deficiency of precipitation over an extended period of time, usually a season or more. Investigations of drought are carried out all over the world. However, because of the complexity of this phenomenon, a uniform methodology for implementing drought studies has not been developed, although some indices of drought are widely used (Dai et al., 2004; Wells et al., 2004; Palmer, 1965).

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Drought is viewed in different ways by different constituency of water users. Drought definitions are of two types: a) *conceptual* and b) *operational* (Wilhite, 2000). *Conceptual* definitions help to understand the meaning of drought and its effects. For example, drought is a prolonged period of deficient precipitation, which causes extensive damage to crops, resulting in loss of yield. These definitions do not provide quantitative answers to 'when", "how long", "how severe" a drought is and are often used as a startup in scientific papers and reports. *Operational* definitions help to identify the drought's beginning, end and degree of severity. To determine the beginning of drought, operational definitions specify the degree of departure from the precipitation average over some time period. This is usually accomplished by comparing the current situation with the historical average. An operational definition for agriculture may compare daily precipitation to evapotranspiration to determine the rate of soil-moisture depletion and express these relationships in terms of drought effects on plant behavior. These definitions are used to analyze drought frequency, severity and duration for a given historical period. Varied definitions, depending upon the influential factor used, of droughts are seen in the literature which can be grouped as follows: a) Precipitation based drought definitions; b) Evapotranspiration based drought definitions; c) Streamflow based drought definitions; d) Soil moisture based drought definitions; and e) Vegetation based drought definitions ((Ped, 1957; WMO, 1975; Wilthie and Glantz, 1985; Farago et al., 1989; Maracchi, 2000; Dai, 2011b). The groups in a) and b) refer to *meteorological drought* conditions, group c) refers to *hydrological droughts* and those in d) and e) refer to the *agricultural droughts*.

Drought propagation depends strongly on climate (Sheffield and Wood, 2011). At European scale, research on drought variability has been mainly focused on regional scales and/or over regions which are exposed to severe droughts [Iberian Peninsula (Estrela et al., 2000; Vicente-Serrano, 2011); the Mediterranean Region (Livada and Assimakopolous (2007) and south-eastern part of Europe (Koleva and Alexandrov (2008)]. Looking at other European regions, Briffa et al. (2009) showed that high summer temperatures in the western and central part of Europe are responsible for the large extent of summer drought conditions. Trnka et al (2009) emphasized that the drought conditions in the central part of Europe are triggered by different atmospheric circulation patterns and that the drought phenomenon is very pronounced in early vegetation period (April – June). Ionita et al. (2012a) showed that summer drought conditions over Europe are strongly influenced by previous winter SST anomalies and different ocean and atmospheric modes of variability (e.g. Atlantic Multidecadal Oscillation (AMO), Pacific Decadal Oscillation (PDO) and North Atlantic Oscillation (NAO)).

Large areas of Europe have been affected by drought during the 20th century. Severe and prolonged droughts observed mainly in the Mediterranean region have highlighted the vulnerability to this natural hazard and alerted the governments, stake holders, operational agencies to the disastrous effects of droughts on the society and economy and the need for mitigation measures (EEA, 2001). In this context, Romania is very likely to experience a wide range of impacts in response to climate change, mainly due to the temperature increases which in turn can perturb the hydrological cycle. In Romania, drought has a very strong impact on agriculture and affects 7.1 million ha, which represent 48% from the total agricultural land. The south, southeast and eastern parts of our country, where also Dobrogea region is located, are the most affected areas (< 600 m^3 water /hectare –extreme and severe pedological drought). During extremely dry years the average yields of various crops represent only $35\% \div 60\%$ of the potential yields. The climate evolution in Romania indicates a diminution of the annual precipitation especially over the south-eastern part of the country (Busuioc et al., 1995), the most affected area being Dobrogea region.

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Dobrogea region is situated in the South-Eastern part of Romania between the lower Danube and Black Sea (Figure 1a). This region is characterized by the existence of two climate units: a) a western unit, where the climate is continental and influenced by the Black Sea (the mean annual temperature is about $11^{\circ}C$ and the precipitation is 400 mm) and b) an eastern unit, where the climate is influenced by the moderate continental belt (Maftei and Barbulescu, 2008). In this context, in this chapter we present the results of the spatio-temporal analysis of drought conditions over Dobrogea region and the influence of the large scale atmospheric circulation and sea surface temperature on the drought variability.

DATA AND METHODS

Data Sets

To calculate the Standardized Precipitation Index (SPI) we used monthly precipitation totals recorded at 47 stations situated in the Dobrogea region (Figure 1b), which cover the period 1965 - 2005. Here we show the results for SPI of one accumulation period of 3 months. The precipitation data are a compilation provided by the National Meteorological Administration (10 stations) and the National Institute of Hydrology and Water Management (36 stations).

To calculate the self-calibrating Palmer drought Index (scPDSI) and the Standardized Evapotranspiration Index for one accumulation period of 12 months (SPEI12), we used monthly mean air temperature and monthly precipitation totals recorded at two stations: Constanta and Sulina. For this two station the mean air temperature and precipitation totals cover the period 1900 – 2004, which allows for a direct comparison of the drought indices over different time spans and to identify the possible changes in different types of drought conditions over these periods. From the long precipitation time series, at Constanta and Sulina stations, we computed also SPI for one accumulation periods of 12 months. The long term data sets for these two stations were extracted from the European Climate Assessment & Dataset project (Tank et al., 2002).

To investigate the link between seasonal modes of SPI3 variability and the Northern Hemisphere atmospheric circulation we used the Geopotential Height at 850mb from the Twentieth Century Reanalysis (V2) data set (NCEPv2, Whitaker et al., 2004; Compo et al., 2006; Compo et al., 2011) on a $2^{\circ} \times 2^{\circ}$ grid, for the period 1965 - 2005. To analyze the relationship of SPI3 with global sea surface temperature we used the Hadley Centre Sea Ice and Sea Surface Temperature data set – HadISST (Rayner et al., 2003). This data set covers the period 1871 – 2012 and has a spatial resolution of 1° x 1°. For the present study we only used data for the period 1965 – 2005. The potential evapotranspiration (PET) data set is extracted from the CRU T.S. 3.20 dataset (Harris et al., 2013), which has a spatial resolution of $0.5^{\circ} \times 0.5^{\circ}$ and covers the period for the period 1900 - 2012. For this study we used just the period 1965 – 2005.

We also made use of the time series of six monthly teleconnection indices: Arctic Oscillation (AO), North Atlantic Oscillation (NAO), East Atlantic pattern (EA), East Atlantic Western Russia pattern (EAWR), Polar-Eurasian pattern (POL) and Scandinavian pattern (SCA). These indices were extracted from the Climate Prediction Center webpage (http://www.cpc.ncep.noaa.gov/data/teledoc/telecontents.shtml). They cover the period 1950 – 2013, but for this study we used just the period 1965 - 2005. From

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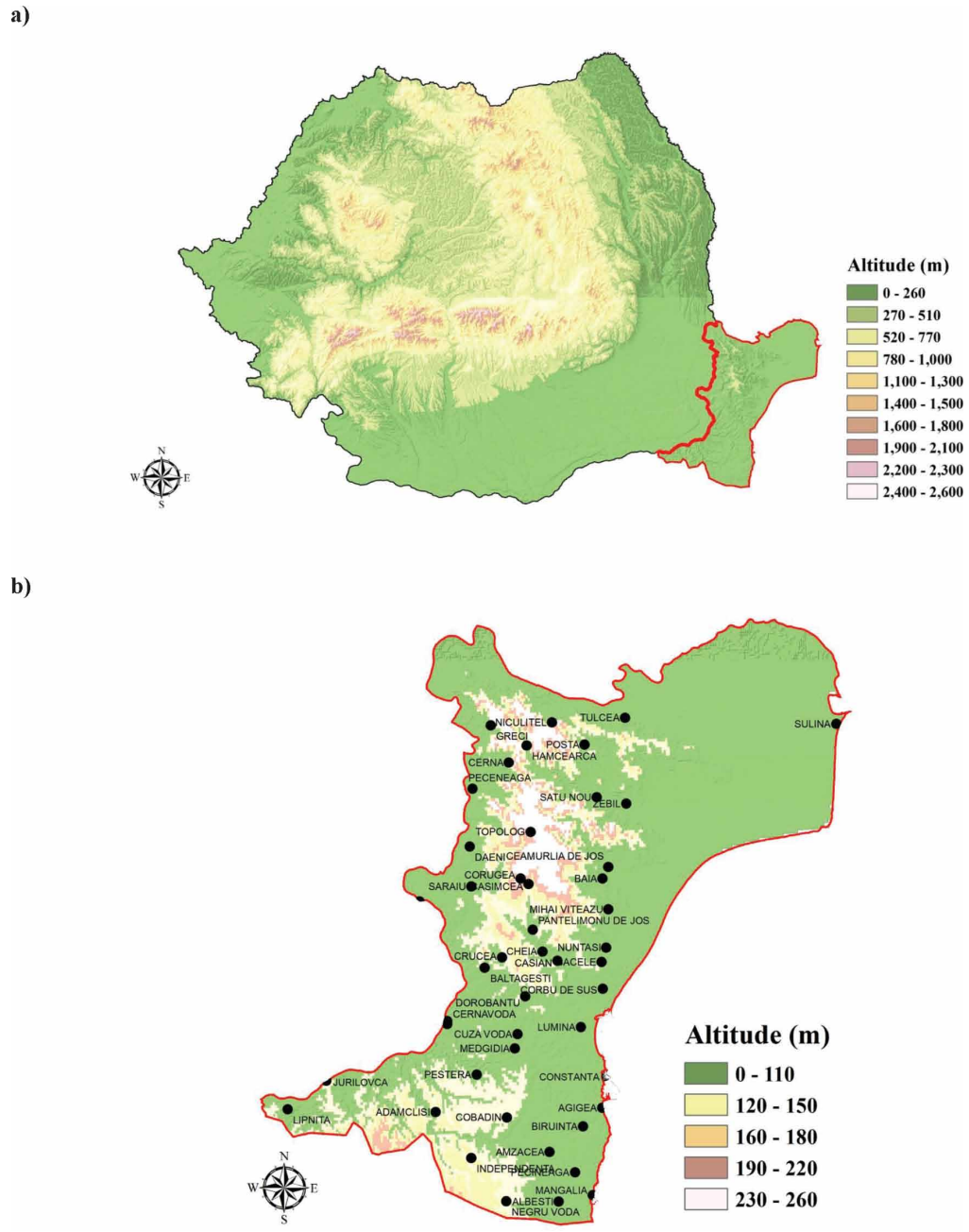
Figure 1. a) The topographical map of Romania and the location of the Dobrogea region (red area); b) The location and names of the hydrological stations used in this study.



the monthly time series the seasonal means were computed by averaging the months December/January/February (DJF), March/April/May (MAM), June/July/August (JJA) and September/October/November (SON). The time series were detrended and normalized by their corresponding standard deviation. A detailed description off all the teleconnection indices used in this chapter is given in the Global teleconnection patterns section.

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Methods

Empirical Orthogonal Functions Analysis (EOF)

The patterns of the dominant modes of SPI3 variability are based on Empirical Orthogonal Function (EOF) analysis (e.g. von Storch and Zwiers, 1999). The EOF technique aims at finding a new set of variables that captures most of the observed variance from the data through a linear combination of the original variables. The EOF analysis represents an efficient method to investigate the spatial and temporal variability of time series which cover large areas. This method splits the temporal variance of the data into orthogonal spatial patterns called empirical eigenvectors. In this study the EOF was applied to the detrended and standardized anomalies of seasonal SPI3. By construction, the EOF patterns and the principal components are independent. Two factors inhibit physical interpretation of EOFs: (1) the orthogonality constraint and (2) the derived patterns may be domain dependent. Physical systems are not necessarily orthogonal and if the patterns depend on the region used they may not exist if the domain changes. Still, even with these short comings, classical EOF analysis has proved to be very useful, especially for climate related variables.

Kriging Method

The spatial representation of the EOF results was done with the usage of the Surfer 11 software package. Generally there are two groups of techniques for estimating grid points on a surface from scattered observations. The technique used to represent the spatial structure of the EOFs is called "local fit", and estimates the surface at successive nodes in the grid using only a selection of the near closed data points. In this regard, the kriging method and specifically the ordinary kriging method was used. The basic function of kriging is:

$$V(x) = \sum_{i=1}^{n} w_i * V(x_i) + \left[1 - \sum_{i=1}^{n} w_i\right] * m$$

where $w_i(x)$ - kriging weights, assigned to the sample data $V(x_i)$.Values $m(x)$ and $m(x_i)$ are expected values (means) of $V(x)$, $V(x_i)$. The number of data n used for the estimation and their weights may vary depending on the estimation point x. If kriging is compared with other methods used for the creation of interpolation surfaces (*i.e.* inverse distance weighting, deterministic splines, Thiessen polygons), it looks more flexible as an approach. Depending on the scale of fluctuation, weights of higher or lower influence may be used, whereas *i.e.* in the Thiessen method the same weights are continuously used regardless of whether the equation has smaller or larger scale fluctuations.

Global Teleconnection Patterns

The global atmospheric circulation has a number of preferred patterns of variability, all of which have expressions in surface climate. Monthly mean surface pressure varies markedly about the long-term mean of the sea level pressure (SLP) distribution. This variability occurs in well-defined spatial patterns (Wallace and Gutzler, 1981; Barnston and Livezey, 1987) particularly during the boreal winter over the

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Northern Hemisphere (NH). Such variations are commonly referred as "teleconnections" in the literature, since they result in simultaneous variations in weather and climate over widely separated points over the earth. Regional climates in different locations may vary out of phase, owing to the action of such teleconnections, which modulate the location and strength of the storm tracks and poleward fluxes of heat, moisture and momentum (Hurrell et al., 2003; Quadrelli and Wallace, 2004; Trenberth et al., 2005b). Such monthly, seasonal and longer-time scales anomalies have direct impacts on humans, as they are often associated with floods, droughts, heat or cold waves and other factors that can directly affect and disrupt agriculture, water supplies, and can modulate the fresh water quality, energy demands and human health. The strength of teleconnections and the way they influence surface climate varies over long time scale.

One of the most prominent patterns that act over the NH and especially over the North Atlantic region and the surrounding continents is the North Atlantic Oscillation (NAO). The NAO refers to a north-south oscillation in atmospheric mass between the Icelandic Low and the Azores High-pressure centers (Walker and Bliss, 1932). The NAO is the dominant pattern of near-surface atmospheric variability over the North Atlantic, accounting for one third of the total variance in monthly SLP in winter. The positive phase of this pattern is associated with higher than normal surface pressure south of 55° N combined with a broad region of anomalously low pressure throughout the Arctic and subarctic. Consequently, this phase is associated with stronger-than-average winds across the mid-latitudes of the Atlantic onto Europe, with anomalously southerly flow over the eastern United States and anomalously northerly flows across Greenland, the northern part of Canada and the Mediterranean region and enhanced easterly trade winds over the sub-tropical North Atlantic (CPC, 2005). During the negative phase, both the Icelandic low and Azores high-pressure systems are weaker-than-normal, so both middle latitude westerlies and the sub-tropical trade winds are also weak. The negative phase brings higher-than-normal pressure over the polar region and lower-than-normal pressure at about 45° N. The negative phase allows cold air to plunge into the Midwestern United States and Western Europe, and storms bring rain to the Mediterranean.

The Arctic Oscillation (also referred to as the northern annular mode) is closely related to the NAO, with the observed time series correlating at 0.95 for monthly data (Deser, 2000). The AO is the dominant mode of variability on interannual time scales in the Northern Hemisphere and exhibits an annular pattern with decreased SLP over the Arctic basin associated with increase SLP at midlatitudes with centers of action in the North Atlantic and North Pacific. As such, the AO essentially encompasses the NAO variability but emphasizes the zonally symmetric nature of the hemispheric variability. The oscillation exhibits a "negative phase" with relatively high pressure over the polar region and low pressure at midlatitudes (about 45 degrees North), and a "positive phase" in which the pattern is reversed. In the positive phase, higher pressure at midlatitudes drives ocean storms farther north, and changes in the circulation pattern bring wetter weather to Alaska, Scotland and Scandinavia, as well as drier conditions to the western United States and the Mediterranean. Weather patterns in the negative phase are in general "opposite" to those of the positive phase.

The East Atlantic (EA) pattern is the second prominent mode of low-frequency variability over the North Atlantic region and appears as a leading mode in all months. The EA pattern is structurally similar to the NAO, and consists of a north-south dipole of anomaly centers spanning the North Atlantic from east to west. The anomaly centers of the EA pattern are displaced southeastward to the approximate nodal lines of the NAO pattern. For this reason, the EA pattern is often interpreted as a "southward shifted" NAO pattern. However, the lower-latitude centre contains a strong subtropical link in association with

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modulations in the subtropical ridge intensity and location. This subtropical link makes the EA pattern distinct from its NAO counterpart. The positive phase of the EA pattern is associated with above-average surface temperatures in Europe in all months and with below-average temperatures over the southern U.S. during January-May and in the north-central U.S. during July-October. It is also associated with above-average precipitation over northern Europe and Scandinavia and with below-average precipitation across southern Europe. In the negative phase the weather patterns are in general "opposite" to those of the positive phase.

The East Atlantic/ West Russia (EA/WR) pattern is one of three prominent teleconnection patterns that affects Eurasia throughout year. The East Atlantic/ West Russia pattern consists of four main anomaly centers. The positive phase is associated with positive height anomalies located over Europe and northern China, and negative height anomalies located over the central North Atlantic and north of the Caspian Sea. The surface temperature anomalies associated with the positive phase of the EATL/ WRUS pattern reflect above-average temperatures over eastern Asia, and below-average temperatures over large portions of western Russia and northeastern Africa. The precipitation anomalies reflect generally above-average precipitation in eastern China and below-average precipitation across central Europe (CPC, 2005).

The Scandinavian pattern (SCA) consists of a primary circulation centre over Scandinavia and two weaker centers of opposite sign over Western Europe and eastern Russia/ western Mongolia. The Scandinavian pattern has been previously referred to as the Eurasia-1 pattern by Barnston and Livezey (1987). The positive phase of the Scandinavia pattern is associated with below-average temperatures across central Russia and also over Western Europe. It is also associated with above-average precipitation across central and southern Europe and below-average precipitation across Scandinavia (CPC, 2005).

The Polar/ Eurasia pattern appears in all seasons. The positive phase of this pattern consists of negative height anomalies over the polar region and positive anomalies over northern China and Mongolia. This pattern is associated with fluctuations in the strength of the circumpolar circulation, with the positive phase reflecting an enhanced circumpolar vortex and the negative phase reflecting a weaker than average polar vortex (CPC, 2005). The Polar/Eurasian pattern is associated with above-average temperatures in eastern Siberia and below-average temperatures in eastern China and above-average precipitation in the polar region north of Scandinavia.

Drought Indices Review

To monitor and quantify drought, various indices have been developed, but a unique and universally accepted drought indicator does not exist yet (Heim, 2002; Dai, 2011b). One of the most used drought index is the Palmer Drought Severity Index (PDSI) (Palmer, 1965). The Palmer Drought Index is based on a supply-and-demand model of soil moisture and it enables the measurement of both wetness (positive values) and dryness (negative values). The index has proven to be most effective in determining long-term drought — a matter of several months — and not as good with conditions over a matter of weeks (Alley, 1984; Weber and Nkemdirim, 1998). One of the main disadvantages of PDSI is that it has a fixed temporal scale and does not allow the identification of different types of drought (e.g. agricultural, hydrological or meteorological). This may act as a drawback because drought is considered a multiscalar phenomenon (McKee et al., 1993, Vicente-Serrano et al, 2010). An improvement was made by McKee et al. (1993) with the development of the Standardized Precipitation Index (SPI), which takes into account the multiscalar nature of droughts. But SPI has a major drawback: it is based only on precipitation and does not take into account the effect of evapotranspiration, which has a strong impact on drought

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conditions. Recently, a new drought indicator, the Standardized Precipitation - Evapotranspiration Index (SPEI) (Vicente – Serrano, 2010) has been developed to quantify the drought condition over a given area. SPEI takes into account both precipitation and evapotranspiration and can be computed on time scales from 1 to 48 months. SPEI combines the sensitivity of PDSI to changes in evaporation demand with the multiscalar nature of SPI. More detailed description of SPEI and the method of computation are given by Vicente-Serrano et al. (2010).

Palmer Drought Severity Index (PDSI) and Self-Calibrating Palmer Drought Severity Index (scPDSI)

The most used drought index is the Palmer Drought Severity Index (PDSI) (Palmer, 1965); an index which is based on a supply-and-demand model of soil moisture and it enables the measurement of both wetness and dryness. The PDSI was developed during the early 1960's by W. C. Palmer as a standard way to quantify the severity of drought conditions. Since then, the PDSI has become one of the most widely used drought assessment tools. This index has proven to be most effective in determining long-term drought - a matter of several months - and not as good with conditions over a matter of weeks (Alley, 1984; Weber and Nkemdirim, 1998).

The index is a sum of the current moisture anomaly and a fraction of the previous index value. The moisture anomaly is defined as:

$$d = P - \hat{P}$$

where *P* is the total monthly precipitation, and $\hat{P}$ is the precipitation value climatologically appropriate for existing conditions' (Palmer, 1965). $\hat{P}$ represents the water balance equation defined as:

$$\hat{P} = \overline{ET} + \overline{R} + \overline{RO} - \overline{L}$$

where *ET* is the evapotranspiration, *R* is the soil water recharge, *RO* is the runoff, and *L* is the water loss from the soil. The over bars signify that these are average values for the given month taken over some calibration period. $\hat{P}$ is a hydrological factor and needs be parameterized locally. The Palmer moisture anomaly index (*Z* index) is then defined as:

$$Z = Kd$$

where *d* represents the deficit or surplus of moisture, adjusted for the seasonal changes in climate, and *PDSI* for month *i* is defined as:

$$PDSI_i = 0.897 PDSI_{i-1} + \frac{1}{3} Z_i$$

K acts as a climate weighting factor and is applied to yield indices with comparable local significance in space and time. PDSI is usually calculated over a monthly period. However, there is nothing to

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prevent calculations across other time periods, e.g. weekly or bi-monthly. The values of 0.897 and 1/3 are empirical constants that Palmer derived using data from two climate divisions. They are known as the Duration Factors, because they determine how long a spell will last.

Values for the duration factors and the climate characteristic can be calculated for each location by examining the historical climate of the location. This will calibrate the behavior of the index based on the climate of the location, giving more consistent results. The duration factors affect the sensitivity of the index to moisture deficits or surpluses by determining how much weight is given to the current moisture anomaly and the previous index value. The duration factors are most important, however, in determining when an established spell ends. If the duration factors do not represent the characteristics of the given climate, an extreme drought may never end, and the PDSI value would get steadily more negative.

Clearly, one location will be more sensitive to a given moisture deficit than another location. Also, one location may be more sensitive to a moisture deficit than to a moisture surplus of the same magnitude. Thus, two sets of duration factors are needed for each location; one will be used during wet spells and the other during dry spells.

Palmer also used an empirical value in the definition of the climate characteristic *K*. Taking into account the classification of PDSI values that Palmer developed, extremely dry *PDSI* values are defined as those at or below -4.00. Similarly, extremely wet PDSI values are at or above 4.00. By intuition, these extreme events should not occur much more often than once in a generation, or twelve months out of every 50 years. This corresponds to a frequency of 2% of extremely dry and extremely wet *PDSI* values. This means that the expected 2nd percentile of the PDSI values is -4.00 and the expected 98th percentile is 4.00. Using these two expected values of the PDSI in a definition of the ratio leads to the following formula for *K*:

$$K = \begin{cases} (-4.00/2^{nd}\ percentile)K^i\ if\ d{<}0 \\ (4.00/98^{th}\ percentile)K^i\ if\ d{\geq}0 \end{cases}$$

This definition of *K* may seem a little confusing because it depends on the PDSI values, which in turn rely on the climate characteristic. The solution to the problem is to calculate the PDSI using as the climate characteristic. Then the *K* can be used as the climate characteristic to recalculate all the PDSI values. This procedure calibrates the PDSI so that 2% of its values fall at or below -4.00 and 2% at or above 4.00. This, in all practicality gives the index upper and lower bounds. These bounds also lend more meaning to the intermediate values of the index.

The self-calibrating Palmer Drought Severity Index (scPDSI) automatically calibrated the behavior of the index at any location by replacing the empirical constants in the index computation with dynamically calculated values. The analysis of the self-calibrating PDSI has shown that it performs much more consistently than the original PDSI (Wells, 2004). The different classes of drought classification based on the values of scPDSI are given in Table 1.

Standardized Precipitation Index

The SPI is a drought index first developed by McKee et al. (1993). The SPI is used for estimating wet or dry condition based on precipitation variable. This wet or dry condition can be monitored by the SPI on a variety of time scales from subseasonal to interannual scales. The SPI is expressed as standard devia-

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tions that the observed precipitation would deviate from the long-term mean, for a normal distribution and fitted probability distribution for the actual precipitation record. Since precipitation is not normally distributed, a transformation is first applied, followed by fitting to a normal distribution. The SPI calculation is based on the long-term precipitation record for a particular location and long-term period (longer than 30 years is desirable). The calculation method is comprised of a transformation of one frequency distribution (e.g., gamma) to another frequency distribution (normal, or Gaussian). The first step to calculate SPI is to adequately choose a particular probability distribution (e.g., gamma distribution, incomplete beta distribution (McKee et al. (1993, 1995)), and Pearson III distribution (Guttman (1998, 1999)) that reliably fits the long-term precipitation time series and conduct fitting to that distribution. Gamma distribution has been widely used, as the gamma distribution has been understood as the reliable fit to the precipitation distribution. The fitting can be achieved through the maximum likelihood estimation of the gamma distribution parameters. The percentile value from this probability distribution is then transformed to the corresponding value in the new probability distribution. As a result, the probability that the rainfall is less than or equal to any rainfall amount will be the same as the probability that the new variate is less than or equal to the corresponding value of that rainfall amount. The normal distribution is usually used for this another transformation so that the mean and standard deviation of the SPI for a certain station and long-term period is zero and one, respectively (Edwards and McKee 1997). Positive SPI values indicate wet condition greater than median precipitation, whereas negative values the dry condition less than median precipitation.

The monthly precipitation time series are modeled using different statistical distributions. The first is the gamma distribution, whose probability density function is defined as:

$$g(x) = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} x^{\alpha-1} e^{-x/\beta} \qquad for\ x > 0$$

where $\alpha > 0$ is a shape parameter, $\beta > 0$ is a scale parameter, and $x > 0$ is the amount of precipitation. $\Gamma(\alpha)$ is the gamma function, which is defined as:

$$\Gamma(\alpha) = \lim_{n\to\infty} \prod_{v=0}^{n-1} \frac{n\,!\, n^{y-1}}{y+v} \equiv \int_0^{\infty} y^{\alpha-1} e^{-y} dy$$

Fitting the distribution to the data requires α and β to be estimated. Edwards & McKee (1997) suggest estimating these parameters using the approximation of Thom (1958) for maximum likelihood as follows:

$$\hat{\alpha} = \frac{1}{4A}\left(1 + \sqrt{1 + \frac{4A}{3}}\right)$$

$$\hat{\beta} = \frac{\overline{x}}{\hat{\alpha}}$$

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where, for *n* observations:

$$A = \ln\left(\overline{x}\right) - \frac{\sum \ln(x)}{n}$$

Integrating the probability density function with respect to x and attach α and β parameters yields the cumulative probability distribution function *G(x)*:

$$G(x) = \int_0^x g(x)dx = \frac{1}{\hat{\beta}^{\hat{a}}\Gamma(\hat{\alpha})}\int_0^x x^{\hat{a}}e^{-x/\hat{\beta}}$$

substituting *t* for $\frac{x}{\hat{\beta}}$ yields the incomplete gamma function:

$$G(x) = \frac{1}{\Gamma(\hat{\alpha})}\int_0^x t^{\hat{a}-1}e^{-t}dt$$

The gamma distribution is undefined for $x = 0$ and $q = P(x=0) > 0$, where $P(x=0)$ is the probability of zero (null) precipitation. Thus, the cumulative probability distribution function becomes:

$$H(x) = q + (1-q) * G(x)$$

The cumulative probability distribution function is converged into the standard normal cumulative distribution function so that both of them have the same probability. The different classes of drought classification based on the values of SPI are given in Table 1.

Table 1. Drought classification by scPDSI and SPI values

scPDSI		SPI	
scPDSI values	**Category**	**SPI Values**	**Category**
4 or more	Extremely wet	2.00 or more	Extremely wet
3.00 to 3.99	Very wet	1.50 to 1.99	Severely wet
2.00 to 2.99	Moderately wet	1.00 to 1.49	Moderately wet
1.00 to 1.99	Slightly wet	0 to 0.99	Mildly wet
0.50 to 0.99	Incipient wet spell		
0.49 to -0.49	Near normal		
-0.50 to -0.99	Incipient dry spell		
-1.00 to -1.99	Mild drought	0 to -0.99	Mild drought
-2.00 to -2.99	Moderate drought	-1.00 to -1.49	Moderate drought
-3.00 to -3.99	Severe drought	-1.50 to -1.99	Severe drought
-4 or less	Extreme drought	-2 or less	Extreme drought

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Standardized Evapotranspiration Index (SPEI)

SPEI is similar to the Standardized Precipitation Index (SPI) (McKee et al., 1993) but it includes the role of temperature. SPEI is a multi-scalar drought indicator based on monthly precipitation totals (PP) and temperature means. The procedure to calculate the index uses the monthly difference between precipitation (PP) and Potential Evapotranspiration (PET) which represents a simple climatic water balance calculated at different time scales to obtain the SPEI (Vicente-Serano et al., 2010).The SPEI is really simple to calculate, and is based on the original SPI calculation procedure. The SPI is calculated using monthly (or weekly) precipitation as the input data. The SPEI uses the monthly (or weekly) difference between precipitation and PET. This represents a simple climatic water balance which is calculated at different time scales to obtain the SPEI. A number of equations exist to model PET based on available data (e.g. the Thornthwaite equation, the Penman-Monteith equation, the Hargreaves equation, etc), and the SPEI is not linked to any particular one. With a value for PET, the difference between the precipitation (P) and PET for the month *i* is calculated:

$$D_i = P_i - PET_i$$

which provides a simple measure of the water surplus or deficit for the analyzed month. The calculated D_i values are aggregated at different time scales, following the same procedure as for the SPI. In this paper we have used the Thornthwaite equation to compute SPEI for one accumulation period of 12 months.

RESULTS

Precipitation Climatology

The climatological background plays a crucial role in the formation and variability of drought conditions as well as on the hydrological processes. The Dobrogea region is characterized by a temperate-continental climate. The precipitation amounts over the Dobrogea region have a strong seasonal cycle. In winter, the highest precipitation amounts (up to 135 mm/season) are recorded over the extreme northern and southern parts (Figure 2a), while the lowest amounts (around 55 mm/season) are recorded in the north-eastern part of the region. In spring, the spatial structure of the precipitation distribution is different than in winter (Figure 2b). There is a clear dipole like structure in the distribution of precipitation between the western part and the eastern part of the Dobrogea region. The highest precipitation amounts are recorded at the stations situated in the northern part (up to 145 mm/season). As in the case of winter, the lowest precipitation amounts are recorded in the north-eastern part of the region. For the summer season, the precipitation distribution follows the same dipole-like path, like for the spring season, but the highest precipitation amounts are recorded in the western part of the Dobrogea region (Figure 2c). Summer, is the season in which the highest precipitation amounts are recorded, up to 160 mm/season at stations located in the western part of the region. In autumn, the highest precipitation amounts are

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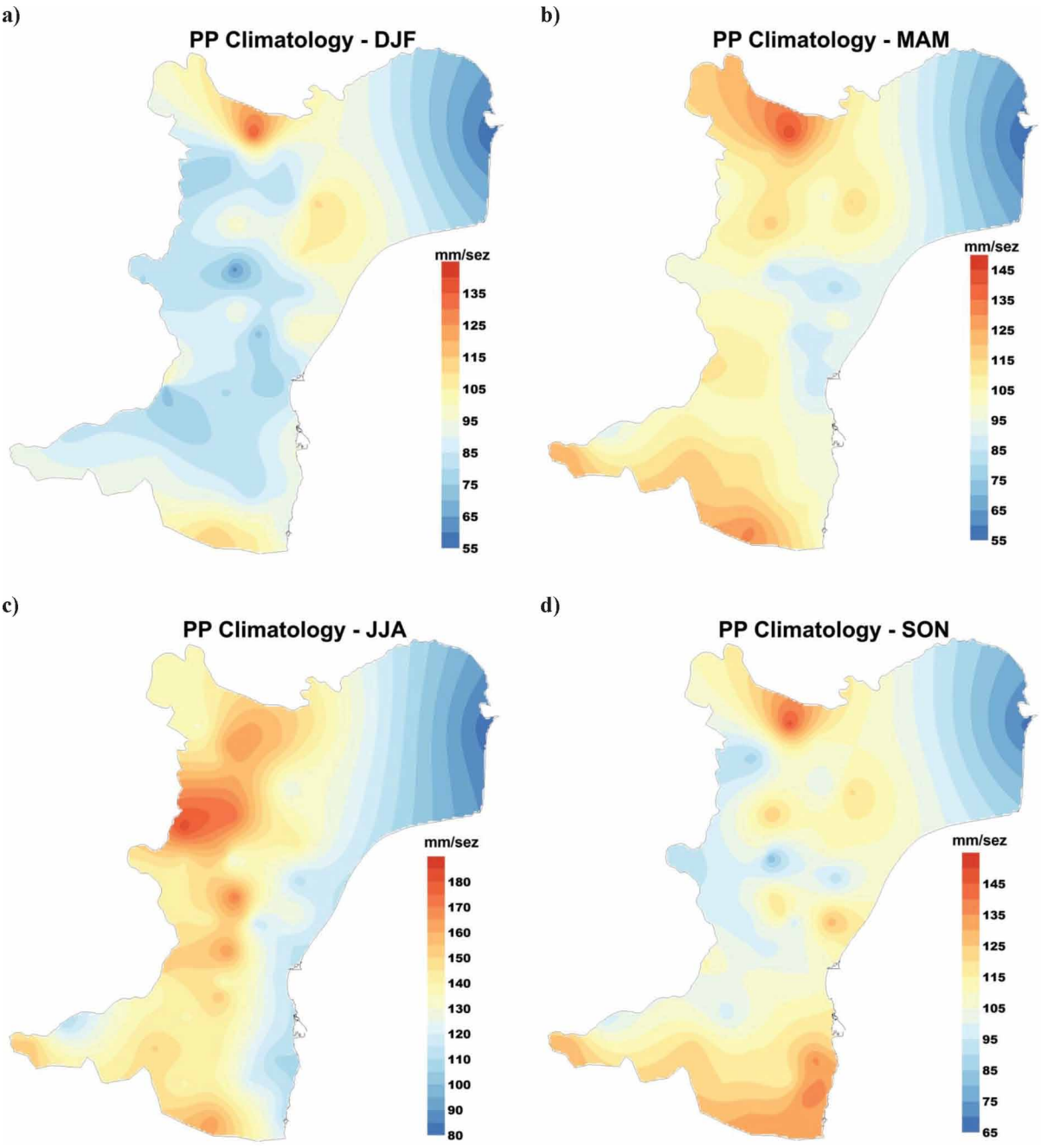
Figure 2. a) The winter precipitation climatology over the Dobrogea region; b) same as a) but for the spring season; c) same as a) but for summer season and d) same as a) but for the autumns season.



recorded in the southern part (up to 125 mm/season) and the northern part (up to 135 mm/season). The lowest precipitation amounts are recorded, like in the case of the other seasons, at the stations situated in the north-eastern part of the region. The north-eastern part of the Dobrogea region is very exposed to low precipitation amounts and more drought events.

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Drought Variability and Large Scale Circulation, Teleconnection Patterns, and Atlantic SST

Drought results from a combination of meteorological, physical and human factors. The primary cause of any drought is a deficiency in rainfall and, in particular, the timing, distribution and intensity of this deficiency in relation to existing storage, demand and water use. Temperature and evapotranspiration may act in combination with rainfall to aggravate the severity and duration of the event. The precipitation and temperature variability is driven mainly by the large-scale atmospheric circulation. As a consequence is very important to analyze the variability of drought conditions in relationship with large scale atmospheric circulation.

The first EOFs resulted from the standardized SPI3 seasonal data (anomaly divided by the standard deviation) allows us to recognize the region with similar or different climatology and to filter out some errors in precipitation observations. Moreover, to identify the physical mechanism, if any, responsible for the connection between the seasonal SPI3 variability and atmospheric circulation, the correlation maps between the principal components corresponding to the first seasonal EOFs and the geopotential height at 850mb, the global SST and the potential evapotranspiration are computed. There are relatively few studies that have analyzed the influence of different teleconnection patterns on the variability of climate variables over Romania (Bojariu and Paliu, 2001; Tomozeiu et al., 2002; 2005; Ionita et al., 2013), but none of the aforementioned studies has dealt with the influence of this well known mode of variability on the drought conditions, especially over the south-eastern part of Romania, a region which is prone to extreme droughts.

Winter

The first EOF of winter SPI3 is characterized by a monopolar structure, with positive loadings over the whole Dobrogea region. The highest loadings are observed in the central and northern part of the region, while the lowest loadings are observed over the southern part of the region (Figure 3a). The first winter EOF explains around 78.17% of the total variance. The monopolar structure emphasizes the fact that a large amount of the drought variability in the Dobrogea region is influence mainly by the same factors. The corresponding principal component (PC1) presents pronounced interannual and decadal variability (Figure 3b). Periods characterized by prolonged drought conditions have been observed for the years 1970 – 1974; 1976 – 1980; 1983 – 1985; 1990 – 1994 and 2001 – 2002, while periods characterized by wet conditions have been recorded for the years: 1965 – 1969; 1981 – 1982; 1995 – 2000 and 2003 – 2005. An interesting aspect of the dry/wet conditions, during the winter season, is the fact that the dry conditions are always grouped in 4 or 5 consecutive years.

In terms of large scale well-known teleconnection patterns, the PC1 was found to be correlated with the winter AO/NAO. The correlation coefficient between winter PC1 and winter AO/NAO is significant (90% significance level) and shows an out-of-phase relationship between PC and AO/NAO implying that wet (dry) conditions are associated with the negative (positive) phase of AO/NAO (Figure 3c). To emphasize this relationship between winter PC1 and AO/NAO, the correlation map between winter PC1 and the geopotential height at 850mb is shown in Figure 3d. Wet (dry) periods over Dobrogea region are associated with positive (negative) Z850 anomalies over the north Atlantic Ocean and Greenland extending up to the eastern Russia and negative (positive) Z850 anomalies over the central Atlantic Ocean and the eastern part of Europe, with a significant and deep cyclonic (anticyclonic) area over the

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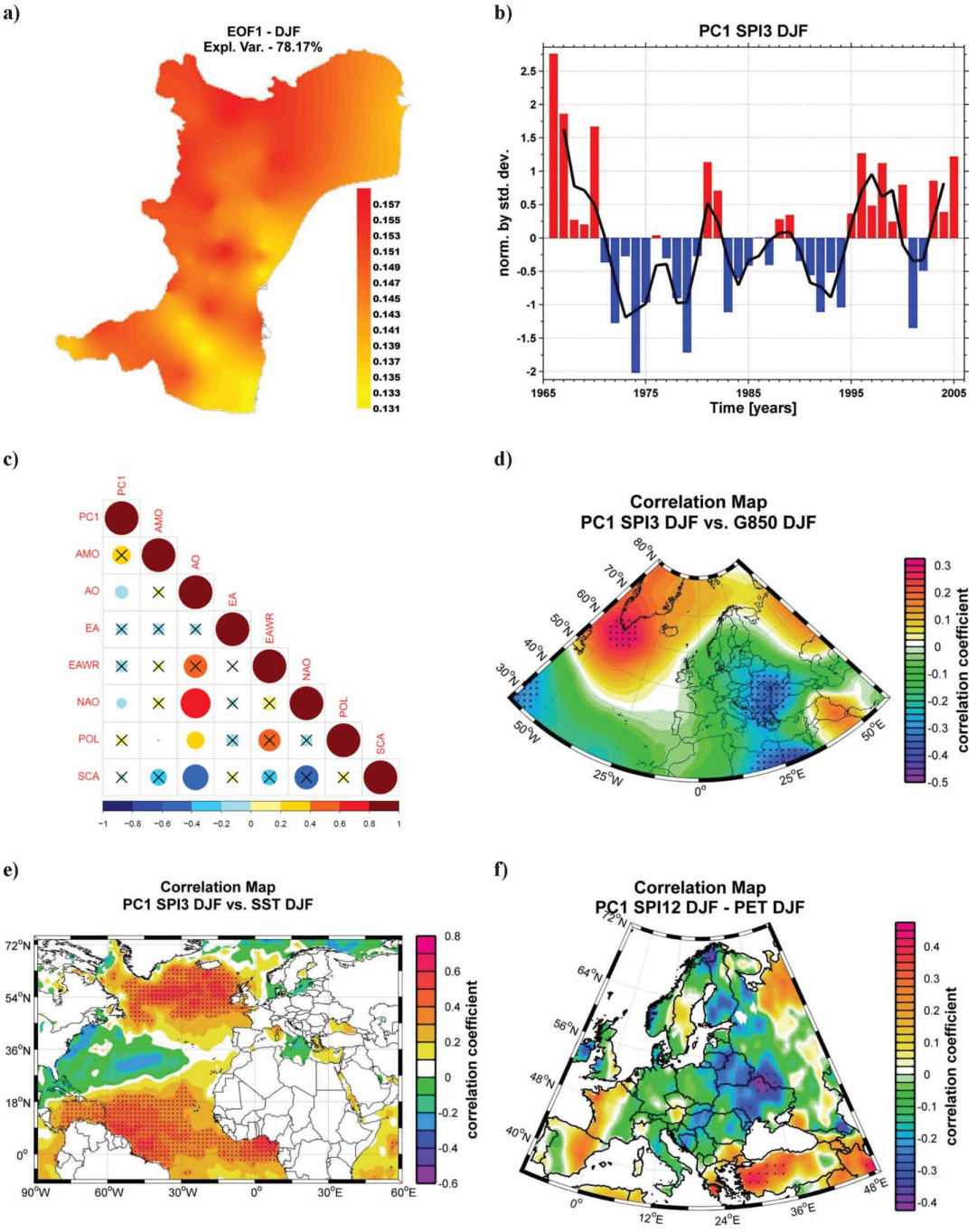
Figure 3. a) First EOF of winter (December/January/February - DJF) SPI3; b) The corresponding time series (PC1); c) The correlation coefficients of winter PC1 with the winter teleconnection pattern indices; d) The correlation map between winter PC1 and winter geopotential height at 850mb; e) The correlation map between winter PC1 and winter sea surface temperature from the Atlantic Ocean basin; f) The correlation map between winter PC1 and winter potential evapotranspiration. (The dotted areas indicate regions where the correlations are exceeding the 95% significance level). In Figure 3b, positive values indicate wet conditions, while negative values indicate drought conditions.



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Black Sea and eastern part of Romania (Figure 3d). Moreover, wet (dry) periods over the Dobrogea region are strongly correlated with SST anomalies from the Atlantic Ocean basin. Wet (dry) periods are associated negative (positive) anomalies in the central Atlantic Ocean flanked by significant positive (negative) SST anomalies in the tropical Atlantic Ocean and the northern part of the Atlantic Ocean (Figure 3e). A similar pattern was identified in the North Atlantic Ocean by other authors (Hurrel, 1995; Deser and Blackmon, 1993; Dima et al, 2001; Ionita et al., 2012a, 2012b). This pattern has been found to have a quasi-decadal variation of about 12 years.

An important aspect of the drought conditions is related to the influence of the evapotranspiration and the soil moisture. As such, in Figure 3f it is shown the correlation map between winter PC1 and the Potential Evapotranspiration at European scale. As it can be inferred from Figure 3f, there are no significant correlations between winter PC1 and PET field. This is not surprisingly for the winter season, since during the winter months the soils are either frozen or covered by snow, thus reducing or cancelling the influence of the potential evapotranspiration on the drought conditions.

Spring

The first EOF of spring SPI3 is characterized, like in the case of the winter season, by a monopolar structure, with positive loadings over the whole Dobrogea region. The highest loadings are observed in the northern part of the region, while the lowest loadings are observed over the central and north-eastern part (Figure 4a). The first spring EOF explains around 76.13% of the total variance. The corresponding principal component (PC1) is characterized by pronounced interannual variability (Figure 4b), with altering wet and dry periods. Periods characterized by prolonged drought conditions have been observed for the years 1967 – 1968; 1972; 1974 – 1976; 1982 – 1983; 1985 – 1987; 1989 – 1991; 1994, 1998, while periods characterized by wet conditions have been recorded for the years: 1966; 1969 – 1971; 1973; 1977 – 1979; 1981; 1984; 1988; 1992 – 1993; 1995 – 1997; 2001 - 2002 and 2004 – 2005. For the spring season, the dry/wet periods vary on shorter time scales comparing to the winter season and they are more exposed to strong interannual variability.

Spring PC1 was found to be negatively significant (99% significance level) correlated with spring AO/NAO index. This significant correlation can be observed also in the spatial structure of the correlation map between spring PC1 and spring Z850. Wet (dry) periods over Dobrogea region are associated with negative (positive) Z850 anomalies over the central North Atlantic Ocean that extend up to the eastern part of Europe and positive (negative) Z850 anomalies over Greenland and northern part of the Atlantic basin. The spatial structure of the correlation map projects onto the Z850 anomalies associated with the negative phase of AO/NAO (Figure 4d) in agreement with the high value of the correlation coefficient between spring PC1 and spring AO/NAO. Wet (dry) periods over the Dobrogea region are also associated with negative (positive) SST anomalies over the east coast of U.S. flanked by positive (negative) SST anomalies in the tropical Atlantic Ocean and in the northern part of the Atlantic Ocean basin. A similar pattern was found also for the winter months, implying a certain persistence of the SST anomalies form the winter season to the spring one, with the same effect on the drought conditions in the Dobrogea region. Spring PC1 shows negatively significant correlations with spring PET (Figure 4f) over the eastern part of Romania, where Dobrogea region is located. The high correlations over the eastern part of Romania imply that during the spring season the potential evapotranspiration plays an important role for the variability of drought conditions.

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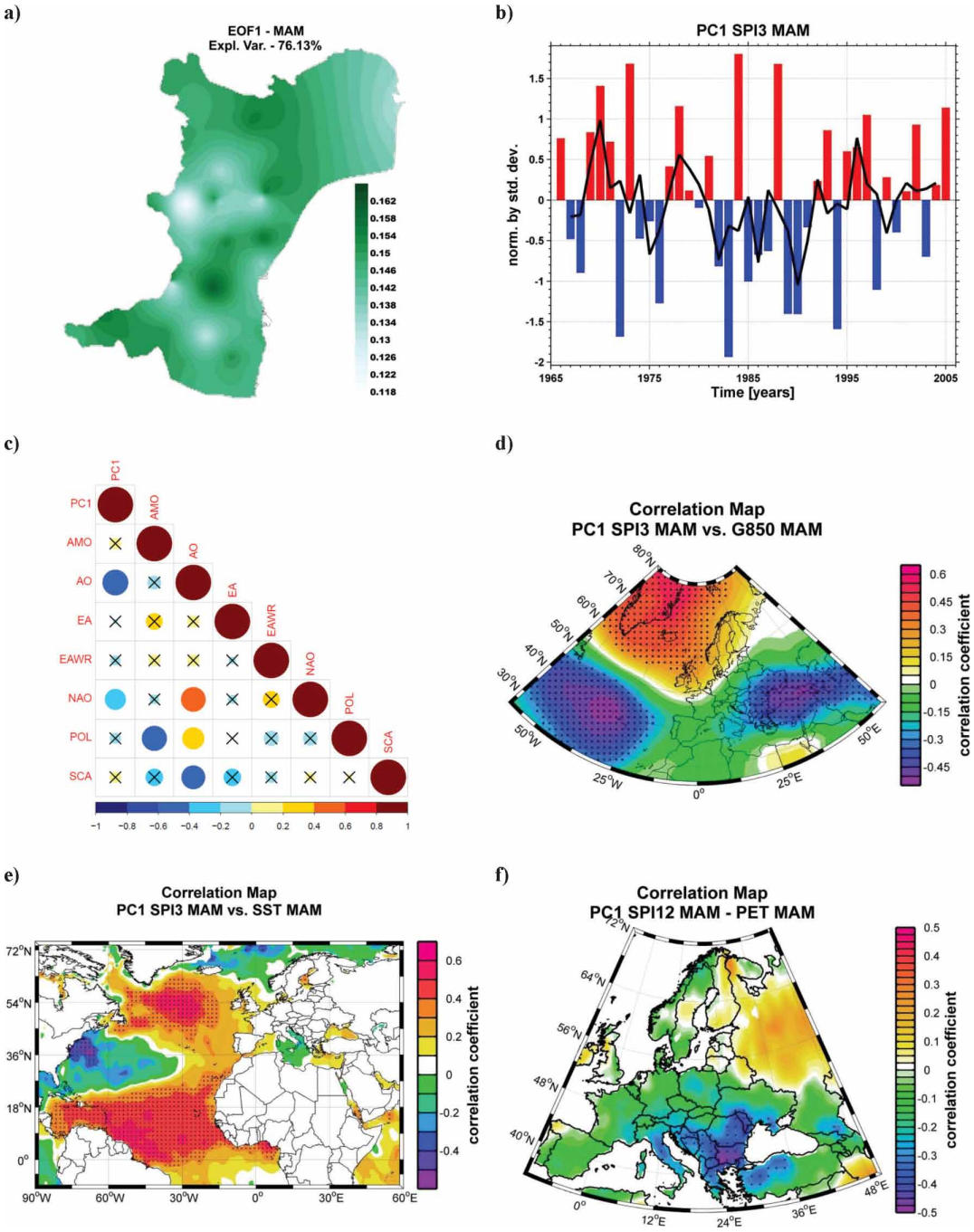
Figure 4. a) First EOF of spring (March/April/May - MAM) SPI3; b) the corresponding time series (PC1); c) The correlation coefficients of spring PC1 with the spring teleconnection pattern indices; d) The correlation map between spring PC1 and spring geopotential height at 850mb; e) The correlation map between spring PC1 and spring sea surface temperature from the Atlantic Ocean basin; f) The correlation map between spring PC1 and spring potential evapotranspiration. (The dotted areas indicate regions where the correlations are exceeding the 95% significance level). In Figure 4b, positive values indicate wet conditions, while negative values indicate drought conditions.



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Summer

The first summer mode of SPI variability (Figure 5a) has the highest loadings over the northern and central part of the Dobrogea region and explains approximately 62.17% of the total variance. The explained variance of summer EOF1 is much smaller compared to the explained variance explained by winter EOF1. This is not surprisingly, since the summer months are characterized by a more variable atmospheric circulation and convective precipitation, while in winter the atmospheric circulation is less variable and the snow cover can play a significant role on the drought/moisture conditions. The corresponding summer PC1 (Figure 5b) is characterized mainly by interannual and high-frequency variability. The driest summers were recorded for the following years: 1966 – 1968, 1976, 1981 – 1982, 1986, 1990, 1995 – 1996 and 2003 – 2004, respectively. In contrast to this, the wettest summers, in Dobrogea region, were recorded for the following years: 1969 – 1972, 1975, 1977 – 1980, 1983, 1987, 1991, 1997, 1999 and 2004 – 2005.

As in the case of the winter season, there is a weak relationship between summer PC1 and well-known teleconnection patterns (Figure 5c), like summer AO/NAO. Based on the correlation map between summer PC1 and summer Z850 (Figure 5d), wet (dry) summers over the Dobrogea region are associated with a low (high) pressure center located over the eastern part of Europe and centered over Romania and a high (low) pressure center over the northern part of the Scandinavian Peninsula. The low pressure center located over Romania favors the advection of moist and warm air from the Mediterranean area towards the southern part of Romania and triggers enhanced precipitation over this area, where Dobrogea region is also located. Wet (dry) summers, over the analyzed region, are also associated with positive (negative) SST anomalies over the tropical Atlantic Ocean and in the southern part of Greenland (Figure 5e).

As in the case of spring season, the potential evapotranspiration plays an important role on the drought conditions over the Dobrogea region. Wet (dry) summers are strongly related with reduced (enhanced) PET, especially over the eastern part of Romania. The correlations between summer PC1 and summer PET have values up to -0.6 over the Dobrogea region.

Autumn

Autumn EOF1 has a retuned explained variance of 68.73% and as in the case of the other seasons, it has the same sign over the entire Dobrogea region, indicating that a large part of the autumn SPI variability is controlled by the same large-scale factors. The corresponding principal component (PC1) presents interannual variability and very pronounced multidecadal variability (Figure 6b). Periods characterized by prolonged drought conditions have been observed for the years 1969, 1973, 1977 – 1994 and 2001 – 2002, while periods characterized by wet conditions have been recorded for the years: 1965 – 1967; 1971 – 1972, 1995 – 1999 and 2002 – 2005. The most striking feature of the temporal evolution of autumn PC1 is the negative values (dry autumns) that persisted for almost 20 years, between 1975 and 1995, with some small exceptions. Autumn PC1 is significantly correlated (90% significance level) to autumn AO/NAO (Figure 6c) and this is also visible in the correlation map between autumn PC1 and autumn Z850. The spatial structure of the correlation map projects onto the negative phase of the AO/NAO. Wet (dry) autumns are associated with negative (positive) Z850 anomalies over the central North Atlantic Ocean and positive (negative) Z850 anomalies over Greenland extending up to the Scandinavian Peninsula. In terms of SST anomalies, the correlation map between autumn PC1 and autumn SST resembles the structure of the correlation map between winter/spring PC1 and winter/spring

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Figure 5. a) First EOF of summer (June/July/August - JJA) SPI3; b) the corresponding time series (PC1); c) The correlation coefficients of summer PC1 with the summer teleconnection pattern indices; d) The correlation map between summer PC1 and summer geopotential height at 850mb; e) The correlation map between summer PC1 and summer sea surface temperature from the Atlantic Ocean basin; f) The correlation map between summer PC1 and summer potential evapotranspiration. (The dotted areas indicate regions where the correlations are exceeding the 95% significance level). In Figure 5b, positive values indicate wet conditions, while negative values indicate drought conditions.

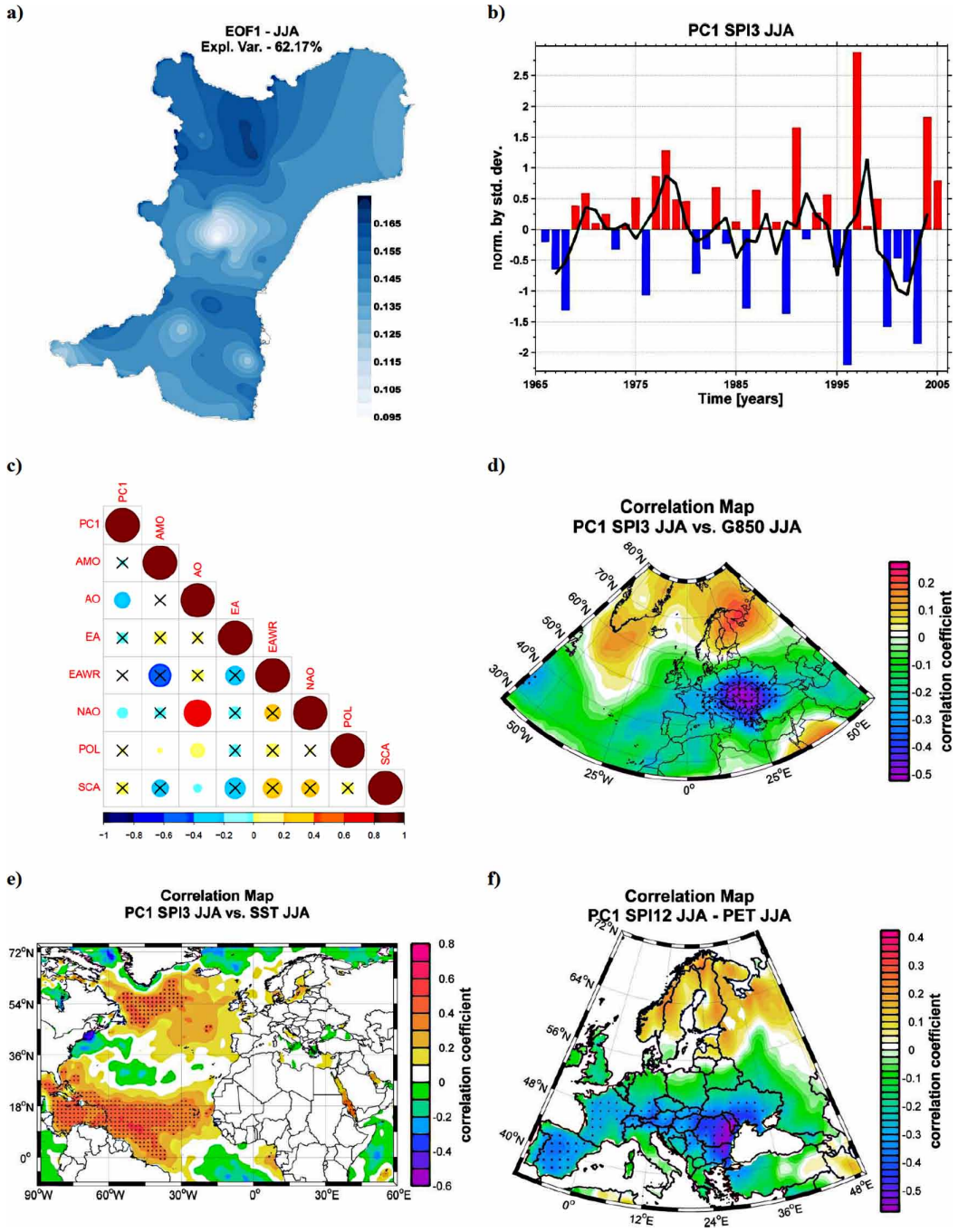

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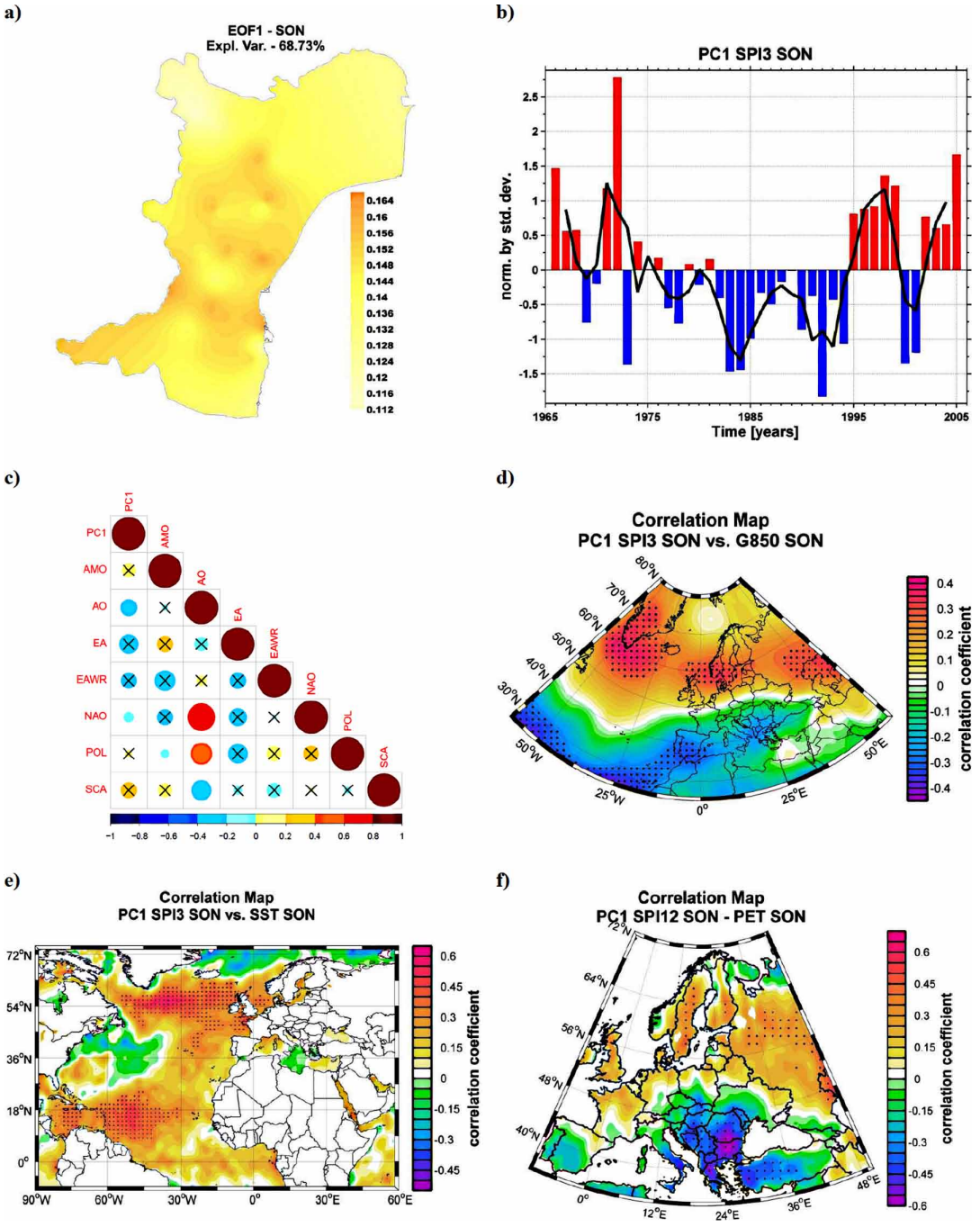
Figure 6. a) First EOF of autumn (September/October/November - SON) SPI3; b) the corresponding time series (PC1); c) The correlation coefficients of autumn PC1 with the autumn teleconnection pattern indices; d) The correlation map between autumn PC1 and autumn geopotential height at 850mb; e) The correlation map between autumn PC1 and autumn sea surface temperature from the Atlantic Ocean basin; f) The correlation map between autumn PC1 and autumn potential evapotranspiration. (The dotted areas indicate regions where the correlations are exceeding the 95% significance level). In Figure 6b, positive values indicate wet conditions, while negative values indicate drought conditions.



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SST. Wet (dry) autumns are associated with significant negative (positive) SST anomalies over the eastern U.S. coast flanked by positive (negative) SST anomalies in the tropical Atlantic Ocean and in the northern part of the Atlantic Ocean. The similarity in the SST anomalies between the autumn, winter and spring seasons shows a kind of persistent feature, implying that a part of the SPI variability is related to similar SST conditions in the Atlantic Ocean basin over different seasons. This persistence can give a hint of potential predictability of SPI variability based on the SST anomalies from the Atlantic Ocean basin. As in the case of spring and summer seasons, the correlation map between autumn PC1 and autumn PET shows the highest negative correlations (~ -0.6) over the southern part of Romania and Bulgaria. Reduced (enhanced) evapotranspiration over the aforementioned regions is associated with wet (dry) conditions over the Dobrogea region.

Drought Indices Comparison

For two stations located in the southern part (Constanta) and eastern part (Sulina) of the Dobrogea region, a long data set, which covers the period 1901 – 2004, for precipitation and temperature, is available. Based on these data sets we have computed the scPDSI, SPI12 and SPEI12 for different time spans: 1900 - 1934, 1935 - 1969 and 1970 - 2004, respectively. The aim of splitting the data sets in different periods was to test if there are significant changes in drought conditions over different periods. The frequency of time in each dry or wet category, expressed as the percentage of months in a given category, is shown in Figure 7 for Constanta and Sulina stations. The percentage of months in a given category is shown for scPDSI, SPI12 and SPEI12, for different periods and different dry/wet categories. We choose SPI and SPEI for an accumulation period of 12 months due to the fact that the highest correlations between scPDSI and SPI and SPEI were for this particular accumulation period.

As can be observed from Figure 7, SPI12 and SPEI12 tend to have almost the same frequencies, for all the analyzed periods, since they are normalized indices, while scPDSI shows lower frequencies for mild-wet category and higher frequencies for dry categories, for both stations and for all the analyzed periods. For Constanta station there is an increase in mild-wet and mild-dry periods for the time frame 1970 – 2004 compared to the time frames 1900 – 1934 and 1935 – 1969, respectively. Moreover, there is a slight decrease in severe and extreme drought for the period 1970 – 2004 (Figure 7d) compared to the other two periods analyzed. The most striking feature of Figure 7 is the disappearance of extreme and severe wet category at Sulina station for the period 1970 – 2004 (Figure 7h). This feature is accompanied, at Sulina station, by a strong increase of moderate, severe and extreme droughts for the same period of time (1970 – 2004) compared to the periods 1900 – 1934 and 1935 – 1969, respectively. While the period 1900 – 1934 was characterized by a high frequency of mild-wetness, at Sulina station, for the periods 1935 -1969 and 1970 - 2004 there is a tendency towards more frequent mild-droughts and a higher frequency towards mild and extreme droughts over the last 35 years of the analyzed period. This tendency towards increased frequency of extreme drought over the last 35 years, at Sulina station, is due to the fact that the amount of precipitation has decreased by an order of $1/3$ compared to the period 1900 – 1934. At Sulina station, the mean annual precipitation for the period 1900 – 1934 is 364.85 mm/year, for the period 1935 – 1969 is 338.20 mm/year, while for the period 1970 – 2004 the annual amount of precipitation is reduced to 250 mm/year. This decreasing trend in the annual precipitation amount at Sulina station is not valid also for Constanta station. For Constanta station, the annual precipitation

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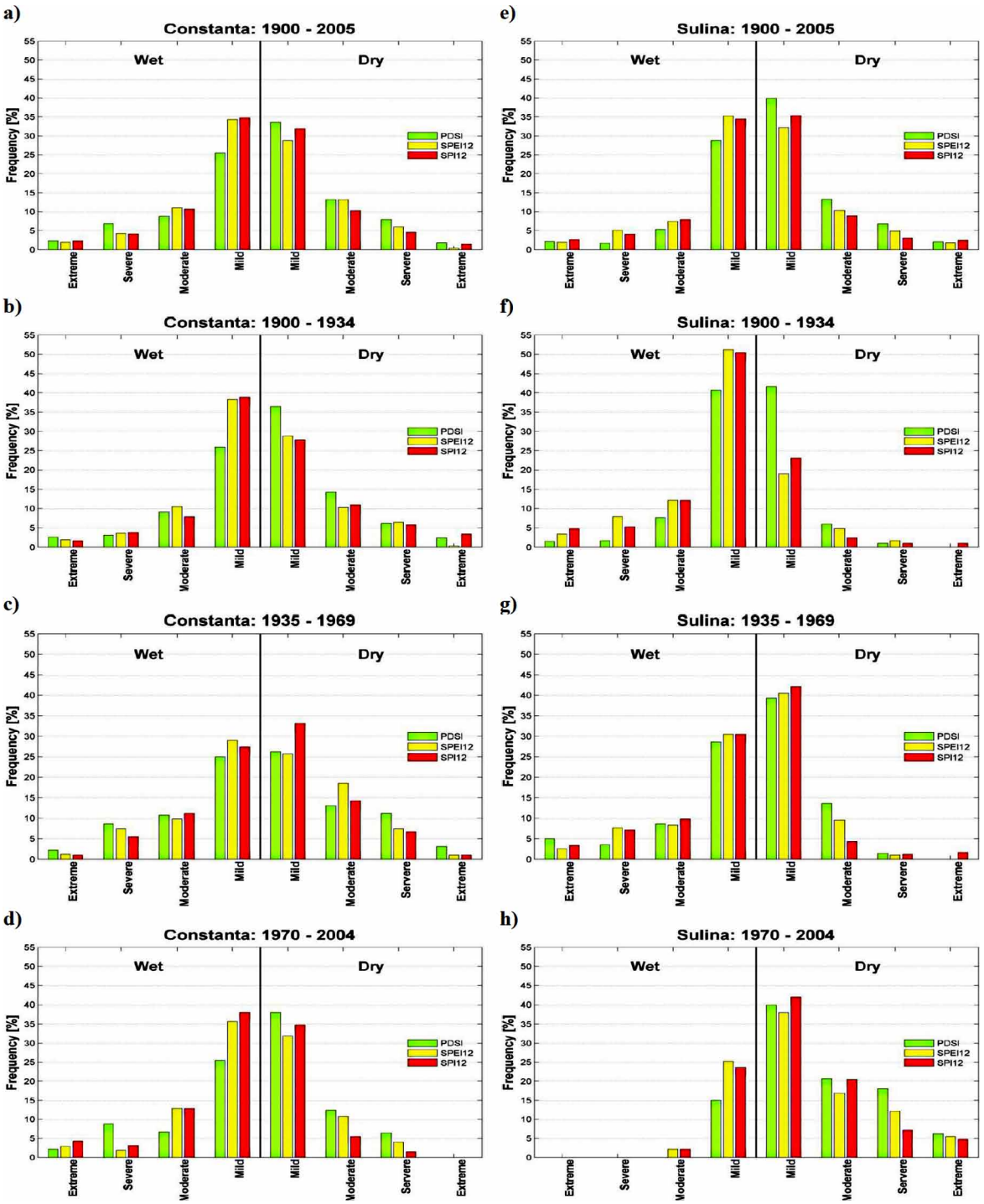
Figure 7. Frequency of time (%) in each dry or wet category of scPDSI, SPEI12 and SPI12 for there different periods at Constanta (left panels) and Sulina (right panels) stations. a) and e) period 1900 – 2005; b) and f) period 1900 – 1934; c) and g) period 1935 – 1969; d) and h) period 1970 – 2000.



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amount for the period 1900 – 1934 is 377.41 mm/year, for the period 1935 – 1969 is 380.89 mm/year, while for the period 1970 – 2004 the annual precipitation amount is 409.62 mm/year, which is even higher compared to the other two periods.

CONCLUSION

In this chapter we have investigated the spatio-temporal variability of seasonal drought variability over Dobrogea region and its relationship with large-scale atmospheric circulation and he North Atlantic SST. The leading modes of variability of SPI3 are definitely season – dependent. Although the spatial structure of the leading modes of seasonal variability of SPI3 may show conformity with each other, the temporal evolution (in terms of principal component time series) differs significantly from one season to another. The analysis of seasonal correlation maps between the principal components time series and seasonal Z850, SST and PET pointed out on a specific and significant role of each of these climatic variables on the seasonal short-term drought variability.

The leading EOFs (EOF1) of the seasonal SPI3 have a monopolar structure, suggesting that a large part of the SPI3 variability is driven by the same mechanisms via the large-scale atmospheric circulation. The first principal component for the winter season is characterized by a strong decadal variability, with a period of approximately 12-14 years. The spring and summer PC1 presents strong interannual variability, while autumn PC1 is characterized also by enhanced decadal to multidecadal variability.

On a seasonal timescale, SPI3 variability is connected to well-known climate modes of variability, namely: AO/NAO. Dry (wet) periods in Dobrogea region are associated with geopotential height anomalies at 850mb that project onto the negative (positive) phase of Arctic/North Atlantic Oscillation. Moreover, the SST anomalies from the Atlantic Ocean realm and potential evapotranspiration anomalies over the south eastern part of Romania play also a significant role on the variability of drought conditions over Dobrogea region. Several studies have established that large-scale SST fluctuations can be linked to atmospheric circulation patterns that produce precipitation fluctuations and streamflow variability (Dai et al., 1997; 2000; Rajagopalan et al., 1998, Gamiz-Fortis et al., 2011; Ionita et al., 2008, 2011, 2012, 2015). Here we show that wet (dry) conditions that prevail over the Dobrogea region are associated with a tripole-like SST pattern in the Atlantic basin characterized by negative (positive) SST anomalies over the eastern coast of U.S. flanked by positive (negative) SST anomalies in the tropical Atlantic Ocean and in the northern part of the Atlantic Ocean. The influence of the potential evapotranspiration anomalies on drought variability was found to be strongest during summer, spring and autumn. PET has little or no effect on drought conditions in winter and this can be due to the fact that during the winter months the soils are either frozen or covered by snow, thus reducing or cancelling the influence of the potential evapotranspiration on the drought conditions.

In conclusion, we have shown that the short-term drought variability over the Dobrogea region is strongly related to large-scale atmospheric patterns and North Atlantic Ocean SST. This kind of analysis can be useful to connect drought variability to climate forcings. A next logical step will be to perform the same analysis for mid-term and long-term drought conditions and identify possible resemblances or differences in the large scale atmospheric patterns responsible for the drought variability at different time scales.

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REFERENCES

Alley, W. M. (1984). The Palmer drought severity index: Limitations and applications. *Journal of Climate and Applied Meteorology*, *23*(7), 1100–1109. doi:10.1175/1520-0450(1984)023<1100:TPDSIL>2.0.CO;2

Barnston, A. G., & Livezey, R. E. (1987). Classification, seasonality and persistence of low frequency atmospheric circulation patterns. *Monthly Weather Review*, *115*(6), 1083–1126. doi:10.1175/1520-0493(1987)115<1083:CSAPOL>2.0.CO;2

Bojariu, R., & Paliu, D. (2001). North Atlantic Oscillation projection on Romanian climate fluctuations in the cold season. In M. Brunet & D. Lopez (Eds.), *Detecting and Modelling Regional Climate Change and Associated Impacts* (pp. 345–356). Springer-Verlag. doi:10.1007/978-3-662-04313-4_29

Briffa, K. R., van der Schrier, G., & Jones, P. D. (2009). Wet and dry summers in Europe since 1750: Evidence of increasing drought. *International Journal of Climatology*, *29*(13), 1894–1900. doi:10.1002/joc.1836

Climate Prediction Centre (CPC). (2005). *Northern hemisphere teleconnection patterns*. (http://www.cpc.ncep.noaa.gov/data/teledoc/telecontents.shtml)

Compo, G. P., Whitaker, J. S., & Sardeshmukh, P. D. (2006). Feasibility of a 100 year reanalysis using only surface pressure data. *Bulletin of the American Meteorological Society*, *87*(2), 175–190. doi:10.1175/BAMS-87-2-175

Compo, G. P., Whitaker, J. S., Sardeshmukh, P. D., Matsui, N., Allan, R. J., Yin, X., ... Worley, S. J. (2011). The Twentieth Century Reanalysis Project. *Quarterly Journal of the Royal Meteorological Society*, *137*(654), 1–28. doi:10.1002/qj.776

Dai, A. (2011b). Characteristics and trends in various forms of the Palmer Drought Severity Index during 1900–2008. *Journal of Geophysical Research*, *116*(D12), D12115. doi:10.1029/2010JD015541

Dai, A., Trenberth, K. E., & Qian, T. (2004). A global dataset of Palmer drought severity index for 1870–2002: Relationship with soil moisture and effects of surface warming. *Journal of Hydrometeorology*, *5*(6), 1117–1130. doi:10.1175/JHM-386.1

Dai, A. G., Fung, I. Y., & DelGenio, A. D. (1997). Surface observed global land precipitation variations during 1900-1988. *Journal of Climate*, *10*(11), 2943–2962. doi:10.1175/1520-0442(1997)010<2943:SOGLPV>2.0.CO;2

Deser, C. (2000). On the teleconnectivity of the "Arctic Oscillation". *Geophysical Research Letters*, *27*(6), 779–782. doi:10.1029/1999GL010945

Dima, M., Rimbu, N., Stefan, S., & Dima, I. (2001). Quasi-decadal variability in the Atlantic Basin involving tropics-midlatitudes and ocean–atmosphere interactions. *Journal of Climate*, *14*(5), 823–832. doi:10.1175/1520-0442(2001)014<0823:QDVITA>2.0.CO;2

Edwards, D. C., & McKee, T. B. (1997). Characteristics of 20th century drought in the United States at multiple time scales. *Climatology Report No. 97-2*, Colorado State Univ., Ft. Collins, CO.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

EEA (European Environmental Agency). (2001). *Sustainable water use in Europe. Part 3: Extreme hydrological events: floods and droughts*. Environmental Issue Report No. 21.

Estrela, M. J., Penarrocha, D., & Millan, M. (2000). Multi-annual drought episodes in the Mediterranean (Valencia region) from 1950–1996. A spatio-temporal analysis. *International Journal of Climatology*, *20*, 1599–1618. doi:10.1002/1097-0088(20001115)20:13<1599::AID-JOC559>3.0.CO;2-Q

Farago, T., Kozma, E., & Nemes, C. (1989). Drought indices in meteorology. *Idojaras*, *93*(1), 45–59.

Gámiz-Fortis, S. R., Hidalgo-Muñoz, J. M., Argüeso, D., Esteban-Parra, M. J., & Castro-Díez, Y. (2011). Spatio-temporal variability in Ebro river basin (NE Spain): Global SST as potential source of predictability on decadal time scales. *Journal of Hydrometeorology*, *409*(3-4), 759–775. doi:10.1016/j.jhydrol.2011.09.014

Guttman, N. B. (1998). Comparing the Palmer drought severity index and the standardized precipitation index. *Journal of the American Water Resources Association*, *34*(1), 113–121. doi:10.1111/j.1752-1688.1998.tb05964.x

Guttman, N. B. (1999). Accepting the Standardized Precipitation Index: A calculation algorithm. *Journal of the American Water Resources Association*, *35*(2), 311–322. doi:10.1111/j.1752-1688.1999.tb03592.x

Harris, I., Jones, P. D., Osborn, T. J., & Lister, D. H. (2013). Updated high-resolution grids of monthly climatic observations. In press. *International Journal of Climatology*. doi:10.1002/joc.3711

Heim, R. R. (2002). A review of twentieth-century drought indices used in the United States. *Bulletin of the American Meteorological Society*, *83*(8), 1149–1165. doi:10.1175/1520-0477(2002)083<1149:AROTDI>2.3.CO;2

Hurrell, J. W. (1995). Decadal trends in the North Atlantic Oscillation: Regional temperatures and precipitation. *Science*, *269*(5224), 676–679. doi:10.1126cience.269.5224.676 PMID:17758812

Hurrell, J. W. (2003). The North Atlantic Oscillation: Climatic significance and environmental effect. *EOS*, *84*(8), 73. doi:10.1029/2003EO080005

Ionita, M., Boroneant, C., & Chelcea, S. (2015). (accepted). Seasonal modes of dryness and wetness variability over Europe and their connections with large scale atmospheric circulation and global sea surface temperature. *Climate Dynamics*. doi:10.100700382-015-2508-2

Ionita, M., Lohmann, G., & Rimbu, N. (2008). Prediction of Elbe discharge based on stable teleconnections with winter global temperature and precipitation. *Journal of Climate*, *21*(23), 6215–6226. doi:10.1175/2008JCLI2248.1

Ionita, M., Lohmann, G., Rimbu, N., & Chelcea, S. (2012b). Interannual Variability of Rhine River Streamflow and Its Relationship with Large-Scale Anomaly Patterns in Spring and Autumn. *Journal of Hydrometeorology*, *13*(1), 172–188. doi:10.1175/JHM-D-11-063.1

Ionita, M., Lohmann, G., Rimbu, N., Chelcea, S., & Dima, M. (2012a). Interannual to decadal summer drought variability over Europe and its relationship to global sea surface temperature. *Climate Dynamics*, *38*(1–2), 363–377. doi:10.100700382-011-1028-y

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Ionita, M., Rimbu, N., Chelcea, S., & Patrut, S. (2013). Multidecadal variability of summer temperature over Romania and its relation with Atlantic Multidecadal Oscillation. *Theoretical and Applied Climatology*, *113*(1-2), 305–315. doi:10.100700704-012-0786-8

Ionita, M., Rimbu, N., & Lohmann, G. (2011). Decadal variability of the Elbe river streamflow. *International Journal of Climatology*, *31*(1), 22–30. doi:10.1002/joc.2054

Klein Tank, A. M. G., Wijngaard, J. B., Können, G. P., Böhm, R., Demarée, G., Gocheva, A., & Petrovic, P. (2002). Daily dataset of 20th-century surface air temperature and precipitation series for the European Climate Assessment. *International Journal of Climatology*, *22*, 1441–1453. doi:10.1002/joc.773

Koleva, E., & Alexandrov, V. (2008). Drought in the Bulgarian low regions during the 20th century. *Theoretical and Applied Climatology*, *92*(1-2), 13–120. doi:10.100700704-007-0297-1

Livada, I., & Assimakopoulos, V. D. (2007). Spatial and temporal analysis of drought in Greece using the Standardized Precipitation Index (SPI). *Theoretical and Applied Climatology*, *89*(3-4), 143–153. doi:10.100700704-005-0227-z

Lloyd-Hughes, B., & Saunders, M. A. (2002). A drought climatology for Europe. *International Journal of Climatology*, *22*(13), 1571–1592. doi:10.1002/joc.846

Maftei, C., & Barbulescu, A. (2008). Statistical analysis of climate evolution in Dobrudja region. In *Proceedings of the World Congress on Engineering*. London, U.K.

Maracchi, G. (2000). Agricultural drought – a practical approach to definition, assessment and mitigation strategies. In J. V. Vogt & F. Somma (Eds.), *Drought and drought mitigation in Europe. Advances in Natural and Technological Hazards Research* (Vol. 14, pp. 63–75). Kluwer Academic Publishers. doi:10.1007/978-94-015-9472-1_5

McKee, T. B., Doesken, N. J., & Kleist, J. (1995). Drought monitoring with multiple time scales. In *Proceedings of the Ninth Conference on Applied Climatology*, American Meteorological Society, 233-236, Dallas, TX.

McKee, T. B. N., Doesken, J., & Kleist, J. (1993). The relationship of drought frequency and duration to time scales. In *Proceedings of the Eight Conference on Applied Climatology*, American Meteor Society, 179–184, Anaheim, CA.

Palmer, W. C. (1965). Meteorological Drought. Res. Paper No. 45: Weather Bureau Washington D.C., 58 pp.

Ped, D. A. (1975). On parameters of drought and humidity. *Papers of the USSSR hydrometeorological center 156*, 19–38 (in Russian).

Quadrelli, R., & Wallace, J. M. (2004). A simplified linear framework for interpreting patterns of Northern Hemisphere wintertime climate variability. *Journal of Climate*, *17*(19), 3728–3744. doi:10.1175/1520-0442(2004)017<3728:ASLFFI>2.0.CO;2

Rajagopalan, B., Kushnir, Y., & Tourre, Y. M. (1998). Observed decadal midlatitude and tropical Atlantic climate variability. *Geophysical Research Letters*, *25*(21), 3967–3970. doi:10.1029/1998GL900065

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Rayner, N. A., Parker, D. E., Horton, E. B., Folland, C. K., & Alexander, L.V., Rowell, … Kaplan, A. (. (2003). Globally complete analyses of sea surface temperature, sea ice and night marine air temperature, 1871-2000. *Journal of Geophysical Research*, *108*, 4407. doi:10.1029/2002JD002670

Thornthwaite, C. W. (1948). An approach toward a rational classification of climate. *Geographical Review*, *38*(1), 55–94. doi:10.2307/210739

Tomozeiu, R., Busuioc, A., & Stefan, S. (2002). Changes in seasonal mean of maximum air temperature in Romania and their connection with large-scale circulation. *International Journal of Climatology*, *22*(10), 1181–1196. doi:10.1002/joc.785

Tomozeiu, R., Stefan, S., & Busuioc, A. (2005). Winter precipitation variability and large-scale circulation patterns in Romania. *Theoretical and Applied Climatology*, doi:10.1007/s00704-004-0082-3.

Trenberth, K. E., Hurrell, J. W., & Stepaniak, D. P. (2005b). The Asian Monsoon: Global Perspectives. In B. Wang (Ed.), Asian Monsoon (pp. 67-87 and color section 9-19), ISBN 35040406107. Praxis publishing Ltd.

Trnka, M., Kysely, J., Možný, M., & Dubrovský, M. (2009a). Changes in Central-European soil-moisture availability and circulation patterns in 1881–2005. *International Journal of Climatology*, *29*(5), 655–672. doi:10.1002/joc.1703

Vicente-Serrano, S. M., Beguería, S., & López-Moreno, J. I. (2010). A multi-scalar drought index sensitive to global warming: The Standardized Precipitation Evapotranspiration Index - SPEI. *Journal of Climate*, *23*(7), 1696–1718. doi:10.1175/2009JCLI2909.1

Vicente-Serrano, S. M., López-Moreno, J. I., Drumond, A., Gimeno, L., Nieto, R., Morán-Tejeda, E., ... Zabalza, J. (2011). Effects of warming processes on droughts and water resources in the NW Iberian Peninsula (1930–2006). *Climate Research*, *48*(2), 203–212. doi:10.3354/cr01002

von Storch, H., & Zwiers, F. W. (1999). *Statistical Analysis in Climate Research*. Cambridge University Press.

Walker, G. T., & Bliss, E. W. (1932). World Weather V. *Memoirs of the Royal Meteorological Society*, *4*(36), 53–84.

Wallace, J. M., & Gutzler, D. S. (1981). Teleconnections in the geopotential height field during the Northern Hemisphere winter. *Monthly Weather Review*, *109*(4), 784–812. doi:10.1175/1520-0493(1981)109<0784:TITGHF>2.0.CO;2

Weber, L., & Nkemdirim, L. C. (1998). The Palmer drought severity index revisited. *Geografiska Annaler*, *80A*(2), 153–172. doi:10.1111/1468-0459.00033

Wells, N., Goddard, S., & Hayes, M. J. (2004). A self-calibrating Palmer Drought Severity Index. *Journal of Climate*, *17*(12), 2335–2351. doi:10.1175/1520-0442(2004)017<2335:ASPDSI>2.0.CO;2

Whitaker, J. S., Compo, G. P., Wei, X., & Hamill, T. M. (2004). Reanalysis without radiosondes using ensemble data assimilation. *Monthly Weather Review*, *132*(5), 1190–1200. doi:10.1175/1520-0493(2004)132<1190:RWRUED>2.0.CO;2

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Wilhite, D. A. (Ed.). (2000). Drought: A Global Assessment (2 volumes, 51 chapters, 700 pages). Hazards and Disasters: A Series of Definitive Major Works (7-volume series), edited by A.Z. Keller: Routledge Publishers, London, U.K.

Wilhite, D. A., & Glantz, M. H. (1985). Understanding the drought phenomenon: The role of definitions. *Water International*, *10*(3), 111–120. doi:10.1080/02508068508686328

Wilhite, D. A., Sivakumar, M. V. K., & Wood, D. A. (2000). *Drought early warning systems in the context of drought preparedness and mitigation*. World Meteorological Organization.

World Meteorological Organization (WMO). (1975). Drought and agriculture. WMO/TN, 138, Geneva, 118 pp.

KEY TERMS AND DEFINITIONS

Drought: A recurrent feature of the climate which occurs in virtually all climatic zones.

Dry Period: A dry period implies below normal precipitation anomalies or discharge.

Empirical Orthogonal Function Analysis (EOF): Represents an efficient method to investigate the spatial and temporal variability of time series which cover large areas.

Teleconnection Patterns: A recurring and persistent, large-scale pattern of pressure and circulation anomalies that spans vast geographical areas. Teleconnection patterns are also referred to as preferred modes of low-frequency (or long time scale) variability.

The North Atlantic Oscillation (NAO): One of the most prominent teleconnection patterns in all seasons, characterized by a north-south dipole of anomalies, with one center located over Greenland and the other center of opposite sign spanning the central latitudes of the North Atlantic.

The Standardized Precipitation and Evapotranspiration Index (SPEI): A meteorological drought indicator which is based on monthly precipitation totals and temperature means.

The Standardized Precipitation Index (SPI): A meteorological drought indicator which is based just on precipitation data.

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Chapter 28
The Role of Mobile Phones Use on Agricultural Output and Household Income in Rural Rwanda

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ABSTRACT

This paper assesses the role information and communication technology (ICT) on agricultural output and household welfare of smallholder farmers. The data used in this study comes from a household survey carried out in Nyabihu District, one densely populated area of rural Rwanda. The findings suggest substantial impact of cellular phones technology adoption by farm households. Using the propensity score matching technique, the author finds that agricultural output for mobile phone users is at least 38 percent higher than non-users, whereas their income levels are 26 percent higher on average. The provision of network infrastructure and electricity at community level will enhance agricultural and rural development through increased adoptions of telecommunication technology by smallholder farmers.

1. INTRODUCTION

The rationale of this section is to investigate the impact of Information and Communication Technologies (ICTs) on agricultural output and income levels. Today, ICTs are meant to include equipment that facilitates capturing, processing, display, and transmission of information such as computers (and their accessories), telecommunication equipment (and related services), and audio visual equipment and services. In the context of this study, we consider telephony (the use of cellular phones by farm households) as a proxy of ICTs adoptions due to its outstanding role to facilitate improved access to information and communication on one hand, and to play as prerequisite to advanced technologies use such as internet on the other (Torero & von Braun, 2006).

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Studies have stressed the leading role of ICTs in economic growth and development at both the micro and macro levels. ICT has become a foundation of every sector of every economy around the world because of its multifaceted role in expanding economic opportunities such as reduction of transaction costs and productivity increase, enhancing a flow of information, increasing choice in market place and widening the geographical scope and others (Kramer, Jenkins, & Katz, 2007). Goyal (2013) proved that ICTs can make difference by closing information gaps, and by empowering smallholders and improve market opportunities of farmers. According to von Braun (2010), ICTs may impact the livelihoods of the poor by increasing their access to markets, improving the quality of public goods and services provision, improving human resources quality, and facilitating effective utilization of social networks.

More specifically, cellular telephone technologies are believed to boost economic growth through job creation, increased agricultural and industrial productivity, and diffusion of innovation among farmers. However, much more skeptical views in respect to benefits of ICTs for the poor have emerged. They postulate that access to (or adoption of) ICTs is itself driven by a number of factors such as education, income, and wealth; consequently, the shortage or lack of the above resources may prevent the poor from ICTs adoptions, widening information gap and increasing income disparities within and between countries (Torero & von Braun, 2006; von Braun, 2010).

Recent statistics show that more than 45 percent of Rwandan households use mobile phone technology in their daily activities (NISR, 2012). The Government of Rwanda believes that ICTs can open doors to more economic opportunities for rural poor; efforts have been put in ICT investments over the past decade. The e-Rwanda Project funded by World Bank and implemented by the Rwanda Information Technology Authority intends to empower rural farmers and enable a full access to information about market prices and successful farming. With a network coverage of about 80 percent of the whole territory, even farmers from very remote areas can use their mobile phone devices to check on agricultural commodity prices and can take better price decisions concerning their produce.

However, though much is said about the role that mobile phones can play in agricultural development in Rwanda, no attempt was made to measure the extent at which this technology has impacted the level of output, fertilizer use, and household income among smallholders. This study contributes to the existing literature by measuring the impact of mobile phone use on agricultural output and household income in small scale farmers in Rwanda. In the following subsections, we consecutively present the ICT strategy in Rwanda, the relevant literature, empirical strategy, data description, results, and subsequent interpretations.

2. RWANDAN ICT STRATEGIES

The institutions and mechanisms to create an enabling environment for ICT development in Rwanda were established in 2000. Today, the most prevalent technologies in Rwanda are internet services, mobile applications, outsourcing, information security, clouds computing, and green ICT that aims at creating awareness on increasing environmental regulation. The National ICT strategies are adopted and implemented in four five-year phases under the "National Information Communication Infrastructure (NICI)" designation and coincide with the main policy document "Vision 2020". The NICI I (or NICI-2005 Plan) was adopted in 2001 and its main focus was to create an enabling environment to the growth of ICT sector in Rwanda through establishment of sound institutional and legal framework. The second

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phase of ICT strategy (NICI II or NICI-2010) was adopted in 2006 and aimed at providing outstanding infrastructures that will support the future of ICT requirements (Rwanda, 2011).

The current phase of the strategy (NICI III or NICI-2015 plan) was adopted in 2011 and is being implemented with a special emphasis to improve ICT service delivery to the citizens. More specifically, as a pre-final phase of the ICT strategy that will drive the country towards its vision 2020, NICI III targets high skill and knowledge based-ICT, ICT enabled private sector development, E-Government, and cyber security.

In order to accomplish these missions, the government of Rwanda has set a number attainable objectives that include capacity building in ICTs and enabling improved access to education and training, fostering innovation through research and development, developing a private-led competitive ICT sector, create ICT awareness in communities, and increased citizen participation and access to services through ICT-enhanced systems. In addition, through the NICI-2015 plan, the government intends to increase transparency and accountability through ICT, establish a legal environment enabling easy adaptation to emerging technologies, and ensure total protection of Rwanda's ICT infrastructures and systems against cyber-attacks. From these missions and objectives, a number of implementable projects have been designed and some being in their execution phases (Rwanda, 2011).

NICI-2015 is being implemented under a strong multi-stakeholder framework in which the Rwanda Development Board (RDB) is designated as coordinating and implementing agency of all ICT related initiatives. The strategic directions are provided by the National Steering Committee chaired by the Ministry in charge of ICT (MINICT). Through this partnership, Rwanda believes to obtain important and quantifiable measures of ICT contributions to the GDP.

3. RELEVANT LITERATURE

A number of studies have emerged over the last decade on the relevance of mobile phones use on economic welfare in developing countries. Aker (2010) found that the expansion on network coverage accompanied by intensive use of mobile phone use by local traders in Niger have significantly reduced market disparities and improved market performance. It is believed that mobile phone adoption in Sub-Saharan countries have positive impact on agriculture and labor market efficiency even though empirical evidences on this matter are still thin (Aker, 2008; Aker & Mbiti, 2010).

Mittal, Gandhi, and Tripathi (2010) found that farmers use mobile phones as means of communication to check on the availability of inputs and market prices, resulting in higher crop yields because of better adjustment of supply to market demand. Similar effects have been observed on fishermen who registered a decrease in losses due to full market information. Mwakaje (2010) analyses the impact of access to ICT, including radios, telephone, internet and newspapers by rural farmers from Rungwe village in Tanzania and found that farmers who used mobile phones in their activities have sold more quantities and at better prices than others.

However, the same study pointed out that access to ICT facilities is constrained by the lack of money income and electricity. Evidence from Uganda confirmed the mobile network expansion enhanced market participation for producers of perishable products such as banana (Muto & Yamano, 2009). Regarding the determinants of mobile phone adoption, Muto and Yamano (2009) found that the age of the household head, the level of education of both male and female adults, and farm asset values are the most important determinants of mobile phone acquisition in Uganda. Younger household heads are likely to

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adopt the mobile phone technology, and this also increases by the level of education and household assets. Evidence from Rwanda showed that mobile phone ownership is associated with wealth, education, and gender (Blumenstock & Eagle, 2010).

Okello, Kirui, Njiraini, and Gitonga (2011) analyzed the drivers of ICT use by smallholder farmers in Kenya, and found that mobile phone adoption is driven by farm and farmer characteristics, capital endowment and regional characteristics. Other things being equal, the use of mobile phones is positively correlated to the male headship, household fare, education, income, and assets and negatively correlated with the family size and age of the household head. Kirui, Okello, and Nyikal (2012a) found that the use of mobile phone-based money transfer services in Kenya has impacted agricultural production among smallholder farmers because farmers use the remitted funds to purchase inputs, equipment and to pay hired labor.

Houghton (2009) analyzed the impact of mobile phone use on agricultural productivity in selected developing nations using a two-stage regression model. The micro-data results showed that mobile phone ownership significantly increase agricultural productivity at household level in Swaziland, Cambodia, and Honduras. In their study on mobile phone and economic development in rural Peru, Beuermann, McKelvey, and Vakis (2012) found that the use of mobile phone has significantly contributed to household income consumption, and reduced extreme poverty by five percent in the area during the study period. The use of mobile phone by smallholder farmers in Oyo State in Nigeria (Bolarinwa & Oyeyinka, 2011) have enhanced a full time access to extension services and increased agricultural output more than non-mobile phone users. Chong, Galdo, and Torero (2009) also confirmed that the level of income per capita was higher for households with access to telephone services.

4. EMPIRICAL STRATEGY

Measuring the impacts of ICTs on rural households' welfare can be done through different methodologies. The frequently used techniques are compensating variations, willingness to pay, consumption functions, and matching (von Braun, 2010). To analyze the impact of mobile phone on outcomes such as agricultural output, fertilizer use and household income, we start from a linear function:

$$Y_i=\beta_0+\beta_1 X_i'+\beta_2 M_i+\varepsilon_I \quad (1)$$

where Y_i is agricultural output, X_i is vector of inputs, M_i is a binary variable representing one if the household owned a mobile phone during the past 12 months, and zero otherwise; βi are unknown parameters to be estimated.

Even though mobile ownership from the equation (1) is treated as exogenous, it may also happen that households with higher agricultural output and income are likely to own mobile phone. Then mobile phone ownership is not random and estimation of this equation by simple OLS will yield biased estimates. As pointed out by Owusu, Abdulai, and Abdul-Rahman (2011) the Heckman two-steps procedure has been used in many applications to correct the selectivity bias but it relies on restrictive normality assumptions. The instrumental variable (IV) technique as a second alternative is more demanding when it comes to find a good instrument and reveal itself difficult to apply.

To solve the selectivity bias associated with mobile phone ownership, we employ the propensity score matching (PSM) developed by Rosenbaum and Rubin (1983). Compared to the techniques described

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above, the PSM requires no assumptions about the functional form in specifying the relationship between outcome and outcome predictors (Ali & Abdulai, 2010; Owusu et al., 2011). As a non-experimental method, the PSM is judged suitable to a non-randomness of mobile phone adoption in our sample (Abebaw & Haile, 2013; Spreeuwenberg et al., 2010) and we will employ statistical matches to address the self-selection problem. The idea behind the PSM is to identify non-adopters of mobile phones who are similar to adopters in their observed characteristics; and the first step is to estimate by Logit model, the propensity score or the predicted probability that a farm household own a mobile phone such that:

$$P(Z_i) = \text{Prob}(M_i=1 \mid Z_i), \tag{2}$$

where M_i=1 if the household own a mobile phone, and M_i=0 otherwise; Z_i is a vector of observed personal, household and farm characteristics susceptible to influence mobile phone adoption. The next step of the PSM consists of selecting the best matching estimator which does not eliminate too many of the original observations in the final matching and try to provide equal covariate means for households in the treatment and control groups (Austin, 2009; Caliendo & Kopeinig, 2008).

Our principal concern is to answer the following question: "What would be the level of agricultural output, and household income in case the households had adopted mobile phone technology?" To answer this question, we will use the predicted propensity score from equation (4.29) to estimate the treatment effects. Following Ali and Abdulai (2010), Abebaw and Haile (2013); Owusu et al. (2011), the average treatment of the treated (ATT), which is in our case the average impact of mobile phone adoption on agricultural output, fertilizer use and income, is given by:

$$\begin{aligned} ATT &= E\left(Y_{1i}^k - Y_{0i}^k M_i = 1\right) = E\left[E\left\{Y_{1i}^k - Y_{0i}^k M_i = 1, P\left(Z_i\right)\right\}\right] \\ &= E\left[E\left\{Y_{1i}^k M_i = 1, P\left(Z_i\right)\right\} - E\left\{Y_{0i}^k M_i = 0, P\left(Z_i\right)\right\}\right] \end{aligned} \tag{3}$$

where Y_1 and Y_0 are the values of treatment variables of mobile phone adopters and non-adopters respectively; *i* stands for household; *k* refers to outcome variables being analyzed such as output, and household income.

The PSM is hereby employed as a probability that a farmer adopts mobile phone technology given pre-adoption socio-economic characteristics. In the absence of experimental data, the PSM technique uses the conditional independence assumption (Burke, Jayne, Freeman, & Kristjanson) to create the conditions of randomized experiment (Ali & Abdulai, 2010). This means that mobile phone technology adoption is random and uncorrelated with the outcome variables if Zi are controlled for (Imbens & Woodridge, 2009).

The literature suggests a number of algorithms the adopters and non-adopters of mobile phone technology with similar propensity score. The most widely used include the nearest neighbor matching which attempts to match close adopters with the closest non-adopter with similar characteristics, caliper matching which uses the nearest neighbor within each maximum propensity score, and the kernel matching method which try to use more non adopters for each adopter in order to reduce variance (Kirui, Okello, & Nyikal, 2012b; Owusu et al., 2011).

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However, a hidden bias may arise when the matching estimator is not robust (Rosenbaum, 2002). This problem is solved by controlling a large number of covariates to minimize the omitted variable bias; the sensitivity analysis is conducted to check the robustness of our estimates to hidden bias.

5. DATA DESCRIPTION

The data used in this section are derived from household surveys conducted in 364 households randomly selected from five sectors of the Nyabihu district in 2012. The area was selected as the most densely populated rural district of Rwanda as per the 2012 population census. About 49 percent were using mobile phones at least 12 months before our visit in 2012, and they were principally households with relatively younger heads. Table 1 compares the means of key characteristics of mobile phone adopters and no adopters. Mobile phone adopters work more outside the farm than non-adopters on average, and are relatively richer.

The levels of household asset, income, and output of mobile phone users are significantly higher than those of non-users. In addition, the summary statistics show that mobile phone users are more educated (5.5 years of schooling) than non-users (4.2 years). This may be due to the fact that the manipulation of mobile phone device requires basic knowledge of at least one foreign language (English or French); this limits the less educated people from adopting such technologies in rural area. The latter prefer use public phone services where dealers operate the devices on their behalf. Besides, statistics show that male headed households are more likely to use mobile phone technology in agriculture than female-headed households.

6. EMPIRICAL RESULTS AND DISCUSSION

As mentioned earlier, the point of departure to implement the propensity score technique is to calculate the propensity scores through a Probit or a Logit estimation of the treatment variable on control variables.

Table 1. Descriptive statistics of sample households by mobile phone adoption

Variable	Non adopters (51 percent)	Adopters (49 percent)	t-value for mean difference
Age of the head	46.72	41.73	3.07***
Gender (% male)	75	82	-1.57
Off-farm job (1=yes)	43.5	56.2	-2.42**
Institutional membership (1=yes)	68.8	71.3	-0.52
Farm size in hectares	0.40	0.46	-0.95
Assets in Rwandan francs (current)	193,836	289,610	-2.95***
Education	4.2	5.5	-4.46***
Output value (current Rwf)	125,578	207,916	-2.69***
Household income (expenditure)	289,207	409,808	-4.01***

* p<0.10, ** p<0.05, *** p<0.01

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Table 2 below presents the Logistic results on the determinants of mobile phone adoption at the household level. The age of household head, household assets, and the head level of education are important factors to enhance mobile phone use in the study area. Other things being equal, older household heads will reduce the log odds of adoption of mobile phone use by 0.017.

However, there is a positive correlation between asset value and mobile phone use on one hand, and a significant positive relationship between education level of the head and the probability of mobile phone adoption on the other hand.

Results from matching presented in Table 3 indicate that mobile phone services have a positive and significant impact on agricultural output value and household income (here household expenditure stands as income proxy). Both Kernel-based and radius or caliper matching algorithms indicate that the level of agricultural output value is 38-43 percent higher for mobile phone users than their counterparts, while the level of household income is 26-27 percent higher for mobile phone users. These results are expected since farmers who use mobile phone are likely to have access to information and stay informed on the availability of inputs and markets prices or both inputs and output. They can also get easy access to extension services more than non-users, which enable smoothness in production activities. With full information on prices, farmers know the best options to sell their produce and maximize profits from their agricultural crops; hence, their agricultural income is higher.

Table 2. Logit results of household level determinants of mobile phone adoption

Variable	Coefficients	Robust Standard Errors
Age of the head	-0.017**	0.008**
Gender (1= male)	-0.139	0.313
Off-farm job (1=yes)	0.096	0.244
Institutional membership (1=yes)	0.034	0.251
Farm size in hectares (log)	0.048	0.116
Assets in Rwandan francs(log)	0.215**	0.101**
Education	0.105**	0.042**
Constant	-2.199*	1.294*
Number of observations	332	
Wald chi2	24.80	Prob>chi2: 0.0008
Pseudo R-squared	0.0613	LR=-215.97

Table 3. Impact of mobile phone use on output and income

Matching algorithm	Outcome indicator	Treated (N=163)	Control (N=169)	ATT T-statistics (.)	Critical value of hidden bias
Kernel-based matching	Output value	201,348	145,919	55,429* (1.66)	1.52-1.53
	Household income	419,680	333,801	85,878***(2.70)	1.16-1.17
Radius matching	Output value	201,348	141,680	60,135* (1.80)	1.41-1.42
	Household income	419,680	329,251	90,429***(2.86)	1.22-2.23

*, **, and *** indicate the statistical significance at 10, 5, and 1 percent, respectively. T-values are indicated between brackets; ATT is the average treatment effect of the treated.

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We tested the conditional independence assumption (CA) after propensity score matching. Table 3 indicates a substantial reduction bias in propensity score covariates after matching (more than 50 percent in each). Except for the education level of the head, the mean differences on covariates between the mobile phone users (treated) and non-users (control) after matching were not statistically different. Figure 1 shows that the mobile phone users and non-users were within the region of common support, indicating that all treated households (mobile phone users) have got corresponding untreated households (non-mobile phone users) with similar characteristics. The quality of matching is judged good as all individuals could be successfully matched and the bias reduction is far above the threshold of 20 percent (Rosenbaum & Rubin, 1983).

The sensitivity analysis results also presented in the last column of Table 3 indicate that our propensity score matching results on output value are more robust to hidden bias than household income. The critical level of gamma (Γ), at which the causal inference of significant impact of use of mobile phone may be questionable is comprised between 1.52 and 1.53, meaning the significance of average treatment effect for output would be questionable only if the odds of mobile phone adoption for two households with similar characteristics differ by the factor of 53 percent. Likewise, the significance of average treatment effect on household income will be questionable if the odds of mobile phone use between two households with the same vector of characteristics differ by the factor of 23 percent. Across two different matching algorithms, the lowest critical value on output ATT is 1.41 and the highest is 1.53 while for household income ATT, the small critical value is 1.16 and the highest is 1.23.

The results suggest that a large amount of hidden heterogeneity will not alter the inference about the estimated treatment effects on output, while the treatment effects on household income are sensible to large amounts of hidden bias.

However, Ali and Abdulai (2010) pointed out that the main purpose of the propensity score matching is to balance the distribution of relevant variables between the groups (here mobile phone uses and non-users) rather than obtaining a precise prediction of selection into treatment. In this regards, the overall indicators of matching before and after matching presented in table 4 confirmed the results presented above that the large absolute mean reduction was obtained after matching indicating the balancing power of our estimates.

The pseudo R-squared is lower after matching and the likelihood ratio tests before and after matching indicate that the joint significance of regressors is always rejected after matching, while it couldn't be rejected before. We conclude that for the two outcomes of interest (output value and household income), there is no systematic difference in covariate distribution between mobile phone users and non-users after matching.

7. CONCLUSION

The paper investigated the role of ICT as a driver of agricultural output, with a focus on the recently cellular phone adoption by smallholder farmers. Our findings suggest that households using mobile phones in their daily activities have performed better on than farm than non-users. Cellular phone adopters achieved 38 and 26 percent more of agricultural output and household income respectively. However, access to mobile phone is itself driven by education level of the household head and household wealth. Relatively

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Table 4. Test of matching quality of covariates

Variable	Unmatched/ Matched	Mean		%bias	% reduction bias	t-test
		Treated	Control			
Head age	Unmatched	42.12	47.91	-35.5		-3.23***
	Matched	42.12	43.01	-5.2	85.3	1.46
Gender	Unmatched	0.82	0.75	18.6		1.69*
	Matched	0.82	0.80	4.2	77.6	-0.88
Off-farm job	Unmatched	0.56	0.45	23.0		2.10**
	Matched	0.56	0.53	6.3	72.8	-1.13
Institutional membership	Unmatched	0.72	0.67	10.7		0.98
	Matched	0.72	0.73	-1.8	83.2	-0.38
Log asset	Unmatched	11.94	11.43	38.7		3.52***
	Matched	11.94	11.79	11.4	70.5	-1.43
Log land	Unmatched	-1.34	-1.49	13.6		1.24
	Matched	-1.34	-1.41	6.7	50.9	-0.48
Education	Unmatched	5.41	4.09	45.4		4.14 ***
	Matched	5.41	5.06	12.3	73.0	-1.97**

*, **, and *** indicate the statistical significance at 10, 5, and 1 percent, respectively. Results presented in this table are based on Kernel-based matching algorithm

Figure 1. Distribution of propensity score

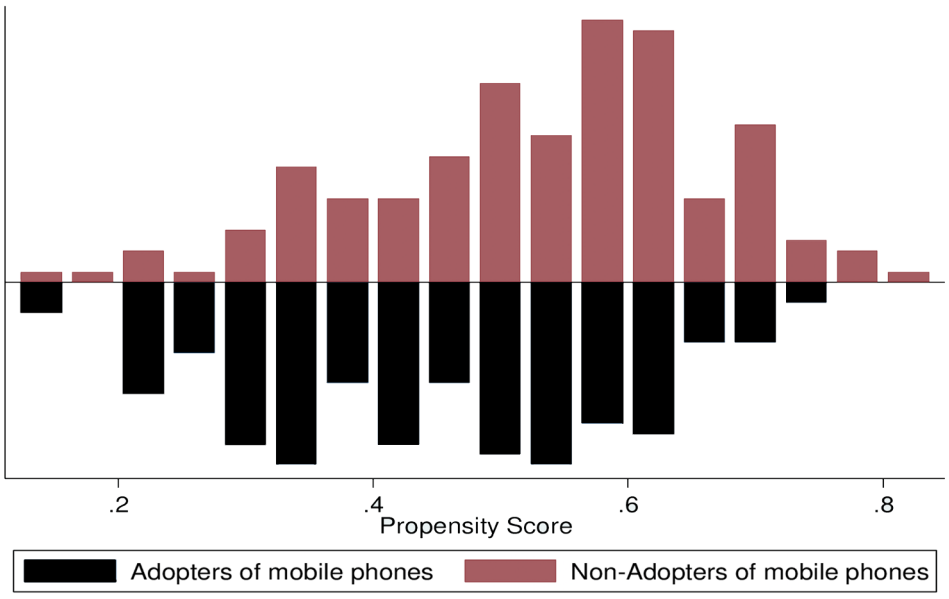

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Table 5. Indicators of matching quality before matching and after matching

Matching algorithm	Outcome	Mean absolute bias (unmatched)	Mean absolute bias (matched)	Absolute bias reduction (%)	Pseudo R2 (unmatched)	PseudoR2 (matched)	LR p-value (unmatched)	LR p-value (matched)
KBM	Output	26.2	8.3	68.3	0.061	0.015	0.000	0.454
	Income	28.2	9.8	65.2	0.074	0.027	0.000	0.134
RM	Output	26.2	10.9	58.4	0.064	0.007	0.000	0.924
	Income	28.2	12.4	56	0.074	0.016	0.000	0.521

KBM: Kernel-based matching; RM: Radius matching

richer households are likely to acquire and use mobile phone, other things remaining unchanged. The maximum from ICT will be obtained if not only necessary ICT infrastructure is expanded in rural area, but also if community illiteracy is carefully addressed. More importantly, facilitating access to credit markets will enhance asset acquisition at household level and, hence, provide means to ICT adoptions in rural area.

REFERENCES

Abebaw, D., & Haile, M. G. (2013). The impact of cooperatives on agricultural technology adoption: Empirical evidence from Ethiopia. *Food Policy*, *38*, 82–91. doi:10.1016/j.foodpol.2012.10.003

Aker, J. C. (2008). Does digital divide or provide? The impact of cell phones on grain markets in Niger. Center for Global Development Working Paper 154.

Aker, J. C. (2010). Information from Markets Near and Far: Mobile Phones and Agricultural Markets in Niger. *American Economic Journal. Applied Economics*, *2*(3), 46–59. doi:10.1257/app.2.3.46 PMID:23946866

Aker, J. C., & Mbiti, I. M. (2010). Mobile Phones and Economic Development in Africa. *The Journal of Economic Perspectives*, *24*(3), 207–232. doi:10.1257/jep.24.3.207

Ali, A., & Abdulai, A. (2010). The Adoption of Genetically Modified Cotton and Poverty Reduction in Pakistan. *Journal of Agricultural Economics*, *61*(1), 175–192. doi:10.1111/j.1477-9552.2009.00227.x

Austin, P. C. (2009). Some Methods of Propensity-Score Matching had Superior Performance to Others: Results of an Empirical Investigation and Monte Carlo simulations. *Biometrical Journal. Biometrische Zeitschrift*, *51*(1), 171–184. doi:10.1002/bimj.200810488 PMID:19197955

Beuermann, D., McKelvey, C., & Vakis, R. N. (2012). Mobile phones and economic development in rural Peru. *The Journal of Development Studies*, *48*(11), 1617–1628. doi:10.1080/00220388.2012.709615

Blumenstock, J., & Eagle, N. (2010). Mobile divides: gender, socioeconomic status, and mobile phone use in Rwanda. *Paper presented at the Proceedings of the 4th ACM/IEEE International Conference on Information and Communication Technologies and Development*. 10.1145/2369220.2369225

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Bolarinwa, K. K., & Oyeyinka, R. A. (2011). Use of cell phone by farmers and its implication on farmers' production capacity in Oyo State Nigeria *World Academy of Science*. *Engineering, and Technology*, *51*, 653–658.

Burke, W. J., Jayne, T. S., Freeman, H. A., & Kristjanson, P. (2007). Factors associated with farm households' movement into and out of poverty in Kenya: The rising importance of livestock.

Caliendo, M., & Kopeinig, S. (2008). Some practical guidance for the implementation of propensity score matching. *Journal of Economic Surveys*, *22*(1), 31–72. doi:10.1111/j.1467-6419.2007.00527.x

Chong, A., Galdo, V., & Torero, M. (2009). Access to Telephone Services and Household Income in Poor Rural Areas Using a Quasi-natural Experiment for Peru. *Economica*, *76*(304), 623–648. doi:10.1111/j.1468-0335.2008.00735.x

Goyal, C. S. (2013). Improving Agricultural Productivity and Market Efficiency in Latin America and the Caribbean: How ICTs can make a Difference? *Journal of Reviews on Global Economics*, *2*, 172–182.

Houghton, D. (2009). *Cell Phones and Cattle: The Impact of Mobile Telephony on Agricultural Productivity in Developing Nations*. Durham, NC: Duke University.

Imbens, G. W., & Wooldridge, J. M. (2009). Recent developments in the econometrics of program evaluation. *Journal of Economic Literature (Stanford)*, *47*(1), 5–86. doi:10.1257/jel.47.1.5

Kirui, O., Okello, J. J., & Nyikal, R. A. (2012a). Awareness of Mobile Phone-Based Money Transfer Services in Agriculture by Smallholder Farmers in Kenya. *International Journal of ICT Research and Development in Africa*, *3*(1), 1–13. doi:10.4018/jictrda.2012010101

Kirui, O., Okello, J. J., & Nyikal, R. A. (2012b, August 18-24). Impact of Mobile Phone-based Money Transfer Services in Agriculture: Evidence from Kenya. *Paper presented at the 2012 Conference*, Foz do Iguacu, Brazil.

Kramer, W. J., Jenkins, B., & Katz, R. S. (2007). *The role of the information and communications technology sector in expanding economic opportunity*. Cambridge, MA: Kennedy School of Government, Harvard University.

Mittal, S., Gandhi, S., & Tripathi, G. (2010). *Socio-economic impact of mobile phones on Indian Agriculture*. Indian Council for Research on International Economic Relations New Delhi.

Muto, M., & Yamano, T. (2009). The Impact of Mobile Phone Coverage Expansion on Market Participation: Panel Data Evidence from Uganda. *World Development*, *37*(12), 1887–1896. doi:10.1016/j.worlddev.2009.05.004

Mwakaje, A. G. (2010). Information and communication technology for rural farmers market access in Tanzania. *Journal of Information Technology Impact*, *10*(2), 111–128.

NISR. (2012, 2013). Final report integrated household living conditions survey, 2011. Retrieved from http://books.google.com/books?id=htoDAQAAIAAJ

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Okello, J. J., Kirui, O., Njiraini, G. W., & Gitonga, Z. (2011). Drivers of Use of Information and Communication Technologies by Farm Households: The Case of Smallholder Farmers in Kenya. *The Journal of Agricultural Science*, *4*(2), 111.

Owusu, V., Abdulai, A., & Abdul-Rahman, S. (2011). Non-farm work and food security among farm households in Northern Ghana. *Food Policy*, *36*(2), 108–118. doi:10.1016/j.foodpol.2010.09.002

Rosenbaum, P. R. (2002). *Observational Studies*. New York: Springer. doi:10.1007/978-1-4757-3692-2

Rosenbaum, P. R., & Rubin, D. B. (1983). The central role of the propensity score in observational studies for causal effects. *Biometrika*, *70*(1), 41–55. doi:10.1093/biomet/70.1.41

Rwanda. (2011). *National ICT Strategy and Plan: National Information Communication Infrastructure*.

Spreeuwenberg, M. D., Bartak, A., Croon, M. A., Hagenaars, J. A., Busschbach, J. V., Andrea, H., & Stijnen, T. (2010). The Multiple Propensity Score as Control for Bias in the Comparison of More Than Two Treatment Arms: An Introduction From a Case Study in Mental Health. *Medical Care*, *48*(2), 166–174. doi:10.1097/MLR.0b013e3181c1328f PMID:20068488

Torero, M., & von Braun, J. (2006). *Information and communication technologies for development and poverty reduction: The potential of telecommunications*. Baltimore, MD: Johns Hopkins University Press.

von Braun, J. (2010). *ICT for the poor at large scale: Innovative connections to markets and services ICT for the Next Five Billion People* (pp. 3–14). New York: Springer. doi:10.1007/978-3-642-12225-5_2

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Chapter 29
Mobile Robotics

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ABSTRACT

Mobile robots are increasingly becoming the subject of research and a very important area of science, so that the 21st century will be named as the century of development of service robots. Mobile robots are an excellent "System Engineering" research example because it includes a lot of scientific research, namely in the area of mechanical engineering, electrical engineering, electronics, computer science, social science, and more. As mobile robots perform their tasks in the same environment as humans, mobile robots should have the abilities that people have. The mobile robots should be able to recognize faces, gestures, signs, objects, speech and atmosphere. Successful realization set of tasks results in bypassing obstacles without collision and destruction in the shortest possible time and distance. They should communicate with people on the basis of emotion. The range of mobile robots application is huge. Mobile robots have found application in many areas, but this chapter will cover the following distribution of mobile robots areas of application: medicine, agriculture, defense, logistics, construction, demolition, professional cleaning, space exploration, education and scientific research. The price of robots is declining steadily and they are coming into ever wider use. It is only a matter of time before robots become available to the population of today's high school students, just as it happened with computers and cell phones.

INTRODUCTION

In the early fifties, more precisely in 1951, Raymond Goertz made the first telecom operator – the hand that "dealt" with radioactive material and was developed for the Atomic Energy Commission. The first robot that could be programmed was also made in fifties – in 1954 – and its constructor was George Dovel, who had his methods patented. Two years later, George Dovel and Joseph F. Engelberg started Unimation Inc. company, which was the first company to deal with robots. In the sixties, precisely in 1962, the first robot was installed on the production line of the General Motors Company. The first robot arm controlled by computer was made a year later in the Los Amigos Hospital in California. Also, 1964

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was a significant year when it comes to education in robotics. In fact, Artificial Intelligence (AI) research laboratories were opened at MIT, Stanford Research Institute, Stanford University, and the University of Edinburgh. Japan, which is among the leading countries engaged in robots manufacturing nowadays, imported its first robot from the United States. In 1968, Kawasaki Heavy Industries Company started production under the license of Unimation Company. At present, robots have a wide application – probably wider than it seems. They are used almost from the beginnings of space exploration (at the spacecrafts Viking 1 and 2, as we have seen) and, of course, to this day. NASA used robots to explore Mars. Similar vehicles were developed after the success of the Pathfinder mission, and those were able to travel 100 meters per day on each Martian day while carrying instruments used to explore the Red Planet. Robots are used a lot by different armies, but probably the biggest progress in this aspect was made by the United States army. Great number of robots is used in potentially dangerous situations. You can see on TV how robots manipulate with bombs or go through minefields. One of these is the Mini Andros, which has two "arms" and can climb and descend the stairs. It is equipped with three video cameras, and thus is useful in exploring new areas, such as large houses where there are dangerous people. Special versions of this robot are equipped with the radiation detector. Nowadays, robots are applied at home, for vacuuming, laundry, surveillance, etc. Lego Mindstorm robots are extremely popular. The project Lego Mindstrom itself was launched fifteen years ago by Lego and Massachusetts Institute of Technology. As the company Lego claims, a user who knows how to use a personal computer can make his first Lego robot up in an hour. Robots are also applied in sport: it is old news that some kind of RoboCup competition is organized every now and then. By 2050, RoboCup project aims to develop a complete humanoid soccer team, claiming it can certainly beat the current world champions. Nowadays, robots and artificial intelligence coexist and thus it is hard to imagine a present-day robot not being some kind of artificial intelligence. As with artificial intelligence, the question with robots, androids, as well as fusion of all three life forms is what if they get out of control? According to Hans Moravec, one of the robot/AI experts, robots will become as smart as a man by 2040, and we are sure they will be much smarter than many of the inhabitants. Despite pessimistic and paranoid predictions, Moravec is not worried. It is considered that robots and artificial intelligence will actually extend the life of man and improve the quality of life in general. As it seems, evolution has led man nearly to the degree that it can build a being as intelligent as himself! We live in a time that will in the distant future undoubtedly be remembered for many things, and it would be a shame we are not aware of it now as well. It is sufficient just to look around and realize that what we only used to read or watch is already around us. Mobile robots' application increases daily, so they are used in medicine, defense, agriculture, civil engineering, logistics, rescue and safety, professional cleaning, inspection and maintenance, space exploration, education, household, etc. It can be claimed there is no segment of a man's life in which mobile robots are not incorporated. With fast computerization of all forms of business and a vast expansion of the Internet, it is expected that there will be a big gap in the 21st century between those technologically advanced and those who have lost their connection with modern times. Most people are not aware of the extent to which robots are already represented within their lives. Their cars and computers are almost certainly partially assembled with the help of a robot. As it has been mentioned, the price of robots is steadily declining and mobile robots are increasingly coming into wide use (Chen, Chen, Chase, 2009; Karabegović, Doleček, 2012; Doleček, Karabegović, 2002; Angeles, 2007; Mulfer, 2010; Doleček, 2015; Teich, 2012; Steckelberg, 2007).

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THE DISTRIBUTION OF MOBILE ROBOTS

As a scientific discipline, mobile robotics is very attractive, challenging and imaginative. Mobile robotics aims to replace humans in performing dangerous, monotonous and heavy tasks, as well as to make human life more comfortable and enjoyable. The development and progress in new technologies, sensor technologies and information technologies has led to the development of hundreds of different types of service robots for non-productive applications. Service robots are designed to perform service tasks in civil engineering, maintenance, inspection, agriculture, therapy, rehabilitation, and fields of application in everyday life: at home, at work, in public environments, etc. It is estimated that today there are nearly 300 different types of service robots for performing all kinds of jobs, which is ensured by mobility, functionality and multimedia communications. Robotics aims at developing service robots that will help every person in everyday life. It is a relatively young technical branch, but already has a rich tradition. It turned out that robots, just like people, went through generational cycles. Each new generation of robots received the more advanced features than the previous one, which primarily relates to the actual degree of intelligence, supporting computing power, enhanced dynamic indicators and advanced control algorithms. The best example is shown in Figure 1.

As it has been mentioned and as it can bee seen from Figure 1, the characteristics of mobile robot are improving from year to year, which increases their application capacities. In order to perform the analysis of the mobile robots distribution in eight years, statistical data about mobile robots application have been retrieved from the International Federation of Robotics (IFR) (Karabegović, Doleček, 2012), as well as from the UN Economic Commission for Europe (UNECE) and the Organisation for Economic Co-operation and development (OECD), as shown in Figure 2. and Figure 3.

Based on Figure 2., it can be concluded that the trend of application (sale) of mobile robots for household and personal use is increasing at annual level from 2008 to 2014, so that it increased from 1.175.000 units of mobile robot in 2008 to 4.750.000 units of mobile robots in 2014. We can conclude that there is a growing trend in mobile robots application for household and personal use. Analysis of these trends yields a conclusion that the market for these robots is to increase constantly in the next 20 years.

Figure 1. Humanoid service robot "ASIMO" by "HONDA" company and its historical development
Honda Worldwide ASIMO History, 2016.

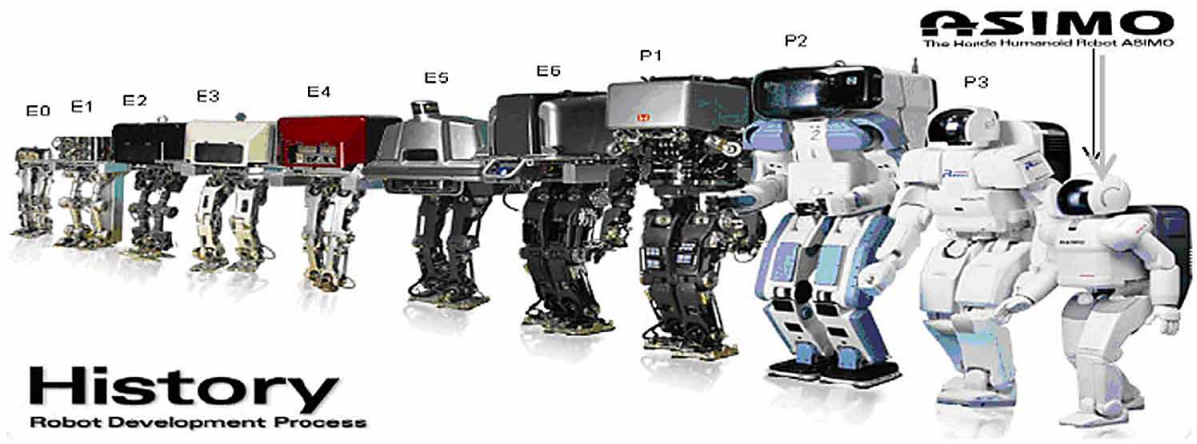

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Figure 2. Mobile robots application in household and personal use at the annual level from 2008-2014
World Robotics 2009-2015; Jason, 2014.

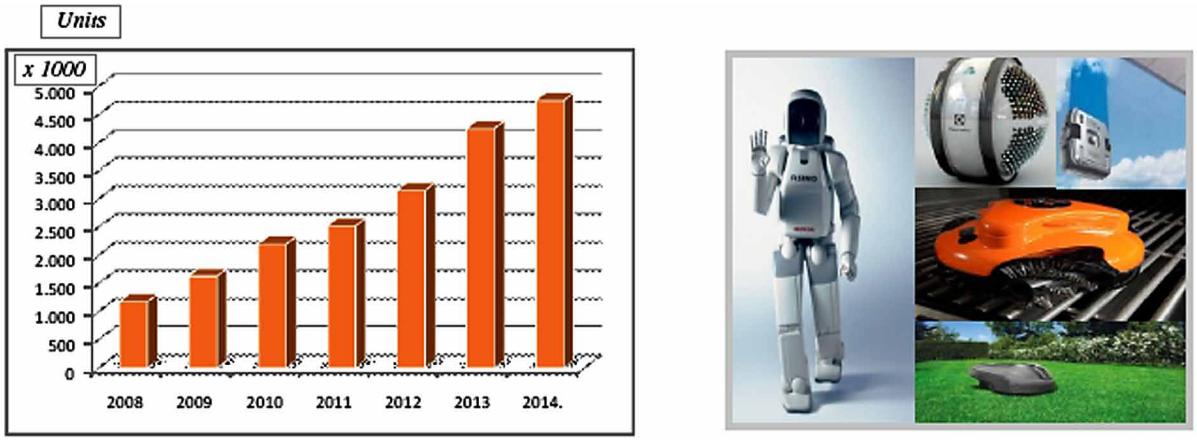
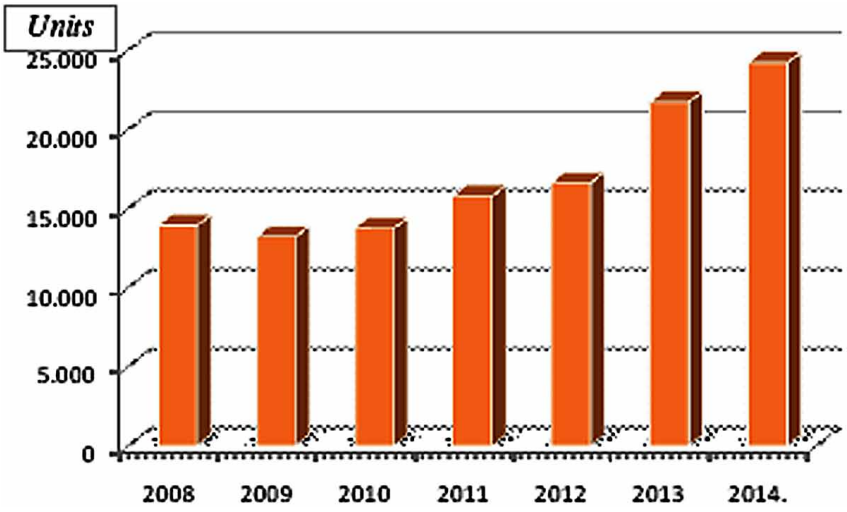


Figure 3. Mobile robots application at annual level for professional services from 2008-2014
World Robotics 2009-2015.



Trend of mobile robots application for professional service increases each year from 2009 to 2014, where it reached the amount of 24.204 units of the robot in 2014. The mobile robots for professional services include the following: mobile robots for agriculture, mobile robots for professional cleaning, mobile robots for inspection and system maintenance, mobile robots for construction and demolition, mobile robots for logistics, mobile robots for medical services, mobile robots for security, mobile robots for defense (military), mobile robots for underwater systems, mobile platforms, mobile robots for public relations, and other mobile robots which are not counted here. It is predicted that the use of these mobile robots will increase from 2013-2016 to approximately 94.000 units, of which around 28.000 mobile robots for defense (military) and about 24.000 mobile robots for agriculture (milking) (World Robotics 2015).

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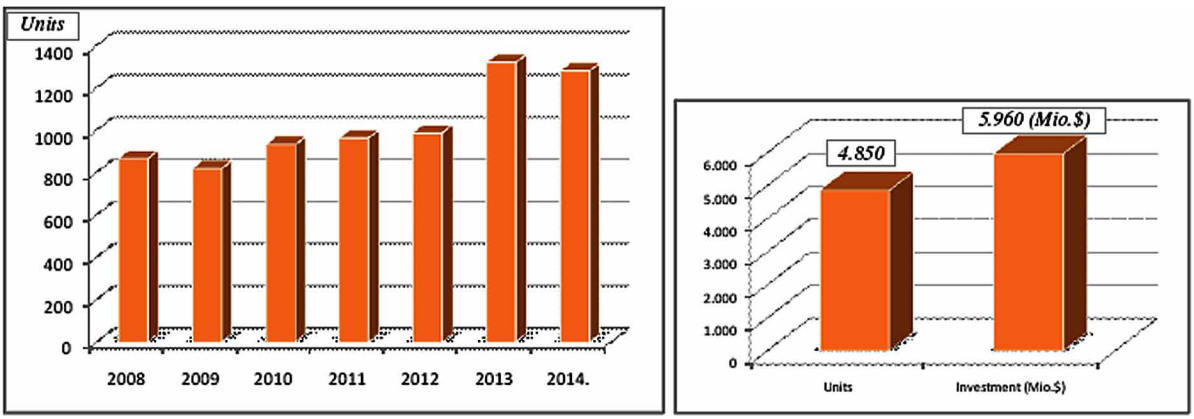
MOBILE ROBOTS APPLICATION IN MEDICINE

Mobile robots in medicine today, among others, have found application in many areas of medicine and some include: performing delicate surgical operation, replacing limbs that are lacking in people, rehabilitation therapy for patients who have had a stroke, visiting patients, serving patients with food and medicine, treating patients at a distance, monitoring operating procedures remotely in medical institutions, as well as carrying out a growing number of other similar tasks related to the health of patients in medical institutions. Mobile robotics can provide numerous benefits at present day. The development of new technologies, primarily sensor and information technologies that are much represented in robotic technologies resulted in the development of various robotic systems designed for different applications in medicine. In the field of medicine, there are potentially many applications of robots thanks to various ''features'' of those systems. One of them is the precision which robots have, where this feature is better than that of a skilled surgeon, e. g. when performing surgical procedures. Precision is very important in neurosurgery, and even orthopedics when e. g. drilling a bone to replace a hip. But these possibilities of robotic technology in medicine were developed only a few years back. The application of mobile robots in medicine is increasing from year to year, as it can be seen in Figure 4. (Meskoě, 2014; Carpanzano, Jovane, 2007).

Based on Figure 4, it can be concluded that the number of mobile robots increases continuously from year to year (886 units applied in medicine) so that it reached 1.280 units of mobile robots in medical institutions. We have to admit this is a very small number of applied mobile robots in medicine in the world, and such trend of application is due to very large investments, as shown in Figure 4 on the right. In the period from 2012-2015, over five million US dollars was invested in mobile robotics in medicine, which is quite a lot. The reason is that it is very sophisticated equipment and very expensive research. In relation to mobile robots used in other branches, the investments in mobile robots in medicine are the largest – as we shall see in continuation. Figure 5. shows in which medical branches mobile robots are used the most.

Figure 4. Mobile robots application at annual level in medicine from 2008-2014, the ratio of investment in medical robotics from 2012-2015 per unit of robot mobile
World Robotics 2009-2015.



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As Figure 5 indicates, mobile robots in medicine are used in colonoscopy, endoscopy, dotted radiation, orthopedics, mini surgery, neurosurgery, etc. The biggest percentage of mobile robots is for mini surgical interventions (31%) and is followed by orthopedics (18%) and neurosurgery (15%) in 2014. The development of new applications of mobile robots in medicine will change this image from year to year. In order to better understand the mobile robots application in medicine, we will present only some applications of mobile robots in certain medical branches in the following figures.

Figure 6 shows the mobile robots application in determining diagnoses in radiology. Also, these are used when one needs to perform radiation on a patient with a certain diagnosis because point of radiation to the patient is precisely defined by mobile robot. The other two images provide an overview of patient services that can be provided by a mobile robot, e. g. measurement of pressure, serving medications or other things a patient needs (Karabegović, Felić, Đukanović, 2013; Karabegović, Karabegović, Husak, 2013; Karabegović, Karabegović, Husak, 2010)

Given that most mobile robots used for small surgical interventions, Figure 7 shows a surgical system for performing surgical operations. It has to be noted that several surgical systems have been developed to this date. The second image shows the mobile robot RP 7, which is used for treatment at distance. It is used in small rural places where it is not profitable to hire a doctor due to very small number of people. It is enough to have an ambulance and a nurse with this robot, while a doctor establishes an Internet connection to examine a patient, determine a diagnosis and recommend future treatment. With

Figure 5. Mobile robots application in medical branches in 2014
World Robotics 2014.

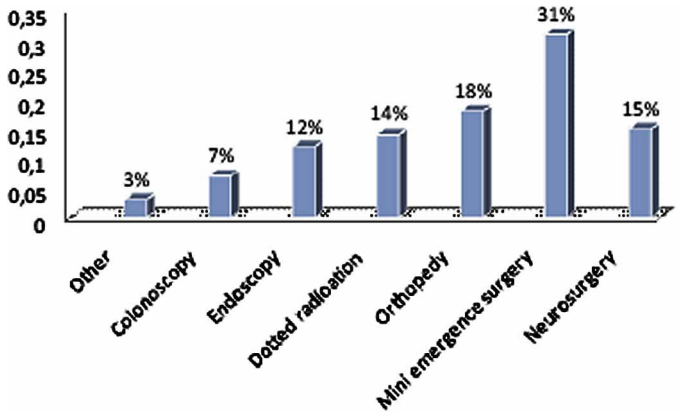

Figure 6. Mobile robots application in radiology and serving patients in medical institutions
Tanya, 2015.

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Figure 7. Mobile robots application in surgery, distant treatment of patients, and rehabilitation of patients
Murrayon, 2013.

this robot, a doctor fully establishes communication with a patient. The last image shows a mobile robot for rehabilitation of patients. Many applications of mobile robots are developed for different types of rehabilitation.

Given that working staff of medical institutions loses a lot of time on serving patients and the very logistics required for the services that are necessary for normal functioning, various mobile robots have been developed depending on the services, and a small number is shown in Figure 8. Mobile robots for logistics in health care facilities are used for: serving patients food and medications, transporting materials to and from testing laboratories, transporting clean and dirty laundry to the laundry service where it is being prepared, etc.

MOBILE ROBOTS APPLICATION IN DEFENCE

World leaders' desire to lead wars of the future with as little human units is obvious, and thus defensive robotic systems play a major role. Robotic vehicles, i. e. service robots should reduce human involvement and the number of war casualties. Their mission is to find and destroy enemy vehicles and units, as well as to take strategic positions. Sensors with which mobile robots are equipped are able to identify armed and

Figure 8. Mobile robots application in logistics of patients and laboratories in medical institutions
RoboCourier Mobiler Roboter, 2016.

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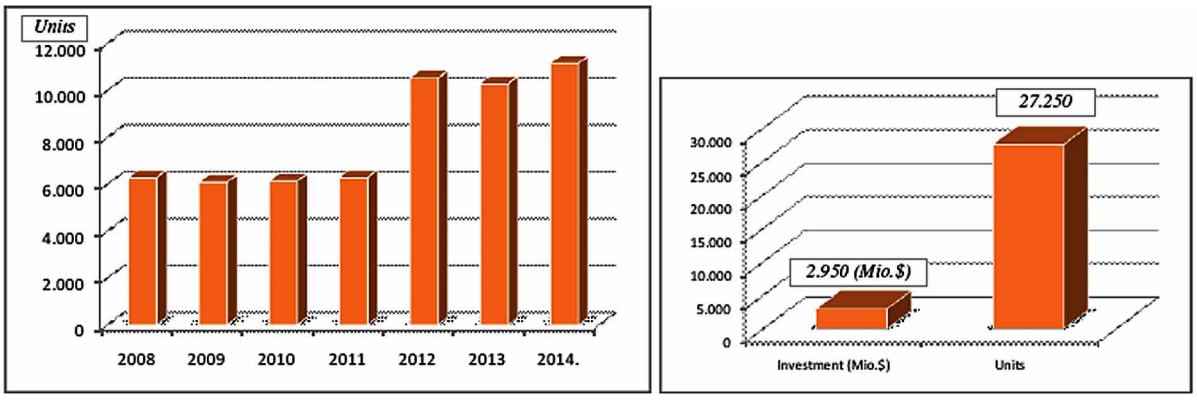
potentially dangerous targets, while a man who controls it via computer and videolink decides whether to act, open fire and destroy them. Unmanned platform should soon take over unconditional, dangerous and boring tasks. Great experience gained using a variety of remotely controlled devices and drones have led researchers to work in the direction of full autonomy. Military mobile robots are made in different shapes and sizes, from unmanned combat vehicles to groups of insect-like devices that will cooperate on specific assignments in not so distant future. Of course, the biggest part in their development takes place in the U.S., where defense community sponsored projects involving many different new technologies. In many cases, inspiration for these projects comes directly from nature, because what is actually being copied are the ways various living organisms perceive and feel their surroundings, determine the course of action, work together, move and perform some of their tasks. The U.S. military has introduced the use of mobile robots on the remote control. These are a transitional step on which to gather experience for the transition to a new generation of remotely controlled service robots. A remote operator only needs to manage a mobile robot on the remote control occasionally, while the service robot will be autonomous most of the time. The ultimate goal of development is one operator managing multiple remotely controlled mobile robots. Such service robots will be reprogrammable, retain a stable behavior even in complex, uncertain and changing conditions, as well as be able to learn. Also, it will be possible to use them safely and reliably in close proximity to people. Removing a crew (a man) from armed system reduces the need for armored protection. Robot's size is also reduced, and thus the conspicuousness of the system. This ultimately means greater flexibility and survivability, greater strategic and operational mobility and ease of logistical support. The most likely direction of development is a combination of unmanned and manned platforms, unmanned service robots being used in the most dangerous options. Number of mobile robots has a growing trend from year to year, as shown in Figure 9. New applications of mobile robots are being developed daily for use in defense purposes (Karabegović, Doleček, 2012).

On the basis of Figure 9, it can be concluded that the trend of application of mobile robots in defense was constant in the period 2008 to 2011 and it ranged around 6.000 units. This is followed by a sudden increase in applications in the period 2012-2014, ranging from 10.000 to 11.000 units of mobile robots. If one compares the application of mobile robots with application of mobile robots in medicine, it can be seen that it is almost ten times higher, which means that research in mobile robotics for defense have

Figure 9. Mobile robots application for defence on annual level from 2008-2014, the ratio of investment in the period 2012-2015 per unit of mobile robot
World Robotics 2009-2015.



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been intensified leading to a number of new solutions in applications. Investments in mobile robotics in defense are significantly smaller – about two times smaller than investments in medicine – because they amounted to approximately 2.950 million U.S. dollars for 27.250 units in the period 2012- 2015. When it comes to defense, a vast number of applications has been developed – from mobile reconnaissance robots to those supplying the units on the ground with the necessary equipment. Because of the limitations of this chapter, we will show only some applications. The following figures show only parts of mobile robots applications in defense.

Figure 10 displays developed mobile robots used for defence purposes, and are equipped with a variety of weapons, camera sensors to heat and night surveillance. The platform of these mobile robots is such that their management and operation is performed from a safe position.

Mobile robots for defense that are used for reconnaissance have been developed and equipped with means for combat, as shown in Figure 11. Depending on the area in which they are used, these mobile robots can be driven by excavators and cranes. Apart from these, mobile robots for fast movement of units on a very rough terrain have also been developed.

Figure 10. Mobile robots application in defence; mobile robots MAARS,Metal Storm and TALON
Army of Robots: 5 Greatest Combat Engineering Tools, 2012; Paul, 2012.

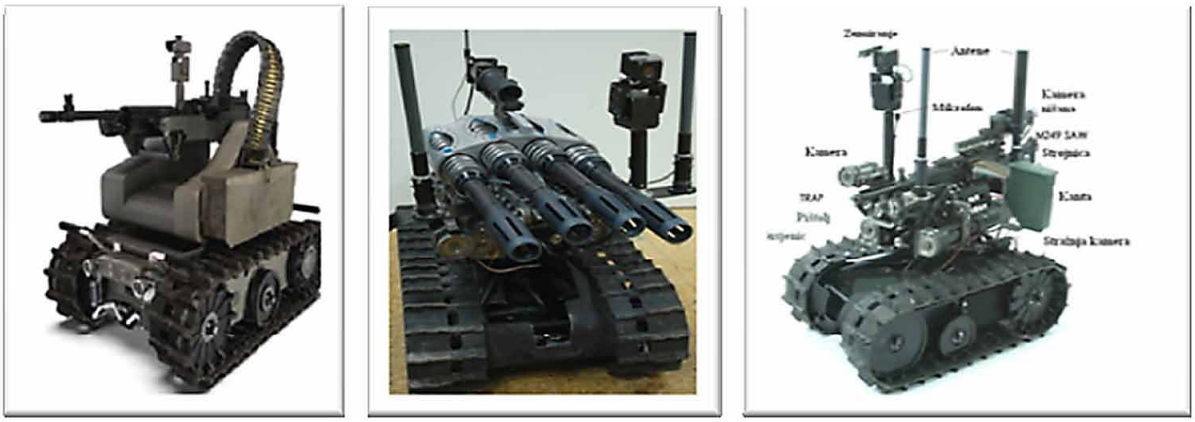

Figure 11. Mobile robots application in defence as combat vehicles Gladiator Tactical, Armed Robotic Vehicle (ARV) UGV and Black Knight
Robotic Armored Assault System –RAAS, 2016.

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Numerous mobile robot applications have been developed for removing explosive devices lagging behind every war. Their development and application is very popular because it is otherwise performed by people, many of which die or become disabled. Figure 12 shows small mobile robots for removing explosives. However, large mobile robots that remove mines have been developed, so that the robot remains intact in case of an explosion and can continue performing its task.

UAV (*Unmanned Air Vehicles*) or automated aerial vehicles are commonly used in military and civil purposes for observation, research, mapping and inspection of areas, as well as for border patrol, the purposes of search and rescue, etc. But primarily, those are military devices used for reconnaissance and combat. These are unmanned aircrafts. See Figure 13. UAV look like small planes and range from small planes maintained and launched by man to large-size aircrafts to be managed remotely, as the RQ-4 Global Hawk. Thus, there are two variants of an unmanned aircraft, one controlled via "remote control" and the other pre-programmed in order to get to the finish line and complete the task. Drones, which have started off as platforms for reconnaissance, nowadays have increased capacities and thus serve as combat platforms. It should be noted that drones have the ability to perform certain actions with respect to pre-programmed procedures. What those procedures are depends from platform to platform and how many devices are capable of performing them.

U.S. Army sees mobile robots as an important, perhaps even a central part of its *Future Combat System* (*FCS*). Some elements of the FCS, including reconnaissance vehicles that monitor enemy's territory, could be unmanned. Removing a crew (a man) from armed system reduces the need for armored

Figure 12. Mobile robots application in removing explosives; mobile robots TALON, PackBot and PackBotEOD
SuperDroid HD2-S Mastiff Tactical / Surveillance Robot w/ 5DOF Arm, 2016; Frank, 2016.

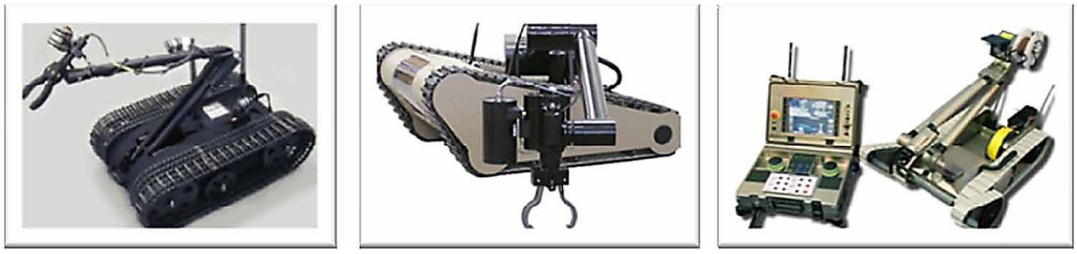

Figure 13. Application of mobile robots as drones for reconnaissance MQ- 1 Predator UAV, MQ-9 Reaper UAV aircraft and Bat-like miniature aircraft with camera
Domestic use of drones make privace advocates anxious, 2016.

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protection. Robot's size is also reduced, and thus the conspicuousness of the system. This ultimately means greater flexibility and survivability, greater strategic and operational mobility and ease of logistical support. The most likely direction of development is a combination of unmanned and manned platforms, unmanned service robots being used in the most dangerous options. These two types of platforms should be similar to each other, so that the enemy is not able to identify mobile robots easily. Forms of service robots depend on the type of a task for which the service robot is developed. Mobile robots which have to go through difficult terrain use crawler belts. Flying service robots look similar to small planes. The American company "BOSTON DYNAMICS" develops robots that can replace a man in the danger zone. A part of the latest research is presented in Figure 14.

MOBILE ROBOTS APPLICATION IN AGRICULTURE

It used to be normal to use robots, namely industrial robots, in the manufacturing process, but today we can find a robot performing any task. Robots are designed to remove human factor from the working environment or places where it is dangerous to operate. The idea of applying mobile robots in agriculture is only a few years old. The main areas of service robots application in agriculture are the harvest, orchards, cow farms, floriculture, etc. There are various idea for mobile robots application in agriculture, such as: planting seeds, mowing, plowing, cultivating a particular culture, gathering the harvest, picking fruit, cultivation of vineyards, transplanting seedlings, flower production, work in greenhouses, as well as work on dairy farms, inspecting and cleaning cows, etc. Figure 15. shows statistical data about mobile robots application in agriculture, which International Federation of Robotics (IFR), the UN Economic Commission for Europe (UNECE) and the Organization for Economic Cooperation and Development (OECD) collected from mobile robots manufacturers (Karabegović, Doleček, 2012).

Trend of mobile robots application in agriculture is growing from year to year, and it was small only in 2009 and 2010 due to the economic and industrial crisis. Since 2010, the application of mobile robots is growing continuously, and it increased from 4.185 units up to 5.890 units in 2014. Investments in mobile robotics in agriculture amounted to $ 4.9 million for 24.950 units of mobile robots for agriculture from 2012-2015. When this is compared with investment in mobile robots in medicine, we conclude that investments are not great given the number of units. The very essence of mobile robots' work in agriculture is to specify, manage and give specific tasks to mobile robots using PCs and mobile phones

Figure 14. Development of mobile robots for defence as in "BOSTON DYNAMICS" company
LS3 - Legged Squad Support Systems, PETMAN, BigDog - The Most Advanced Rough-Terrain Robot on Earth, 2016.

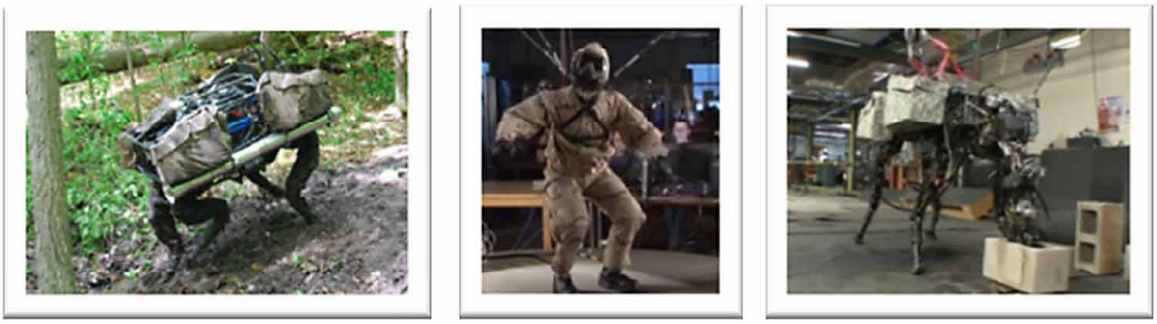

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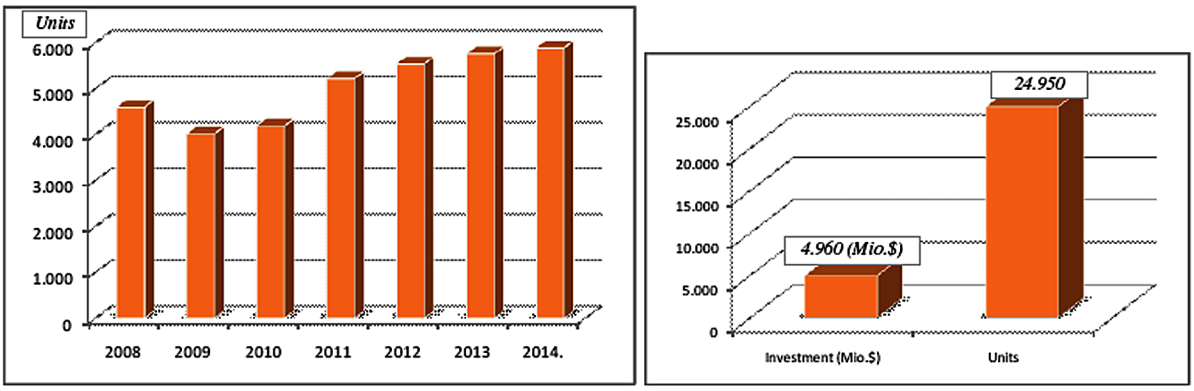
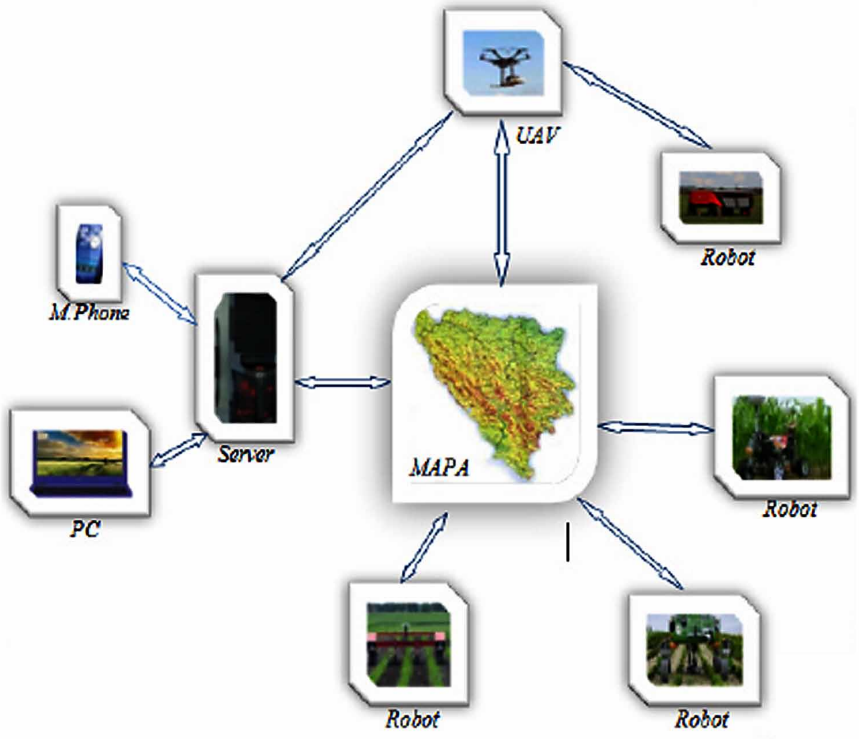
Figure 15. Mobile robots application in agriculture at annual level from 2008-2014 and investment ratio from 2012-2015 per unit of mobile robot
World Robotics 2009-2015



via server with a folder containing the processing area. The robots need to accomplish those tasks for a particular plant culture, as shown in Figure 16.

Communication, monitoring and control of mobile robots in agriculture are realized through server via a PC, a mobile phone, a GPS on the basis of which a processing plot is defined. Monitoring the

Figure 16. The manner of monitoring, management and communication with mobile robots when performing certain tasks in agriculture
Karabegović, Doleček, 2012.



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performance of certain tasks with a mobile robot is made using "DRON", and all operations are performed from a center that may be located near the execution of tasks. For the types of mobile robots in agriculture, significant and useful factors are: high quality and productivity of work, reduced manual work and avoiding risks, i. e. increased safety, as shown in Table 1.

Table 1 shows the assessment of the relevance of factors for mobile robots in agriculture, with the degree of relevance marked from 0 (*not relevant*) to two points (*high relevance*). As a result of investments in mobile robotics in agriculture, many mobile robots applications were developed for this purpose, and a certain part of those is shown in the following figures.

Different applications of mobile robots in agriculture were developed, such as mowing lawns. The first robot presented in Figure 17 is used for smaller parcels, but a mobile robot has also been developed for mowing large plots with real mowers. The other two mobile robots are used for processing certain plant cultures and removal of harmful weeds from crops.

Given that a large work force is used for picking fruit, various applications of mobile robots have been developed for picking fruit – such as apples, pears, oranges, tangerines, grapefruit, etc. – in order to avoid physical work and reduce the time for harvest of a certain culture. See Figure 18. Mobile robots for grape vine pruning have been developed, as well as mobile robots to work in greenhouses for various types of vegetables.

Apart from working in the fields and greenhouses, mobile robots are used in livestock on farms. The largest number of mobile robots is used for milking cows on farms, monitoring and keeping cows, as well as for cleaning – as shown in Figure 19.

Table 1. Relevant factors and their estimation for mobile robots in agriculture

Robots in Agricultural Field	High Quality of Production Work	Reduction of Manual Work	Increasing Security and Risk Avoidance
Agriculture	•	••	
Milking robots	•	••	
Other robots for cattle breeding		••	•
Forestry robots		•	••

World Robotics 2009-2015.

Figure 17. Mobile robots application in agriculture; mowing, crop processing and weed extracting
Robots in agriculture, 2015.

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Figure 18. Mobile robots application for fruit picking, grape vines pruning and greenhouse work
Key, 2013.

Figure 19. Mobile robots application for cow milking, monitoring cows and cleaning cows on a farm
Amy, 2016; Edwards, 2016.

Automation of milking process is one of the most remarkable achievements in the modernization of farm work, as well as the process of milking cows. A robot for milking was first used in 1992 on a farm in the Netherlands. Already in 2001, automated milking systems (AMS) were used around the world on more than 1.100 farms. Nowadays, the number of AMS exceeds 10.000 at around 8.500 farms in the world. Most users are from the group of developed countries. The AMS should replace the work of employees in the milking process, i.e. to keep the necessary records of production and to be in operation 24 hours a day. The constant development of sensor technology, information technologies and new technologies leads to the development of mobile robotics, as well as the need for the rapid production in agriculture; improved quality of the product leads to the development of ever increasing number of mobile robots applications in agriculture and animal husbandry.

MOBILE ROBOTS APPLICATION IN LOGISTICS

Mobile service robots operate in diverse environments such as warehouses, manufacturing processes, airports, post offices, hospitals, transport networks, etc. For small proportions, logical mobile robots provide transport services in the offices (mail delivery and other services necessary for employees), hospitals and public institutions, and will largely be used to transport people and goods, which will in-

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crease the efficiency of road transport. In the future, the number of mobile robots applications in logistics will expand and grow, which will increase the efficiency and reduce the costs of logistics, because the logistics requirements will be processed more quickly with optimal routes. Mobile robots for logistics can perform the following tasks: delivery, transport, packaging, sorting and handling. Mobile robots in logistics can be classified into: courier systems (post offices, hospitals), logistics in factories, outdoor and field logistics, and other logistics. They are installed in offices, post offices, airports, hospitals and other public facilities for transport and delivery of a variety of goods, industrial production processes for the transfer of various items (pieces, boxes, toolbars, between machines, for transfer to a point or a warehouse) as well as indoor and outdoor warehouses, such as marine and water ports, airports, and transshipment centers for handling goods of any kind. Figure 20. shows the distribution of mobile robots for logistics, and statistical data retrieved from the International Federation of Robotics (IFR) and the UNECE are collected from manufacturers of mobile robots for logistics (Karabegović I. Doleček V., 2012).

Trend of mobile robots application for logistics is continuously increasing year by year. In 2008, 533 units of mobile robots were applied in logistics, whereas in 2014 the number amounted to 2.650 units. It can be said that the number of mobile robots units has increased five times in seven years. Investments in mobile robots in logistics amounted to $ 1.25 million for 10.500 mobile robot units from 2012-2015. It is a very small investment in comparison to investments in mobile robotics in medicine, agriculture and defense, but it is a significant increase in application of mobile robots for logistics. Many mobile robots applications in logistics have been developed so far, as it is shown in the figures that follow. But the work on the improvement of existing mobile robots and the development of others continues.

The structure of a robot itself depends on the institution in which mobile robot logistics is applied and the tasks which are performed. Figure 21. shows mobile robots for luggage transfer at airports, mobile robots to work in hospitals, as well as a mobile robot serving the personnel in offices (Bostelman, 2015; Karabegović, Husak, 2010).

In the manufacturing processes in industry, mobile robots (Figure 22) for logistics are developed for transporting a finished product to storage or supplying certain job posts with production material.

Figure 20. Mobile robots application in logistics on annual level from 2008-2014 and investment ratio from 2012-2015 per unit of a mobile robot for logistics
World Robotics 2009-2015.

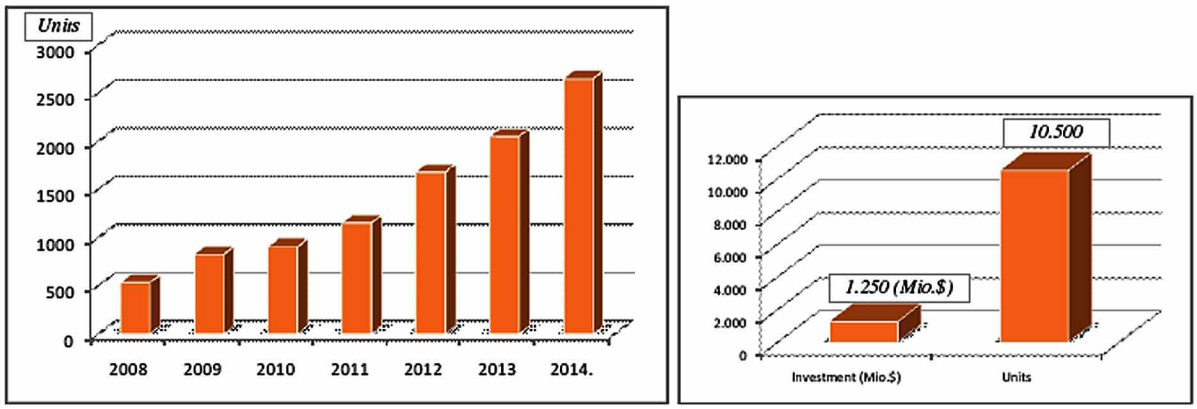

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Figure 21. Mobile robots application for logistics at airports, in hospitals and offices
Smart Technology from SITA Improves Passenger Experience at America's Friendliest Airport, 2016; High-Tech 'TUG' Robots Will Do Heavy Lifting at Mission Bay, 2016.

Figure 22. Mobile robots application for logistics in factories for finished products transport
Automated Guided Vehicles-AGV, 2016.

Figure 23 shows different applications of mobile robots for logistics in ports with heavy containers, unmanned guided trucks and transport of heavy items to warehouses. This shows only a small part of the application of mobile robots for logistics that have been developed and are already in use. But new mobile robots applications for logistics are being developed every day, and the most interesting are those for transportation of people. Certain applications of these robots have already been developed and are in the test phase of research.

In the future, it is expected to develop new applications of mobile robots for logistics in all segments of society. with the development of mechatronic systems, it can be said that cars are becoming mobile robots for logistics, because unmanned cars have already been developed to drive to the assigned destination.

MOBILE ROBOTS APPLICATION IN CONSTRUCTION, DEMOLITION

Mobile robots and their application in construction, demolition can be defined through several application areas at certain stages of the production of building materials, construction of certain parts of structures, installation of facilities, maintenance of finished facilities, etc. Their application in civil engineering

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Figure 23. Mobile robots application for logistics in ports for container transport, unmanned guided truck for pallets transport and heavy trucks for steel coils transportation
Ullrich, 2015.

Figure 24. Application of mobile robots for logistics that are used in transportation of people
Theis, 2016.

can be roughly divided into four categories: transport of materials and servicing of machinery, assembly operations, processing operations, processes of maintenance and product control. Mobile robots in construction, demolition are the most applicable in the production of building materials, when and where robots themselves can be mass produced.

Today, the production processes of construction materials are technologically computerized to that extent that often one such factory is actually one automated production system. A classic industrial robot and mobile robots in the production of construction materials are used only in some phases of work or the production of certain materials in the brick industry, the production of plaster and glue, styrofoam production, the production of concrete structures, etc. Robots, i.e. automated structures in construction, can have a wide range of applications in situations in which the presence of people is dangerous or problematic. For instance, robots have already found application in the construction and testing on other planets, where the construction with human resources is disabled. They are applied in underwater research and construction in environments that prevent and hinder movement, in soil testing, in construction of underground installations and tunnels, in studying igneous changes in volcanoes, and the like. Figure 24 shows the distribution of mobile robotic systems in construction, demolition. Statistical data retrieved from the International Federation of Robotics (IFR) and the UNECE have been collected from the manufacturers of mobile robots (Karabegović, Doleček, 2012, Marques, Almeida, Armada, Fernández, Montes, González, Baudoin, 2016)

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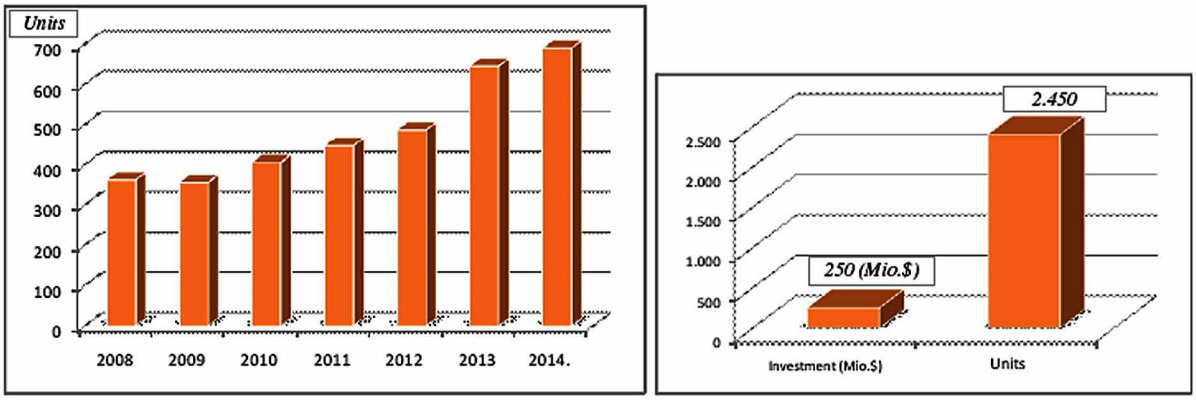
Figure 25. Distribution of mobile robots in construction, demolition at annual level from 2008-2014 and investment ratio from 2012-2015 per unit of mobile robot in civil engineering
World Robotics 2009-2015.



As seen in Figure 25, the trend of mobile robots application in construction, demolition is growing, so that it amounted to 362 units in 2008, and 689 units of mobile robots in 2014. If we consider the investments in the development of these robots from 2012-2015, they are very small (only $ 250 million) in comparison to the investments in the development of mobile robots in medicine, agriculture, defense and logistics. We believe the time will come for the development of new mobile robot applications in construction, demolition and the increase in their use in the future. Let's present certain applications of mobile robots in construction, demolition that have been developed and are already being applied.

As it can be seen from Figure 26, mobile robots autonomously perform tasks which are programmed or that are managed by a server who provides commands to perform certain operations. In addition to these applications, many others have been developed.

The use of robotic systems in construction, demolition is still in its infancy and it needs to be said that robotics does not follow this branch of production at the same pace as other industrial manufacturing processes. See Figure 27. Certainly, the desire for greater capital gain will lead to a reduction of workers in civil engineering, which will definitely lead to larger robotization in this industry.

Figure 26. Mobile robots application in construction, demolition for drilling, placing panels for groundwork and masonry
Kalinovsky, 2015; Vicki, 2016.

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Figure 27. Mobile robots application in construction, demolition for filling walls, flattening surface and drilling holes
Fleischer, 2014.

Glass facades on high buildings need to be cleaned every few months and considering that these are the objects that are most often located in the central city areas, where there is no access for potential robust cleaning cranes, the robotic systems for cleaning are used. Se Figure 28. These systems are remotely controlled or completely independent and connected to a movable base. A mobile unit of such robot either follows a conveyor belt or descends from the roof. Cleaning systems of high buildings usually cost a lot and in recent years, they are combined with the structural elements of a facade, while smaller buildings use standard systems with conveyor belts. Prices of these systems are declining and adapting to broader market, with the aim to enter into use in individual households. In the construction of these facilities, the process of introducing a mobile robot will be slower because it is a specific process. But surely, robots are already used for installing ceramic tiles, plastering, painting, etc., particularly when it comes to large surfaces. Given that the basic robotic applications can be traced through four basic categories of industrial robot applications, we look at the specific operations which robotic systems perform in certain phases of construction. The widest use of mobile robots is in the process of transferring materials and servicing of other machines, primarily in brick manufacturing, where robots serve for sorting, furnace servicing and palletizing. Similar jobs are also automated and robotized in the industrial production of powdery building materials. To a large extent, these jobs are similar to the tasks that robots perform in other industries, while the specifics of the work of robots applied in civil engineering can be seen

Figure 28. Mobile robots application in construction, demolition for cleaning glass facades, floors, as well as cleaning and control of brick facades
Zaragoza, 2009; FourAutomated Facade Cleaning System - GEKKO Facade cleaning capabilities, 2016.

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in the process of servicing operations such as mining and tunneling, where robots are used primarily due to the presence of hazardous substances and complex working conditions for men. The specifics can also be seen in the processing of glass and ceramic products, where there is a high concentration of toxic gases and high operating temperature. Robots also have a wide use in the processes of cleaning and maintenance of buildings and parts of buildings, mostly floors, tanks, pipelines, high facades, etc.. In this case, complex robotic systems are used to detect defects and contamination, as well as to remediate specific breakdowns that can not be repaired with the help of human labor. Robotic systems are often used for the removal of mines or demining areas. The development of robotic systems depends not only on the technical aspects and modular components, but also limitations of working conditions. In robotic systems used outdoors have to be taken into account following: protection from dust, protection against moisture and temperature, resistance to vibration, impact resistance, length of continuous operation (because power supply), the wireless communication range depending on demined location, etc.The civil engineering sector in which the most attention in the future will be devoted to the possible application of robotic systems is the area of construction and installation of elements on buildings, in order to speed up the construction process, avoid difficult and dangerous working conditions for people, and reduce labor costs.

MOBILE ROBOTS APPLICATION FOR PROFESSIONAL CLEANING

When it comes to cleaning mobile robots, we need to distinguish between mobile robots used for professional cleaning of facilities and those for home use. Professional mobile robots are commonly used for cleaning floors, tanks, windows, vehicles, pipes, pools, etc. Professional cleaning robots have a rising annual trend of usage. The largest application of cleaning mobile robots is for cleaning floors and swimming pools. Cleaning mobile robots are used in various fields, thus we will cover and analyze those areas, i.e. cleaning elements, where the use of service robots is the largest. International Federation of Robotics (IFR), the UN Economic Commission for Europe (UNECE) and the Organization for Economic Cooperation and Development (OECD) have adopted the introductory system for the classification of service robots for cleaning according to the categories and types of interaction, and thus service robots for cleaning have the following classification: floor cleaners, window and facade cleaners, tank and pipe cleaners, plane and car cleaners, and other cleaning robots. Annual application of mobile cleaning robots is shown at Figure 29. (Karabegović, Doleček, 2012).

Based on Figure 29, it can be concluded that the distribution of mobile robots for professional cleaning has a growing trend, so a continuous increase from 2008 to 2014 reached 360 units of robots. The investments in the development of mobile robots for professional cleaning in the period from 2012-2015 was $ 750 million, which is a very small amount considering the investments in the development of mobile robots in medicine, agriculture, defense and logistics. Let us show some of the developed applications of mobile robots for professional cleaning that are already being applied for various cleaning tasks (Dai, Taylor, Sanguanpiyapan, Lin, 2004; Karabegović, Kadić, Ujević, 2003)

Given the fact that labor costs of cleaning in large production systems are major issue, the increase in the number of cleaning robots is inevitable. In addition to cleaning floors, the robots are ever more applied in the so-called smart floors in order to reduce high price of robots. See Figure 30. Smart floors are equipped with RFID straps which enable simpler robotic navigation, and thus manage to reduce costs of the total cleaning process. Mobile robots for floor cleaning are standard cleaning machines equipped

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Figure 29. Distribution of cleaning mobile robots at annual level from 2008-2014 and investment ratio from 2012-2015 per unit of a cleaning mobile robot
World Robotics 2009-2015.

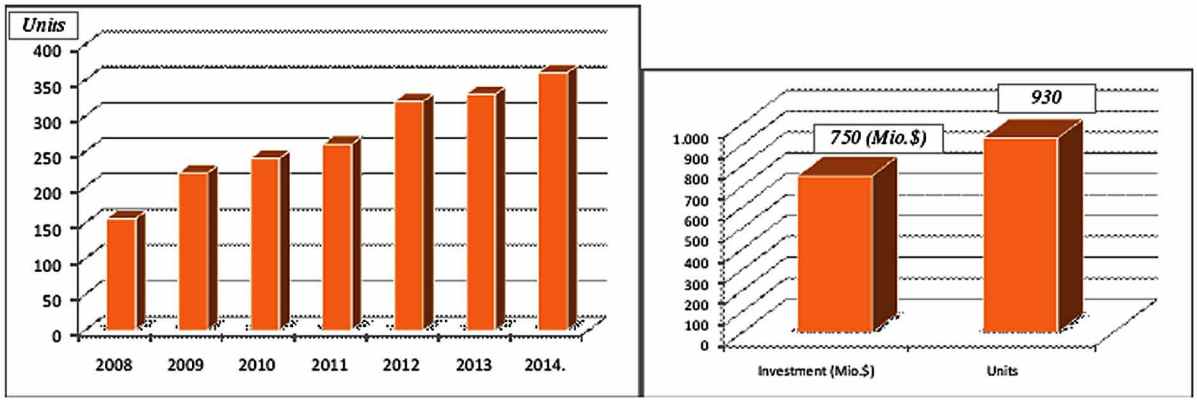

Figure 30. Certain applications of mobile robots for professional cleaning
iRobot Roomba 800 Robot Vacuums, 2016.

with the necessary robotic features that enable independent movement, navigation and control, as well as with sensors to determine distance and obstacles in order to avoid collisions with the elements of the environment. Navigation systems these robots range from those requiring cables and human management to very sophisticated ones, which clean the entire area automatically without human intervention. The most commonly used navigation system applies initial programming circuit to memorize the path at the area to be cleaned, and then controls the movements during the cleaning. Cleaning mobile robots are programmed to reach places that need cleaning, carry out the necessary cleaning operations (washing, scraping, drying), after which they return to the station to charge with detergents and water needed for cleaning. Many of them use their own elevators through radio connections, and thus fulfill their obligations on several floors of a building. They are the most effective on large areas, lobbies, airports, and railway stations. A large number of companies– both in Europe and in the world– is engaged in the production of these service robots. Mobile robots for cleaning glass windows and facades are of great interest nowadays, because large buildings are being built, containing glass facades that demand cleaning every few months. Mobile robots for window cleaning usually consist either of remote and controlled

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cleaning units or fully automated cleaning units that can be mounted on a mobile base climbing. The climbing base mainly uses vacuum suction cups to fix to a wall. A mobile unit either follows the path or is suspended from the roof, moving freely across the facade. While a specific solution can be useful for large buildings, smaller buildings will rely on standard systems. Other efforts are directed to the window cleaning systems for the consumer market with a target sale price. Basic requirements are that these devices are easy to use, safe and maybe even useful for cleaning bathroom tiles. Let us show some of the constructions of mobile robots for cleaning glass facades (Siegwart, Nourbakhsh, Scaramuzza 2011; Iype, Porat,1989).

The characteristics of these mobile robots are: high quality of cleaning, automated operations of all systems, and a remote control. See Figure 31. A mobile robot is mounted on the crane, which goes towards a roof. It moves over the glass using very sensitive wheels or vacuum discs, in order not to damage the glass. The most famous robot for cleaning external airframe is Skywash robot, which integrates all the features of advanced robotic systems, pre-rendering movement programmed using CAD airplane model, while the location of an object is performed using a 3D sensor, i.e. 3D distance camera. Managing movement is performed using tactile sensors. A redundant arm is installed on the mobile platform, with security add-ons that provide maximum security. There are 5 major joints in his arms and an extra one for brush rotating. The robot contains a database about the geometry of a plane. Skywash is being supervised by man from the starting position so long as the robot does not come near the plane.

Cleaning mobile robots make cleaning and maintaining a pool easier. They act independently of a wastewater treatment device and at the same time, they help mixing the water in a pool by cleaning. There are different structural designs in this field of robotics too. Some of the service robots do not climb pool walls or have the option of disabling the climbing function, because most of the impurities are located at the bottom and climbing walls is more of an attraction than useful work. These service robots have telecontrol (remote control), which enables bringing the robot in the corners which it cannot reach on its own due to its mode of action. Indoor air control systems are inaccessible places for cleaning, so mobile robots of various structures have been developed for cleaning of these facilities, one of which is presented in Figure 32. Mobile robots for this use are simple in design, have four wheels, and can be rotated at an angle of 360 degrees in a very small space. They have cameras installed on both sides, so that a person operating with the robot can at any time see what needs to be cleaned. It is remotely controlled and capable of cleaning about 25 meters of a ventilation channel at once. A mobile robot is

Figure 31. Applications of mobile robots for cleaning glass facades
A milestone in automated facade cleaning: rollout of gekko facade at serbot buochs, 2010; Hope, 2010.

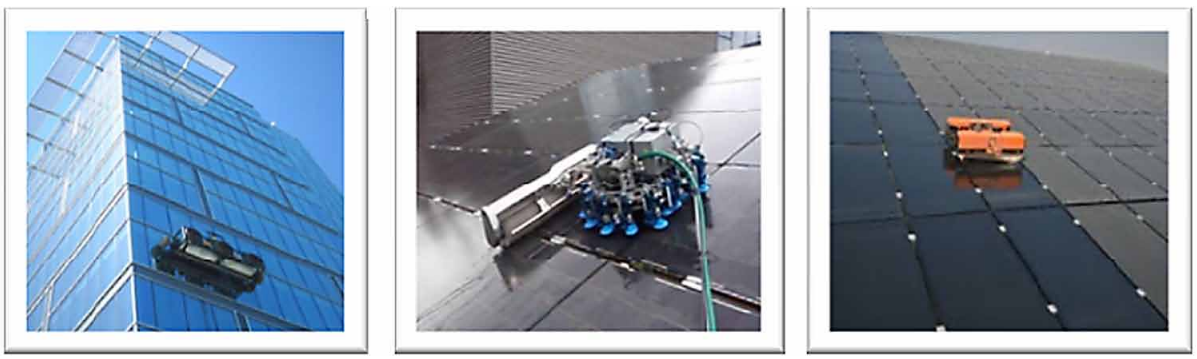

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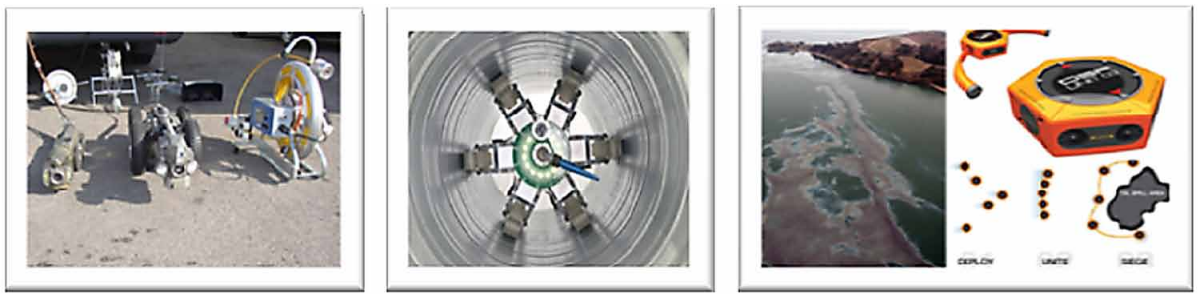
Figure 32. Application of mobile robots for a professional cleaning of airplanes, pools and ventilation shafts
Which NORDIC DINO is most suitable for your aircraft?.2013; Swimming Pool Chemicals and Equipment, 2013.

designed so that it is similar to a car, has a four-wheel drive and is very easy to operate on. There is a turbo rotary brush attached to it, which pushes all dirt to a vacuum cleaner installed on some of ventilation openings and collecting all the dirt accumulated in the channels. Nozzles are hooked up at the rear end of the robot, as well as a tank in which chemicals are poured to disinfect a cleaned area. Sewage is a basic infrastructure of every city, village or industrial plant. Although of a vital importance, sewage systems are usually worn and leaky, causing immense damage to the environment and posing a direct threat to drinking water sources, and thus human health. One of the parts of the entire cleaning system is the CCTV inspection of sewage, which enables persons controlling the sewage to get to know the real state of the facilities. This equipment includes digital service robots with cameras in the ex-performance that are able to capture the sewage pipes of all shapes and materials, with diameters from 100 to 1.500 mm. The result of such inspections contains comprehensive and detailed written and video documentation that reflects on the existing condition of examined pipes and can be used in the development of a digital cadastre (GIS) of the sewage system. Mobile robots for cleaning pipes and channels with larger diameter have been developed and are presented here at Figure 33. A mobile robot is equipped to use the high technology of cleaning with dry ice, but can also use other cleaning methods. It is designed with six legs which provide stability when cleaning and moving through pipes and channels during cleaning. The mobile robot can go through and clean circular, rectangular and square shaped channels

Figure 33. Application of mobile robots for professional cleaning and sewage structure inspection, large-diameter pipes and a mobile robot for cleaning oil spills
Cleaning and Inspection of Ducts, 2013; Brynn, 2011.



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with maximum efficiency, because the rotation of a cleaning squirt and the speed of a cleaning rotor can be adjusted depending on the degree of contamination. The robot can clean the horizontal, sloping and vertical chanells, as well as channels in the form of the letter S. It is equipped with a camera. Monitoring of the control and cleaning processes is done using the display on a computer (Karabegović, Karabegović, Husak, 2012).

We are witnessing the disastrous consequences resulting from oil spills at sea. The sooner the oil slick is removed from the water surface, the lesser harmful effects on wildlife. Guided by this idea, the "JI HOON KIM" company came up with the idea to develop a set of modular mobile robot (Figure 33) called OSP robots– the cleaners of oil spills in seas or lakes, which can be quickly transported to the contaminated site by helicopter or boat and put into operation.

MOBILE ROBOT APPLICATION FOR SPACE EXPOLORATION

Mobile robots have a major role in space exploration. Various self-propelled robots are used for data collection from celestial bodies, for samples collection and analyzis, debris collection, photography, etc. Some of them are controlled by radio waves from the ground, while others have built-in electronic computers, so they move independently driven by a computer program. Self-propelled mobile robots have built-in sensors to receive data from the environment, a robotic arm to perform complex operations of samples collection, cameras and camcorders. Various remotely operated vehicles, so-called rovers, are used for different research of planet surfaces. One of them is a mobile robot named Viking, which has two automatic chemical laboratories, meteorological and seismological station, laboratory for photography, and two computers. A computer-guided hand digs and transmits soil samples in biological and chemical laboratory, where the samples are analyzed (Rita, Tyler, Kaczmarek, 2003). NASA has developed two most famous robotic vehicles (rovers) named "Spirit" and "Opportunity" intended for space exploration. Unlike the robots on Earth that act in a structured environment, robotic space vehicles operate in an unstructured and unfamiliar environment. Therefore, mobile robot explorers have to learn using their own sensors, including nine cameras located on each of them. The rovers have two navigation cameras for three-dimensional view of environment, two for view of the ground (to avoid collisions), and panoramic cameras to capture the planet's surface. The CPU in research devices is designed to withstand extreme cold and radiation on the planet Mars. During the night on Mars, when the robot is at rest, a team of experts from the Earth programmes its activities for the next day using very powerful computers, and then send him commands where to go or what actions to perform. When it comes to avoiding obstacles that mobile robotic rovers encounter during their research missions and that can not be predicted from the Earth, robots themselves make decisions how to avod them. Data from cameras for collision avoidance assist them to analyze the immediate environment in which they move at speed of a snail (the maximum speed is five centimeters per second), with regular stops for field observation. In addition to recording, robots examine the planet using several instruments on a mechanical arm. The arm has a shoulder, elbow and wrist in order to facilitate the movement and is equipped with four sensors, a microscopic camera to capture rocks from close up, as well as a spectrometer for measuring alpha-radiation to determine the mineral composition of the soil. The control of the arm is carried out using the prepared commands, while smaller movements are operated independently by a mobile robot itself. The following pictures show service robots – or we can say robotic vehicles – for testing the surface of a planet. Those are different variants, depending on the manufacturer (Karabegović, Doleček, 2012).

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In addition to these vehicles, researchers have developed an SUV robot, named Athlete, for research on other planets, and it is shown in Figure 34. The Astrobotic Technology Inc., the USA, has developed a mobile robot Rover in cooperation with NASA, and it is shown in Figure 35. It is a lunar robot whose role at the surface of the Moon will be to make reception stations as close to the landing site of rockets as possible. At the reception stations, it is necessary to make levees around the landing site because stones and earth rise when rockets land and take-off due to the lack of oxygen. Thus, the levees should provide security for the facilities.

In addition to service robots, i.e. robotic vehicles and robotic platforms used for space exploration, there is another very important system – a mobile robotic arm of a spacecraft. In the last two Discovery's missions, the robotic arm is a key part of the new system of control of the thermal shield. It carries a camera that checks the state of the shield, and if necessary transfers an astronaut to the place where repairs need to be made.

Mobile robots for space exploration are analyzed as capable devices, which can perform manipulation, assembly and maintenance in orbit either independently or as assistants to astronauts, or serve as explorers at distant moons, planetoids and planets in the deep space. See Figure 36. Vehicles without a driver or automatically controlled vehicles used in space must be either telecontrolled from an extreme distance or automatically moved. The signals that take some time will be transferred and often all the

Figure 34. Mobile robot application for space exploration, robotic vehicles (rovers) and a robotic platform for sampling on the Moon and Mars
MESR - Mars Exploration Science Rover, 2015.

Figure 35. Mobile robot application for space exploration, "Athlete" robot and a rover for building reception stations
NASA's Human Robotic Systems Project, 2008.

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Figure 36. Application of mobile robots named mobile robotic arm of a spacecraft
Canadarm2 to release Cygnus from the International Space Station, 2016.

obstacles can be seen, the robot can change the "protection of teleoperation". Price of such mobile robots is very high. An additional price of mobile robot that was sent to explore space is another important factor. Therefore, the prices of such mobile robots belong to the overall mission of the prices, which include the development, production, launching, operation and postmission of data processing.

CONCLUSION

Nowadays, mobile robotics occupies an increasingly important place in the life and work of man. The beginning of the 21st century will be marked by a significant expansion in the practical applications of mobile robotics and intelligent machines in general. As new technologies are evolving and the end of further development and new knowledge is not known, it is certain that the mobile robotics will also develop to unimagined possibilities. Even now, the development and achievements in the field of mobile robotics reached such a level of development that a large part of humanity is not aware of how advanced robotics is. They are not aware that mobile robots do not serve as enemies of man i.e. humanity, as they are usually presented in science fiction movies. On the contrary, scientists from several disciplines strive to improve, facilitate, and beautify life for people and humanity. Generally speaking, the continuous improvement of mobile robot's quality is estimated, as well as the increase in its application, so that they will increasingly become systems that are easy to put into operation, to programme, to optimize and use to perform almost all the tasks currently performed by man. This will naturally lead to a large increase in their application, which is already evident from the annual statistical data on the use of mobile robots. Mobile robots are becoming ever more important for scientific research, as well as for the industry, because they are used and will be used in new areas of industrial branches. Nowadays, robots and artificial intelligence coexist and thus it is hard to imagine a present-day robot not being some kind of artificial intelligence. It is considered that robots and artificial intelligence will actually extend the life of man and improve the quality of life in general. For laymen, it is difficult to assess which of the scientists are right; the truth is that some of the possibilities and theories are concerning, but we have already realized that by reading some of the great works of science fiction. As it seems, evolution has led man nearly to the degree that it can build a being as intelligent as himself! The whole thing is now far advanced, and it is probably impossible to control them, but maybe just try to turn them in our favor.

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In any case, the century in which we live has already brought us a good deal of scientific excitement, and those who do not find this outcome positive are actually rare. We live in a time that will in the distant future undoubtedly be remembered for many things, and it would be a shame we are not aware of it now as well. The ever increasing use of robots has its social consequences. With their introduction in factories, a large number of unskilled and semi-skilled workers who have been on simple, dangerous and boring jobs will remain jobless. They have no choice but to pre-qualify. An increase in the use of mobile robots entails an increase in their production, and thus a reduction in their prices, i.e. the accessibility of procurement of mobile robots and their use itself. The application of mobile robots is increasing from day to day; the development of new technologies is leading to the robots' higher functionality, and hence the increase in their applications.

REFERENCES

A milestone in automated facade cleaning: rollout of gekko facade at serbot buochs. (2010). Retrieved from https://www.serbot.ch/en/success-stories/rollout-gekko-facade-switzerland

Amy, F. (2016). *DeLaval milking robots installed to milk 4,500 cows in Chile*. Retrieved from http://www.agriland.ie/farming-news/delaval-milking-robots-installed-to-milk-4500-cows-in-chile

Angeles, J. (2007). *Fundamentals of Robotic Mechanical Systems: Theory, Methods, and Algorithms*. Berlin: Springer Verlag. doi:10.1007/978-0-387-34580-2

Army of Robots. (2012). *5 Greatest Combat Engineering Tools*. Retrieved from https://www.idfblog.com/2012/02/08/army-robots-tools-idfs-combat-engineering-corps/

Automated Guided Vehicles (AGV). (2016). Retrieved from http://www.dmwandh.com/warehouse-automation/automated-guided-vehicles/

Automated Guided Vehicles (AGVs). (2016). Retrieved from http://www.ssi-schaefer.us/automated-systems/systems-products/conveyor-transport/automated-guided-vehicles.html

Bostelman, M. S. R. (2015). *Literature review of mobile robots for manufacturing*. National Institute of Standards and Technology. Retrieved from http://nvlpubs.nist.gov/nistpubs/ir/2015/NIST.IR.8022.pdf

Brynn, M. (2011). *10 Incredible Real-Life Robots*. Retrieved from http://www.womansday.com/life/a2343/10-incredible-real-life-robots-116174/

Canadarm2 to release Cygnus from the International Space Station. (2016). Retrieved from http://www.asc-csa.gc.ca/eng/default.asp

Carpanzano, E., & Jovane, F. (2007). Advanced Automation Solutions for Future Adaptive Factories. *Annals of the CIRP*, *56*(1), 435–438. doi:10.1016/j.cirp.2007.05.104

Chen, X. Q., Chen, Y. Q., & Chase, J. G. (2009). Mobiles robots – Past, present and future. In *Mobile robots – State of the art in land, sea, air, and collaborative missions*. Retrieved from http://www.intechopen.com/books/mobile-robots-state-of-the-art-in-land-sea-air-and-collaborative-missions/mobiles-robots-past-present-and-future

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Cleaning and Inspection of Ducts. (2013). Retrieved from http://www.jettyrobot.com/

Dai, J. S., Taylor, P. M., Sanguanpiyapan, P., & Lin, H. (2004). Trajectory and orientation analysis of the ironing process for robotic automation. *International Journal of Clothing Science and Technology*, *16*(1/2), 215–226. doi:10.1108/09556220410520496

Doleček, V. (2015). Future of technology. *2nd International Conference "New technologies NT-2015" Development and Application*, 1-12.

Doleček, V., & Karabegović, I. (2002). *Robotics, Tehnički fakultet*. Bihać, Bosnia and Herzegovina.

Doleček, V., & Karabegović, I. (2008). *Robots in industry. Tehnički fakultet*. Bihać, Bosnia and Herzegovina.

Domestic use of drones make privacy advocates anxious. (2016). Retrieved from http://peopleus.blogspot.ba/2011/07/domestic-use-of-drones-make-privacy.html

Edwards, J. (2016). *Agricultural Robots Help Australian Farms Boost Productivity*. Retrieved from https://www.roboticsbusinessreview.com/agricultural-robots-help-australian-farms-boost-productivity/

Fleischer, M. (2014). *This Robot Can Eat Concrete - Say What!?* Retrieved from http://www.brit.co/ero/

Four Automated Facade Cleaning System - GEKKO Facade cleaning capabilities. (2016). Retrieved from https://www.youtube.com/watch?v=uRxxhHWdW3o

Frank, T. (2016). *iRobot sells off defense & security division*. Retrieved from https://www.therobotreport.com/news/irobot-spins-off-defense-security-division

High-Tech. (2016). *'TUG' Robots Will Do Heavy Lifting at Mission Bay*. Retrieved fromttp://www.ucsfmissionbayhospitals.org/articles/high-tech-tug-robots-do-heavy-lifting-at-mission-bay.html

Honda Worldwide ASIMO Histrory. (2016). Retrieved from http://www.world.honda.com

Hope, G. (2010). *Robot window cleaners to take over Dubai*. Retrieved from http://www.constructionweekonline.com/article-7496-robot-window-cleaners-to-take-over-dubai/

iRobot Roomba 800 Robot Vacuums. (2016). Retrieved from http://www.robotshop.com/en/irobot-roomba-800-series-robot-vacuums.html

Iype, C., & Porat, I. (1989). Fabric alignment using a robotic vision system. *International Journal of Clothing Science and Technology*, *1*(1), 39–43. doi:10.1108/eb002944

Jason, S. (2014). *A New Honda ASIMO is Coming*. Retrieved from http://www.autoguide.com/auto-news/2014/04/new-honda-asimo-coming.html

Kalinovsky, D. (2015). *Builder worker in safety protective equipment operating construction demolition machine robot.* Retrieved from https://www.123rf.com/photo_46807560_builder-worker-in-safety-protective-equipment-operating-construction-demolition-machine-robot-focus-.html

Karabegović, I., & Doleček, V. (2012). *Service robots. Tehnički fakultet*. Bihać, Bosnia and Herzegovina.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Karabegović, I., Felić, M., & Đukanović, M. (2013). Design and Application of Service Robots in Assisting Patients and Rehabilitations of Patients. *International Journal of Engineering & Technology, 13*(2), 11-17.

Karabegović, I., & Husak, E. (2010). Robot integration in Modelling and Simulation of Manufacturing Process. *1st International Scientific Conference on Engineering MAT 2010*, 37-41.

Karabegović, I., Kadić, S., & Ujević, D. (2003). Application of modular robotization line and intelligent textiles in clothing production. *2nd DAAAM International Conference on Advanced Technologies for Developing Countries*.

Karabegović, I., Karabegović, E., & Husak, E. (2010). Ergonomic integration of service robots with human body. *4th International ergonomics conference*, 249-254.

Karabegović, I., Karabegović, E., & Husak, E. (2012). Application of Robotic Technology in The Textile and Clothing Industry. *5th međunarodno znanastveno-stručno savjetovanje Tekstila znanosti i gospodarstva*, 285-290.

Karabegović, I., Karabegović, E., & Husak, E. (2013). Application of Service Robots in Rehabilitation and Support of Patients. *Časopis Medicina fluminensis*, *49*(2), 167-174.

LS3 - Legged Squad Support Systems. (2016). *PETMAN, BigDog - The Most Advanced Rough-Terrain Robot on Earth*. Retrieved from http://www.bostondynamics.com/robot_bigdog.html

Marques, L., de Almeida, A. T., Armada, M., Fernández, R., Montes, H., González, P., & Baudoin, Y. (2016). *State of the art review on mobile robots and manipulators for humanitarian demining*. Retrieved from http://www.fp7-tiramisu.eu/sites/fp7 tiramisu.eu/files/publications/State%20of%20the%20Art%20Review%20on%20Mobile%20Robots%20and%20Manipulators%20for.pdf

Meskoě, B. (2014). *The Guide to the Future of Medicine*. Technology and The Human Touch Paperback.

MESR - Mars Exploration Science Rover. (2015). Retrieved from http://www.asc-csa.gc.ca/eng/rovers/mesr.asp

Muller, R. A. (2010). *Physics and Technology for Future Presidents: An Introduction to the Essential Physics Every World Leader Needs to Know*. Hardcover.

Murrayon, P. (2013). *iRobot's RP-Vita Telepresence Robots Start Work At Seven Hospitals*. Retrieved from http://singularityhub.com/2013/05/18/irobots-rp-vita-telepresence-robots-start-work-at-seven-hospitals/

NASA's Human Robotic Systems Project. (2008). Retrieved from http://www.alamy.com/stock-photo-nasas-human-robotic-systems-project-focused-on-human-and-robotic-mobility-28096675.html

Paul, M. (2012). *Robot infantry get ready for the battlefield*. Retrieved from https://www.newscientist.com/article/mg19125705-600-robot-infantry-get-ready-for-the-battlefield/

Rita, B., Tyler, M., & Kaczmarek, M. (2003). Seeing with the brain. *International Journal of Human-Computer Interaction*, *15*(2), 285–295. doi:10.1207/S15327590IJHC1502_6

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RoboCourier Mobiler Roboter. (2016). Retrieved from http://www.swisslog.com/de/Products/HCS/Automated-Material-Transport/RoboCourier-Autonomous-Mobile-Robot

Robotic Armored Assault System – RAAS. (2016). Retrieved from http://www.globalsecurity.org/military/systems/ground/fcs-arv.htm

Robotics, W. (2009). *International Federation of Robotics (IFR)*. New York, Geneva: United Nations.

Robotics, W. (2010). *International Federation of Robotics (IFR)*. New York, Geneva: United Nations.

Robotics, W. (2011). *International Federation of Robotics (IFR)*. New York, Geneva: United Nations.

Robotics, W. (2012). *International Federation of Robotics (IFR)*. New York, Geneva: United Nations.

Robotics, W. (2013). *International Federation of Robotics (IFR)*. New York, Geneva: United Nations.

Robotics, W. (2014). *International Federation of Robotics (IFR)*. New York, Geneva: United Nations.

Robotics, W. (2015). *International Federation of Robotics (IFR)*. New York, Geneva: United Nations.

Robots in agriculture. (2015). Retrieved from https://www.intorobotics.com/35-robots-in-agriculture/

Siegwart, R., Illah, R. N., & Scaramuzza, D. (2011). *Introduction to autonomous mobile robots* (2nd ed.). London: The MIT Press.

Smart Technology from SITA Improves Passenger Experience at America's Friendliest Airport. (2016). Retrieved from http://airfax.com/blog/index.php/2016/11/15/smart-technology-from-sita-improves-passenger-experience-at-americas-friendliest-airport/

Stackelberg (2007). *Technology & the Future: Managing Change and Innovation in the 21st Century*. Academic Press.

SuperDroid HD2-S Mastiff Tactical / Surveillance Robot w/ 5DOF Arm. (2016). Retrieved from http://www.robotshop.com/ca/en/superdroid-hd2-s-mastiff-tactical-surveillance-robot-w-5dof-arm.html

Swimming Pool Chemicals and Equipment. (2013). Retrieved from http://mikepayne-poolsupplies.blogspot.ba/2013_01_01_archive.html

Tanya, M. A. (2015). *Robots and Healthcare Saving Lives Together*. Retrieved from http://www.robotics.org/content-detail.cfm/Industrial-Robotics-Industry-Insights/Robots-and-Healthcare-Saving-Lives-Together/content_id/5819

Teich, A. H. (2012). *Technology and the Future*. Berlin: Springer Verlag.

Theis, M. (2016). *Austin's futuristic rapid transit pod system: Can Garriott pull it off?* Retrieved from http://www.bizjournals.com/austin/news/2015/10/29/austins-futuristic-rapid-transit-podsystem-can.html

Ullrich G. (2015). *Automated Guided Vehicle Systems*. doi:10.1007/978-3-662-44814-4_2

Vicki S. (2016). *Building Enthusiasm for Construction Robotics*. Retrieved from http://insideunmanned-systems.com/building-enthusiasm-for-construction-robotics/

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Which NORDIC DINO is most suitable for your aircraft? (2013). Retrieved from http://admin.aviator.eu/wp-content/uploads/2014/02/Aviator_NordicDino_web.pdf

Zaragoza, T. (2009). *Automation and Robotics News*. Retrieved from http://academic.evergreen.edu/z/zaragozt/arnewsarchive.htm

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Chapter 30
Farmers' Access and Use of Mobile Phones for Improving the Coverage of Agricultural Extension Service:
A Case of Kilosa District, Tanzania

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ABSTRACT

This study sought to investigate on the access and use of mobile phones for improving the coverage of agricultural extension services among farmers in the pre-harvest stages of maize value chain in Kilosa district. The study examined the use of mobile phones as a means for improving the coverage of agricultural extension services. The study adapted a cross sectional study design and a multistage sampling technique. Data were mainly collected using structured questionnaires. The results revealed that majority of respondents used mobile phones and had a positive attitude on the contribution of mobile phone in their farming business. The study results also indicated that mobile phones offered an affordable solution to farmers' information needs and information requirements. The study concluded that the use of mobile phone to communicate agricultural information depends on information needs of farmers. The study recommended that farmers need to be encouraged and supported to access and use mobile phones in their farming business.

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1. BACKGROUND INFORMATION

Agriculture is one of the major sectors of Tanzania's national economy which contributes about 24.0 percent to the Gross Domestic Product (GDP) in addition to the other sectors of mining, industry, and tourism (Osberg & Bandara, 2012). The agricultural sector employs over 75 percent of the population which constitute majority of the poor small-holder subsistence farmers who utilize about 85 percent of the land cultivating not more than 2.0 million ha (Sibuga, 2008).The agricultural sector in Tanzania has continued facing a number of challenges including poor agricultural extension services resulting in low performance, low levels of production, low output quality, and a low contribution of the sector to the national socio-economic goals, underutilization of available resources, poor quality food products that lead to weak competitiveness in the international market and poor implementation of legal and regulatory frameworks (POPC, n.d). The agricultural extension services mainly aim at providing knowledge; information and technology that farmers would require to improve their productivity and quality of their lives and livelihoods (UN, 2005). The agricultural extension services in Tanzania are mainly funded by the Government despite the presence of private sectors, Non-Governmental Organizations (NGOs), and farmer-led initiatives which have been supplementing extension service delivery of the public extension services through cost-sharing (Kapange, 2010).

Nonetheless, Rutatora and Mattee (2001) observe that these experiences have not improved the quality of extension services which have been considered to improve the agriculture sector in Tanzania. Because of financial difficulties faced by the Government, the allocated budgets for agricultural sector do not support sufficient visits by field extension staff to farmers. Consequently, the agricultural sector has continued to perform poorly leading to low yields which are insufficient to raise people's income and promote food security among the households in Tanzania (Kapange, 2010).

In an attempt to improve provision of agricultural extension service, some countries such as Pakistan, India, Brazil, and the United States of America have opted for the use of Information and Communication Technology (ICT) (Katz, 2002; Hassan & Semkwiji, 2011). It is observed the agricultural sector has improved in those countries through the introduction of ICT in the Agricultural Extension Services (Hassan & Semkwiji, 2011; Siani, 2012). Furthermore, it is reported that the introduction of mobile phones services in agricultural sector in Pakistan, India, Brazil, and the United States of America has enabled farmers and other actors in the different value chains to receive high amount and quality of the agricultural extension service. In addition, the speed of services delivery has been improved significantly as a result of mobile phone intervention (Thomson, 2006; Buys et al., 2009; Aker & Mbiti, 2010; Goggin, 2012; Acker, 2011; Etim, 2012a; Etim, 2012b; Etim, 2013c).

This phenomenon points to Sub-Saharan African countries such as Tanzania whose access and use of mobile phones has increased tremendously. For instance, it is reported the access and use of mobile telephone has increased ten times as many mobile phones as landlines whereby 60 percent of the population has mobile phone coverage (Aker & Mbiti, 2008). In Tanzania, the 2012 national population census indicated there were 46.9 million people of which 28 million people were mobile phone subscribers and spend an average of 56.7 minutes on domestic calls a month (TCRA, 2015). In addition, in Sub-Saharan African countries, entertainment applications (games), voice calls and text messaging have been noted to be dominant in the access and usage of mobile phone (Aker & Mbiti, 2008). With such a boom in access and usage of mobile phones in Sub-Saharan African countries, mobile phone technologies are not fully implemented in extension services in the agriculture sector where over 75 percent of the people

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live in rural areas are highly engaged in agriculture for both as a source of food and income (Miller et al., 2013; ITU, 2014).

Therefore, this research sought to find how the access and use of mobile phone could help to improve the coverage of agricultural extension service among farmers in the pre-harvest stages of maize value chain. Cognizant of the role of mobile phones in achieving development goal, and given the recent nature of mobile phone in Tanzania, there are still concerns regarding the manner and the extent to which access and use of mobile phone improves the coverage of agricultural extension service in Tanzania. Previous research (e.g., Sife et al., 2010; Furuholt & Matotay, 2011) in the country has largely focused on how mobile phones contribute towards empowerment and improved rural livelihood and poverty reduction in general. Little (if any) has been documented with regards to how the access and use of mobile phones can improve the coverage of agricultural extension service in Tanzania from the user's perspective.

As presented earlier, the existing system of agricultural extension service provision faces a number of challenges including few extension officers and limited resources to serve many farmers (Due et al., 1997). There are few consultancies because extension officers and farmers often live in geographically dispersed areas (Anderson & Feder, 2007) and financial constraints which lead to irregular visits. For example, extension workers only wait until the budget supports them to visit farmers for extension service provision or re-visit farmers for feedback on the quality of the advice, new ideas and techniques rendered to farmers (Siani, 2012).

As Aker and Mbiti (2010) state, integrating mobile phones into the extension infrastructure will help to strengthen or develop an open system between farmers, extension agents, and other actors in the maize value chain to synergize the local and scientific knowledge so they do not only receive advice, but also give feedback hence creating a virtuous circle. In addition, the use of mobile phones in agricultural extension service has the potential to significantly reduce communication and information search costs whereby phone calls and Short Message Service (SMS) can replace the need for face-to-face interactions thereby reducing travel costs and saving time.

In addition, bringing mobile phone into use can also support the implementation of Tanzania's ICT Policy (2003) as it stands for efficiency, effectiveness, and sustainability in the provision of services and basic utilities by supporting the development and deployment of nationwide e-agriculture, e-health, e-tourism, e-education and e-commerce transactions (URT, 2003). Additionally, implementing the Agriculture Sector Development Strategy (ASDS) 2001 creates an enabling and conducive environment for improving profitability of the sector as the basis for improved farm incomes and rural poverty reduction in the medium and long-term plans (ASDS, 2001).

2. RESEARCH METHODOLOGY

2.1. Description of the Study Area

The research was conducted in the Kilosa District in Morogoro Region. Kilosa is located on the eastern part of Tanzania, and about 270 kilometers from Dar es Salaam and situated between 6 to 10S and 35E, with and altitude ranging between 300-600 meters above sea level. The District covers 14,918 square kilometers, and in 2002 had a population of more than 489,512 (NBS, 2012). The main ethnic groups in the District are the Sagara, Kaguru, Kwiva, Vidunda and some Gogo. The Kilosa District is comprised of nine Divisions, 36 Wards, and 132 Villages, with Kilosa town being its administrative headquarters.

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The District is divided into three ecological and six agro-economic zones including the flood plain, the plateau, and the mountainous or upland zones.

2.2. Research Design

The study used a cross sectional design. The design allows data collection at a single point time and reasonable costs (Bryman, 2015).

2.3. Sampling Techniques and Sampling Procedures

A multistage sampling design was used to obtain the study sample. Multistage sampling is a technique which involves more than one stage to obtain the sample. The sampling techniques for this study included; cluster sampling and simple random sampling. In this study, the selection of study sample followed the existing administrative units such as division, wards, and villages. The clustering sampling was used to obtain the clusters or groups. One of the divisions was selected among division clusters. Then, six wards were selected randomly from the selected division. Thereafter, two villages were selected randomly from each of the selected wards hence forming 12 villages. The following were sampled villages and the respective number of respondents for this study (Table 1).

2.4. Data Collection

Both primary and secondary data were collected. Structured interviews and questionnaires were administered to 200 respondents (Table 1). Documentary review was employed to gather information about

Table 1. Sampled Villages and their respective number of respondents

Villages	Frequency	Percent
Batini	16	8.0
Mbuyuni	16	8.0
Mvumi A	17	8.5
Mvumi B	16	8.0
Msowero	18	9.0
Mambwegwa	16	8.0
Ukaguru	16	8.0
Madudu	17	8.5
Tangini	18	9.0
Kikwajuni	16	8.0
Sikutari	17	8.5
Mkwajuni	17	8.5
Total	**200**	**100.0**

Source: Field data (2013)

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extension service in the district; specifically, reports from Kilosa agriculture and livestock development office, and agricultural extension officers were reviewed.

2.5. Data Processing and Data Analysis

Data collected were analyzed using the Statistical Package for Social Scientists (SPSS). Descriptive statistics analysis was conducted since it is mostly used in value chain analysis (Raikes et al., 2000; Kaplinsky & Morris, 2001) by computing frequencies/ percentages, measures of central tendency, measure of dispersion, and independent chi-square to show the association among variables.

2.6. Generalization of the study findings

The study was conducted in only 12 villages which were sampled from six wards of Kilosa district in the Morogoro region. However, the findings can be generalized beyond the 12 villages involved in the study provided there are similar situation to such selected study areas. It is therefore considered that the implication from the study will be applicable to other rural areas in the Kilosa district in the Morogoro region and elsewhere in Tanzania with a similar situation.

3. RESULTS AND DISCUSSION

3.1. Respondents' Social-economic Characteristics

In this aspect, the goal of the study is to establish the socio-economic characteristics of farmers. The sampled respondents are characterized by both male and female with the latter being in the majority (Table 2). A total of 72 percent of the respondents are married. Furthermore, a total of 89 percent of the respondents reported they had attained formal education while the remaining 11 percent reported not to have attained any formal education.

When asked to indicate their annual income, a total of 70 percent of respondents reported to have an annual profit which ranged from 500,000 to 1 million Tanzania Shillings (TAS). Further investigation revealed that respondents (50.5%) who did their transaction on maize production through mobile phones generated extra annual incomes ranging from 20,000 to 100,000 TAS.

3.2. Respondents' Other Factors Influencing Mobile Phone Ownership

Most of the respondents in Table 3 use electricity as a source of power to charge their mobile phones. When asked to indicate where they charge their phones, a total of 77.5 percent of the respondents do not charge their phone from their home as they depend on the neighborhood source of power. Furthermore, it was reported that because of many respondents charging their phones in the neighborhood which is a distance less than a kilometer, they prefer walking to and from charging their phones as compared to other means of transport.

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Table 2. Respondents profile (N=200)

Respondents' category	Frequency	Percentage
Respondents' Sex		
Male	95	47.5
Female	105	52.5
Total	**200**	**100.0**
Respondents' Age		
18-25	24	12.0
26-33	47	23.5
34-41	46	23.0
42-49	33	16.5
50-57	26	13.0
58-65	12	6.0
>66	12	6.0
Total	**200**	**100.0**
Marital status		
Married	144	72.0
Single	30	15.0
Divorced	10	5.0
Widow	16	8.0
Total	**200**	**100.0**
Education level		
no formal	22	11.0
standard four	6	3.0
standard seven	154	77.0
Secondary	16	8.0
College	2	1.0
Total	**200**	**100.0**
Annual Income		
<500,000	92	46.0
500,001-1ml	48	24.0
1,000,001-1.5ml	19	9.5
1.6-2ml	11	5.5
2.1-2.5ml	6	3.0
2.6-3.1ml	7	3.5
3.2-3.3ml	1	.5
3.4-3.9ml	8	4.0
> 4mil	8	4.0
Total	**200**	**100.0**

Source: Field data (2013).

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Table 3. Factors influencing mobile phone ownership (N=200)

Variables		Frequency	Percentage
source of power to charge mobile phone	use of electricity	147	73.5
	solar panel	41	20.5
	generator	6	3.0
	battery	6	3.0
	Total	**200**	**100.0**
Places for charging mobile phone	at home	45	22.5
	at neighbour's house	36	18.0
	mobile phone dealer	43	21.5
	shop	63	31.5
	kiosk	13	6.5
	Total	**200**	**100.0**
cost of charging mobile phone per week	500	133	66.5
	1000	29	14.5
	1500	7	3.5
	2000	3	1.5
	>2000	1	.5
	Cost nothing	27	13.5
	Total	**200**	**100.0**
Distance mobile phone charging station	<0.5km	174	87.0
	1km	19	9.5
	1.5km	6	3.0
	2km	1	.5
	Total	**200**	**100.0**
Means of transport used to charge mobile phone	By walking	125	62.5
	Own bicycle	27	13.5
	Own motorcycle	2	1.0
	Public transport	1	.5
	At home, no transport	45	22.5
	Total	**200**	**100.0**

Source: Field data (2013).

3.3. Respondents' Socio-Economic Characteristics and the Amount of Money Spent on Voucher/ Airtime for the Mobile Phone

It was also important to examine the socio-economic characteristics of the respondents and the amount of money spent per day to buy voucher/ airtime for the mobile phone and try to gauge on the pattern of the money spent on the voucher. Table 4 illustrates that a total of 95(47.5%) were male of which 55 (57.8%) or more than half spend 500 TAS to purchase a voucher / airtime for the mobile phone. Mean-

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while, of the respondents interviewed, a total of 105(52.5%) were female of which 83(79.0%) spend more than 500 TAS to buy a voucher / airtime for the mobile phone. A chi-square test results revealed there was statistical significant influence on the gender of the respondents and the amount of the money spend per day to buy a voucher/ airtime for the mobile phone at $\chi^2 = 12\ .412$ and $\rho > 0.015$.

This is because with a minimum amount of 500 TAS an individual can connect to so-called Extreme (i.e., bonus promotion airtime) and obtain more airtime minutes unlike the usual airtime minutes given for the equivalent amount of money. Therefore, the results found similar to that of Souter et al. (2005), in his study whereby telecommunications were found to have a significant correlation with the socio-economic characteristics of individuals.

Furthermore, Table 4 shows that a total of 108 (54%) persons had a standard 7th Grade education level which is more than half of the sampled population spending 500 TAS to purchase voucher / airtime for the mobile phone. This was followed by a total of 16 (8%) respondents with no formal education who spend 500 TAS to buy voucher / airtime for the mobile phone. The chi-square test results revealed there was high statistical significant influence on the education level and the amount of the money spend per day to buy a voucher/ airtime for the mobile phone shown at $\chi^2 = 60.456$ and $\rho > 0.000$.

Table 4 also illustrates that a total of 144 (72.0%) persons were married of which a total of 95 (65.9%) persons spend 500 TAS to buy a voucher/ airtime for the mobile phone. A total of 30 (15.0%) of the respondents were single of which a total of 20 (66.65%) spend 500 TAS to purchase voucher / airtime for the mobile phone. A total of 10 (5.0%) of the respondents were divorced of which 8 (80%) spend 500 TAS to buy a voucher / airtime for the mobile phone. However, a chi-square test results revealed there was no statistical significant influence on the marital status of the respondents and the amount of the money spend per day to buy a voucher/ airtime for the mobile phone shown at $\chi^2 = 13.349$ and $\rho > 0.344$.

Furthermore, Table 4 and the chi-square test results indicate there was high statistical significant influence on the respondents' annual income and the amount of the money spend per day to buy a voucher/ airtime for the mobile phone shown at $\chi^2 = 64.999$ and $\rho > 0.000$.

3.4. Socio-Economic Characteristics of the Respondents and Perception on the Use of Mobile Phone for Communicating Agricultural Information

Table 5 shows that all 200 respondents interviewed confirmed owning mobile phones. This shows that mobile phone penetration is also far higher compared to that of the entire nation during the last quarter of 2009 as highlighted by Samuel et al. (2005) where the rate was only (39.0%). Table 5 indicates the perception on the use of mobile phone for communicating agricultural information by farmer's socio-economic characteristics such as sex, marital status, age, income, and education level attained.

Although 52.4 percent of female respondents agree that owning a mobile phone is a good thing for communicating agricultural related information as opposed to male respondents (Table 5), the chi-square test revealed the respondent's gender had no statistical significant influence on the use of mobile phone for communicating agricultural information at $\chi^2 = .035$ and $\rho > 0.05$. This insignificant influence on gender could be due to the reason that both men and women are conversant in the use of mobile phone.

Similarly, the findings on education levels and mobile phones usages concur with the observations by Bertolini (2002), Dunn and Dunn (2006); and Baumüller (2012) that primary education had a stronger influence on mobile phone ownership. This is because as presented in Table 5 the majority of those

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Table 4. Socio-economic characteristics of the respondents and the amount of money spent per day to buy a voucher/ airtime for the mobile phone (n=200)

	The amount of the money (TAS) spent per day to buy a voucher/ airtime for the mobile phone						Chi-square test	
Variables	**500**	**1000**	**1500**	**2000**	**>2000**	**Total**	**χ^2 - value**	**P- value**
Sex of the respondents								
Male	55	30	2	6	2	95	12.412	0.015
Female	83	15	3	2	2	105		
Education level								
No formal education	16	6	0	0	0	22	60.456	0.000
Standard four	4	1	0	0	1	6		
Standard seven	108	35	4	5	2	154		
Secondary	10	3	1	1	1	16		
College	0	0	0	2	0	2		
Age of the respondents								
18-25	17	5	2	0	0	24	21.450	0.612
26-33	29	13	2	2	2	47		
34-41	33	11	0	2	0	46		
42-49	22	5	1	3	2	33		
50-57	17	8	0	0	1	26		
58-65	9	2	0	1	0	12		
>66	11	1	0	0	0	12		
Marital Status								
Married	95	37	3	7	2	144	13.349	0.344
Single	20	6	2	1	1	30		
Divorced	8	1	0	0	1	10		
Widow	15	1	0	0	0	16		
Annual income								
<500,000	78	12	0	2	0	92	64.999	0.000
500,001-1mill	28	13	2	2	3	48		
1,000,001-1.5 mill	12	5	0	2	0	19		
1.6-2 mill	7	3	1	0	0	11		
2.1-2.5 mill	2	3	0	1	0	6		
2.6-3.1 mill	3	1	2	0	1	7		
3.2-3.3 mill	1	0	0	0	0	1		
3.4-3.9 mill	3	4	0	1	0	8		
>4 mill	4	4	0	0	0	8		

Source: Field data (2013).

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Table 5. Socio-economic characteristics of the respondents and perception on the use of mobile phone for communicating agricultural information (n=200)

	Owning a mobile phone a good thing for communicating agricultural information					Chi-square test	
Variables	**Yes**	**%**	**No**	**%**	**Total**	**χ^2 - value**	**P- value**
Sex of the respondents							
Male	91	47.6	4	44.4	95	.035	0.851
Female	100	52.4	5	55.6	105		
Education level							
No formal education	21	11.0	1	11.1	22	2.916	0.572
Standard four	5	2.6	1	11.1	6		
Standard seven	147	77.0	7	77.8	154		
Secondary	16	8.4	0	0	16		
College	2	1.0	0	0	2		
Age of the respondents							
18-25	23	12.0	1	11.1	24	8.588	0.198
26-33	46	24.1	1	11.1	47		
34-41	45	23.6	1	11.1	46		
42-49	30	15.7	3	33.3	33		
50-57	26	13.6	0	0	26		
58-65	11	5.8	1	11.1	12		
>66	10	5.2	2	22.2	12		
Marital Status							
Married	138	72.3	6	66.7	144	.950	0.813
Single	28	14.7	2	22.2	30		
Divorced	10	5.2	0	0	10		
Widow	15	7.9	1	11.1	16		
Annual income							
<500,000	88	46.1	4	44.4	92	6.443	0.598
500,001-1mill	47	24.6	1	11.1	48		
1,000,001-1.5 mill	18	9.4	1	11.1	19		
1.6-2 mill	11	5.8	0	0	11		
2.1-2.5 mill	5	2.6	1	11.1	6		
2.6-3.1 mill	6	3.1	1	11.1	7		
3.2-3.3 mill	1	5	0	0	1		
3.4-3.9 mill	8	4.2	0	0	8		
>4 mill	7	3.7	1	11.1	8		

Source: Field data (2013).

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with a primary school education believe owning mobile phone is good for communicating agricultural information and a chi-square test revealed the respondents' education levels had no any statistical significant influence on the use of mobile phone for communicating agricultural related information at $\chi^2 = 2.916$ and $\rho > 0.572$.

This insignificance could be probably due to the basic knowledge required for one to make use of their mobile phone unlike other ICTs such as computers and other electronic devices. This agrees with the observations made by Khalil et al. (2009) that wireless technologies have reached rural populations because of the advantages such as mobility, ease of use, flexible deployment, and relatively low and declining cost.

Given the conclusion by Porter et al. (2012) and Brooks et al. (2013) that the majority of ICTs users tend to be young adults, an investigation on whether or not age was a factor for mobile phone usage in communicating agricultural information was conducted. The findings show that 47.8 percent who believe on communicating agricultural information through mobile phone were between the ages of 26 and 41. The chi-square test refutes Sounders et al.'s observation since it revealed that age of respondents had no any statistical significant influence on the use of mobile phone for communicating agricultural related information at $\chi^2 = 8.588$ and $\rho > 0$.

Additionally, the findings indicate that marital status has no influence on the use of mobile phone for communicating agricultural related information and a chi-square test shows there was no statistical significant difference at $\chi^2 = .950$ and $\rho > 0.813$ (Table 5). Lastly, a chi-square test results revealed that there was no statistical significant influence on the annual income obtained and the use of mobile phone for communicating agricultural information.

3.5. Benefits of Using Mobile Phone to Access Agricultural Extension Service

Khalil et al. (2009) observe that due to the many advantages such as mobility, ease of use, flexible deployment, and relatively low and declining cost, wireless technologies have reached rural populations, As it can be seen in Table 6, a total of 95.5 percent of the respondents believe that owning a mobile phone is advantageous for communicating maize related information, while only 4.5 percent do not agree. Furthermore, when asked on the areas where mobile strengthened their involvement in the maize value chain, more than half of the respondents (see Table 6) indicated to have been in the position of getting maize market information through their mobile phone. Approximately 25 percent of farmers use mobile phones to enquire input related information and a few respondents (10.5%) conduct the money transaction via their mobile phones. These findings are similarly to Kleih et al. (2004)'s study which found that cost savings, combined with quick access to information and instant communication with trade partners opens new market possibilities.

Apart from the areas in which mobile phone use has strengthened farmer's involvement in maize value chain, it was discovered there are other benefits on the use of mobile phone by farmers such as reducing risks and loss, increase of stable customers, etcetera. For example, looking at below listed different views and benefits on why farmers preferred using mobile phone in communicating maize related information:

N.L.M from Batini Village: I always use my mobile phone to communicate with retailers so to find out what is the current price for the maize when I want to sell my maize produce and this has helped to

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Table 6. Areas that mobile phone has strengthened farmer's involvement in maize value chain (n=200)

		Frequency	Percentage
mobile phone is used to communicate maize related information	Yes	191	95.5
	No	9	4.5
	Total	**200**	**100.0**
Areas mobile strengthened involvement in the maize value chain	Maize market related information	103	51.5
	Weather related information	6	3.0
	Maize transport related information	3	1.5
	Disease related information	8	4.0
	Maize processing related information	2	1.0
	Input related information	50	25.0
	Money transfer information	21	10.5
	I cannot say	7	3.5
	Total	**200**	**100.0**

Source: Field data (2013).

reduce the risk of getting loss from selling the maize to brokers who come and persuade us to sell on their own price

A.R.M from Msowero Village: From mobile phone use, I have increased the number of potential buyers who normally call and enquire maize cargo available for market and sometimes the payments are made through M-PESA. I always don't prefer walking with huge amount of money I get from selling maize.

- Types of agricultural information communicated by farmers

3.6. Number of Calls Made by Famers Requesting for Land Preparation Information

The study also investigated on the consultancies made by farmers to different actors requesting land preparation related information and the frequency of contact. It was found that a majority of the respondents (see Table 7) call their fellow farmers requesting land preparation information during land preparation season. Additionally, a total of 48.5 percent of respondents were found to call their fellow farmers twice a day requesting for such information.

Interestingly, relatively few farmers (approximately 16 percent) contact the extension agent for agricultural information during land preparation. A total of131 farmers, more than half of the sampled population, call their fellow farmers requesting land preparation information during the land preparation season, whereas a total of 97 farmers contact their fellow farmers twice a day requesting for the land preparation information during land preparation season.

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Table 7. Number of calls made by famers requesting for land preparation information (n=200)

		Number of calls made using mobile requesting for land preparation related information							Total
		twice in a day	Four times in a week	Once in a month	Once in two month time	Twice in two month time	Once in four month time	Once in six month time	
Type of actor called during land preparation season	Input supplier	22	3	4	0	0	0	4	33
	Fellow farmer	97	15	7	5	2	1	4	131
	Maize broker	2	1	0	0	0	0	0	3
	Transporter	1	0	0	0	0	0	0	1
	Extension agent	24	4	1	1	0	1	1	32
Total		**146**	**23**	**12**	**6**	**2**	**2**	**9**	**200**

Source: Field data (2013).

3.7. Number of Calls Made by Farmers Requesting for Maize Planting Season Related Information

Table 8 shows the number of calls made by farmers to respective actors requesting maize planting season related information during the season. The data also indicates that many farmers (approximately 76 percent) contact their fellow farmers requesting for maize planting season related information during the season. Reviewing the number of calls per day indicates that 46.0 percent of the farmers call their fellow farmers twice a day requesting for maize planting season related information during the season.

Table 8. Number of calls made by farmers requesting for maize planting season related information (n=200)

		Number of calls made by farmers using mobile phone requesting for the maize planting season related information							Total
		twice in a day	Four times in a week	Once in a month	Once in two month time	Twice in two month time	Once in four month time	Once in six month time	
Type of actor called during the maize planting season	Input supplier	7	2	1	0	0	0	1	11
	A fellow farmer	92	29	17	5	2	1	6	152
	An extension agent	18	7	7	1	1	2	1	37
Total		**117**	**38**	**25**	**6**	**3**	**3**	**8**	**200**

Source: Field data (2013).

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3.8. Number of Calls Made by Farmers Requesting for Herbicide Application Season Related Information

The study was further interested in investigating the number of calls made by farmers to respective actors requesting herbicide application season related information during the herbicide application. Table 9 shows that a total of 54 percent of the respondents seek herbicide application information from their fellow farmers as opposed to 24.5 of respondents who call the extension agents. On the rate of calls, the finding indicates that very few farmers have regular contact on the use of herbicides as only 22.5 percent of the farmers call their fellow farmers twice a day requesting for the herbicide application season related information during the herbicide application.

It was observed most of the calls made by farmers on the three types of agricultural related information (Table 7, Table 8, Table 9) on the pre harvest stages of maize value chain were direct to their fellow farmers. Furthermore, the findings indicate the planting season has the highest consultancy rate followed by land preparation season. The herbicide application season is the least consulted season. The study also discovered that farmers prefer calling their fellow farmers because of either lack of extension officers or poor cooperation shown by extension officers to farmers as it is clearly indicated in the below comments:

B.M. from Mkwajuni Village, I have remained calling my fellow farmer because the Agricultural Extension Officer (AEO) reported in our Ward and requested for the permission to go and collect his belongings he has never come back since then and we are told he has gone for further training.

S.R.A from Sikutari Village, There was one time in 2009 the all maize plants in one of my farm were invaded or affected by worms. I was given the Agricultural Extension Officer's number and called him for my surprise he promised to come but he did not come, I kept on calling but he never picked up. With that I got a huge loss and lost hope on the Agricultural Extension Officer's assistance. I just call my fellow farmers for any assistance needed.

Table 9. Number of calls made by farmers requesting for herbicide application season related information (n=200)

		Number of calls made using mobile phone requesting for the herbicide application season related information							Total
		twice in a day	Four times in a week	Once in a month	Once in two month time	Twice in two month time	Once in four month time	Once in six month time	
Actor called during the herbicide application	Input supplier	18	15	3	5	1	1	0	43
	A fellow farmer	45	26	24	3	6	2	2	108
	An extension agent	15	19	8	6	0	1	0	49
Total		**78**	**60**	**35**	**14**	**7**	**4**	**2**	**200**

Source: Field data (2013).

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3.9. Communication Channels used by Farmers to Get Maize Related Information

Investigating the other ways farmers employ to get maize related information shows that farmers also use other ways of communication used in the maize value chain to obtain information. Table 10 indicates that radio, newspaper, letters, television, leaflets, and face-to-face were found to be the common means of communication maize related information with the radio being the highly favored and leaflet being the least favored.

3.10. To Determine the Constraints in the use of Mobile Phones to Access Agricultural Extension Service among Actors in the Pre-Harvest Stages of Maize Value Chain

Although network problems were reported to be the major challenge that limits farmers to fully use their mobile phones to send and receive maize related information, the findings indicate a total of 89 percent of the farmers are constrained with mobile phone operating costs such as battery charging costs and recharging credits (Table 11). These findings concur with previous studies (Samuel et al*.,* 2005; URT, 2010) which suggest the improvement of the positive correlation between mobile phone ownership and access to electricity. Likewise, Gollakota (2008) observes that despite the positive effects associated with the use of ICT tools for enhancing livelihood opportunities, electric power and cost are hindering factors. Other challenges reported include unavailability of voucher and lack of mobile phone maize related contents. These limit farmers to fully utilize their mobile phone to send and receive maize related information.

3.11. Extension Agents' Views on the Use of Mobile Phones for Communicating Agricultural Related Information

The study findings indicated that most farmers seek agricultural related information from their fellow farmers much more than they request the same from extension agents. This drove an interest to gauge the extension agents' views on the interest of using mobile phones in communicating agricultural related

Table 10. Communication channels used by farmers to get maize related information (n=200)

Variables	Frequency	Percent
Radio	96	48.0
Newspapers	4	2.0
Letter writing	3	1.5
Television	51	25.5
face to face	44	22.0
leaflets	2	1.0
Total	**200**	**100.0**

Source: Field data (2013).

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Table 11. Challenges facing farmers in using mobile phone to communicate maize related information (n=200)

Variables		Frequency	Percentage
mobile phone operating costs limit actor to fully use mobile phones to send and receive maize related information	Yes	178	89.0
	No	22	11.0
	Total	200	100.0
network problem limit actor to fully use mobile phones to send and receive maize related information	Yes	185	92.5
	No	10	5.0
	I don't know	5	2.5
	Total	200	100.0
unavailability of voucher limit actor to fully use mobile phones to send and receive maize related information	Yes	176	88.0
	No	9	4.5
	I do not know	15	7.5
	Total	200	100.0
Lack of mobile phone maize related contents limit actor to fully use mobile phone to send and receive maize related information	Yes	131	65.5
	No	69	34.5
	Total	200	100.0
lack of awareness limit actor to fully use mobile phones to send and receive maize related information	Yes	60	30.0
	No	140	70.0
	Total	200	100.0

Source: Field data (2013).

information. A total of10 extension agents were interviewed and all of them owned mobile phones. When asked whether they communicate with farmers about the maize related information using their mobile phone, they all agreed to do so; however, at a different rate. For example, only 40 percent reported to communicate with farmers about maize related information more than three times a week. Approximately 60 percent (see Table 12) called only twice a week and they had different views on it as follows:

J.M from Kimamba A ward. I have a positive hope in the use of mobile phone for communicating agricultural related information, for example and just from my ward, am the only agricultural extension officer, am to visit different villages within my ward for something which is always difficult during the agricultural season so needed by farmers in the different villages which is always difficult to divide myself for

G.M from Rudewa ward. YES that we are two agricultural extension officers in this ward but one may fall sick that can't be in the position to visit the villages but with a help of a mobile phone can just respond to the queries and give simple directives to farmers instead of leaving and making more matters worse

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Table 12. Frequency of calls from Extension agents to farmers on maize related information (n=10)

		Frequency	Percentage
use of mobile phone by extension agent to communicate with farmers about the maize related information	Yes	10	100.0
	Total	10	100.0
Frequency of extension agent communicating with the farmers about maize-related information	twice a week	3	30.0
	Thrice a week	3	30.0
	More than three times a week	4	40.0
	Total	10	100.0

Source: Field data (2013)

T.S from Msowero ward. I make calls but haven't officially acknowledged it that it would be, but if incorporated as a means or ways of agricultural extension provision will help the constrained budget received from the government that can't surfers the sufficient visit to farmers for agricultural extension provision

Furthermore, the following have been noted by extension agents as the most frequency of calls made by farmers inquiring about agricultural related information as follows:

Calls made during input application

When asked to what type of input application do farmers do frequently call, almost all the extension agents (see Table 13) reported that famers frequently call inquiring about the type of maize variety to plant, followed by the type of fertilizer to use. The least frequent calls that extension agents received were inquires on the type of insecticide to spray.

Calls made during farm operation activities

Furthermore, the findings presented in Table 14 on the frequency of calls made by famers to extension agents during farm operation activities indicate the most frequent calls received from farmers were during land preparation, followed by sowing periods with the least frequent calls made during weeding.

3.12. Challenges Facing Extension Agents on the Use of Mobile Phone

Apart from the various challenges noted in Table 15, the following were major challenges mentioned by extension agents in the use of mobile phone for communicating agricultural related information as follows:

J.M from Kimamba A ward. The most embarrassing thing in the use of mobile phone for communicating agricultural related information is that, majority of farmers do beep us instead of calling. They think that we always have enough credit hours or airtime to call them back for something not true

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Table 13. Frequency of calls made by farmers to Extension agents on maize input information (n=10)

		Frequency	Percentage
most farmers call extension agent using their mobile phones to enquire about maize-related information	Yes	10	100.0
	Total	10	100.0
Frequency of calls from farmers to extension agent on type of maize variety to plant	Most frequent	9	90.0
	Least frequent	1	10.0
	Total	10	100.0
Frequency of calls from farmers to extension agent on type of fertilizer to use	Most frequent	6	60.0
	Least frequent	4	40.0
	Total	10	100.0
Frequency of calls from farmers to extension agent on type of insecticide to spray	Most frequent	5	50.0
	Least frequent	5	50.0
	Total	10	100.0

Source: Field data (2013).

Table 14. Frequency of calls from farmers to Extension agents on farm operation information (n=10)

		Frequency	Percentage
frequency of farmers call extension agent to enquire maize related information during land preparation	Most frequent	10	100.0
	Total	10	100.0
frequency of farmers call extension agent to enquire maize related information during sowing	Most frequent	6	60.0
	Least frequent	4	40.0
	Total	10	100.0
Frequency of farmers call extension agent to enquire maize related information during weeding?	Most frequent	3	30.0
	Least frequent	7	70.0
	Total	10	100.0
frequency of farmers call to extension agent to enquire maize related information during harvesting	Most frequent	2	20.0
	Least frequent	8	80.0
	Total	10	100.0

Source: Field data (2013).

S.N from Mkwajuni ward. Just from mobile phone communication or conversation, it is sometimes difficult to know the real situation being conveyed of what is actually happening on the farm or ground and weather the description given back is appropriately

Additionally, extension agents mentioned network problems and mobile phone operating costs as the major challenges that limit them to fully use your mobile phones to send and receive maize related

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information. In addition, many extension agents (see Table 15) noted the lack of mobile phone maize related contents, unavailability of vouchers, and awareness limit extension agents to fully use their mobile phone to send and receive maize related information.

3.13. Broader 'Community' Impacts on the Use of Mobile Phones for Agricultural Extension

The findings of this study indicate mobile phones are noted to be the most exciting forms of ICTs for agriculture particularly in the context of developing nations. They enhance ways in which communities acquire, exchange, and or manipulate information to maintain social networks or to provide access to information on socio-economic opportunities. For example, in the agriculture sector mobile phones farmers asserted to have had made informed decisions much more easily through the information communicated to respond to opportunities which have improved their agricultural productivity and bargaining power of farm produce.

The ownership of mobile phones by different agricultural stakeholders in the Kilosa District has widely spread and increasingly assisted to overcome isolation and make communication between rural farmers, extension officers, policy makers, transporters, traders, processors, input suppliers' and researchers from SUA easier. This concurs with what different researchers (Goodman, 2005; De Bruijn, 2009) who attempted establish the linkages between mobile phones, livelihoods and poverty reduction among communities.

Table 15. Challenges facing extension agents in communicating maize related information using mobile phones (n=12)

		Frequency	Percentage
mobile phone operating costs limit extension agent to fully use your mobile phones to send and receive maize related information	Yes	10	100.0
	Total	10	100.0
network problem limit extension agent to fully use your mobile phones to send and receive maize related information	Yes	10	100.0
	Total	10	100.0
unavailability of voucher limit extension agent to fully use your mobile phones to send and receive maize related information	Yes	8	80.0
	No	2	20.0
	Total	10	100.0
lack of mobile phone maize related contents limit extension agent to fully use your mobile phone to send and receive maize related information	Yes	9	90.0
	No	1	10.0
	Total	10	100.0
lack of awareness limit extension agent to fully use your mobile phones to send and receive maize related information	Yes	9	90.0
	No	1	10.0
	Total	10	100.0

Source: Field data (2013).

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For example, Goodman (2005) reports that mobile phones have become increasingly important to agro-based entrepreneurs as it creates an infrastructure service to improve the efficiency of agriculture markets; hence, contributing to farmers' empowerment. Therefore, the economic and social returns of mobile phones are high to the communities which use it as communal tool.

In line with the above discussions, Table 6 shows that the information needs for the majority of the respondents' (51.5%) regards marketing information. This indicates the information seeking behavior is skewed towards marketing information rather than information related to farm productivity. Surprisingly, the main source of the marketing information for most of respondents is their fellow farmers and not the extension officers (Tables 6, 7, 8). The other source of communicating agricultural related information mentioned by many respondents is the radio (Table 9).

Table 3 shows that majority of respondents' (77.5%) charge their mobile phone in the neighborhood as opposed to those who charge them from their home. This implies that even though mobile phone is uplifting the well-being of rural farmers, there is a destructive phenomenon arising from it. Some philosophers have termed this emerging revolution of mobile phones to have brought a negative effect called possessive individualism[1]. In Kilosa, this negative effect has been addressed through the use of Kilosa Community radio which is used to communicate agriculture information for entire communities. Essentially, community radio is a means for "community" communication as it broadcasts different topics related to agricultural husbandry, marketing, and livestock keeping (Sanga et al., 2013).

Additionally, in Kilosa there is a private information centre called KIRSEC which works in collaboration with the Kilosa Community radio, the Kilosa District Council, and the Sokoine University of Agriculture. Through these different initiatives in Kilosa, the communication between rural farmers, extension officers, researchers, policy makers, producers, processors and traders have been strengthened using integration of multiple communication channels (Sanga et al., 2013).

These channels include web- based farmers' advisory information systems, mobile- based farmers' advisory information systems, community radio, and conventional face-to-face agriculture extension systems (Sanga et al., 2013). The application of the integrated system has helped to address the rise of possessive individualism brought by the mobile revolution. There remains much work to reap the wider impacts of mobile technology to different farming communities in developing world. The question forwarded by Toyama (2010) to whether technology can end poverty is still valid to different farming communities in Tanzania. Toyama recommended

…the value of a technology remains contingent on the motivations and abilities of organizations applying it—villagers must be organized, content must be produced, and instructors must be trained (Toyama, 2010: p.8)

Without observing the warning by Toyama (2010), we might experience the negative effects of mobile phones. Some communities have already started experiencing the negative effects of mobile phones. DeMaagd (2010) observe that there is a negative association between investment in mobiles and GDP in developing countries possibly because mobiles represent a diversion of resources away from other productive uses. Similarly, the study by Diga (2007) establishes that at the micro-level in some rural Ugandan households are sacrificing expenditure on purchasing food so that they can pay for mobile airtime. Additionally, some communities' members admitted that they don't go to social functions so that they can

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save money for mobile phones and airtime. The findings by Diga (2007) is similar to that of Mpogele et al. (2008) who assert that respondents reported that they sometimes "substitute important needs (e.g. education, buying food, and clothes) for mobile phone ownership/usage" (Mpogole et al., 2008, p. 7).

Furthermore, Mpogole et al. (2008) noticed that respondents walk between 3 to 7 kilometers 2 to 3 times per week to recharge their mobile batteries. This is almost similar to this study which found most respondents walk less than 0.5 kilometers to charge their phones. Thus, for a single round trip the respondents travel almost one kilometer and for the whole week they might travels more than three round trips thus making more than three kilometers in total.

4. CONCLUSION AND RECOMMENDATIONS

This study found that mobile phones have provided rural farmers with a fast and easy mode of communication, thereby increasing famers' ability to access agricultural related information. In addition, mobile phones help rural farmers to secure better markets and price, save time and money, and promptly communicate their agricultural related information. Furthermore, the study found that mobile phone offers an attractive solution to many rural poor individuals and communities due to its general accessibility and collective ownership models.

The use of mobile phones have made market information available to farmers thus improving their position in the value chain by increasing their knowledge and ability to make better informed decisions which has increased their bargaining power with local middlemen. Mobile phones make a great contribution in reducing information costs, simply because as farmers communicate verbally with other actors in value chain, they do sharply, cheaply and without geographical limitation. The study findings again indicated that mobile phone technology is highly accessible to people in the study area.

In terms of access to agricultural information through mobile phones, it was evident that farmers in the study area took the advantage of increased numbers of mobile phone to access information related to their farming activities. This observation is similar to Sanga et al. (2013) who report that farmers used their mobile phones to contact different agricultural stakeholders to meet both technical and agricultural market information. In order to address the negative effect brought by the rise of mobile communication, which favors one to one communication sharing rather than networking communities or providing a shared public or community access point, we have developed an integrated system called 'Ushaurikilimo'. This system is found at http://www.ushaurikilimo.org.

4.1. What Is 'Ushaurikilimo'?

Sokoine University of agriculture in collaboration with a number of partners has developed Ushaurikilimo. 'Ushaurikilimo' is a Swahili word that stands for 'Agro-Advisory'.

'Ushaurikilimo.org' is an Agro-Advisory Service that allows any agriculture actors (e.g. farmer, extension officer, policy maker, trader, etc) to ask for advisory to agriculture extension officer using either web or mobile phone. This means the system is an integrated system which has modules for mobile based farmers' advisory information system (M-FAIS) and web based farmers' advisory information system (W-FAIS). M-FAIS & W-FAIS allows farmers to get advice in various agricultural issues such as agro-

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nomic practices, post-harvest operations, livestock husbandry, forestry, veterinary services, community development and market. A farmer can send a question to either 0688099408. After that the farmer is answered by agriculture experts via his or her mobile phone.

This system is developed by experts from Sokoine University of Agriculture under funding of EPINAV.

4.2. Recommendations

Based on the stated conclusion above, the recommendations from this study are as follows:

i. The Government, NGOs and other stakeholders should work together to help farmers own mobile phones, for instance through loans.
ii. Farmers should be provided with basic education on mobile phone usage, since views from Agricultural Extension Officers (AEO) and input suppliers reported that provision of education to farmers concerning mobile phones use could increase better use of mobile phones in communicating agricultural information to Tanzania farmers in particular.
iii. The Government should provide mobile phones to AEO and to some outstanding farmers to accelerate the adoption of new technologies.
iv. The use of mobile phone has a bright future to increase delivery of agricultural information; the Government should therefore reduce mobile phone tariffs, particularly through encouraging rigorous competition between mobile phone services providers.
v. The Government should introduce public phone booths for many farmers to be able to communicate agricultural information.
vi. Rural farmers need to be provided with education on the use, modes of application and benefits associated with mobile phones in the art of communicating agricultural information.
vii. Agricultural and Irrigation District Office should mount basic ICT courses for training farmers using their Agricultural Extension Staff in maize husbandry.
viii. Agricultural and Irrigation District Office should liaise with Kilosa District Council for lowering airtime charges so that many farmers can afford.
ix. Agricultural and Irrigation District Office should develop localized agricultural, and livestock contents and market information for web and mobile based famers' advisory information systems i.e. M-FAIS & W-FAIS.

REFERENCES

Acker, J. C. (2011). Dial "A" for agriculture: using information and communication technologies for agricultural extension in developing countries (Working Paper). Tufts University, Economics Department and Fletcher School, Medford, MA.

Aker, C., & Mbiti, M. (2008). Mobile Phones and Economic Development in Africa. *Invited presentation at the Center for Global Development*, Washington DC, USA.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Aker, J. C., & Mbiti, I. M. (2010). Mobile phones and economic development in Africa. Center for Global Development Working Paper.

Anderson, J. R., & Gershon, F. (2007). Handbook of agricultural economics. Agricultural Extension. 3, 2343-2378.

Baumüller, H. (2012). Facilitating agricultural technology adoption among the poor: The role of service delivery through mobile phones. ZEF Working Paper Series.

Bertolini, R. (2004). Information and Communication Technologies in Low income Countries, Retrieved on March 1, 2013, from: http://www.undp.wg/info21/inder.htm

Brooks, K., Zorya, S., Gautam, A., & Goyal, A. (2013). Agriculture as a sector of opportunity for young people in Africa. World Bank Policy Research Working Paper 6473.

Bryman, A. (2015). *Social research methods*. Oxford: Oxford University Press.

Buys, P., Susmita, D., Thomas, S., & Wheeler, D. (2009). Determinants of a digital divide in Sub-Saharan Africa: A spatial econometric analysis of cell phone coverage. *World Development*, *37*(9), 1494–1505. doi:10.1016/j.worlddev.2009.01.011

De Bruijn, M. (2009). *Mobile phones: The new talking drums of everyday Africa*. African Books Collective.

DeMaagd, K. (2010). Pervasive versus productive: the case of mobile phones in developing economies. *Proceedings of SIG GlobDev's First Annual Workshop, Paris, France*.

Diga, K. (2007). *Mobile cell phones and poverty reduction: Technology spending patterns and poverty level change among households in Uganda* [Doctoral dissertation]. School of Development Studies, University of KwaZulu-Natal.

Due, J. M., Magayane, F., & Temu, A. A. (1997). Gender again—Views of female agricultural extension officers by smallholder farmers in Tanzania. *World Development*, *25*(5), 713–725. doi:10.1016/S0305-750X(96)00129-5

Dunn, H., & Dunn, L. (2006).Gender standing Mobile Telephony.Women, Men and Their Use of the Cellular Phones in the Caribbean.A Working Paper. Retrieved from http://www.dirsi.net/english/files/background%20papers/070216--dunn.pdf

ENDNOTES

Etim, A.S. (2012a). Managing content for information centers and large repositories using the DITA framework. *Journal of Technology Research*.

Etim, A. S. (2012b). The emerging market of Sub-Saharan Africa and technology adoption: Features users desire in mobile phones. *International Journal of ICT Research and Development in Africa*, *3*(1), 14–16. doi:10.4018/jictrda.2012010102

Etim, A.S. (2013c). Mobile technology adoption for microfinance delivery in Sub-Saharan Africa. *Research in Business and Economics Journal*, 7.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Furuholt, B., & Matotay, E. (2011). The Developmental Contribution from Mobile Phones Across the Agricultural Value Chain in Rural Africa. *The Electronic Journal on Information Systems in Developing Countries*, 48.

Goggin, G. (2012). *Cell phone culture: Mobile technology in everyday life*. New York: Routledge.

Gollakota, K. (2008). ICT use by businesses in rural India: The case of EID Parry's Indiaggriline. *International Journal of Information Management*, *28*(4), 336–341. doi:10.1016/j.ijinfomgt.2008.04.003

Goodman, D. (2005). Linking mobile phone ownership and use to social capital in rural South Africa and Tanzania. *The Vodafone Policy Paper Series*, *2*(03), 53–65.

Hassan, A. K., & Semkwiji, D. (2011). The Role of Mobile Phones on Sustainable Livelihood. The Economic and Social Research Foundation (ESRF) Discussion Paper No. 33.

International Telecommunication Union (ITU). (2014). Manual for measuring ICT access and use by households and individuals. Geneva: ITU. Retrieved from http://www.itu.int/dms_pub/itu-d/opb/ind/D-IND-ITCMEAS-2014-PDF-E.pdf

Kapange, B. (2010). ICTs and National Agricultural Research Systems–The case of Tanzania, Ministry of Agriculture. Food Security and Cooperatives.

Kaplinsky, R., & Morris, M. (2001). A Handbook for Value Chain Research (Working Paper). Institute for Development Studies.

Katz, E. (2002*). Innovative approaches to financing extension for agriculture and natural resources management*. Eschikon: LBL.

Khalil, M., Dongier, P., & Qiang, C. Z.-W. (2009). Overview. In Information and communications for development (IC4D) Information and communications for development (pp. 3–17). Washington, DC: The World Bank.

Kleih, U., Okoboi, G., & Jonowski, M. (2004). Farmers and Traders' sources of market information in Lira District. *Uganda Journal of Agricultural Science*, *1*(9), 693–700.

Miller, C., Saroja, V. N., & Linder, C. (2013). *ICT uses for inclusive agricultural value chains*. FAO Rome.

Mpogele, H., Usanga, H., & Tedre, M. (2008). Mobile Phones and Poverty Alleviation: A Survey Study in Rural Tanzania. *Proceedings of The 1st International Conference on M4D Mobile Communication Technology for Development (M4D 2008, General Tracks)* (pp. 62-72). Karlstad University.

National Bureau of Statistics. NBS. (2012). 2012 Population and Housing Census: Population Distribution by Administrative Areas. Project Report. National Bureau of Statistics.

Osberg, L., & Bandara, A. (2012). *Why Poverty Remains High in Tanzania: And What to Do about It?* REPOA.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Porter, G., Hampshire, K., Abane, A., Munthali, A., Robson, E., Mashiri, M., & Tanle, A. (2012). Youth, mobility and mobile phones in Africa: Findings from a three-country study. *Information Technology for Development*, *18*(2), 145–162. doi:10.1080/02681102.2011.643210

Raikes, P., Jensen, M. F., & Ponte, S. (2000). Global commodity chain analysis and the French Filièreapproach: Comparison and critique. *Economy and Society*, *29*(3), 390–417. doi:10.1080/03085140050084589

Rutatora, D., & Mattee, A. (2001). Major Agricultural Extension Providers in Tanzania. *African Study Monographs*, *22*(4), 155–173.

Samuel, J., Shah, N., & Hadingham, W. (2005). Mobile Communications in South Africa, Tanzania and Egypt: Results from Community and Business Surveys. *The Vodafone Policy Paper Series*, *2*(1), 44–52.

Sanga, C. Kalungwizi, V. J., & Msuya, C. P. (2013). Building an agricultural extension services system supported by ICTs in Tanzania. International Journal of Education and Development using Information and Communication Technology, 9(1), 80-99.

Siani, C. (2012). From Motorbike to Mobile Phone; new extension services for rural farmers through mobile ICT.

Sibuga, P. (2008). *Situation Analysis of Agricultural Research and Training in the United Republic of Tanzania. Implementation and Coordination of Agricultural Research and Training (ICART)*.

Sife, A. S., Kiondo, E., & Lyimo-Macha, J. G. (2010). Contribution of mobile phones to rural livelihoods and poverty reduction in Morogoro Region, Tanzania. *The Electronic Journal of Information Systems in Developing Countries*, 42.

Souter, D., Scott, C., Garforth, R., Jain, O., & McKemey, K. (2005). The economic impact of telecommunications on rural livelihoods and poverty reduction: a study of rural communities in India (Gujarat), Mozambique and Tanzania.

TCRA. (2015). Quarterly communications statistics. Retrieved from http://www.tcra.go.tz/images/documents/telecommunication/telcomStatsJune15.pdf

The President's Office, Planning Commission (POPC) (n. d.). *Transforming Agriculture in Tanzania*.

Thomson, J. A. (2006). *GM Crops: The Impact and the Potential*. Collingwood, Australia: CSIRO Publishing.

Toyama, K. (2010). Can technology end poverty. *Boston Review, 35*(6). Retrieved from: http://www.bostonreview.net/forum/can-technology-end-poverty/%E2%80%9Cshiny-new-gadget%E2%80%9D-works

United Nations. (2005). Global E-government Readiness Report: From E-Government to E-Inclusion UNPAN/2005/14.

United Republic of Tanzania Vice president's office. (2010). National strategy for growth and reduction of poverty (NSGRP II).

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

United Republic of Tanzania (URT) (2001). Agriculture Sector Development Strategy (ASDS) of 2001.

United Republic of Tanzania (URT) (2003). Tanzania National ICT Policy of 2003.

ENDNOTES

[1] http://gurstein.wordpress.com/2012/07/21/the-mobile-revolution-and-the-rise-and-rise-of-possessive-individualism/

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Chapter 31
Biological Alchemy:
Gold From Garbage or Garbage Into Gold

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ABSTRACT

The story of garbage processing is changing globally and is being considered as a potential option in the hierarchy of integrated solid waste management that involves stabilization of organic material by the joint action of earthworms and microorganisms. Vermicomposting is an economically viable technique in which the job is done by certain species of earthworms that enhances the process of waste conversion and produces a better end product vermicompost. Vermicompost is highly nutritive fertilizer and more powerful growth promoter over the conventional compost. It is rich in nitrogen, phosphorus and potassium commonly referred as NPK, micronutrients, growth hormones and enzymes. Its commercialization is a good business opportunity and is emerging as an industry itself. The farmers need to raise the crops by organic farming that will reduce the cost and will decrease the impact on environment. The present chapter is an attempt to highlight different approaches of converting waste into vermicompost and the importance of vermicomposting as compared to synthetic fertilizers.

INTRODUCTION

Different types of inorganic and organic waste is a worldwide menace and it is becoming more and more difficult to manage this problem day by day due to rapid increase in population and industrialization which leads to decrease in land space and as well as changes in our life style (Singh et al., 2011). Nowadays most of the waste generated is either disposed of in an open dump in developing countries

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or in landfills in the developed ones. However, land filling and open dumping requires a lot of land and could also result in several environmental problems.

A sustainable approach to handle this will be to treat and reprocess organic waste on-site, and to produce useful products. Composting is the most economical and sustainable option for organic waste management as it is easy to operate and can be conducted in contained space provided it is managed properly to produce a good quality produce (Thyagarajan et al., 2010). Composting is a natural process of organic waste treatment which is currently practiced with various modifications (Nair, Vanja, & Anda, 2006).

The composting of waste by earthworms is a simple biotechnological process, in which certain local species of earthworms are used to enhance the process of waste conversion and produce vermicompost (Nagavallemma et al., 2004). Vermicomposting of different types of solid wastes, prior to land application may be a sustainable waste management technique, as the vermicast and vermiwash obtained at the end of vermicomposting process is rich in plant nutrients and is devoid of pathogenic organism. Utilization of vermicompost produced from urban/municipal solid waste in agriculture will facilitate in growth of organic farming and countries economy by lowering the consumption of inorganic fertilizer and avoiding land degradation and soil toxicity problem. Vermicomposting of urban/MSW can be an excellent and best sustainable practice, as it will be helpful in recycling valuable plant nutrients (Singh et al., 2011). Process of vermicomposting differs from composting in many ways (Gandhi, Sangwan, Kapoor, & Dilbaghi, 1997). It is a process in which earthworms and microorganism need moderate temperature 10-32°C (not atmospheric temperature but temperature within the pile of moist organic material) which is known as mesophilic process. Earthworms, through a unique type of biological process, are capable of transforming garbage into 'gold' (Vermi, 2001; Tara Crescent 2003).

Vermicomposting involves the stabilization of organic solid waste through earthworm consumption that converts the waste into earthworm castings. Vermicomposting is the method of combined activity of microorganisms and earthworms. Vermicompost is one of the richest soil conditioners there and improves soil structure and increases its water holding capacity. It brings beneficial microbial activity to plants and provides essential nutrients, available over a long period of time. Plants that receive vermicompost are more productive and resistant to parasites and disease (Singh, 2009). It is proving to be highly nutritive 'organic fertilizer' and more powerful 'growth promoter' over the conventional composts and a 'protective' farm input (increasing the physical, chemical & nutritive value of soil by improving its microbial content, which restore its natural fertility) against the 'destructive' chemical fertilizers which has destroyed the soil properties and decrease its natural fertility over the years. It is rich in NKP (nitrogen 2-3%, potassium 1.85-2.25% and phosphorus 1.55-2.25%), micronutrients, and beneficial soil microbes and also contains 'plant growth hormones and enzymes (Katiyar, Jat, & Singh, 2013).

The earthworm choice for vermicomposting is the key step as it affects the rate of waste stabilization. The different type of earthworms can be used for waste management and sludge stabilization all over the world. The earthworm's species having the capability to colonize organic throw away naturally, high rates of organic matter consumption, digestion and assimilation, able to tolerate a wide range of environmental stress, having high reproductive rates by producing large number of cocoons having short hatching time, rapid growth and maturation rate of hatchlings to adults (Domínguez & Edwards, 2004) are suitable to be used in vermicomposting process. Earthworms sustain aerobic conditions in the waste mixture, ingest solids, and convert a share of the organic matter into biomass and respiration products (Benitez, Nogales, Elvira, Masciandro, & Ceccanti, 1999). Earthworms expels the residual partially stabilized matter as discrete material commonly known as vermicasting (Benitez et al., 1999). The amount turned over by earthworm depends on the availability of total suitable organic waste. If the

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soil physical conditions like temperature and moisture content are suitable the number of earthworms increases in the piles, until the food becomes a limiting factor. The smaller earthworms feeding on the litter produces cast in form of almost entirely fragmented litter, whereas the larger earthworms consume large proportion of soil, and their casts have less organic matter.

Environmental degradation is a major threat confronting the world, and the violent use of chemical fertilizers contributes largely to the deterioration of the environment through depletion of fossil fuels, generation of carbon dioxide (CO_2) and contamination of water resources. It leads to the loss of soil fertility due to imbalanced use of fertilizers that has damaged agricultural productivity and causes soil microbial degradation. Now there is a growing realization that the adoption of ecological and sustainable farming practices can only reverse the declining trend in the global productivity and environmental protection (Wani & Lee, 1992; Wani, Rupela, & Lee, 1995; Aveyard 1988,).

Chemical fertilizers which ushered the 'green revolution' in the 1950-60's came as a 'mixed blessing' for mankind and soil health. It boosted food productivity, but at the cost of environment and society. It dramatically increased the 'quantity' of the food produced but decreased its 'nutritional quality' and also the 'soil fertility' over the years. It killed the native soil microorganisms which help in renewing natural fertility. Over the years it has worked like a 'slow poison' for the soil with serious 'withdrawal symptoms'. The excessive use of 'nitrogenous fertilizer' (urea) has also led to increase in the level of 'inorganic nitrogen' content in groundwater (through leaching effects) and in the human food with grave consequences for the human health.

In order to meet the needs of ever growing population widespread use of chemical pesticides became a necessity for the growth of high-yielding varieties of crops which was highly 'susceptible to pests and diseases'. Continued and long term application of chemical pesticides induced 'biological resistance' in crop pests and diseases and much higher doses are now required to eradicate them. Studies indicate that there is significant amount of 'residual pesticides' contaminating our food stuff long after they are taken away from farms for human consumption.

Adverse effects of agro-chemicals on the agricultural ecosystem (soil, flora, fauna & water bodies in farms) and also on the health of farmers using them and the society consuming the chemically grown food have now started to become more evident all over the world. According to World Health Organization (WHO) and United Nation Environment Program (UNEP) nearly 3 million people suffer from 'acute pesticide poisoning' and some 10 to 20 thousand people die every year from it in the developing countries (UNEP/GEMS, 1992). US scientists predict that up to 20,000 American people may die of cancer, each year, due to the low levels of 'residual pesticides' in the chemically grown food. Higher use of agro chemicals also adversely affecting their economy as the cost of agrochemicals has been rising all over the world. The only solution that may tackle the problem is organic farming.

Organic farming systems with the aid of various nutrients of biological origin such as compost are thought to be the answer for the 'food safety, farm security and environmental balance' in future. Among them 'composts' made from biodegradation of organics of MSW (municipal solid waste) which is being generated in huge amount every day all over the world are most important. The organic fraction of the MSW (about 70-80%) containing plenty of nitrogen (N), potash (K) and phosphorus (P) is a good source of macro and micronutrients for the soil. Composts also contain plenty of 'beneficial soil microbes' which help in 'soil regeneration' and 'fertility improvement' and protect them from degradation while also promoting growth in plants (De Brito Alvarez, Gagne, & Antoun, 1995; Weltzien, 1989). Composts also protect plants from pests and diseases.

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The modern practice of agriculture and denudation of forests exert an impact on the soil as a habitat, affecting soil fauna and species diversity (Evans, Mc, & Guild, 1948). Earthworms, being one of the major inhabitants of the soil, are often exposed to these manmade hazards. The species that can tolerate repeated soil disturbances and relatively limited supply of organic material are favored at the expense of those that cannot. Although agricultural practices affect earthworm population in general, sometimes they also favor the growth of certain species (Edwards & Lofty, 1972). However, large populations are recorded from uncultivated areas (Edwards & Lofty, 1977). Despite such limitations, earthworms still exist in their variety and diversity in variety of soil types.

Because of the predominance of the earthworms in some tropical and temperate soils, they increase their ecological importance. Many workers have worked on the various aspects of the ecophysiology of earthworms inhabiting different ecosystems (Block & Banage, 1968; Abrahamsen, 1972; Dash & Patra, 1977; Kale & Krishnamoorthy, 1978, 1981a). Much more investigation are required with regards to qualitative and quantitative composition of earthworms, their seasonal variations in different soil conditions prevailing in India and to device and utilize earthworm based biotechnologies of welfare of human beings.

Composts are aerobically decomposed products of organic wastes such as the cattle dung and animal droppings, farm, agriculture and forest wastes and the municipal solid wastes (MSW). Bombatkar (1996), called them as 'miracle' for plant growth. They supply required macro and micro nutrients to plant roots and stimulate growth; increase organic matter content of the soil including the 'humic substances' that affect nutrient accumulation and promote root growth (Canellas, Olivares, Okorokova, & Facanha, 2000; Siminis, Loulakis, Kefakis, Manios, & Manios, 1998). They in fact improve the total physical and chemical properties of the soil. Vermicompost and vermiwash also add useful micro-organisms to the soil and provide food for the existing soil micro-organisms and thus increase their biological properties and capacity of self-renewal of soil fertility (Ouédraogo, Mando, & Zombre, 2001; Shiralipour, McConnell, & Smith, 1992). One ton of compost may contain 10 lbs of nitrogen (N), 5 lbs of phosphorus (P_2O_5) and 10 lbs of potash (K_2O). Compost made from poultry droppings contains highest nutrient level among all compost (Bombatkar, 1996).

Earthworms consume various organic wastes and reduce the volume by 40-60%. Each earthworm weighs about 0.5 to 0.6 gm, eats waste equivalent to its body weight and produces cast equivalent to about 50% of the waste it consumes in a day. These castings have been analyzed for chemical and biological properties. The moisture content of worm castings ranges between 32 and 66% and it is evident that vermicompost provides all nutrients in readily available form and also enhances uptake of nutrients by plants. Sreenivas, Muralidhar, & Rao (2000), studied the beneficial integrated effect of application of fertilizer and vermicompost on soil available Nitrogen (N) and uptake of ridge gourd (*Luffa acutangula*) at Rajendranagar, Andhra Pradesh, India. Soil nitrogen increased significantly with increasing levels of vermicompost and highest N uptake was obtained at 50% of the recommended fertilizer rate plus 10 t ha^{-1} vermicompost. Similarly, the uptake of N, phosphorus (P), potassium (K) and magnesium (Mg) by rice (*Oryza sativa*) plant was highest when fertilizer was applied in combination with vermicompost (Jadhav, Talashilkar, & Pawar, 1997).

Vermicompost is a nutritive 'organic fertilizer' rich in NKP (nitrogen 2-3%, potassium 1.85-2.25% and phosphorus 1.55-2.25%), micronutrients, and beneficial soil microbes like 'nitrogen-fixing bacteria' and 'mycorrhizal fungi' and are scientifically proving as 'miracle growth promoters and protectors'. Kale & Bano (1988) reported 7.37% nitrogen (N) and 19.58% phosphorus as P_2O_5 in vermicast. Moreover, Suhane, (2007) found that exchangeable potassium (K) was over 95% higher in vermicompost.

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A good amount of calcium (Ca), magnesium (Mg), zinc (Zn) and manganese (Mn) have also been reported. Additionally, vermicompost contain enzymes like amylase, lipase, cellulase and chitinase, which continuously break down organic matter in the soil (to release the nutrients and make it available to the plant roots) even after they have been excreted by the earthworms. Annual application of proper amount of vermicompost also lead to significant increase in soil enzyme activities such as 'urease', 'phosphomonoesterase', 'phosphodiesterase' and 'arylsulphatase'. The soil treated with vermicompost has significantly more electrical conductivity (EC) and near neutral pH. Vermicompost has very 'high porosity', 'aeration', 'water holding capacity'and 'moisture content'. Vermicasts have a vast surface area, for providing strong absorbability and retention of nutrients by the compost. They appear to retain more nutrients for longer period of time. Study showed that soil mixed with vermicompost had significantly greater 'soil bulk density' and hence porous, lighter and never show compactness. Increase in porosity has been attributed to increase in number of pores in the range of 30-50 μm and 50-500 and decrease in number of pores greater than 500 μm.

In tropical countries like India high temperature conditions result in nutrient deficient soil. High inputs of chemical fertilizers also decrease soil organic matter to a large extent. In both the cases, a series of chain reactions take place leading to biological degradation of the soil. For such soils, vermi-conservation technology using burrowing earthworms like *Polypheritima elongata* and *Lumbricus terrestries,* appears to be appropriate rather than vermicomposting worms (Bhawalkar, 1993, 1994, 1996). It combines soil processing with waste processing at the same time (Two-in-one Package). Reclamation of soil may be achieved using this technology.

WASTE INTO VERMICOMPOST

The various industrial wastes which have been already vermicomposted and turned into nutrient rich manure include paper waste (Elvira, Sampedro, Benitez, & Nogales, 1998; Kaur, Singh, Vig, Dhaliwal, & Rup, 2010), textile industry sludge (Garg & Kaushik, 2005), guar gum industrial waste (Suthar, 2006), sugar industry wastes (Sen & Chandra, 2007), distillery sludge (Suthar & Singh, 2008), leather industry (Ravindran, Dinesh, Kennedy & Sekaran, 2008) and beverage industry sludge (Singh, Kaur, Vig, & Rup, 2010), agroindustrial sludge (Suthar, 2010), primary sewage sludge (Hait & Tare, 2011), tannery industries (Ravindran & Sekaran, 2011). A number of workers have tried to process poultry manure through vermicompostiong. The manure from poultries has high nutritive value and is sometimes used in animal feeds, therefore, its use in the production of earthworms for preparation of worm meal. Despite the deleterious effect of poultry manure on the earthworm *Perionyx excavates* (Kale & Krishnamoorthy, 1981b), and its failure as feed in mass production of the earthworm *Eudrilus eugeniae* (Graff, 1981), six different dietary formulations with poultry manure as base were tried in an attempt to establish the feasibility of use of poultry manure in mass culturing of the earthworm *Eudrilus eugeniae*, a prolific breeder, for worm meal. Worm meal has been recognized as a valuable source of protein in animal diet (Sabine, 1978; Guerrero, 1983). The nutritive value of a variety of worm meals and their use as the pig's diet, poultry and fish food has been demonstrated by various workers (Sabine 1978; Graff, 1981). Earthworm species employed for vermicomposting of solid organic wastes is shown in Table 1.

Investigation by (Lowe & Butt, 2002) highlighted the ability of *E. eugeniae* to partially detoxify the wastes and convert the toxic cassava peels in to valuable vermicompost. In general, an organic C loss has been observed during the vermicomposting process (Kale, Bano, & Krishnamoorty, 1982; Garg &

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Table 1. Earthworm species employed for vermicomposting of Solid Organic Wastes (SOW)

S.No.	Solid Organic Waste (SOW)	Species Employed	Reference
1	Potato peels	*Pheretima elongate*	(Munnoli, Arora & Sharma, 2000)
2	Press mud	*Pheretima elongate* *Eudrilus eugeniae, Eisenia fetida* *Megascolex megascolex*	(Singh, 1997) (Munnoli, 2007) (Munnoli and Bhosle, 2008)
3	Canteen waste	*Eisenia fetida*	(Kale, 1994)
4	Tomato skin seed	*Pheretima elongate*	(Singh, 1997)
5	Onion residue	*Eisenia fetida/Eudrilus eugeniae*	(White, 1996)
6	Sericulture waste	*Perionyx excavates*	(Gunthilingaraj and Ravignanam, 1996)
7	Sericulture waste	*Phanerochaete chrysosporium*	(Kallimani, 1998)
8	Board mill sludge	*Lumbricus terrestris*	(Butt, Nieminen, & Siren, 2005)
9	Sugar cane residues	*Pheretima elongate*	(Bhawalkar, 1995)
10	Gaur gum	*Eudrilus eugeniae*	(Bhawalkar,1995; Suthar 2006)
11	Agricultural residues	*Eudrilus eugeniae*	(Kale, 1994)
16	Sago waste	*Lampito mauritii*	(Rajesh, Yeom, Esakkiraj, Kumar, & Lee, 2008)
17	Sago waste	*Eisenia fetida*	(Subramanian, Sivrajan, & Sarvanapriya, 2010)
18	Onion waste	*Eudrilus eugeniae*	(Mishra, Singh, Upadhyay, & Singh, 2009)
19	Garlic waste	*Eisenia fetida*	(Mishra, et al., 2009)
20	Source separated from human feces	*Eisenia fetida*	(Yadav, Vinod, & Mansoor, 2010)
21	Paper mill sludge	*Eisenia fetida*	(Kaur et al., 2010)
22	Press mud, bagassi, sugar cane trash	*Drawida willsi*	(Kumar, Verma, Singh, Umesh, & Shweta, 2010)
23	Press mud	*Perionyx ceylanensis*	(Mani and Karmegam, 2010)
24	Kitchen waste, Garden waste, cow dung	*Eisenia fetida*	(Wani, et al., 2013)

Kaushik, 2005; Suthar, 2007). Earthworm transforms substrate conditions, which consequently affects the carbon losses from the substrates through microbial respiration in the form of CO_2 and even through mineralization of organic matter Table 2. The inoculation of worms in waste material considerably enhances the amount of nitrogen (N) due to earthworm mediated nitrogen mineralization of wastes. It also

Table 2. Rating of substrates for vermicomposting

S. No.	Types of Substrates	C:N Ratio	Suitability
1	Fish, scrap poultry manure, night soil, activated sludge, pig manure, sheep dropping, meat scraps, cotton seed meal and other oil seed residues	1-19	Most suitable due to high Nitrogen content
2	Garbage, sea weed, butter cup, amaranthus, lettuce, cabbage and vegetable waste which are fresh, green and succulent including wastes from food processing industries	19-27	Moderately suitable
3	Saw dust flax, waste straw, coir waste, etc. including all crop residues with high lignocelluloses content, high carbon and low moisture	27-208	Less suitable

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observed by different researchers that the earthworm also enhances the nitrogen levels of the substrate by adding their excretory products, mucous, body fluid, enzymes and even through the decaying tissues of dead worms in vermicomposting sub-system (Suthar, 2007).

The earlier investigators proved that earthworms prefer food with higher quality of fungus and calcium (Cooke & Luxton, 1980; Parthasarathi & Ranganathan, 2000) and higher content of sugar and nitrogen (Lee, 1985; Edwards & Bohlen, 1996). Kurien & Ramasay (2006) used taro (*Colocasia esculenta*) as feeding material for *Eudrilus eugeniae* and *Eisenia foetida* and showed that vermicasts were produced with steadily increasing output in all the reactors.

Shweta, Kumar, Sharma, & Sonal, (2006), vermicomposted bagasse, rice bran, flower waste, leaf litter, banana leaf, fruit waste, kitchen waste and saw dust in combination with cow dung and mixed dung alone showed that mixed dung was best substrate to increase the biomass and cocoon production. Wani, Mamta, & Rao, (2013) indicated that vermicomposting of different organic waste like garden waste, kitchen waste and cow dung not only produces a value added product (vermicomposting) but at the same time reduce the quantity of waste (Table 3). The vermicompost of cow dung, garden waste and kitchen waste in combination were used with brinjal plants under field conditions. Different treatments affected significantly the seed germination of test crops. Plant height, number of leaves and fruit weight was higher in the vermicompost treated field as compared to control and no disease incidence was observed in the fruits of vermicompost treated plot. The study revealed that vermicompost amendments affected brinjal crop differently and we recommend that vermicompost should be used by farming community instead of synthetic fertilizers while raising brinjal crops Mamta, Wani, & Rao (2012).

Kostecka (1999) found that flax seeds are very attractive to *E. foetida* and can be useful for quick reproduction. The great attractiveness was confirmed by rapid vermicomposting and accumulation of 43 percent of *E. foetida* in the bed and a considerable increase of earthworm number and biomass. Dominguez, Edwards, & Webster (2000) reported that maximum weight and highest growth rate were attained in the mixture with food waste whereas; smallest size and lowest growth rate was achieved in the mixture of sewage sludge with sawdust. Earthworms showed much higher reproductive rates in the paper and cardboard mixtures compared to sewage sludge alone. Vermicomposting using *Lumbricus rubellus* for 49 days was conducted after 21 days of pre-composting. Three different combinations of treatments were prepared with eight replicates for each treatment (T1) namely cow dung: kitchen waste in 30:70 ratios, cow dung: coffee grounds in 30:70 ratio (T2), and cow dung: kitchen waste: coffee grounds in 30:35:35 ratio (T3). The multiplication of earthworms in terms of numbers and weight were measured at

Table 3. Nutrient content and different physico-chemical parameters in garden waste, kitchen waste and cow dung

Waste	pH	MC	TOC	Humus	Nitrogen	Phosphorus	Potassium
Garden waste	6.3 ± 0.06^{a}	2.7 ± 0.10^{a}	11.7 ± 0.24^{a}	68.7 ± 0.91^{a}	1.02 ± 0.07^{a}	0.37 ± 0.03^{a}	0.60 ± 0.02^{a}
Kitchen waste	7.2 ± 0.04^{b}	3.1 ± 0.08^{b}	13.3 ± 0.31^{b}	63.9 ± 1.99^{b}	1.30 ± 0.02^{b}	0.50 ± 0.02^{b}	1.01 ± 0.18^{b}
Cow dung	8.1 ± 0.06^{c}	2.6 ± 0.04^{b}	18.4 ± 1.16^{b}	64.1 ± 0.94^{c}	1.97 ± 0.07^{c}	0.62 ± 0.03^{c}	0.88 ± 0.18^{c}

All values are in mean ± 1 S.E. Values bearing different superscripted alphabets differ from each other at $P < 0.05$ (based on Duncan's multiple range test).

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the end of vermicomposting. Consequently, only T2 showed significant increase (from its initial stage) compared to other treatments. The presence of coffee grounds in T2 and T3 showed higher percentage of nutrient elements in vermicasts produced. The data reveal that coffee grounds can be decomposed through vermicomposting and to help to enhance the quality of compost produced rather than sole use of kitchen waste in vermicomposting (Adi & Noor, 2009).

Experimental studies on the agronomic impacts of earthworms & its vermicompost on crop plants all over the world is conclusively proving that their application in farm soil over subsequent years can lead to enhanced production of 'safe food', both in 'quantity & quality' without recourse to agro-chemicals. Several scientists working on vermiculture throughout the world have confirmed the positive role of earthworms and its metabolic products (vermicast) on crop growth and development. Important among them are Alam, Jahan, Ali, Ashraf, & Islam, (2007); Ansari (2008); Atiyeh, Arancon, Edwards, & Metzger, (2000) Atiyeh et al. (2000); Arancon et al. (2003) Arancon, Edwards, Bierman, Welch, & Metzger, (2004) Arancon, Edwards, & Bierman, (2006); Bhat & Khambata (1994); Bhatia (2000); Bhatia, Sinha, & Sharma (2000); Baker & Barrett (1994); Garg & Bhardwaj (2000); Krishnamoorthy & Vajranabhaiah (1986); Palanisamy (1996); Reddy (1988); Scheu (1987); Sharma (2001); Suhane (2007); Spain, Lavelle, & Mariotti (1992); Tomar, Bhatnagar, & Palta (1998); Valani (2009); Wilson & Carlile (1989) ; Webster (2005).

Studies on vegetable and cereal crops done in India at University of Rajasthan (1997-2001) and at Bihar Agriculture University (2007-2009) and in Australia at Griffith University (2007-2009), has also testified and strengthened the views of other workers. Application of vermicompost in potted and field crops displayed excellent growth performances in terms of height of plants, number of leaves, color and texture of leaves, appearance of fruiting structures as compared to chemical fertilizers and the organic compost. There is also less incidences of pest and disease attack and reduced demand of water for irrigation.

The post-harvest residues of some local crops, e.g. wheat (*Triticum aestivum*), millets (*Penniseum typhoides* and *Sorghum vulgare*), and pulse (*Vigna radiata*) were subjected to recycle through vermi-composting by using the epigeic earthworm *Eudrilus eugeniae* Kinberg, under controlled conditions. The crop residues were amended with animal dung; and three types of vermibeds were prepared: (i) millet straw (S. *vulgare* + *Pennisenum typhoides* in equal quantity) + sheep manure (1:2 ratio) (MS), (ii) pulse bran (*Vigna radiata*) + wheat straw (*Triticum aestivum*) + cow dung (1:1:2 ratio) (PWC), and (iii) mixed crop residues (mixing of all types crop residues, used in this study)+cow dung in 1:1 ratio (MCR + CD). The fourth treatment was cattle shed manure (CSM). At the end, ready vermicompost showed lower organic C content and higher concentrations of other important plant nutrients. Organic carbon (C) content decreased in the order: MCR+CD (27.6%) > PWC (22.8%)>CMS (22.6%) >MS (19.4%). The ready vermicompost obtained from MCR+CD vermibed showed the maximum increase (% of initial level) in content of total N (143.4%), available P (111.1%) and exchangeable K (100.0%). The end product showed reduction in C:N ration between the ranges of 60.7% (CSM) and 70.3% (MCR + CD), at the end of the vermicomposting process. The composting earthworm *E. eugeniae* exhibited the highest values of biological parameters: maximum mean individual biomass (1261.25±7.0 mg), biomass gain (955.84±11.03 mg), growth rate (10.62±0.10mgwt.worm^{-1} day^{-1}), cocoon numbers (87.67±6.51), and reproduction rate (0.66±0.01 cocoonsworm^{-1} day^{-1}) in CSM container, while MS vermibeds showed the least values of these parameters. During tests, the maximum mortality for *E. eugeniae* was recorded in MS (16.67±7.63%) followed by CSM> PWC>MCR+CD. Results indicated that the C:N ratio of the substrate drastically influenced the growth characteristics of *E. eugeniae*, and it showed the close relations with maximum individual biomass gain (R2 = 0.96), individual growth rate (R2 = 0.82), and

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reproduction rate (cocoonworm^{-1} day^{-1}) (R2 = 0.72), in different treatments. This study clearly indicates that vermicomposting of crop residues and cattle shed wastes can not only produce a value added product (vermicomposting) but at the same time acts as best culture medium for large-scale production of earthworms.

A laboratory study was undertaken to examine the temporal changes in physico-chemical properties during vermicomposting of sago industry waste. The sago industry waste was mixed with cow dung, poultry manure at different proportions, and it kept for pre-treatment for 21 days and subsequently vermicomposted for a period of 45 days under shade. Earthworm species (*Eisenia foetida*) was introduced at the rate of 50 gm/kg of waste. The moisture content of substrate and temperature were monitored at regular intervals. The vermicomposts were sampled at the interval of every 15 days 0, 15, 30 and 45 days for the assessment of temporal changes in physicochemical properties. The data revealed that equal proportion of sago wastes; cow dung and poultry manure produced superior quality manure with desirable C: N ratio and higher nutritional status than other methods of composting. *E. foetida* is an earthworm suitable for composting organic wastes such as poultry manure with extreme pH and high temperature and sago waste with high organic carbon in a shorter period of time interval. This study suggests that the sago industry solid waste could be effectively converted into highly valuable manure that can be exploited to promote crop production.

Vermicomposting converts household waste into compost within the period of 30 days, reduces the C:N ratio and retains more N than the traditional methods of preparing composts (Gandhi et al., 1997). The C:N ratio of the raw olive cake, vermicomposted olive cake and manure were 42, 29 and 11, respectively. Both the raw olive cake and vermicomposted olive cake immobilized soil N.

ADVANTAGES OF VERMICOMPOST

High Levels of Bio-Available Nutrients for Plants

Vermicompost contains most nutrients in plant-available forms such as ‘nitrates’ (N), ‘phosphates’ (P), ‘soluble’ potassium (K), and magnesium (Mg) and ‘exchangeable’ phosphorus (P) and calcium’ (Ca) (Edwards, Domínguez, & Arancon, 2004; Edward & Burrows, 1988). Vermicomposts have large particulate surface areas that provide many micro-sites for microbial activities and for the strong retention of nutrients (Arancon et al., 2004; Arancon et al., 2006). Nutrient content and different physio-chemical parameters in garden waste, kitchen waste and cow dung as obtained by Wani et al., (2013) is shown in Table 3.

High Level of Beneficial Soil Microorganisms Promoting Plant Growth

Vermicompost are rich in ‘microbial populations & diversity’, particularly ‘fungi’, ‘bacteria’ and ‘actinomycetes’ (Brown, 1995; Chaoui, Zibilske, & Ohno, 2003; Scheu, 1987; Singh, 2009). Parle, 1963, reported bacterial count of 32 million per gram in fresh vermicast compared to 6-9 million per gram in the surrounding natural soil. Scheu, (1987) reported an increase of 90% in respiration rate in fresh vermicast indicating corresponding increase in the microbial population. Suhane, (2007) found that the total bacterial using Actinomycetes, Azotobacter using count was more than 1010 per gram of vermicompost.

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Rich in Growth Hormones

Vermicompost further stimulates plant growth even when plants are already receiving 'optimal nutrition' as it has consistently improved seed germination, raise seedling growth and development and increased plant productivity much more than would be possible from the mere conversion of mineral nutrients into plant-available forms. Arancon, (2004) found that maximum benefit from vermicompost is obtained when it constitutes between 10 to 40% of the growing medium. Neilson, (1965); Tomati, Grappelli, & Galli (1988) have also reported that vermicompost contained growth promoting hormone 'auxins', 'cytokinins' and flowering hormone 'gibberellins' secreted by earthworms. Canellas et al., (2000) found that humic acids isolated from vermicompost enhanced root elongation and formation of lateral roots in maize roots. Pramanik, Ghosh, Ghosal, & Banik (2007) also reported that humic acids enhanced 'nutrient uptake' by the plants by increasing the permeability of root cell membrane, stimulating root growth and accelerating proliferation of 'root hairs'.

Vermicompost Is Free of Pathogens

Nair et al., (2006) indicated that vermicomposting leads to greater reduction of pathogens after 3 months of storage. Whereas, the samples which were subjected to only thermofilic composting, contained higher levels of pathogens even after 3 months.

Vermicompost Has No Toxic Chemicals

Several studies have found that earthworms effectively bioaccumulate or biodegrade several organic and inorganic chemicals including 'heavy metals', 'organochlorine pesticide' and 'polycyclic aromatic hydrocarbons' (PAHs) residues.

Vermicompost Protects Plants Against Various Pests and Diseases

There has been considerable evidence in recent years regarding the ability of vermicompost to protect plants against various pests and diseases either by suppressing or repelling them or by inducing biological resistance in plants to fight them or by killing them through pesticidal action (Anonymous, 2001; Al-Dahmani, Abbasi, Miller, & Hoitink, 2003).

Induce Biological Resistance in Plants

Vermicompost contains some antibiotics and actinomycetes which help in increasing the 'power of biological resistance' among the crop plants against pest and diseases. Pesticide use was significantly reduced where earthworms and vermicompost were used in agriculture (Singh, 1993; Suhane, 2007).

Repel Crop Pests

There seems to be strong evidence that worm's varmicastings sometimes repel hard-bodied pests (Anonymous, 2001; Arancon, 2004). Edwards & Arancon, (2004) reports statistically significant decrease in arthropods (aphids, buds, mealy bug, spider mite) populations and subsequent reduction in plant dam-

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age, of tomato, pepper and cabbage trials with 20% and 40% vermicompost additions. GEORG (2004), doing commercial vermicomposting in California, U.S., affirms that his product repels many different insects pests. There explanation is that this is due to production of enzymes 'chitinase' by worms which breaks down the chitin in the insect's exoskelton (Munroe, 2007).

Suppress Plant Disease

Edwards & Arancon (2004) found that use of vermicompost in crops inhibited the soil-born fungal diseases. They also found substantial suppression of plant-parasitic nematodes in field trials with pepper, tomatoes, strawberries and grapes. The high levels of agronomically beneficial microbial population in vermicompost protects plants by out-competing plant pathogens for available food resources, by starving them and also by blocking their access to plant roots by occupying all the available sites. Edwards & Arancon, (2004), reported the agronomic effects of small applications of commercially produced vermicompost, on attacks by fungus *Rhizoctonia* on radish and *Pythium* on cucumber, in the greenhouse, by *Verticillium* on strawberries and by *Phomposis* and *Sphaerotheca fulginae* on grapes at the field. In all these experiments vermicompost use suppressed the incidence of the disease significantly and also found that the ability of pathogen suppression disappeared when the vermicompost was disinfectd/sterilized, convincingly indicating that the biological mechanism of disease suppression involved was 'microbial antagonism. Szczech, Rondomanski, Brzeski, Smolinska, & Kotowski, (1993); Orlikowski, (1999); Rodriguez, Zavaleta, Sanchez, & Gonzalez, (2000); Zaller, (2006) also found that the aqueous extracts of vermicomposts depress soil-borne pathogens and pests, in their field experiment that only half as many plants of tomatoes sprayed with aqueous extract of vermicompost were infected with *Phytopthora infestans* (that cause 'late-blight' disease) as those of control ones.

NUTRITIONAL QUALITY OF VERMICOMPOST

The nutritional quality of vermicompost is determined primarily by the type of the substrate (raw materials) and species of earthworms used for composting, along with microbial inoculants, liming, aeration, humidity, pH and temperature. Cattle dung has been found to yield most nutritive vermicompost when composted by *Eisinea fetida*. Pramanik et al., (2007) found that application of lime at the rate of 5 gm/kg of substrate and 'microbial inoculation' by suitable 'cellulolytic', 'lignolytic' and 'N-fixing' strains of microbes not only enhance the rate of vermicomposting but also results into nutritionally better vermicompost with greater enzymatic (phosphatase and urease) activities. Kaushik & Garg (2004) found that inoculation with N-fixing bacteria significantly increased the 'nitrogen' (N) content of the vermicompost. Liming generally enhance earthworm activities as well as microbial population. Earthworms after ingesting microbes into its gut proliferate the population of microbes to several times in its excreta (vermicast). It is therefore advantageous to use beneficial microbial inoculants whose population is rapidly increased for rapid composting and also better compost quality. Pramanik et al., (2007) studied the vermicomposting of four substrates viz. cow dung, grass, aquatic weeds and municipal solid wastes (MSW) to know the 'nutritional status and enzymatic activities' of the resulting vermicomposts in terms of increase in total nitrogen (N), total phosphorus (P) and potassium (K), humic acid contents and phosphatase activity.

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Total Nitrogen

Sinha, Sunil, Dalsukh, & Chauhan, (2009) found that cow dung recorded maximum increase in nitrogen (N) content (275%) followed by MSW (178%), grass (153%) and aquatic weed (146%) in their resulting vermicomposts over the initial values in their raw materials without liming and microbial inoculation. Application of lime without microbial inoculation, however, increased N content in the vermicompost from 3% to 12% over non-limed treatment, irrespective of substrates used.

Total Phosphorus and Potassium

Similarly, the vermicompost prepared from cow dung had the highest total phosphorus (12.70 mg/g) and total potassium (11.44 mg/g) over their initial substrate followed by those obtained from aquatic weeds, grasses and MSW. This was also irrespective of lime application and microbial inoculation. Among the microbes inoculated for vermicomposting, *Bacillus polymyxa* a free-living N-fixing bacterium was most effective in increasing total phosphorus (11-22%) in the vermicompost after liming.

Humic Acid

It was highest in vermicompost prepared from cow dung (0.7963 mg/g), followed by those from grasses (0.6147 mg/g), aquatic weeds (0.4724 mg/g) and MSW (0.3917 mg/g). And this was without liming and microbial inoculation. However, microbial inoculation again increased humic acid contents in vermicompost from 25% to 68% depending upon the substrate used. Inoculation by *Phanerochaete chrysoporium* recorded highest humic acid contents without liming as compared to other inoculants. But under limed condition, inoculation by *B. polymyxa* was most effective in increasing humic acid contents irrespective of substrates used for vermicomposting.

Phosphatase Activity

Vermicompost obtained from cow dung showed the highest 'acid phosphatase' (200.45 µg *p*-nitrophenol/g/h) activities followed by vermicompost from grasses (179.24 µg *p*-nitrophenol/g/h), aquatic weeds (174.27 µg *p*-nitrophenol/g/h) and MSW (64.38 µg *p*-nitrophenol/g/h). The 'alkaline phosphatase' activity was highest in vermicompost obtained from aquatic weeds (679.88 µg *p*-nitrophenol/g/h) followed by cow dung (658.03 µg *p*-nitrophenol/g/h), grasses (583.28 µg *p*-nitrophenol/g /h) and MSW (267.54 µg *p*nitrophenol/ g/h). This was irrespective of lime application and microbial inoculation. However, when inoculated by fungi all showed maximum phosphatase activities under both limed and non-limed conditions (Vinotha, Parthasarthi, & Rangnathan, 2000).

IMPROVED CROP GROWTH AND YIELD

Vermicompost plays a major role in improving growth and yield of different crops, vegetables, flower and fruit crops. The use of in soil vermicompost gave higher germination (93%) of mung bean (*Vigna radiata*) compared to the control (84%). Further, the growth and yield of mung bean was also significantly higher with vermicompost application. In the same way, in another pot experiment, fresh and dry

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matter yields of cowpea (*Vigna unguiculata*) were higher when soil was amended with vermicompost than with biodigested slurry (Karmegam, Alagermalai, & Daniel, 1999; Karmegam & Daniel, 2000). The efficiency of vermicompost was evaluated in a field study by Desai, Sabale, & Raundal, (1999) and according to their application the vermicompost along with fertilizer N gave higher dry matter (16.2 g plant^{-1}) and grain yield (3.6 t ha^{-1}) of wheat (*Triticum aestivum*) and higher dry matter yield (0.66 g plant^{-1}) of the following coriander (*Coriandrum sativum*) crop in sequential cropping manner. Similarly, a positive response was obtained with the application of vermicompost to other field crops such as sorghum (*Sorghum bicolor*) (Patil & Sheelavantar 2000) and sunflower (*Helianthus annuus*) (Devi, Agarwal & Dayal, 1998; Devi and Agarwal, 1998).

Application of vermicompost at 5 t ha^{-1} significantly increased (5.8 t ha^{-1}) yield of tomato (*Lycopersicon esculentum*) in farmers' fields in Adarsha watershed, Kothapally, Andhra Pradesh in comparison to control (3.5 t ha^{-1}). Similarly, greenhouse studies at Ohio State University in Columbus, Ohio, USA have indicated that the vermicompost enhances transplant growth rate of vegetables. Application of vermicompost with a transplant grown without vermicompost had the highest amount of red marketable fruit at harvest and there were no symptoms of early blight lesions on the fruit at harvest. The yield of pea (*Pisum sativum*) was also higher with the application of vermicompost (10 t ha^{-1}) along with the recommended Nitrogen, Phosphorus and Potash than with these fertilizers alone (Reddy et al., 1998). Vadiraj, Siddagangaiah, & Potty, (1998) reported that application of vermicompost produced herbage yields of coriander cultivars that were comparable to those obtained with chemical fertilizers.

The fresh weight of flowers such as *Chrysanthemum chinensis* increased with the application of different levels of vermicompost. Also, the number of flowers per plant (26), flower diameter (6 cm) and yield (0.5 t ha^{-1}) were maximum with the application of 10 t ha^{-1} of vermicompost along with 50% of recommended dose of NPK fertilizer. However, the vase life of flowers (11 days) was high with the combined application of vermicompost at 15 t ha^{-1} and 50% of recommended dose of NPK fertilizer (Nethra, Jayaprasad & Kale, 1999).

ECONOMICALLY VIABLE TECHNIQUE

The new economic theory of development today is 'Environmental-Economics' which advocates for judicious balance between 'economy and ecology' in all developmental programs including agricultural development and amalgamation of 'economic development' programs with 'ecological conservation' strategies to usher in the era of sustainable development. The cost of production of vermicompost is simply insignificant as compared to chemical fertilizers. While vermicompost is produced from a 'cheap raw material' (community wastes including farm wastes) which is in plenty all over the world and is growing in quantity with the growing human population, the chemical fertilizers are obtained from 'petroleum products' which are not only very 'costly raw materials' but also a 'vanishing resource' on earth. While vermicompost can be produced 'on farms' by all farmers, big and small, the chemical fertilizers has to be produced in 'factories' at a high economic and environmental cost. This means vermicompost can be afforded by all farmers. The worms itself becomes an economically valuable products for the farmers to be sold to fishery, poultry, dairy and pharmaceutical industries.

Vermicompost production is also an 'economically productive' process as it 'reduces wastes' at source and consequently saves landfill space. Construction of engineered landfills incurs 20-25 million US dollars upfront before the first load of waste is dumped. Over the past 5 years the cost of landfill

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disposal of waste has increased from $ 29 to $ 65 per ton of waste in Australia. Then, landfills have to be monitored for at least 30 years for emissions of GHG and toxic gases & leachate (Waste Juice) which also incur cost. During 2002-2003, waste management services within Australia cost $ 2458.2 million. Even in developing nations where there are no true landfills, dumping of wastes incurs high cost on local government.

Earthworms converts a product of 'negative' economic & environmental value i.e. 'waste' into a product of 'highly positive' economic and environmental values i.e. 'high nutrition content organic fertilizer' (brown gold) which improve soil fertility and enhance farm productivity to produce 'safe food' (green gold) in farms. Vermiculture can maintain the global 'human sustainability cycle-i.e. producing food in farms back from food & farm wastes. Vermicomposting is a self-regulated, self-improved and self-enhanced, very less or no-energy requiring zero-waste technology, easy to construct and maintain. It excels all other waste conversion technologies by the fact that it can utilize waste organics that otherwise cannot be utilized by others. It excels all other biological or mechanical technologies for production of 'bio-fertilizer' because it achieves 'greater utilization' than the rate of 'destruction' achieved by other technologies and the process becomes faster with time as the army of degrader worms and the decomposer microbes multiply in millions in short time (Sinha, Sunil, Agarwal, Asadi, & Carretero. 2002; Sinha, Nair, Bharambe, Swapnil, & Bapat, 2008). Earthworms involves about 100-1000 times higher 'value addition' in any medium (composting wastes or soil) wherever it is present (Appelhof, 1997; Appelhof, 2003).

Production of chemical fertilizers in industries is an 'environmentally damaging' process in its entire lifecycle, since harnessing of raw materials from the earth crust, to their processing in factories and their use in agriculture farms. It generates huge amount of toxic and hazardous wastes and pollutants at every stage of production and use. It also uses copious amount of energy in production process and emits huge volumes of greenhouse gases (GHG). It is an 'economically unproductive' process of development. Huge money has to be spent on infrastructure development for production of chemical fertilizers and in installations of equipments for pollution control, transport and then on safe disposal of hazardous waste in engineered landfills. Its application in farms pollutes the soil and water bodies and kills beneficial soil organisms with severe economic and environmental implications.

A matter of considerable economic and environmental significance is that the 'cost of food production' by vermiculture will be significantly low by more than 60-70% as compared to chemical fertilizers and the food produced will be a 'safe chemical-free food' for the society. It is a 'win-win' situation for both producers (farmers) and the consumers (feeders). The cost of production of vermicompost is simply insignificant as compared to chemical fertilizers. While the former is produced from 'human waste'-a raw material which is in plenty all over the world, the latter is obtained from 'petroleum products' which is a vanishing resource on earth. Vermicompost can be produced 'on-farm' at low-cost by simple devices, while the chemical fertilizers are high-tech & high-cost products made in factories (Munroe, 2007). As vermicompost also helps the crops to attain maturity and reproduce faster, it shortens the 'harvesting time' (Sinha, et al., 2009). This further cuts on the cost of production and also adds to the economy of farmers as they can grow more crops every year in the same farm plot.

Vermicompost Application Reduces Use of Chemical Pesticides and Cost

Continued application of chemical pesticides induced 'biological resistance' in crop pests and diseases and logrithamatically much higher doses are now required to eradicate them. There has been considerable evidence in recent years regarding the ability of vermicompost to protect plants against various pests

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and diseases either by suppressing or repelling them or by 'inducing biological resistance' in plants to fight them or by killing them through pesticidal action (Suhane, 2007).

Vermicompost Application Reduces Use of Water for Irrigation and Cost

Studies indicate that vermicompost is able to retain more soil moisture thus reducing the demand of water for irrigation by nearly 30-40%. (Sinha et al., 2009, Suhane, 2007; Suhane, Sinha, & Singh, 2008).

Better Growth and Higher Yield With Lower Amount of Vermicompost

Studies indicate that smaller amounts of vermicompost in fact promote better growth performances of crops. Subler, Clive, & Metzger, (1998) reported that in all growth trials the best growth responses were exhibited when the vermicompost constituted a relatively small proportion (10%-20%) of the total volume of the container medium. Valani, (2009) found that 200 gm of vermicompost applied in pot soils performed better growth in wheat crops than those with 400 gm & 500 gm of vermicompost. Singh, (1993) found that in the farm plots where vermicompost was applied in the 2nd, 3rd and 4th successive years, the growth & yield of wheat crops increased gradually over the years at the same rate of application of vermicompost i.e. at the rate of 20 Q/ha. In the 4th successive year the yield was 38.8 Q/ha which was very close to the yield (40.1 Q/ha) where vermicompost was applied at the rate of 25 Q/ha use of vermicompost in farm soil eventually leads to increase in the number of earthworm population in the farmland over a period of time as the baby worms grow out from their cocoons. It infers that slowly over the years, the earthworms build up the soil's physico-chemical and biological properties, the amount of vermicompost can be slowly reduced while maintaining the same yield. The yield per hectare may also increase further as the soil's natural fertility is restored and strengthened. In a study in Australia, Webster, (2005) found that vermicompost increased yield of 'cherries' for three years after 'single application'. Yield was much higher when the vermicompost was covered by 'mulch'. At the first harvest, trees with 5 and 20 mm vermicompost plus mulch yielded cherries of the value of $ 63.92 and $ 70.42 respectively. After three harvests, yield per tree were $ 110.73 and $ 142.21 respectively for the 5 mm and 20 mm vermicompost with mulch.

With vermicompost alone (without mulch), trees yielded cherries of $ 36.46 per tree with 20 mm vermicompost in the first harvest and after three harvest $ 40.48 per tree. Webster, (2005) also studied the agronomic impacts of compost in vineyards and found that the treated vines produced 23% more grapes due to 18% increase in number of bunch of grapes. The yield in grapes was worth additional $ 3,400/ha.

Chemical Fertilizers Are Needed to Maintain Growth and Yield

On the contrary, in chemical agriculture, the amount of chemicals used per hectare has been steadily increasing over the years to maintain the yield constant as the soil became 'addict'. Nearly 3- 4 times of agro-chemicals are now being used per hectare what was used in the 1960s. And the cost of chemical fertilizers has also been steadily increasing since then. There is also significant loss of chemical fertilizer from the farm soil due to oxidation in sunlight. Suhane, (2007) calculated that upon application of 100 kg urea (N) in farm soil, 40-50 kg gets oxidised and escapes as 'ammonia' (NH_3) into the atmosphere, about 20-25 kg leaches underground which pollutes groundwater, while only 20-25 kg is available to be used up by the plants.

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COMMERCIAL VERMICULTURE

Vermiculture is a growing and developing industry not only for managing waste and land very economically but also for promoting 'sustainable agriculture' by enhancing crop productivity both in quantity & quality at significantly low economic cost than the costly agrochemicals (Bogdanov, 1996). Earthworms not only converts 'waste' into 'wealth' it itself becomes a valuable asset as worm biomass. Large-scale production of nutrient rich 'vermicompost' (especially from the municipal solid wastes) with potential to replace chemical fertilizers and protein rich 'earthworms' can be a good business opportunity today with awareness growing about use of these products in agriculture and other allied industries (GEORG, 2004). MSW is growing in huge quantities in every country with growing population and there will be no dearth of raw materials for production of vermicompost. Vermiculture have also enhanced the lives of poor in India and have generated self-employment opportunities for the unemployed. It has become good source of livelihood for many. In several Indian villages NGO's are freely distributing cement tanks and 1000 worms and encouraging men & women to collect waste from villages and farmers, vermicompost them and sell both worms and vermicompost to the farmers. People are earning from Rupees 5 to 6 lakhs (Approx. $ 15-20 thousands) every year from sale of both worms and their vermicompost to the farmers. Mostly they use farm waste and also municipal solid wastes (MSW) collected from streets and waste dumpsites. It is estimated that one ton of earthworm biomass on an average contain approximately one million worms (Anonymous, 1980). One million worms doubling every two months can become 64 million worms at the end of the year. Considering that each adult worm (particularly *E. fetida*) consume waste organics equivalent to its own body weight everyday, 64 million worms (weighing 64 tons) would consume 64 tons of waste everyday and produce 30-32 tons of vermicompost per day at 40-50% conversion rate (Visvanathan, Trankler, Joseph, & Nagendran, 2005). In any vermiculture practice, earthworms biomass comes as a valuable by-product and they are good source of nutritive 'worm meal'. They are rich in proteins (65%) with 70-80% high quality essential amino acids 'lysine' and 'methionine' and are being used as feed material to promote 'fishery', 'dairy' and 'poultry' industry. They are also finding new use as a source of 'collagen' in the manufacture of pharmaceuticals and in the making of 'antibiotics' from the ceolomic fluid as it has anti-pathogenic properties.

Nonetheless, the importance of local (native) species should not be ignored and due attention to them must be given. Kale et al., (1982) tried South Indian variety, Oriental worm, *Perionyx excavatus* for composting of animal wastes under laboratory conditions. Similarly *Perionyx sansibarious* in Kerala and *P. pallus* in Maharastra have been tested for organic waste degradation and they were found to be highly satisfactory. Agrawal, (2009) has also shown that the local variety, *Perionyx cressiseptatus* can be employed for vermicomposting, particularly of high moisture content waste. Kale and Bano (1988) recommended a mixed culture of exotic worms with local species. Many species of epigeic earthworms were tested for mass cultivation over different parts of the world, including the tropical and temperate regions. According to (Kale, 1993) three earthworm species, *Eisenia foetida, Edurilus eugeniae* and *Perionyx excavatus* come in the order of preference for their ability to degrade the wastes. They are very efficient and adaptable in cultures under semi natural conditions in India.

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CONCLUSION

Although vermicomposting is being engineered into a novel and green technology, earthworms have been used routinely for the treatment and transformation of waste products for at least 100 years so far. The waste industry which is based on the exploitation of earthworms in now properly controlled and engineered systems also depends on the metabolic activities of earthworms which degrade the organic matter in vermicompost. Anthropogenic activities have caused widespread pollution of the natural environment. vermicomposting has grown into a green, attractive, highly beneficial and promising alternative to traditional physico-chemical techniques for the different types of wastes, as it can be more cost-effective and it can selectively degrade the wastes without damaging the site or its indigenous flora and fauna. However, vermicomposting technologies have had limited applications due to the constraints imposed by substrate and variability in environmental condition, and the limited biodegradative potential and viability of naturally occurring earthworms.

This review was not intended to address the much voluminous literature on vermicomposting, but rather to revisit the basic of vermicomposting and demonstrate that the application of vermicomposting in the fields of waste management. The application of diverse vermicomposting technologies must be based on sound and reliable scientific data obtained in both fundamental as well as research environmental laboratories. For the development of vermicomposting processes to succeed at commercial scale, it is necessary to link different disciplines such as microbial ecology, biochemistry and microbial physiology, organic farming together with biochemical and bioprocess engineering. In short, the key to successful vermicomposting resides in continuing to develop the scientific and engineering work that provides the real bases for both the vermicomposting and its evaluation; and simultaneously in explaining and justifying the valid reasons which allow scientists and engineers to actually use these technologies for the welfare and safety of a public which is more and more concerned about the environment and its protection.

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REFERENCES

Abrahamsen, G. (1972). Ecological study of Lumbricidae (Oligochaeta) in Norwegian coniferous forest soils. *Pedobiologia*, *12*, 267–281.

Adi, A. J., & Noor, Z. M. (2009). Waste recycling: Utilization of coffee grounds and kitchen waste in vermicomposting. *Bioresource Technology*, *100*(2), 1027–1030. doi:10.1016/j.biortech.2008.07.024 PMID:18752936

Agrawal, D. (2009). *Study on comparative vermicomposting performance of different species of earthworms in Gwalior.* Unpublished doctoral dissertation, Jiwaji University Gwalior, India.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Alam, M. N., Jahan, M. S., Ali, M. K., Ashraf, M. A., & Islam, M. K. (2007). Effect of vermicompost and chemical fertilizers on growth, yield and yield components of Potato in Barind soils of Bangladesh. *Journal of Applied Sciences Research*, *3*(12), 1879–1888.

Al-Dahmani, J. H., Abbasi, P. A., Miller, S. A., & Hoitink, H. A. J. (2003). Suppression of bacterial spot of tomato with foliar sprays of compost extracts under greenhouse and field conditions. *Plant Disease*, *87*(8), 913–919. doi:10.1094/PDIS.2003.87.8.913

Anonymous. (1980). Report and Recommendations on Organic Farming-Case [*Organic Farmers in USA*. US Board of Agriculture, USA.]. *Studium (Roma)*, 69.

Anonymous. (2001). Vermicompost as Insect Repellent. *BioCycle*, 1–19.

Ansari, A. A. (2008). Effect of Vermicompost on the Productivity of Potato (*Solanum tuberosum*), Spinach (*Spinacia oleracea*) and Turnip (*Brassica campestris*). *World Journal of Agricultural Sciences*, *4*(3), 333–336.

Appelhof, M. (1997). *Worms Eat My Garbage*. Kalamazoo, Michigan: Flower Press. Retrieved from http://www.wormwoman.com

Appelhof, M. (2003). *Notable Bits*. Kalamazoo, Michigan: Worm Ezine. Retrieved from http://www.wormwoman.com

Arancon, N. (2004). An Interview with Dr. Norman Arancon in Casting Call. Retrieved from (http://www.vermico.com)

Arancon, N. Q., Edwards, C. A., Bierman, P., Metzger, J. D., Lee, S., & Welch, C. (2003). Effects of vermicomposts on growth and marketable fruits of field-grown tomatoes, peppers and strawberries. *Pedobiologia*, *47*, 731–735.

Arancon, N. Q., Edwards, C. A., Bierman, P., Welch, C., & Metzger, J. D. (2004). Influences of vermicomposts on field strawberries-1: Effects on growth and yields. *Bioresource Technology*, *93*(2), 145–153. doi:10.1016/j.biortech.2003.10.014 PMID:15051076

Arancon, N. Q., Edwards, C. I., & Bierman, P. (2006). Influences of vermicomposts on field strawberries-2: Effects on soil microbiological and chemical properties. *Bioresource Technology*, *97*(6), 831–840. doi:10.1016/j.biortech.2005.04.016 PMID:15979873

Atiyeh, R. M., Arancon, N. Q., Edwards, C. A., & Metzger, J. D. (2000). Influence of earthworm processed pig manure on the growth and yield of greenhouse tomatoes. *Journal of Bioresource Technology*, *75*(3), 175–180. doi:10.1016/S0960-8524(00)00064-X

Atiyeh, R. M., Subler, S., Edwards, C. A., Bachman, G., Metzger, J. D., & Shuster, W. (2000). Effects of Vermicomposts and Composts on Plant Growth in Horticultural Container Media and Soil. *Pedobiologia*, *44*(5), 579–590. doi:10.1078/S0031-4056(04)70073-6

Aveyard, J. (1988). Land degradation: Changing attitudes - why? *Journal of Soil Conservation*, *44*, 46–51.

Baker, G., & Barrett, V. (1994). *Earthworm Identifier; Publication of Council of Scientific and Industrial Research Organization (CSIRO)*. Australia: Division of Soil & Land Management.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Benitez, E., Nogales, R., Elvira, C., Masciandaro, G., & Ceccanti, B. (1999). Enzyme activities as indicators of the stabilization of sewage sludges composting with *Eisenia foetida. Bioresource Technology*, *67*(3), 297–303. doi:10.1016/S0960-8524(98)00117-5

Bhat, J. V., & Khambata, P. (1994). Role of earthworms in agriculture. (pp. 22-36). New Delhi: Indian Council of Agriculture Research (ICAR).

Bhatia, S. (2000). *Earthworm and Sustainable Agriculture: Study of the Role of Earthworm in Production of Wheat Crop*, Unpublished doctoral dissertation, University of Rajasthan, Jaipur, India.

Bhatia, S., Sinha, K. R., & Sharma, R. (2000). Seeking Alternatives to Chemical Fertilizers for Sustainable Agriculture: A Study on the Impact of Vermiculture on the Growth and Yield of Potted Wheat Crops (*Triticum aestivum* Linn). *International Journal of Environmental Education and Information*, *19*(4), 295–304.

Bhawalkar, U. S. (1993). *Turning Garbage into Gold. An Introduction to Vermiculture Biotechnology*. Pune: Bhawlkar Earthworm Research Institute.

Bhawalkar, U. S. (1994). Converting waste into resources. *Information centre for Low External Input Agriculture Newsletter*, *10*, 20–21.

*Bhawalka*r, U. S. (1996). *Vermiculture Ecotechnology*. Bhawalkar Ecological Research Institute, Pune. 283.

Bhawalkar, V. S. (1995). *Vermiculture bioconversion of organic residues*. India: IIT Mumbai.

Block, W., & Banage, W. B. (1968). Population density and biomass of earthworms in some Uganda soils. *Revue d'Écologie et de Biologie du Sol*, *5*, 515–521.

Bogdanov, P. (1996). *Commercial Vermiculture: How to Build a Thriving Business in Redworms*. Oregon: Vermi Co. Press.

Bombatkar, V. (1996). *The Miracle Called Compost*. Pune: The Other India Press.

Brown, G. G. (1995). How do earthworms affect microfloral and faunal community diversity? *Journal of Plant and Soil*, *170*(1), 209–231. doi:10.1007/BF02183068

Butt, K. R., Nieminen, M. V., Siren, T., Ketoja, E., & Nuutinen, V. (2005). Population and behaviour level responses of arable soil earthworms to broad mill sludge application. *Biology and Fertility of Soils*, *42*(2), 163–167. doi:10.100700374-005-0010-4

Canellas, L. P., Olivares, F. L., Okorokova, A. L., & Facanha, R. A. (2000). Humic Acids Isolated from Earthworm Compost Enhance Root Elongation, Lateral Root Emergence and Plasma Membrane H^+-ATPase Activity in Maize Roots. *International Journal of Plant Physiology*, *130*(4), 1951–1957. doi:10.1104/pp.007088 PMID:12481077

Chaoui, H. I., Zibilske, L. M., & Ohno, T. (2003). Effects of earthworms casts and compost on soil microbial activity and plant nutrient availability. *Soil Biology & Biochemistry*, *35*(2), 295–302. doi:10.1016/S0038-0717(02)00279-1

Cooke, A., & Luxton, M. (1980). Effect of microbes on food selection by *Lumbricus terrestris. Revue d'Écologie et de Biologie du Sol*, *17*, 365–370.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Dash, M. C., & Patra, U. C. (1977). Density biomass and energy budget of a tropical earthworm population from a grassland site in Orissa, India. *Revue d'Écologie et de Biologie du Sol*, *14*, 461–471.

De Brito Alvarez, M. A., Gagne, S., & Antoun, H. (1995). Effect of compost on rhizosphere microflora of the tomato and on the incidence of plant-growth promoting rhizobacteria. *Journal of Applied and Environmental Microbiology*, *61*, 194–199. PMID:16534902

Desai, V. R., Sabale, R. N., & Raundal, P. V. (1999). Integrated nitrogen management in wheat-coriander cropping system. *Journal of Maharasthra Agricultural Universities*, *24*(3), 273–275.

Devi, D., & Agarwal, S. K. (1998). Performance of sunflower hybrids as influenced by organic manure and fertilizer. *Journal of Oilseeds Research*, *15*(2), 272–279.

Devi, D., Agarwal, S. K., & Dayal, D. (1998). Response of sunflower [*Helianthus annuus* (L.)] to organic manures and fertilizers. *Indian Journal of Agronomy*, *43*(3), 469–473.

Domínguez, J., & Edwards, C. A. (2004). Vermicomposting organic wastes: A review. In S. H. S., Hanna & W. Z. A., Mikhail (Ed.), Soil zoology for sustainable development in the 21st century (pp. 369-396). Egypt: El Cario.

Dominguez, J., Edwards, C. A., & Webster, M. (2000). Vermicomposting of sewage sludge: Effect of bulking materials on the growth and reproduction of the earthworm *Eisenia Andrei*. *Pedobiologia*, *44*(1), 24–32. doi:10.1078/S0031-4056(04)70025-6

Edwards, C. A., & Burrows, I. (1988). The potential of earthworms composts as plant growth media. In C. A. Edward & E. F. Neuhauser (Eds.), *Earthworms in Waste and Environmental Management* (pp. 21–32). The Hague, The Netherlands: SPB Academic Publishing.

Edwards, C. A., & Bohlen, P. J. (1996). *Biology and ecology of earthworms*. London: Chapman and Hall.

Edwards, C. A., & Arancon, N. (2004). The Use of Earthworms in the Breakdown of Organic Wastes to Produce Vermicomposts and Animal Feed Protein. In C. A. Edwards (Ed.), *Earthworm Ecology* (pp. 345–438). Washington, New York: CRC Press. doi:10.1201/9781420039719

Edwards, C. A., & Lofty, J. R. (1972). *Biology of Earthworms*. London: Chapman and Hall. doi:10.1007/978-1-4899-6912-5

Edwards, C. A., & Lofty, J. R. (1977). *Biology of Earthworms*. London: Chapman and Hall. doi:10.1007/978-1-4613-3382-1

Edwards, C. A., Domínguez, J., & Arancon, N. Q. (2004). The influence of vermicomposts on plant growth and pest incidence. In S. H. Shakir & W. Z. A. Mikhail (Ed.), Soil Zoology for Sustainable Development in the 21st Century (pp. 397-420). Egypt: Self-Published.

Elvira, C., Sampedro, L., Benitez, E., & Nogales, R. (1998). Vermicomposting of sludges from paper mill and dairy industries with Eisenia andrei: A pilot scale study. *Bioresource Technology*, *63*(3), 205–211. doi:10.1016/S0960-8524(97)00145-4

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Evans, A. C., Mc, W. J., & Guild, L. (1948). Studies on the relationships between earthworms and soil fertility. IV. On the life cycles of some British *Lumbricidae. Annals of Applied Biology*, *35*(4), 471–484. doi:10.1111/j.1744-7348.1948.tb07391.x

Gandhi, M., Sangwan, V., Kapoor, K. K., & Dilbaghi, N. (1997). Composting of household wastes with and without earthworms. *Environment and Ecology*, *15*(2), 432–434.

Garg, K., & Bhardwaj, N. (2000). Effect of vermicompost of parthenium on two cultivars of wheat. *Indian Journal of Ecology*, *27*, 177–180.

Garg, V. K., & Kaushik, P. (2005). Vermistabilization of textile mill sludge spiked with poultry droppings by an epigeic earthworm *Eisenia foetida. Bioresource Technology*, *96*(9), 1063–1071. doi:10.1016/j.biortech.2004.09.003 PMID:15668203

Feasibility of developing the organic and transitional farm market for processing municipal and farm organic wastes using large-scale vermicomposting. (2004). Good Earth Organic Resources Group. Nova Scotia, Canada: Good Earth Organic Resources Group.

Graff, O. (1981). Preliminary experiments of vermicomposting of different waste materials using Eudrilus eugeniae*,* Kinberg. In M. Appelhof (Ed.), *Proceedings of Workshop on role of Earthworms in Stabilization of Organic Residues* (pp. 191-197). Western Michigan University, Kalamazoo, Michigan.

Guerrero, R. D. (1983). The culture and use of Perionyx excavatus as a protein resource in the Philippines. In J. E. Satchel (Ed.), *Earthworm Ecology from Darwin to Vermiculture* (pp. 309–313). London: Chapman and Hall. doi:10.1007/978-94-009-5965-1_26

Gunthilingaraj, K., & Ravignanam, T. (1996). Vermicomposting of Sericulture wastes. Madras. *Agricultural Journal*, *83*, 455–457.

Hait, S., & Tare, V. (2011). Vermistabilization of primary sewage sludge. *Bioresource Technology*, *102*(3), 2812–2820. doi:10.1016/j.biortech.2010.10.031 PMID:21036608

Jadhav, A. D., Talashilkar, S. C., & Pawar, A. G. (1997). Influence of the conjunctive use of FYM, vermicompost and urea on growth and nutrient uptake in rice. *Journal of Maharashtra Agricultural Universities*, *22*(2), 249–250.

Kale, R. D. (1993). Regeneration, Predators and Parasites of Earthworms. *Earthworm resources and Vermiculture*, 101-103.

Kale, R. D. (1994). *Vermicomposting of Waste Materials. Earthworm Cinderella of Organic Farrming*. New Delhi: Prism Book Pvt Ltd.

Kale, R. D., & Bano, K. (1988). Earthworm cultivation and culturing technique for production of ‘Vee Comp. 83 E UAE’ and ‘Vee meal 83P UAS’ Mys. *The Journal of Agricultural Science*, *22*, 339–344.

Kale, R. D., & Krishnamoorthy, R. V. (1978). Distribution of earthworms in relation to soil conditions in Bangalore. In Edwards & G. K. Veeresh (Ed.), Soil Biology and Ecology in India, UAS Technical Service (pp. 63-69).

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Kale, R. D., & Krishnamoorthy, R. V. (1981a). *Enrichment of soil fertility by earthworm activity*, G.K.V.K, UAS Technology, *37*, 64-68.

Kale, R. D., & Krishnamoorthy, R. V. (1981b). What effects the abundance and diversity of earthworms in soils? *Indian Academy of Science*, *90*(1), 117–121.

Kale, R. D., Bano, K., & Krishnamoorty, R. V. (1982). Potential of *Perionyx excavatus* for utilizing organic wastes. *Pedobiologia*, *23*, 419–425.

Kallimani, C. S. (1998). *Bioconversion of sericulture waste using Eudrilus eugeniae and Phanerochaete crysosporium. University of Agricultural science*. Dharwad.

Karmegam, N., & Daniel, T. (2000). Effect of biodigested slurry and vermicompost on the growth and yield of cowpea Vigna unguiculata (L.). *Environment and Ecology*, *18*(2), 367–370.

Karmegam, N., Alagermalai, K., & Daniel, T. (1999). Effect of vermicompost on the growth and yield of greengram (Phaseolus aureus Rob.). *Tropical Agriculture*, *76*(2), 143–146.

Katiyar, A. K., Jat, A. S., & Singh, R. P. (2013). Use of Bio- organic manures for wheat production in sandy loam soils. *Indian Research Journal of Genetics & Biotechnology*, *5*(4), 274–277.

Kaur, A., Singh, J., Vig, A. P., Dhaliwal, S. S., & Rup, P. J. (2010). Co-composting with and without Eisenia fetida for conversion of toxic paper mill sludge to a soil conditioner. *Bioresource Technology*, *101*(21), 8192–8198. doi:10.1016/j.biortech.2010.05.041 PMID:20624603

Kaushik, P., & Garg, V. K. (2004). Dynamics of biological and chemical parameters during vermicomposting of solid textile mill sludges mixed with cow dung and agricultural residues. *Bioresource Technology*, *4*(2), 203–209. doi:10.1016/j.biortech.2003.10.033 PMID:15158514

Kostecka, J. (1999). Usefulness of flax seeds in *Eisenia foetida* (Savigny) earthworm breeding. *Pedobiologia*, *43*(6), 776–781.

Krishnamoorthy, R. V., & Vajranabhaiah, S. N. (1986). Biological Activity of Earthworm Casts: An Assessment of Plant Growth Promoter Levels in the Casts. [Animal Science]. *Proceedings of the Indiana Academy of Sciences*, *95*(3), 341–351. doi:10.1007/BF03179368

Kumar, R., Verma, D., Singh, B. L., & Umesh, U. (2010). Composting of sugar-cane waste by-products through treatment with microorganisms and subsequent vermicomposting. *Bioresource Technology*, *101*(17), 6707–6711. doi:10.1016/j.biortech.2010.03.111 PMID:20403689

Kurien, J., & Ramasamy, E. V. (2006). Vermicomposting of taro (*Colocasia esculenta)* with two epigeic earthworm species. *Bioresource Technology*, *97*(11), 1324–1328. doi:10.1016/j.biortech.2005.05.018 PMID:16051486

Lee, K. R. (1985). *Earthworms: their ecology and relationships with soil and land use*. London: Academic Press.

Lowe, C. N., & Butt, K. R. (2002). Growth of Hatchling earthworms in the present of the adults: Interaction in laboratory culture. *Biology and Fertility of Soils*, *35*(3), 204–209. doi:10.100700374-002-0471-7

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Mamta, Wani, K. A., & Rao, R. J. (2012). Effect of vermicompost on growth of brinjal plant (*Solanum melongena)* under field Conditions. *Journal on New Biological Reports*, *1*(1), 25–28.

Mani, P., & Karmegam, N. (2010). Vermistabilisation of press-mud using *Perionyx celanensis. Bioresource Technology*, *101*(21), 8464–8468. doi:10.1016/j.biortech.2010.06.002 PMID:20594835

Mishra, R. K., Singh, B. K., Upadhyay, R. K., & Singh, S. (2009). Technology for vermicompost production. *Indian Farming*.

Munnoli, P. M. (2007). *Management of industrial organic solid wastes through vermiculture biotechnology with special reference to microorganisms*. Goa, India: Goa University.

Munnoli, P. M., & Bhosle, S. (2008). Soil aggregation by vermicompost of press mud. *Current Science*, *95*, 1533–1535.

Munnoli, P. M., Arora, J. K., & Sharma, S. K. (2000). *Organic waste management through vermiculture: A case study of Pepsi Food Channoo Punjab*. Kolkata: Sapana Printing Works.

Munroe, G. (2007). *Manual of On-farm Vermicomposting and Vermiculture*. Canada: Publication of Organic Agriculture Centre of Canada..

Nagavallemma, K. P., & Wani, S. P. Stephane, Lacroix., Padmaja, V. V., Vineela, C., Babu, Rao, M., & Sahrawat, K. L. (2004). *Vermicomposting: Recycling wastes into valuable organic fertilizer*. Global Theme on Agrecosystems (Report no. 8). Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Nair, J., Vanja, S., & Anda, M. (2006). Effect of pre-composting on vermicomposting of kitchen waste. *Bioresource Technology*, *97*(16), 2091–2095. doi:10.1016/j.biortech.2005.09.020 PMID:16269241

Neilson, R. L. (1965). Presence of Plant Growth Substances in Earthworms, Demonstrated by the Paper Chromatography and Went Pea Test. Nature, (London), 208, 1113-1114.

Nethra, N. N., Jayaprasad, K. V., & Kale, R. D. (1999). China aster [*Callistephus chinensis* (L)] cultivation using vermicompost as organic amendment. *Crop Research*, *17*(2), 209–215.

Orlikowski, L. B. (1999). Vermicompost extract in the control of some soil borne pathogens. *International Symposium on Crop Protection* (Vol. 64, pp. 405-410).

Ouédraogo, E., Mando, A., & Zombre, N. P. (2001). Use of compost to improve soil properties and crop productivity under low input agricultural system in West African *Journal of Agricultural Ecosystems and Environment, 84*, 259-266.

Palanisamy, S. (1996). *Earthworm and Plant Interactions; Paper presented in ICAR Training Program*. Coimbatore: Tamil Nadu Agricultural University.

Parle, J. N. (1963). A microbiological study of earthworm casts. *Journal of General Microbiology*, *31*(1), 13–23. doi:10.1099/00221287-31-1-13

Parthasarathi, K. & Ranganathan, L. S. (2000). Longevity of microbial and enzyme activity and their influence on NPK content in pressmud vermicasts. *European Journal of Soil Biology, 35* (3), 107-1 13.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Patil, S. L., & Sheelavantar, M. N. (2000). Effect of moisture conservation practices, organic sources and nitrogen levels on yield, water use and root development of rabi sorghum [*Sorghum bicolor* (L.)] in the vertisols of semiarid tropics. *Annals of Agricultural Research*, *21*(21), 32–36.

Pramanik, P., Ghosh, G. K., Ghosal, P. K., & Banik, P. (2007). Changes in organic-C, N, P and K and enzyme activities in vermicompost of biodegradable organic wastes under liming and microbial inoculants. *Bioresource Technology*, *98*(13), 2485–2494. doi:10.1016/j.biortech.2006.09.017 PMID:17081750

Rajesh, B. J., & Yeom, I. T., Esakkiraj, Kumar, N., & Lee, Y. W. (2008). Bio management of sago-sludge using an earthworm, *Lampito mauritii. Journal of Environmental Biology*, *29*, 753–757. PMID:19295077

Ravindran, B., Dinesh, S. L., Kennedy, L. J., & Sekaran, G. (2008). Vermicomposting of solid waste generated from leather industries using epigeic earthworm *Eisenia foetida. Applied Biochemistry and Biotechnology*, *151*(2-3), 480–488. doi:10.100712010-008-8222-3 PMID:18509607

Ravindran, R., & Sekaran, G. (2011). Bacterial composting of animal fleshing generated from tannery industries. *Waste Management (New York, N.Y.)*, *30*(12), 2622–2630. doi:10.1016/j.wasman.2010.07.013 PMID:20727727

Reddy, M. V. (1988). The effect of casts of Pheretima alexandri on the growth of Vinca rosea and Oryza sativa. In C. A. Edwards & E. F. Neuhauser (Eds.), *Earthworms in Environmental and Waste Management* (pp. 241–248). The Netherlands: SPB Bakker.

Reddy, R., Reddy, M. A. N., Reddy, Y. T. N., Reddy, N. S., Anjanappa, N., & Reddy, R. (1998). Effect of organic and inorganic sources of NPK on growth and yield of pea [*Pisum sativum*(L)]. *Legume Research*, *21*(1), 57–60.

Rodriguez, J. A., Zavaleta, E., Sanchez, P., & Gonzalez, H. (2000). The effect of vermicompost on plant nutrition, yield and incidence of root and crown rot of Gerbera (*Gerbera jamesonii H Bolus*). *Fitopathologia*, *35*, 66–79.

Sabine, J. R. (1978). The nutritive value of earthworm meals. In R. Hartenstein (Ed.), Utilization of soil organisms in sludge management. (pp. 122-130), Syracuse, State University of New York, London.

Scheu, S. (1987). Microbial Activity and Nutrient Dynamics in Earthworms Casts. *Journal of Biological Fertility Soils*, *5*, 230–234.

Sen, B., & Chandra, T. S. (2007). Chemolytic and solid-state spectroscopic evaluation of organic matter transformation during vermicomposting of sugar industry wastes. *Bioresource Technology*, *98*(8), 1680–1683. doi:10.1016/j.biortech.2006.06.007 PMID:17157000

Sharma, R. (2001). *Vermiculture for Sustainable Agriculture: Study of the Agronomic Impact of Earthworms and their Vermicompost on Growth and Production of Wheat Crops* [Unpublished doctoral dissertation]. University of Rajasthan, Jaipur, India.

Shiralipour, A., McConnell, D. B., & Smith, W. H. (1992). Uses and Benefits of MSW Compost: A Review and Assessment. *Journal of Biomass and Bioenergy*, *3*(3-4), 267–279. doi:10.1016/0961-9534(92)90031-K

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Shweta., Kumar, P., Sharma, D., & Sonal. (2006). Fluctuation in biomass and cocoon production of *Eudrilus eugeniae* during the vermicomposting using different organic wastes. *Journal of Applied Zoological Researches, 17* (2), 217-220.

Siminis, C. I., Loulakis, M., Kefakis, M., Manios, T., & Manios, V. (1998). Humic substances from compost affect nutrient accumulation and fruit yield in tomato. *Acta Horticulturae*, *469*, 353–358.

Singh, J. (1997). Habitat preferences of selected Indian earthworm species and their efficiency in reduction of organic material. *Soil Biology & Biochemistry*, *29*(3-4), 585–588. doi:10.1016/S0038-0717(96)00183-6

Singh, J., Kaur, A., Vig, A. P., & Rup, P. J. (2010). Role of *Eisenia fetida* in rapid recycling of nutrients from bio sludge of beverage industry. *Ecotoxicology and Environmental Safety*, *73*(3), 430–435. doi:10.1016/j.ecoenv.2009.08.019 PMID:19945748

Singh, K. (2009). *Microbial and Nutritional Analysis of Vermicompost, Aerobic and Anaerobic Compost. 40 CP Honours Project for Master in Environmental Engineering*. Brisbane, Australia: Griffith University.

Singh, R. D. (1993). *Harnessing the Earthworms for Sustainable Agriculture* (pp. 1–16). Pune, India: Institute of National Organic Agriculture.

Singh, R. P., Singh, P., Ademir, S. F., & Araujo, M. (2011). Management of urban solid waste: Vermicomposting a sustainable option. *Resources, Conservation and Recycling*, *55*(7), 719–729. doi:10.1016/j.resconrec.2011.02.005

Sinha, R. K., Nair, J., Bharambe, G., Swapnil, P., & Bapat, P. D. (2008). Vermiculture Revolution. In J. I. Daven & R. N. Klein (Eds.), *Progress in Waste Management Research* (pp. 157–227). NY, USA: NOVA Science Publishers.

Sinha, R. K., Sunil, H., Dalsukh, V., & Chauhan, K. (2009). Vermiculture and Sustainable Agriculture. *American-Eurasian Journal of Agricultural and Environmental Sciences*, *5*, 1–55.

Sinha, R. K., Sunil, H., Agarwal, S., Asadi, R., & Carretero, E. (2002). Vermiculture Technology for Environmental Management: Study of Action of Earthworms *Elsinia fetida, Eudrilus euginae* and *Perionyx excavatus* on Biodegradation of Some Community Wastes in India and Australia. *The Environmentalist*, *22*(2), 261–268. doi:10.1023/A:1016583929723

Spain, A. V., Lavelle, P., & Mariotti, A. (1992). Stimulation of Plant Growth by Tropical Earthworms. *Soil Biology & Biochemistry*, *24*(12), 1629–1633. doi:10.1016/0038-0717(92)90161-P

Sreenivas, C., Muralidhar, S., & Rao, M. S. (2000). Vermicompost, a viable component of IPNSS in nitrogen nutrition of ridge gourd. *Annals of Agricultural Research*, *21*(1), 108–113.

Subler, S., Clive, E., & Metzger, J. (1998). Comparing Vermicomposts and Composts. *BioCycle*, *39*, 63–66.

Subramanian, S., Sivarajan, M., & Saravanapriya, S. (2010). Chemical changes during vermicomposting of sago industry solid wastes. *Journal of Hazardous Materials*, *179*(1-3), 318–322. doi:10.1016/j.jhazmat.2010.03.007 PMID:20359816

Suhane, R. K. (2007). *Vermicompost*. Pusa, Bihar, India: Rajendra Agriculture University, Bihar. (In Hindi)

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Suhane, R. K., Sinha, R. K., & Singh, P. K. (2008). Vermicompost, Cattle-dung Compost and Chemical Fertilizers: Impacts on Yield of Wheat Crops. Bihar, India: Publication of Rajendra Agriculture University, Bihar.

Suthar, S. (2006). Potential utilization of guar gum industrial waste in vermicomposting production. *Bioresource Technology*, *7*(18), 2474–2477. doi:10.1016/j.biortech.2005.10.018 PMID:16311031

Suthar, S. (2007). Production of vermifertilizer from guar gum industrial wastes by using composting earthworm *Perionyx sansibaricus* (Perrier). *The Environmentalist*, *27*(3), 329–335. doi:10.100710669-007-9032-9

Suthar, S. (2010). Recycling of agro-industrial sludge through vermitechnology. *Ecological Engineering*, *36*(8), 1028–1036. doi:10.1016/j.ecoleng.2010.04.015

Suthar, S., & Singh, S. (2008). Feasibility of vermicomposting in biostabilization of sludge from a distillery industry. *The Science of the Total Environment*, *394*(2-3), 237–243. doi:10.1016/j.scitotenv.2008.02.005 PMID:18313726

Szczech, M., Rondomanski, W., Brzeski, M. W., Smolinska, U., & Kotowski, J. F. (1993). Suppressive effect of commercial earthworm compost on some root infecting pathogens of cabbage and tomato. *Biological Agriculture and Horticulture*, *10*(1), 47–52. doi:10.1080/01448765.1993.9754650

Crescent, T. (2003). Vermicomposting. Development Alternatives [DA] Sustainable Livelihoods. (http://www.dainet.org)

Thyagarajan, LakshmiPriya, T., Meenambal, L. Mangaleshwaran, N. Lakshminarasimaiah & N. Ramesh. (2010). Recycling of Pulp and Paper Industry Sludge with Saw Dust by Aerobic Composting Method. *Nature Environment and Pollution Technology, 9* (1): 149-154

Tomar, V. K., Bhatnagar, R. K., & Palta, R. K. (1998). Effect of Vermicompost on Production of Brinjal and Carrot. [Indian Agricultural Research Bulletin]. *Bhartiya Krishi Anusandhan Patrika*, *13*(3-4), 153–156.

Tomati, V., Grappelli, A., & Galli, E. (1988). The Hormone like Effect of Earthworm Casts on Plant Growth. *Biology and Fertility of Soils*, *5*(4), 288–294. doi:10.1007/BF00262133

UNEP/GEMS. (1992). The Contamination of Food. UNEP/GEMS Environment Library No. 5, Nairobi, Kenya.

Vadiraj, B. A., Siddagangaiah, D., & Potty, S. N. (1998). Response of coriander (*Coriandrum sativum* L.) cultivars to graded levels of vermicompost. *Journal of Spices and Aromatic Crops*, *7*(2), 141–143.

Valani, D. (2009). *Study of Aerobic, Anaerobic and Vermicomposting Systems for Food and Garden Wastes and the Agronomic Impacts of Composts on Corn and Wheat Crops; Report of 40 CP Honours Project for the Partial Fulfillment of Master of Environmental Engineering Degree*. Australia: Griffith University.

(Vermicomposting technology for waste management and agriculture: an executive summary. 2001). Retrieved from http://www.vermi.com

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Vinotha, S. P., Parthasarathi, K., & Ranganathan, L. S. (2000). Enhanced phosphatase activity in earthworm casts is more of microbial origin. *Current Science*, *79*, 1158–1159.

Visvanathan, C., Trankler, J., Jospeh, K., & Nagendran, R. (2005). *Vermicomposting as an Eco-tool in Sustainable Solid Waste Management*. India: Asian Institute of Technology, Anna University.

Wani, K. A., Mamta, & Rao, R. J. (2013). Bioconversion of garden waste, kitchen waste and cow dung into value-added products using earthworm *Eisenia fetida. Saudi Journal of Biological Sciences*, *20*(2), 149–154. doi:10.1016/j.sjbs.2013.01.001 PMID:23961230

Wani, S. P., & Lee, K. K. (1992). Biofertilizers role in upland crops production. In H. L. S. Tandon (Ed.), *Fertilizers, organic manures, recyclable wastes and biofertilizers* (pp. 91–112). New Delhi, India. Fertilizer Development and Consultation Organization.

Wani, S. P., Rupela, O. P., & Lee, K. (1995). Sustainable agriculture in the semi-arid tropics through biological nitrogen fixation in grain legumes. *Plant and Soil*, *174*(1-2), 29–49. doi:10.1007/BF00032240

Webster, K. A. (2005). Vermicompost Increases Yield of Cherries for Three Years after a Single Application, Eco Research, South Australia. Retrieved from (www.ecoresearch.com.au

Weltzien, H. C. (1989). Some effects of composted organic materials on plant health. *Agriculture, Ecosystems & Environment*, *27*(1-4), 439–446. doi:10.1016/0167-8809(89)90104-7

White, S. (1996, June). Vermiculture bioconversion in India. *Worm Digest*, 65.

Wilson, D. P., & Carlile, W. R. (1989). Plant growth in potting media containing worm-worked duck waste. *Acta Horticulturae*, *238*, 205–220.

Yadav, K. D., Vinod, T., & Mansoor, A. M. (2010). Vermicomposting of source separated human faeces for nutrient recycling. *Waste Management (New York, N.Y.)*, *30*(1), 50–56. doi:10.1016/j.wasman.2009.09.034 PMID:19850460

Zaller, J. G. (2006). Foliar Spraying of Vermicompost Extracts: Effects on Fruit Quality and Indications of Late-Blight Suppression of Field-Grown Tomatoes. *Biological Agriculture and Horticulture*, *24*(2), 165–180. doi:10.1080/01448765.2006.9755017

ADDITIONAL READING

Albanell, E., Plaixats, J., & Cabrero, T. (1988). Chemical changes during vermicomposting (Eisenia fetida) of sheep manure mixed with cotton industrial wastes. *Biology and Fertility of Soils*, *6*(3), 266–269. doi:10.1007/BF00260823

Coleman, D. C. (1985). Through a red darkly: an ecological assessment of root soil microbial faunal interactions. In A. H. Fitter, D. Atkinson, D. J. Read, & M. B. Usher (Eds.), *Ecological interaction in Soil* (pp. 1–21). London, UK: Blackwell Scientific Publications.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Edwards, C. A., & Burrows, I. (1988). The potential of earthworm composts as plant growth media (pp. 211-220). In C. A Edwards & Neuhauser. (Eds.), Earthworms in Environmental and Waste Management. Netherlands: SPB Academic Publishers.

Garg, V. K., & Gupta, R. (2009). Vermicomposting of Agro-Industrial Processing Waste. *Biotechnology for Agro-Industrial Residues Utilisation,* 431-456.

Garg, Vinod., Kumar., Gupta, Renuka., & Yadav, Anoop. (2008). Potential of Vermicomposting Technology in Solid Waste Management. *Current Developments in Solid-state Fermentation,* 468-511.

Mengel, K., Kirkby, E. A., Kosegarten, H., & Appel, T. (2001). *Principles of Plant Nutrition* (5th ed.). Dordrecht: Kluwer Academic Publishers. doi:10.1007/978-94-010-1009-2

Monireh, Majlessi., Akbar, Eslami., Hossein, Najafi., Saleh., Simin, Mirshafieean., & Sara, Babaii. (2012). Vermicomposting of food waste: assessing the stability and maturity. *Iranian Journal of Environmental Health Science & Engineering*, 9-25.

Parmelee, R. W., Bohlen, P. J., & Blair, J. M. (1998). Earthworms and nutrient cycling processes: intergrating across the ecological hierarchy. In C. A. Edwards (Ed.), *Earthworm Ecology* (pp. 123–143). New York, USA: St Lucie Press.

Shi-wei, Z., & Fu-Zhen, H. (1991). The nitrogen uptake efficiency from 15N labeled chemical fertilizer in the presence of earthworm manure (cast). Pp. 539- 542. In G. K Veeresh, D. Rajgopal, & C. A. Viraktamath (Eds.), Advances in Management and Conservation of Soil Fauna. New Delhi, India: Oxford and IBH publishing.

Tomati, U., Grappelli, A., & Galli, E. (1987). The presence ofgrowth regulators in earthworm-worked wastes. In Bonvicini Paglioi, A. M., & Omodeo, P. (Ed.). *On Earthworms, Proceeding of International Symposium on Earthworms, Selected Symposium and Monograph*. (pp. 423-435). Mucchi, Modena: Unione Zoologica Italiana.

KEY TERMS AND DEFINITIONS

Anthropogenic: The term anthropogenic used by Russian geologist Alexey Pavlov denotes the influence of human beings on the environment However, the term was used in English by British ecologist Arthur Tansley in reference to human influences on climax plant communities.

Ecophysiology: The branch of physiology that deals with the physiological processes of organisms in relation to environment.

Garbage: All easily decomposable and putrefying organic (animal and vegetable) waste from preparation, handling, storage, and sale or serving of food refuse other than industrial-waste and effluents.

Organic Farming: Organic farming is a form of agriculture that relies on techniques such as crop rotation, green manure, compost, and biological pest control.

Vermiculite: Vermiculite is a hydrous, silicate mineral that is classified as a phyllosilicate and that expands greatly when heated. Exfoliation occurs when the mineral is heated sufficiently, and the effect is routinely produced in commercial furnaces. Vermiculite is formed by weathering or hydrothermal alteration of biotite or phlogopite.

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Vermitea: Worm tea, usually referred to as vermicompost tea, or VCT, is a type of compost tea that is made by soaking vermicompost in oxygenated, de-chlorinated water. Worm leachate is the excess water that drips through the worm bin and picks up undigested material.

Vermiwash: Vermiwash is a liquid that is collected after the passage of water through a column of worm action and is very useful as a foliar spray. It is a collection of excretory products and mucus secretion of earthworms along with micronutrients from the soil organic molecules.

Waste: Waste and wastes implies unwanted or unusable materials. The term is often subjective (because waste to one person is not necessarily waste to another) and sometimes objectively inaccurate (for example, to send scrap metals to a landfill is to inaccurately classify them as waste, because they are recyclable.

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Chapter 32
Making Agricultural Learning Accessible:
Examining Gender in the Use of Animations via Mobile Phones

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ABSTRACT

Worldwide women play an important role in agriculture but they still are marginalized in extension education programs. Traditionally, male-dominated extension services may contribute to gender bias in terms of access to information, participation, implementation and innovation. Limitations women face in accessing extension programs are related to social and cultural constructions. Recently, mobile phone technology has facilitated the work of extension agents and has provided participants new resources to improve their yields; nevertheless, farmer productivity in Mozambique varies between genders. This paper illustrates how agricultural messages designed as animations, and delivered via smartphones result in learning for farmers better than traditional extension presentations. This chapter focuses on the creation of educational materials by Scientific Animations Without Borders (SAWBO), and then illuminates the gaps and solutions related to gender agricultural learning. Lastly, a case study of Mozambican gender agricultural learning using animations is presented.

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BACKGROUND

The International Telecommunications Union (ITU) estimates Africa leads the world in the growth of mobile subscribers with a growth rate of over 40%, which is twice as high as the global average (ITU, 2015). Mobile phones have impacted various aspects of progress in developing countries; mobile phones allow people to communicate with others, access information, make decisions about buying and selling, and improve learning for those in rural areas. Sanya (2013) in her study of Kenyan rural women discovered that mobile phones empower women and democratize technology. Yet in most cases simply introducing mobile phones does not reduce the digital gap between men and women. This chapter focuses on one specific experiment designed to test whether rural Mozambican women could learn effectively using animations provided via smartphones.

This chapter is important because it attempts to discuss the following issues that face Mozambican agricultural learning: First, in the African agricultural sector there is a shortage of extension agents supporting local farmers linked to the Structural Adjustment Programs of the 1980s. Davis (2008; 2009) observed that only 13% of farmers in Mozambique were reached by extension agents in 1980. The Mozambican Ministry of Agriculture and Food Security (MASA, 2015) confirms that only 8.3% of farmers were reached by extension agents in 2014.

Mobile phones may provide option for reaching more farmers to increase these numbers. In agriculture learning, mobile phones and other new portable devices can provide a solution linking farmers to extension agents and providing other forms of support because mobile technologies are accessible in rural areas, can upload and store both audio and video materials asynchronously when farmers wish, and allow multiple plays in sharing agricultural information. Because of these advantages, mobile phones offer exciting delivery options. Mobile phones may particularly support women in agriculture who are more constrained than their male counterparts from attending trainings, meetings and other activities that involve agriculture learning.

Second, in addition to the shortage of extension agents, there is limited research on the specific extension needs of women farmers (FAO, 2006). Research shows female extension agents as central in reducing problems for female farmers in accessing agricultural extension services (Kondylis, Mueller, Sheriff & Zhu, 2015). Specifically, Kondylis and colleagues explore the impact a female messenger has in dissemination of information and whether this effect accrues to female farmers. Their results demonstrated how adding a female messenger addresses a gender bias in dissemination of sustainable land management (SLM) techniques in Mozambique. The reasons for this were listed as:

1. Increases in access to female farmers results through increases in the supply of extension services;
2. Inclusion of female messengers to the already existing male ones improves outreach farmers;
3. Adding female instructors encourages women to seek advice;
4. Female messengers help provide more relevant information to female farming practices; and
5. In male-headed households female messengers reinforce practices learned by female farmers from their husbands.

Third, the needs of women farmers are not yet fully understood (Trauger, Sachs, Barbercheck, Kiernan, Brasier & Findeis, 2008). Trauger, et al., found that women farmers require specialized kinds of knowledge and information within certain context and through certain means of communication. Additionally, extension models rely on teaching models where farmers' participation is limited. Instead the

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roles of creation of knowledge and experience sharing are still controlled by extension agents and may not include female perspectives. Scholars have long suggested the need to shift extension approaches towards including farmers' experiences and local knowledge (Kloppenburg 1991, Flora, 1992 and Lockie, 2006).

Fourth, patriarchal systems that privilege men also affect women as follows: Poor rural women farmers have other obligations, such as childcare, which may hinder their participation in trainings. In some parts of Mozambique women are not allowed to interact with men outside their culture, thus inhibiting their participation in the training (Bowen, 1989: Gallina & Chidiamassaba,2010). Also, patriarchy hinders women's access to land and thus relegates them to subsistence farming. Due to this method of farming female farmers are less likely to benefit from male dominated cash crops, agricultural learning, and training opportunities which may be the focus of extension service trainings.

SCIENTIFIC ANIMATIONS WITHOUT BORDERS (SAWBO)

Founded in 2011, Scientific Animations Without Borders (SAWBO) is a program with a mission of creating educational materials in the form of animations for low literacy learners in local languages. So far, SAWBO has more than 35 videos in more than 90 different languages. These videos span the sectors of agriculture, health, and empowerment for women. These videos can be accessed from a variety of SAWBO channels and used on mobile phones, tablets, televisions and overhead projectors. The program relies on volunteers from all over the world to translate, record, voice overlay, share, deploy and train others. SAWBO values indigenous knowledge with a goal of giving voice to the most impoverished communities, capturing their local knowledge and languages and sharing it globally. SAWBO has already established research on the impact of indigenous knowledge (Bello-Bravo & B. Pittendrigh; 2012).

SAWBO uses learner-centered, interactive ways of teaching which allow learners to draw on prior knowledge and bring the fore what they know in interacting with the presented content. Borrowing from adult learning theory, these video animations provide literacies to marginalized communities and empower community members by imparting knowledge and skills as well as raising awareness with the goal of transforming communities. SAWBO's approach is aligned with other similar initiatives and draws from established practices for serving these communities. For example, Van Mele (2011) found that 77% of organizations training rural farmers in the Democratic Republic of Congo are now using video as a part of their training.

SAWBO animation videos are developed for low literate learners. The short length of the videos allows for quick downloads of simple, concise otherwise complicated information, culturally appropriate visuals, and narration in local languages. The videos allow for diverse groups to use mobile phones without time and space limits.

Limitations include access to Wi-Fi, affordability and the cost of maintaining the mobile phone in addition to access to electricity for charging. In addition, techniques shown in the video animations may require new skills and need demonstrations supported by a facilitator. Follow-ups with end-users also may represent a challenge. Lastly, the content requires scientific peer reviewing, which is time consuming.

There are numerous models of agricultural learning based on the use of mobile devices. Trauger, Sachs, Barbercheck, Kiernan, Brasier and Findeis (2008) discussed these models as follows: First, the technology transfer model, which is based on persuasion by agricultural extension educators, faculty, or other agricultural professionals, delivers specific recommendations to farmers about the practices or technologies they should adopt. Secondly, the advisory approach is common in projects managed by

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donor agencies and non-governmental organizations which use participatory approaches to promote predetermined packages of technology. A third model, the human resource development model, continues to be employed in the agricultural extension activities of land-grant universities in the United States. In this model, top-down teaching methods are used, but learners are expected to make their own decisions about how to use the knowledge they acquire.

The SAWBO animated videos model borrows from the second category and includes participatory methods for extension education based on adult learning principles that specifically take into account gender characteristics and needs of women farmers. The social reality of rural based women farmers is culturally constructed, and therefore, their knowledge about farming reflects this. Furthermore, Hassanein (1997) identified how the gendered social location of women farmers influences their information exchange and produces local knowledge that is easily transmitted and translated to other farmers, who were then able to adopt it for their own purposes.

ADULT LEARNING THEORY

Central to the description of this initiative is the theory of andragogy. Malcolm Knowles' definition of the theory of andragogy (1980) describes adult learning and provides a set of guidelines for practice. The main features of the theory are self-concept including self-directedness, focus on experiential learning, reliance on past experiences, readiness to learn, and an emphasis on problem-solving. Based on humanistic psychology, Knowles' concept of andragogy presents the individual learner as one who is autonomous, free, and growth-oriented.

The two dimensions of andragogy as elaborated by Knowles are its assumptions about the characteristics of adult learners and the process elements of adult education stemming from these characteristics. He initially described four basic assumptions and added a fifth and sixth in later publications as follows:

1. **Self-Concept:** As people mature, they move from having a dependent personality toward being more self-directed.
2. **Experience:** As people mature, they amass a growing set of experiences that provide a fertile resource for learning.
3. **Readiness to Learn:** As people mature, they are more interested in learning subjects that have immediate relevance to their jobs or personal lives
4. **Orientation to Learning:** As people mature, their time perspective changes from gathering knowledge for future use to immediate application of knowledge. As such, adult learners become more problem-centered rather than subject-centered (Knowles, 1980).
5. **Motivation to Learn:** As people mature, they become more motivated by various internal incentives, such as need for self-esteem, curiosity, desire to achieve, and satisfaction of accomplishment.
6. **Relevance:** As people mature, they need to know why they need to learn something (Knowles, 1984).

Knowles intended to separate the principles he defined for adults from those used in pedagogy – the teaching of children. In his book, *The Modern Practice of Adult Education: From Pedagogy to Andragogy*, Knowles (1980, p. 43) contrasts andragogy "the art and science of helping adults learn" with pedagogy,

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"the art and science of helping children learn". He contends that adults will learn faster if what they are studying has an immediate effect on their current situation in life. Figure 1 illustrates Knowles' adult learning theory.

The application of Knowles' theory in the SAWBO videos relies on the positioning of the adult learner as self-directed with a focus on relevant and experiential learning based on established prior knowledge and a predilection to solve problems. To this end, the videos focus on establishing the learners' prior knowledge and provide highly relevant information with a basis in directing the learners' involvement in experiential learning.

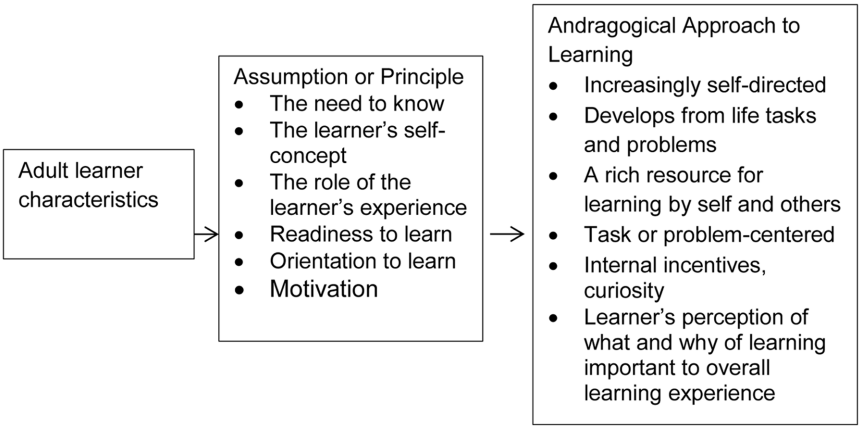
AGRICULTURAL LEARNING IN THE ERA OF MOBILE LEARNING

Recently, new participatory approaches in the context of agriculture have been facilitated with technology. Information and Communication Technology for Development (ICT4D) has been used to meet new needs in different contexts. Information and communication technologies for development (ICT4D) refers to using information and communication technologies to address social, economic, and political issues and promote social, economic and political development. The movement has an emphasis on helping poor and marginalized people and communities.

Mobile learning represents a new approach for extension agents and educators to encourage informal learning in rural areas. In addition to supporting learning, mobile phone usage can bring awareness of information and can allow for educators to respond directly to the demands and the needs of farmers in rural areas. In this way, mobile phones are a prime method for involving communities in the ideals espoused by ICT4D.

The availability and affordability of mobile phones for farmers in developing countries have led to a new paradigm in agricultural education known as mobile learning (Muyinda, 2007). The use of mobile phones has gone beyond traditional communication; farmers can use their mobile phones to check prices, to send money, to access videos, and to receive or send messages or receive information that it is relevant for them.

Figure 1. Model of Knowles's learning theory



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The Advanced Distributed Learning (2013) defined mobile learning as "leveraging ubiquitous mobile technology for the adoption or augmentation of knowledge, behaviors, or skills through education, training, or performance support while the mobility of the learner may be independent of time, location, and space" (Advanced Distributed Learning, 2013, p.5). Pedagogically, the m-learning framework developed by Kearney, Schuch, Burden, and Aubusson (2012) identified three major affordances or capabilities of mobile devices for learning within sub-domains of activity: personalization (learner agency and customization), authenticity (contextual and situated relevance), and collaboration (conversation and data sharing).

Agriculture learning is germane to mobile informal learning. Proponents of informal learning, Watkins and Marsick (2001), explained that informal learning goes hand-in-hand with doing. Informal learning is not highly structured; it may be planned or not planned, but it is generally directed by the learner. Another characteristic of informal learning is that the learning process can unfold as opportunities arise allowing a serendipitous approach (Marsick & Volpe, 1999).

Mobile learning lends itself well with the serendipitous nature of informal learning because the mobile phone allows for information seeking and sharing in whatever context or setting the learner is in (Bell, 2015; Pachler, Bachmaire, & Cook, 2010; Sharples, Taylor, & Vavoula, 2007). The most significant outcome of m-learning is knowledge recall followed by learning satisfaction wherein learners report they enjoyed the experience. Technology acceptance or task performance was the next most frequently assessed outcome. Some of the benefits of mobile technologies include a natural ubiquity that supports situated learning and therefore gives users access and possibilities to share information, support, feedback and reinforcement (Naismith et al, 2004).

AFRICAN WOMEN AND TECHNOLOGY

On February 29th 2016, at the Mobile World Summit in Barcelona, the United Nations Secretary-General Adviser stated that:

The digital divide remains a yawning gulf that leaves the poor, those living in rural areas and a disproportionate number of women stranded on the wrong side. Mobiles do not merely contribute to development – they are an important dimension of development. (United Nations, 2016)

African women have long been active in using older communication technologies, such as the radio, to address their rights and inform their work in agriculture learning. Yet, the advent of Information and Communication Technology (ICTs) options has not fully reached this population leaving a gap between rich and poor countries as well as between rich and poor citizens, and particularly a gap between genders. This gap is often referred to as the digital divide. In order to fill this gap, programs have emerged with a focus on supporting populations disadvantaged by this divide. To involve women and bridge the digital gender divide means engaging in the construction of content with women's needs in mind as well as promoting, accessing, and participating in selecting technologies meaningful to women.

Recent proliferation of communication technologies has transformed communication and transformed how people learn. Current research on technology, especially mobile device usage in Africa, uses the modernization and 'leapfrogging' paradigm (Chiumbu, 2012; Sanya, 2013). The term "leapfrogging" was originally used to describe a phenomenon in economic development where technology was used

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to bypass some of the accumulated and enculturated processes that may perpetuate disparities between industrialized and developing countries.

Chiumbu (2008) wrote that the arrival of the digital era provides great opportunities for developing countries in accessing information and knowledge. The authors of this chapter agree with Chiumbu's assertion but posit that marginalized communities or groups should not be 'add ons' as this shift takes place. As opportunities for inclusion emerge, other considerations have to be kept in mind to center these populations as part of the conversation and not as an afterthought. For example, if women are to become users and producers of technologies, then previous existing problems resulting from gender inequity should be considered and surmounted, such as the lack of access to extension agriculture education due to time, distance and lack of female extension workers.

SAWBO AND MOBILE LEARNING EXPERIENCES

Globally, government-funded extension programs have often been the officially designated agencies for the transference and dissemination of information associated with agricultural production. They represent the local and country-wide source for the implementation of agricultural technologies in developing countries. However, there is an emerging potential for new partners to participate in the extension process and for global partners to be connected to local, in the field, partners in order to create and disseminate content. In today's global context, new opportunities exist to bring organizations, along with and/or beyond agricultural extension agencies, into these aforementioned roles (Cho & Bolan, 2002).

The old, highly structured, linear model of knowledge transfer (scientists → extension → users) is outdated and has the potential to be replaced by more interactive models based on networked systems, where such systems integrate producers of knowledge, adaptations to content, advice through diverse mechanisms, and the final educational product that may inform other components of this process (Murphy, 2012). Such models include a feedback loop from the end users via intermediary groups such as non-governmental organizations (NGOs), farmers associations and cooperatives to guide the development of new content. Additionally, as part of this feedback loop, expert knowledge can now be obtained through virtual Internet-based interactions and, in some cases, through crowdsourced feedback to improve on educational content being produced.

A significant number of development projects use live-action or animated videos, or both, as a component of their training programs and as supporting materials for their educational training (Bello-Bravo & Baoua, 2012; Bello-Bravo, Olana, Enyadne, & Pittendrigh, 2013; Bello-Bravo & Pittendrigh, 2012; Gandhi, Veeraghavan, Toyama, & Ramprasad, 2007; Ladeira & Cutrell, 2010; Medhi, Cutrell, & Toyama, 2012). Van Mele et al. (2010) found that approximately 78% of development organizations (e.g., universities, research institutes, and NGOs) use videos in their farmer-focused training programs.

Video-based educational content has multiple advantages, especially for agriculture training in developing countries (Van Mele, 2011). These videos can be shown almost anywhere at anytime and when as well as where the proper audio and visual equipment is in place (Coldevin,2003).

The continual increase in use of video capable cell phones, even in remote areas in developing nation countries, may ultimately result within the next decade in an almost ubiquitous access to a form of audio-visual viewing equipment. Even if target audiences do not own phones, an educator's phone can become a *de facto* portable video-viewing device for target audiences.

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Visually based educational content has been shown to be an effective learning tool. Medhi, Prasad and Toyama (2007) demonstrated that live-action videos and static hand-drawn images were accurately understood by low-literate audiences. Further, Ladeira and Cutrell (2010) observed that participants were motivated to pay attention to live-action video resulting in enhanced learning. Videos have the capacity to explain complicated concepts as well as raise awareness and influence people's decisions (Lie & Mandler, 2009). Thus, there are precedents for combining visual and audio approaches for content development for educational programs.

Cognitive learning, as per information processing theory, involves the following: receiving, constructing, transforming, remembering, and storing information. Using visual and audio approaches, learners can connect existing knowledge with external stimulus in long-term memory. Live-action videos allow for easy local input into the content of the video. However, it is not practical when including cost- and time-effective feedback from global experts on any given topic. Additionally, unlike live action filming, animations can be created and adapted in a more culturally neutral manner.

Although there has been a rapid increase in the potential to view video-based educational content, there exist significant challenges as to how to systematically and cost effectively transfer knowledge from global experts to low literate learners in developing nation countries. With between 800 million and a billion low-literate learners globally, and very limited resources for creation of education materials for these groups, low-cost high throughput systems for creation and sharing of content for this incredibly diverse segment of the human population are needed.

Many low-literate learners live in rural areas, speak local language(s), and have extremely limited access to life improving knowledge. At the same time there is a considerable amount of explicit expert knowledge that exists in the global research and educational communities that does not make its way into educational material and language variants that would be appropriate for these low-literate learners. Experts in a given technique may be willing to contribute a small amount of their time to help create content that can be used by large numbers of people. However, a significant number of these people may not be in a position to disrupt their current life patterns in order to disseminate their knowledge more broadly. Conversely, educators of low-literate learners including, but not limited to, individuals, NGOs, government or inter-government organizations, may not have easy access to content for educational programs involving low-literate learners as the final target populations.

Scientific Animations Without Borders (SAWBO) has developed a methodology, described here, to achieve the goal of direct creation, with global expert knowledge, of educational content that can be placed into numerous languages and deployed directly to educators of low-literate learners, and in some cases directly to diverse language speakers across the globe, in a highly cost-effective and efficient manner. The process begins with (1) defining the topic area, (2) establishing contact with global experts through online searches and crowdsourcing, and (3) clearly defining and strictly adhering to a hyper-collaborator strategy with those global experts for the creation of accurate content, which involves goals, responsibilities, outcomes and attribution. Content is created with experts often working virtually with SAWBO. The SAWBO team produces the scripts, storyboards and final animations, with continual input from global experts, and the project is only complete once the expert and SAWBO team agree on the accuracy of all aspects of the content. Once released in English, a similar process is followed with language experts from around the globe to place content into a great diversity of languages. All animations are free and for educational purposes only. The goal of the methodology is to develop a standardized system to:

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1. Work with global experts to create accurate content where small amounts of time (hours) from these experts is used and in a manner that is non-disruptive to their life-style or work life;
2. Obtain this expert knowledge as a volunteer activity;
3. Create content in a virtual manner, through online interactions, thereby minimizing production costs;
4. Create finalized content appropriate for low-literate learners that is both scientifically accurate, as culturally neutral as possible, and acceptable to low-literate learners;
5. Place finalized content into a great diversity of languages;
6. Make that content easily accessible to educators of low-literate learners; and
7. Where possible leave that content with the low-literate learners for their future reference or use.

The SAWBO systems approach entails the following:

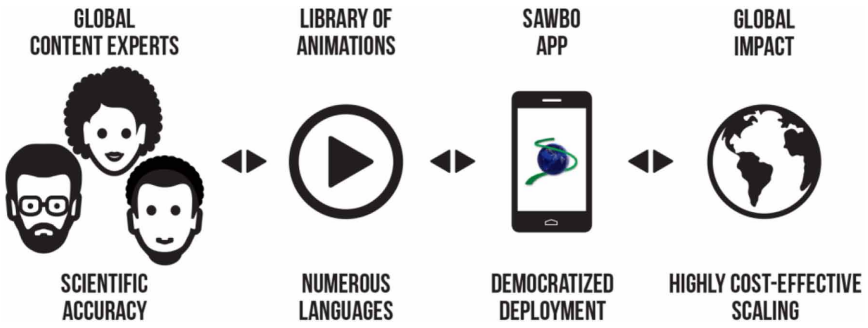
1. Continually create educational content with experts on diverse topics;
2. Place content into diverse local languages; and
3. Make it accessible to educators who can deploy such content in their communities as part of their own educational programs.

The material is defined by the funders after doing a feasibility study or when there is an urgent need, such as in the case of Ebola and Zika. While this model is prevalent, at other times the end-user approaches the SAWBO team to request an animation based on the needs of their community. NGOs also work collaboratively with SAWBO to create educational materials that are important for their mission. This approach allows organizations of any size, from small community-based organizations to large government and international organizations, to have access to education content in local languages that is scientifically accurate and accessible at no cost to these groups. Figure 2 illustrates this approach.

THE CASE OF MOZAMBICAN FARMERS LEARNING USING ANIMATIONS

Mozambique has a population of about 25 million people with approximately 18.4 million who own mobile cellular phones yielding a subscription of 75 per 100 inhabitants (The Central Intelligence

Figure 2. SAWBO systems approach



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Agency, 2016). According to The Central Intelligence Agency (2016), agriculture is the mainstay of Mozambique's economy and contributes to more than one quarter of the Gross Domestic Product (GDP) while employing 80% of the labor force consisting primarily of subsistence farmers. Regarding farming activities, 99.65% of farmers are smallholders with an average of 1.2 hectares (ha), 0.33% are medium sized farmers with 6.6 ha and 0.07% are large farmers with an average 282 ha (Mole, 2006). Small scale farmers grow food for their own consumption, especially grain and beans and/or peanuts. Approximately 400,000 commercial farmers earn their income from crop sales, and their yields per sector are double those of subsistence farmers.

Productivity levels are low because of a lack of modernization; after 30 years of independence, most peasant farms have not changed. Coughlin (2006) recognizes that only 3% of rural households have access to credit, less than 5% are part of a farmer association, and extension services reach only 13% of households. According to Walker et.al, (2015) the "Mozambique Agriculture Value Chain Analysis" reported that in Mozambique and due to the reduction in funding, farmer's access to public sector extension services declined from 13.5 percent in 2002 to 8.3 percent in 2014. For common beans producers Walker et al, (2015) recognized that about 15 to 20 percent receive extension service.

Rural men and women are said to allocate roughly equal amounts of time to crop production. Women spend more time fetching water, and men allocate more time to livestock production. Women also engage in other activities such as food processing, cooking, cleaning, other housekeeping, collection of firewood, and childcare leading to longer working hours and less participation in extension. Additionally, women are relegated to food crops production while both men and women are involved in the production activities for cash crops.

A World Bank study done in 2005 concludes that access to rural extension services increases farm production by about 8.4% in rural areas. Extension services have been very successful in promoting natural pesticides and improvement of soil conservation (World Bank, 2006). The number of government extension workers is around 7000 on the ground. In 2004, about 260 private extension agents worked for the cotton and tobacco companies, and 1300 worked for International and Governmental Organizations (INGOs), although many were organizing farmers' groups rather than doing agricultural extension.

Flaherty and Nhamusso (2014) noted that public spending on research and development in Mozambique has increased by 14% from 2008 to 2011. This increase is due to higher salaries and capital investment. At the same time the number of agricultural researchers has also been augmented. Agricultural research and development in Mozambique depends on ever-diminishing donor funding. Mozambique has created new policies, strategies, and initiatives to fortify its national research and technological innovation system. A recent policy development brings together international organizations and research centers. One outcome of this collaboration is the expansion of the national research, academic organizations, extension agencies and producers.

This case study is a summary of research conducted in Zambêzia Province, Mozambique by a team from two American-based universities. (Mocumbe, Abbott, Mazur, Bello-Bravo & Pittendrigh; 2016). The study was part of a multidisciplinary research project funded by USAID's Feed the Future initiative (Mazur et al. 2013). The project team plans to use the results of this research to engage farmers and other relevant stakeholders in a participatory process of considering a set of management practices and technologies that may help improve their farming activities.

A total of 314 bean-growing farmers from two different administrative posts in rural Zambézia province, Mozambique participated in the study. Farmers were assigned randomly by groups to one of three experimental treatments:

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1. Message via extension demonstration only;
2. Message via smartphone animation only;
3. Messages by both extension demonstration and animation.

The topic of the experiment was use of a sealed container (jerrican) to safely store beans after harvest. Previous interviews had shown that farmers suffered serious bean losses due to weevil infestations after harvest, and that few farmers knew how to store beans in air-tight containers to avoid losses. It is important to note that the rural Mozambique farmers were involved in pre-testing the storyboards for the animation, although they did not produce the animation. Notably, even though they identified post-harvest storage as a serious problem, they did not approach SAWBO and ask for the animation to be produced. The decision was made in collaboration with the *Instituto de Investigação Agrária de Moçambique* (IIAM) an agricultural research institute based in Mozambique and a research project funded by USAID's Feed the Future initiative (Mazur et al. 2013).

Results showed that the three experiment treatment groups did not differ significantly from each other in knowledge about the jerrican storage method prior to the experiment. However, women knew significantly less than men prior to the experiment. After treatment, all three experimental groups increased their knowledge of the storage method significantly. Both men and women learned significantly from the animations delivered via mobile phones. However, the rate of learning from the extension only treatment was less than the rate that included animations (Mocumbe, 2016).

Comparison of post-test scores indicated that animation only and the animation plus extension treatment showed significantly higher learning than the extension only treatment. Women's knowledge of the jerrican method was still slightly less than that of the men after the treatment, but not significantly. Women, who knew significantly less than men at the beginning, were able to learn as much as men from the animations and in doing so narrowed the gap in knowledge to a statistically non-significant difference. Thus, even though they started at a lower level, they learned just as much as men from the animation. Women who received the animation treatment and the animation with demonstration treatment had higher scores than women who received the extension only treatment. The same was true for men, indicating that the animation seemed to work with equal effectiveness for both groups. Finally, 98% of farmers said that they intended to use this storage method in the future. So, ultimately the animation and animation plus extension models had good results indicating viability for future dissemination.

OBSERVATIONS

Data from these observations support the findings shared as a result of this study to explain the effects that were attained. As such, the observations served as a type of case study to deepen understanding of why and/or how the intervention treatment worked to create the impact measured in the study's quantitative data results.

Observations are not just about 'hanging out' but rather involve planning and self-awareness on the part of the observer (DeWalt & DeWalt, 2001). Observation entails the systematic noting and recording of events, behaviors, and artifacts (objects) in the social setting chosen for study. The observational record is frequently referred to as *field notes*—detailed, nonjudgmental, concrete descriptions of what has been observed. In this case study observations were made on how the farmers learned. The observations are

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important in explaining how experience sharing and collective learning emerged and led to successful learning by these farmers.

The observations took place in Zambêzia (Mozambique) the summer of 2015 by one of the authors of this paper. There were two groups of 12 -15 farmers for each treatment, a morning and an early afternoon group. Both groups were involved in a treatment group of animation plus extension in order to assess the impact of the animation on the learners' experiences and specifically to examine how women engaged in the learning event. These groups were mixed gender, some with more men or women. Most of the participants, both men and women, had low levels of education. Men did not have more education than women.

Participants paid attention when watching the video, they were engaged. When they first watched the video they seemed to giggle at the animation. They were impressed that the video was in their local language. The first time, they seemed not to be paying attention to the content. The second time they paid more attention to the content than to the animation. Some requested to watch the video three times.

One group that watched the video three times volunteered to do the demonstration. A male and female participant got in the front of the crowd with the beans and the jerrican. They started performing what they had learned. As they did this, they interacted with the group in a playful manner. The other participants gave them suggestions as indicated in the instruction. It was a conversational activity where the whole group was engaged in the learning while the volunteers did the action. Sometimes a participant from the crowd came to check in order to confirm that the instructions had been carried out properly, for instance that the jerrican lid was sealed tightly.

During the process the women were not afraid of talking. At the beginning of the program, the women did not say much; however, during the demonstration they were involved in providing instruction. Their comments provided evidence that they knew what they were doing. On the other hand the men seemed to be more reserved than the women. It is plausible to say that this may have happened because women are more involved in the storage process than men. Figure 3 illustrates the research process.

Researchers, Mocumbe, Abbott, Mazur, Bello-Bravo and Pittendrigh (2016) indicated that the case study is not without its limitations. The gain in knowledge by these women could have been due in part to the 'novelty effect,' especially because these farmers were experiencing learning with animations for the first time. Therefore, this could have stimulated effective learning. Secondly, the women in the study generally do not attend extension service sessions as men do, and therefore their inclusion along with the 'novelty effect' might have positively influenced their learning.

A limitation to the case study that should be noted is the size of the participant group. The training procedure focused on smaller groups of farmers; whereas typically extension training groups include 20-25 people. This use of small numbers within a group allowed for group learning and engagement, and the farmers were able to view the videos with limited distraction. Third, this group of farmers lived in the same community and had existing relationships that allowed them to participate and engage with each other openly. It would be interesting to find out what the results would be like if the farmers did not know each other.

SOLUTIONS AND RECOMMENDATIONS

Here, the authors of this chapter provide recommendations based on the study findings. First, the authors suggest that a central focus of agricultural learning should be women. Barriers that women face

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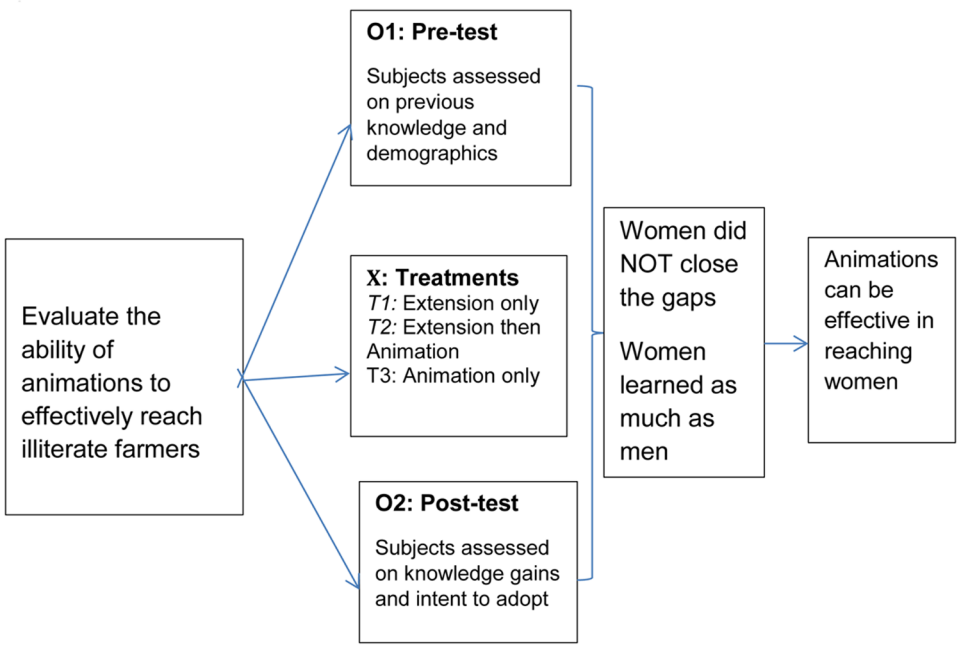
Figure 3. Illustration of the experiment



in agricultural education are based in stereotypes and social constructions based on gender identity and embodiment. Female farmers often are not visited by male extension providers because social customs do not allow communication between genders and husbands do not share the information they gain from extension visits with their wives. Additionally, agricultural learning in Mozambique may render women who actively participate in agricultural production invisible by introducing expert knowledge actors who are mostly trained males. These models position men as learners while women lose control of the technological process and the end product (Everts, 1998).

For these reasons, African rural smallholder farmers, particularly those involving women as primary players, have been generally marginalized in technical service and male dominated agricultural education. Training and employing female extension agents is thought to be one of the solutions to the seclusion of smallholder women farmers from extension services. The advent of mobile phones technology offers a direct way of connecting with the women, especially when the information is relevant and accessible to them. Additionally, providing information via animations allows for personalization for women by providing animated female actors in the role of service providers and sharers of information.

Secondly, the authors of this chapter assert that more innovative ways of agricultural learning that are culturally specific should be considered. To this end, learning could be offered in more formats than direct instruction including blended learning which combines online learning and/or resources with direct learning methods involving practical, face-to-face, problem-solving activities. Agricultural learning and extension training are good settings for teaching through these methods because the process of learning is anchored in an already formed community of farmers ready to use new acquired knowledge (Czarniawska, 1997). According to Mortera-Gutierrez (2005) blended learning includes a variety of approaches to learn through combining different delivery methods that can include technology-based

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and traditional face-to-face instructions where learning by doing, learning from experience, and learning by telling can take place.

A discussion of blended learning must take into consideration the digital divide. The digital divide is a major constraint in the use of technology in developing countries. Various local and international organizations are devising models of blended learning for agricultural learning to bridge the digital divide. For example, several centers of the Consultative Group for International Agricultural Research (CGIAR) are presently exploring approaches to address the increasing demand for learning in agriculture and natural resources management through e-learning.

Blended learning in rural agricultural setting will require flexibility and innovation. The use of animations offers an online platform that takes advantage of blended learning models and/or offers instructors using direct instruction additional resources to convey content to learners. With reference to the case study, the farmers were involved in an active dialogical process with the volunteers to confirm and elaborate on processes learned in the instructional event based on access to animations and guided demonstrations based on those animations. This event involved dialogue among all participants in the event. Greene (2001) maintains that dialogue is not just about talking, but it entails having a narrative process where people listen to each other, share experiences, and can inquire to find out meanings. Participants contribute and add other related experiences that they have while reflecting on the values and assumptions within. Dialogue, then, is characterized by respect, inclusion and engagement and is based in the blended learning environment.

FUTURE RESEARCH DIRECTIONS

Future research directions offered are three pronged:

1. Understanding various literacies that stem from mobile learning;
2. Examining the indigenization of content material for local access distributed via mobile learning; and
3. Strengthening of women's participation for intended and unintended outcomes via mobile learning platforms.

The outcomes of mobile phone learning are not entirely predictable; Sanya (2013) understood the multiple roles of the user as ranging from innovator to a creative user. To Sanya, mobile phones break down the top-down approach and allow individuals to share discuss and establish communities that are supportive. Sanya (2013) also saw the mobile phone as facilitating literacies where they were nonexistent before. As discussed earlier SAWBO has animations on health, agriculture and empowerment of women that can be accessed free of charge. Once the farmers know how to access one SAWBO animation, they can access the others and gain other knowledge.

The authors of this chapter see learning using animations as addressing two things. First, the farmer learns how to manipulate the cellphone, and second, the farmer can access additional animations. Therefore the farmers gain portable skills that they can use in other mobile related projects in the community. This dynamic exists for both male and female farmers and can be regarded as gender-neutral.

The type of literacy that the authors of this chapter see emanating from the mobile learning experience using animations is informed by discussions by Barro (2009) and Giroux (1993) of literacy as literacies;

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that is, not only written forms which provide marginalized people with skills and knowledge that can empower them for better citizenship and participation in their communities. A significant proposal for future research is the follow-up of the farmers to not only understand how they are applying and transferring the knowledge they gained from the SAWBO resources but also scrutinizing the various forms of literacies gained from such trainings.

Second, Gakuru, Winters and Stepman (2009) recognized that information and communication technologies (ICT) provided the easiest way to disseminate information to farmers and also changed their agricultural learning. Traditional forms of ICTs are still relevant in providing advisory services. National ministries, NGOS and research organizations work together within information centers to facilitate technology transfers in the agricultural sector. E-agriculture is an emerging field that combines agricultural informatics, agricultural development and entrepreneurship through ICT and the internet. E-agriculture allows for integration of knowledge and information in order to reach various stakeholders at varying levels.

According to (Gakuru et al., 2009) there are challenges despite the widespread adoption of mobile phones. For example, farmers face issues of cost, the carrying capacity of the SMS, and the potential of the device to transmit the clarity of voice and pictorial illustration. Despite these challenges, voice solution, especially through animations, is considered to be a reliable platform for the farmers to access customized information.

Organizations such as SAWBO rely on the voice solution, specifically, voice overlay, to customize for language and therefore deliver the information in a natural and accessible manner to the farmers. We suggest that future research takes into account how farmers, especially women, are given voice and opportunities in the creation of the technologies and information. Locally informed projects have been known to have greater impact and to also gain ownership compared to impose ones (Chambers1983).

Lastly, from a gender perspective, some cultural traditions allow collective learning within cultural socializing and storytelling that is beneficial to women in agricultural learning. As noted in the case study, in Mozambique farmers were not passive consumers of information but contributors to their learning. Future research could benefit from considering unique regional and demographic factors that lead to women learning and learning more aligned with women's needs and learning preferences. Correspondingly, examining how project planning deliberately seeks to strengthen women's participation in agricultural programs and recognizing their ability to exercise leadership and collective learning is also necessary. Measures to support women in extension and agricultural learning will boost their participation in decision making and community engagement.

CONCLUSION

International development initiatives have included the use of mobile phones for training programs in developing countries. As discussed throughout this chapter, these efforts include those by SAWBO, especially because mobile phones are critical in Mozambican agricultural learning. As the authors of this paper have observed, the key rationale behind using mobile phones to provide agricultural content in local languages is situated in the opportunities that mobile learning offers to farmers in rural areas, such as individual access to animations after training sessions and collective participation in learning using local languages.

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In sum, accounting for cultural variations may lead to studies within developing nations where innovative use of technology as it intersects with culture and gender can shape and inform learning to transform lives. The result may be a restoration of the balance between gender participation and an elimination of gendered inequalities in terms of access to agricultural learning and extension services perpetuated through cultural and external forms of patriarchy.

REFERENCES

Advanced Distributed Learning. (2013). Basics. In *Mobile Learning Handbook*. Retrieved on March 20, 2016, from https://sites.google.com/a/adlnet.gov/mobile-learning-guide/basics

Barro, M. A. (2005). *The role of literacy in enhancing women's agency and well -being: A qualitative inquiry of the effects of the Tostan educational program on the lives of women in a rural community in Senegal.* ProQuest Dissertations & Theses Full Text. (Order No. 3182220)

Bell, A. (2015, January). *Mobile informal learning: An examination of pedagogic activities and outcomes in recent m-learning research*. University of Illinois at Urbana Champaign.

Bello-Bravo, J., & Baoua, I. (2012). Animated videos as a learning tool in developing nations: A pilot study of three animations in Maradi and surrounding areas in Niger. *The Electronic Journal of Information Systems in Developing Countries*, *55*(4), 1–11.

Bello-Bravo, J., Olana, G. W., Enyadne, L. G., & Pittendrigh, B. R. (2013). Scientific Animations Without Borders and Communities of Practice: Promotion and Pilot Deployment of Educational Materials for Low-Literate Learners around Adama (Ethiopia) by Adama Science and Technology University. *The Electronic Journal of Information Systems in Developing Countries*, *56*(4), 1–11.

Bello-Bravo, J., & Pittendrigh, B. (2012). Scientific Animations Without Borders: A new approach to capture, preserve and share indigenous knowledge. *The Journal of World Universities Forum*, *5*(2), 11–20.

Bowen, M. (1989). Peasant agriculture in Mozambique: The case of Chokwe, Gaza Province. *The Economic Journal*, *116*, 869–902.

Brouwer, R., & Brito, L. (2012). Cellular phones in Mozambique: Who has them and who doesnt? *Technological Forecasting and Social Change*, *79*(2), 231–243. doi:10.1016/j.techfore.2011.08.006

Central Intelligence Agency. (2016). *Mozambique*. Retrieved from https://www.cia.gov/library/publications/the-world-factbook/geos/mz.html

Chambers, R. (1983). *Rural development: Putting the last first*. New York, NY: Routledge.

Chiumbu, S. (2008). *Understanding the Role and Influence of External Actors and Ideas in African Information, Communication and Technology Policies: The African Information Society Initiative* (Unpublished doctoral dissertation). University of Oslo, Sweden.

Chiumbu, S. (2012). Exploring mobile phone practices in social movements in South Africa–the Western Cape Anti-Eviction Campaign. *African Identities*, *10*(2), 193–206. doi:10.1080/14725843.2012.657863

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Cho, K. M., & Boland, H. (2002). *Participatory Learning for Agricultural Extension and Future Development in Myanmar*. Institute of Rural Sociology and Extension, University of Giessen. Retrieved from http://www.tropentag.de/2002/abstracts/full/302.pdf

Coldevin, G. (2003). *Participatory communication: A key to rural learning systems*. Rome, Italy: The Food and Agriculture Organization of the United Nations.

Coughlin, P. (2006). *Agricultural intensification in Mozambique infrastructure, policy and institutional framework – When do problems seeks signal opportunities. Maputo: Econpolicy Research Group. Study and survey for AFRINT (Africa Food Crisis Study)*. Lund University.

Czarniawska, B. (1997). Learning Organizing in a Changing Institutional Order, Examples from City Management in Warsaw. *Management Learning*, *28*(4), 475–495. doi:10.1177/1350507697284006

Davis, K. E. (2008). Extension in Sub-Saharan Africa: Overview and assessment of past and current models, and future prospects. *Journal of International Agricultural and Extension Education*, *15*(3), 15–28.

Davis, K. E. (2009). Extension in Sub-Saharan Africa: Overview and assessment of past and current models, and future prospects. *Rural Development News*, *1*, 48–53.

DeWalt, K. M., & De Walt, B. R. (2001). *Participant observation: A guide for fieldworkers*. Walnut Creek, CA: AltaMira Press.

Dondeyne, S., Kaarhus, R., & Allison, G. (2012). Nature conservation, rural development and ecotourism in central Mozambique: which space do local communities get? In Making Sense of Place: multidisciplinary perspectives (pp. 291-301). Woodbridge, UK: The Boydell Press.

Engel, P. G., & van den Bor, W. (1995). Agricultural education from a knowledge systems perspective: From teaching to facilitating joint inquiry and learning. *European Journal of Agricultural Education and Extension*, *1*(4), 1–23. doi:10.1080/13892249485300311

Engel, P. G. H., & van den Bor, W. (1995). Agricultural education from a knowledge systems perspective: From teaching to facilitating joint inquiry and learning. *European Journal of Agricultural Education and Extension*, *1*(4), 1–23. doi:10.1080/13892249485300311

Escobar, A. (1995). *Encountering Development: The Making and Unmaking of the Third World*. Princeton, NJ: Princeton University Press.

Everts, S. (1998). *Gender & Technology: Empowering Women, Engendering Development*. London: Zed Books.

FAO. (2006). *Gender and food security: education, extension and communication*. United Nations. Retrieved from http://www.fao.org/Gender/en/educ-e.htm

Flaherty, K., & Nhamusso, A. (2014). *Agriculture R & D Indicators Mozambique. Agricultural science and technology indicators ASTI factsheet*. Retrieved on March 20, 2016 from http://www.asti.cgiar.org/pdf/factsheets/Mozambique-Factsheet.pdf

Flora, C. B. (1992). Reconstructing agriculture: The case for local knowledge. *Rural Sociology*, *57*(1), 92–97. doi:10.1111/j.1549-0831.1992.tb00459.x

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Gakuru, M., Winters, K., & Stepman, F. (2009). Innovative Farmer Advisory Services using ICTs. Accra, Ghana: Forum for Agricultural Research in Africa (FARA).

Gallina, A., & Chidiamassamba, C. (2010). *Gender Aware Approaches in Agricultural Programmes–Mozambique Country Report: A special study of the National Agricultural Development Programme (ProAgri II)*. UTV Working Paper 2010: 6. Estocolmo, Swedish International Development Cooperation Agency.

Gandhi, R., Veeraraghavan, R., Toyama, K., & Ramprasad, V. (2007). Digital green: Participatory video for agricultural extension. Proceedings of the IEEC/ACM Information and communication technologies and development, 21-30.

Giroux, H. (1993). Literacy and politics of difference. In C. Lankshear & P. Mclaren (Eds.), *Critical literacy: Politics, praxis, and postmodern*. Albany, NY: SUNY Press.

Greene, J. (2001). Dialogue in evaluation: A relational perspective. *Evaluation*, *7*(2), 181–203. doi:10.1177/135638900100700203

Griffin, C. (1991). A critical perspective on sociology and adult education. In J. M. Peters & P. Jarvis (Eds.), *Adult education: Evolution and achievements in a developing field of study* (pp. 259–281). San Francisco, CA: Jossey-Bass.

Hall, D., Hirsch, P., & Li, T. M. (2011). *Powers of Exclusion: land dilemmas in Southeast Asia*. NUS Press.

Hassanein, N. (1997). Networking knowledge in the sustainable agriculture movement: Some implications of the gender dimension. *Society & Natural Resources*, *10*(3), 251–257. doi:10.1080/08941929709381024

Ikdahl, I., Hellum, A., Kaarhus, R., & Benjaminsen, T. A. (2005). *Human rights, formalization and women's land rights in southern and eastern Africa, Studies in Women's Law 57*. Institute of Women's Law: University of Oslo.

International Telecommunication Union. (2014). *Mobile Broadband uptake continues to grow at double digits rates*. Retrieved from http://www.itu.int/en/ITU-D/Statistics/Documents/facts/ICTFactsFigures2014-e.pdf

Kaarhus, R., & Dondeyne, S. (2015). Formalizing land rights based on customary tenure: Community delimitation and womens access to land in central Mozambique. *The Journal of Modern African Studies*, *53*(02), 93–216. doi:10.1017/S0022278X15000166

Kearney, M., Schuck, S., Burden, K., & Aubusson, P. (2012). Viewing mobile learning from a pedagogical perspective. *Research in Learning Technology*, *20*(1063519), 1–17.

Kloppenburg, J. Jr. (1991). Social theory and the de/reconstruction of agricultural science: Local knowledge for an alternative agriculture. *Rural Sociology*, *56*(4), 519–548. doi:10.1111/j.1549-0831.1991.tb00445.x

Knowles, M. S. (1980). *The modern practice of adult education*. Chicago, CA: Follett Publishing Company.

Knowles, M. S. (1984). *Andragogy in Action. Applying modern principles of adult education*. San Francisco, CA: Jossey Bass.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Kondylis, F., Mueller, V., Sheriff, G., & Zhu, S. (2016). Do Female Instructors Reduce Gender Bias in Diffusion of Sustainable Land Management Techniques? Experimental Evidence from Mozambique. *World Development*, *78*, 436–449. doi:10.1016/j.worlddev.2015.10.036

Kulkarni, S., & Karwankar, A. (2012). IVRS for College Automation. *International Journal of Advanced Research in Computer and Communication Engineering*, *1*(6), 449–453.

Ladeira, I., & Cutrell, E. (2010). Teaching with storytelling: An investigation of narrative videos for skills training. In *Proceedings of the 4th ACM/IEEE International Conference on Information and Communication Technologies and Development* (p. 22). ACM. 10.1145/2369220.2369240

Lie, R., & Mandler, A. (2009). *Video in development: Filming for rural change*. Retrieved on March 20, 2016 from http://www.anancy.net/documents/file_en/Video_in_Development.pdf

Lockie, S. (2006). Networks of Agri-Environmental Action: Temporality, Spatiality and Identity in Agricultural Environments. *Sociologia Ruralis*, *46*(1), 22–39. doi:10.1111/j.1467-9523.2006.00400.x

Marsick, V. J., & Volpe, M. (1999). The nature and need for informal learning. *Advances in Developing Human Resources*, *1*(3), 1–9. doi:10.1177/152342239900100302

Marsick, V. J., & Watkins, K. E. (2001). Informal and incidental learning. *New Directions for Adult and Continuing Education*, *2001*(89), 25–34. doi:10.1002/ace.5

MASA. (2005). *Ministro da Agricultura e Segurança Alimentar*. Retrieved on March 20,2016 from http://www.masa.gov.mz/index

Mazur, R. E., Abbott, E., Lenssen, A., Luvaga, E., Yost, Y., Bello-Bravo, J., . . . Maria, R. (2013). Farmer Decision Making Strategies for Improved Soil Fertility Management in Maize-Bean Production Systems, 2013-2017. Project funded by the Feed the Future Innovation Lab for Collaborative Research on Grain Legumes, Michigan State University. USAID cooperative agreement award No. AID-EDH-A-00-07-00005.

Medhi, I., Cutrell, E., & Toyama, K. (2010). It's not just illiteracy. India HCI in conjunction with the IFIP TC13 Special Interest Group on Interaction Design & International Development, Mumbai, India.

Mocumbe, S. (2016.) *Use of animated videos through mobile phones to enhance agricultural knowledge among bean farmers in Gurúè District, Mozambique* (Unpublished master thesis). Iowa State University, Ames, IA.

Mocumbe, S., Abbott, E., Mazur, R., Bello-Bravo, J., & Pittendrigh, B. (2016). *Use of Animated Videos through Mobile Phones to Enhance Agricultural Knowledge and Adoption among Bean Farmers in Gúruè District, Mozambique*. Presentation at the *Conference of the Association for International Agricultural and Extension Education*, Portland, OR.

Mole, P. (2006). *Smallholder Agricultural Intensification in Africa – Mozambique, Microstudy report. Maputo: Econpolicy Research Group. Study and survey for AFRINT (Africa Food Crisis Study)*. Sweden: Lund University.

Mortera-Gutierrez, F. J. (2005). *Faculty best practices using blended learning in e-learning and face-face instruction.* Retrieved from http://www.uwex.edu/disted/conference

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Muyinda, P. B. (2007). MLearning: Pedagogical, technical and organizational hypes and realities. *Campus-Wide Information Systems*, *24*(2), 97–104. doi:10.1108/10650740710742709

Naismith, L., Lonsdale, P., Vavoula, G. N., & Sharples, M. (2004). *Literature Review in Mobile Technologies and Learning, NESTA*. Bristol, UK: National Endowment for Science Technology and the Arts.

Pachler, N., Bachmair, B., & Cook, J. (2010). *Mobile learning: structures, agency, practices*. Boston, MA: Springer US. doi:10.1007/978-1-4419-0585-7

Ribot, J. C., & Peluso. (2003). A theory of access. *Rural Sociology, 68*(2), 153-181.

Sanya, N. B. (2013). Disrupting patriarchy: An examination of the role of e-technologies in rural Kenya. *Feminist Africa*, *18*, 12–24.

Sharples, M., Taylor, J., & Vavoula, G. (2007). A theory of learning for the mobile age. In R. Andrews & C. Haythornthwaite (Eds.), *The Sage Handbook of Elearning Research* (pp. 221–247). London: Sage. doi:10.4135/9781848607859.n10

Tisdell, E. J. (1998). Postructural feminist pedagogies: The possibilities and limitations of feminist emancipatory adult learning theory and practice. *Adult Education Quarterly*, *48*(3), 139–156. doi:10.1177/074171369804800302

Trauger, A., Sachs, C., Barbercheck, M., Kiernan, N. E., Brasier, K., & Findeis, J. (2008). Agricultural education: Gender identity and knowledge exchange. *Journal of Rural Studies*, *24*(4), 432–439. doi:10.1016/j.jrurstud.2008.03.007

United Nations. (2016). *Sustainable Development Goals: 17 Goals to Transform our World.* Retrieved on March 20, 2016, from http://www.un.org/sustainabledevelopment/globalpartnerships

Van Mele, P. (2011). *Video mediated farmer-to-farmer learning for sustainable agriculture*. Ghent, Belgium: Agro-Insight.

Van Mele, P., Wanvoeke, J., Akakpo, C., Dacko, R. M., Ceesay, M., Beavogui, L., ... Anyang, R. (2010). Video bridging Asia and Africa: Overcoming cultural and institutional barriers in technology mediated rural learning. *Journal of Agricultural Education and Extension*, *16*(1), 75–87. doi:10.1080/13892240903533160

Walker, T., Silim, S., & Cunguara, B. (2015). *Pigeonpea in Mozambique: An Emerging Success Story of Crop Expansion in Smallholder Agriculture*. Research Paper 78E. Republic of Mozambique, Ministry of Food Security and Directorate of Economics.

Whitehead, A., & Tsikata, D. (2003). Policy discourses on womens land rights in Sub–Saharan Africa: The implications of the re–turn to the Customary. *Journal of Agrarian Change*, *3*(1-2), 67–112. doi:10.1111/1471-0366.00051

World Bank. (2005). *Mozambique Country Economic Memorandum*. Washington, DC: World Bank, Report 32615-MZ.

World Bank. (2006). *Mozambique Agricultural Development Strategy – Stimulating Smallholder Agricultural Growth*. Washington, DC: World Bank, Report 32416-MZ.

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KEY TERMS AND DEFINITIONS

Agricultural Learning: Knowledge would be able to synthesize, analyze, and communicate basic information about agriculture.

Animations: Animation is a type of optical illusion; it is the process by which we see still pictures move. It involves the appearance of motion caused by displaying still images one after another at the rate of 24 pictures per second. The most common method of presenting animation is as a motion picture or video program, although several other forms of presenting animation also exist. There are 2D and 3D animations. The difference between 2D and 3D can be illustrated by drawing a rectangle and a cube. Rectangle is a 2D figure whereas cube is a 3D figure. 3D presents the object from every possible direction like in real life. 2D bitmap or vector graphics are used to create 2D animation figures.

Extension Services: The extended public education and information service operated by the government, NGOs and universities.

Gender: Refers to the attitudes, feelings, and behaviors that a given culture associates with a person's biological sex. Gender is a social construct that is different from the biological make up of a person.

Informal Learning: Learning that takes place in spaces surrounding people, activities and events. Planned and structured learning such as short courses organized in response to identified interests and needs but delivered in flexible and informal ways and in informal community settings. It can be considered as complementary to learning from everyday experience.

Learning: Learning is a change in an individual, due to the interaction of that individual, and his/her environment, which fills a need and makes him/her more capable of dealing adequately with his/her environment.

Patriarchy: Patriarchy is tethered to social and economic systems that secure women's subordination regardless of race, class, culture and ethnicity. Specifically, as an economic system of oppression, patriarchy marginalizes women from the access to property, forms of wealth accumulation, and production. As a social system, it privileges male social and economic organizing and therefore facilitates their access to roles of political leadership and enacting social mores.

SAWBO: Scientific Animations Without Borders™ (SAWBO) is a University of Illinois at Urbana Champaign based program. SAWBO transforms extension information on relevant topics such as agriculture, disease, and women's empowerment into 2D, 2.5D, and 3D animations, which are then voice overlaid into a diversity of languages from around the world.

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Chapter 33
A Genetic Algorithm to Goal Programming Model for Crop Production With Interval Data Uncertainty

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ABSTRACT

This chapter presents how Genetic Algorithm (GA) is effectively employed to Goal Programming (GP) formulation of an agricultural planning problem having interval model parameters and a set of chance constraints for optimal production of seasonal crops in uncertain environment. In model formulation, the planned-interval goals associated with objectives of the problem are converted into their equivalent two-objective deterministic goals. The chance constraints are also converted into their deterministic equivalents to solve the problem by using GP methodology. In goal achievement function, minimization of deviational variables associated with model goals is evaluated on the basis of priorities by employing a GA scheme to reach optimal decision. In the decision process, sensitivity analysis with variations of priority structure of goals is performed, and then the notion of Euclidean distance function is used to identify the priority structure under which optimal production of crops can be obtained in the decision environment. A case example is considered to demonstrate the approach.

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INTRODUCTION

The history of human civilization shows that domestication of plants went on as far as 7800 B.C. and forest gardening for plant-based food production, world's oldest form of agriculture, was started as far back as 5200 B.C. Actually, development of agricultural production system is the root of starting human civilization. The rapid rise in human civilization due to technological innovations, significant improvements in agricultural techniques were taken place from the mid-12th century to 13th century and stayed steady until 18th century (Campbell, & Overton, 1993). However, owing to rapid rise of mechanization in the late 19th century and 20th century, farming tasks could be done with a tremendous speed and became more sustainable due to innovation of tillage tools. In reality, advancement of technology has led to enable to start the modern farming system on earth (Mazoyer, & Roudart, 2006). It is worthy to mention that crop production problem is actually a management science problem with multiplicity of objectives, where the objectives are to optimize production of crops and thereby to meet the need of agricultural products in society. The general mathematical programming (MP) model for allocation of cultivable land with regard to yielding of crops to optimal levels was first presented by Heady (1954). It may be mentioned that, although land utilization system for cultivation as well as water supply system for irrigation were improved a lot prior to middle of the last century, Green Revolution was actually taken place during 1960s due to the pioneer contributions of Nobel Laureate Norman Ernest Borlaug. The effective mathematical models were then developed to take measure for better water supply and land allocation decisions for crop production. A bibliography on the modeling of agriculture planning problems was first presented by Nix (1979). Then, study on implementation of management science models to farm planning problems were made deeply towards growth of agro-economic scenarios in the modern world.

Now, since agricultural planning problems are typically multiobjective problems in the premises of limited supply of farming resources and optimal of production of several crops to meet food products in society, goal programming (GP) method (Ignizio, 1976), that is based on satisficing philosophy (Simon, 1945), was introduced to a crop production planning problem by Wheeler, and Russell (1977). The survey on the study of agricultural planning models was further conducted by Norton, and Schiefer (1980), Glen (1987) among others.

However, in most of the cases of modeling the real-world multiobjective decision making (MODM) problems, it may be noted that decision makers (DMs) are faced with the problem of setting precise model parameters to the problems owing to inherent imprecise nature of parameters and ambiguity in human judgments. To cope with the situation, fuzzy programming (FP) (Zimmermann, 1987) approach based on the theory of fuzzy sets, initially proposed by Zadeh (1965), has been employed to farm planning problems with imprecisely defined model data by Slowinski (1986). Again, Fuzzy goal programming (FGP) (Pal, & Moitra, 2003) as an extension of FP within the framework of GP has been used to agricultural land allocation problem by Biswas and Pal (2005).

Further, in a farm planning environment, it is to be observed that some of model data, which are inherently associated with resource utilization constraints, are probabilistically uncertain (Liu, 2003) in nature. The stochastic programming (SP) (Charnes, & Cooper, 1959) method was studied (Kall, & Wallace, 1994; Sahinidis, 2004) extensively and implemented to practical problems (Bravo, & Ganzalez, 2009; Pal, Chakraborti, & Biswas, 2009). However, the use of such an approach to agricultural system is yet to be studied deeply in literature.

Again, in an uncertain environment, it may become difficulty to DMs to specifying fuzziness of model parameters as well as defining of probability distributions of them (Jiang, Han, Liu, & Liu,

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2008). To overcome the situation, interval programming approach (Bitran, 1980) to MODM problems with interval parameters sets has been studied (Israel, & Robers, 1970), where an interval designates a bounded set of real numbers. Actually, seeds of interval programming could be traced in third century BC, when Archimedes (the father of mathematics) calculated the value of π (*pi*) with incorporation of certain lower and upper bounds ($223/71 < \pi < 22/7$) on it. A book on the modern interval arithmetic rules was first prepared by Moore (1966). The study on interval analysis and its crucial role to global optimization problems has also been well presented by Hansen (2003).

The GP (Ignizio, 1982) formulation of MODM problems with interval parameter sets, called interval-valued GP (IVGP), was introduced by Inuiguchi, and Kume (1991).The study on development of IVGP methodologies have been surveyed by Olivera, and Antunes (2007). The interval programming method to practical problems has also been well discussed in (Assavapokee, Realff, & Ammons, 2008; Jiang, Han, Liu, & Liu, 2008). The IVGP method to university resource planning problem has been demonstrated by Pal, Kumar, and Sen (2012). However, deep study on methodologies of interval programming along with implementation to MODM problems is yet to come widely in literature.

Again, it is to be noted that the different types of objectives involved in a decision making situation are generally incommensurable and conflicting in nature and also nonlinear characteristic are inherent to some of them in actual practice. To cope with such a situation, the conventional linearization technique (Ravindran, Ragsdell, & Reklaitis, 2007) in the framework of traditional single-objective optimization domain (Charnes, Cooper, & Ferguson, 1955) have been used to solve nonlinear MODM problems (Pal, & Moitra, 2003). But, computational load increases for use of such an approach and local optimal solution (Deb, 2002) is derived in most of the cases of practical problems.

To overcome the above difficulties, GA tools (Holland, 1973) in a paradigm of natural computing have appeared (Michalewicz, 1996) to solve MODM problems. The GAs to FGP models have been studied by Taguchi, Ida, and Gen (1998); Pal, Chakraborti, and Biswas (2009) and others. But, study on GAs as goal satisficers (Deb, 2002) is yet to be widely documented in literature. Further, use of bio-inspired computing to agricultural problems with inexact data is yet to be widely circulated in literature.

The objective of this chapter is to study a priority based extended goal programming (EGP) formulation of farm planning problem with interval data sets for production of seasonal crops with proper utilization of land and irrigable water as well as other productive resources. In the proposed approach, the objectives of utilization of total cultivable land, various farming resources and achievement of possible production of crops are described with interval data sets. The constraints on utilization of reserve water are crisply described, whereas total water utilization constraints for cultivation of seasonal crops are defined probabilistically owing to the stochastic nature of rainfall in a plan period. In the sequel of model formulation, planned-interval goals defined for interval goals are converted into standard form of goals by employing interval arithmetic rules(Moore, 1979) and introducing under- and over-deviational variables to them. Here, certain socio-economic goals in fractional form are transformed into their linear equivalents to employ linear IVGP methodology. The probabilistically defined resource utilization constraints are also converted into their deterministic equivalents to evaluate IVGP model of the problem. Then, from the optimistic point of view of DM, extended GP (EGP), which is convex combination of *minsum* GP (Ignizio, 1976) and *minmax* GP (Romero, 1991), are considered within the framework of standard EGP model to minimizing of total regret arising out of all possible deviations of planned values of goals in the decision environment. In model execution, GA scheme is employed in an iterative manner to achieve the goal levels according to priorities assigned to them. Again, sensitivity analysis is performed on the priorities of model goals to derive different possible solutions of the problem. Then,

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Euclidean distance function (Yu, 1973) is used to obtain the best solution for crop production under a given priority structure of model goals of the problem.

An example of Hooghly District of West Bengal (WB) in the tropical country India is considered to illustrative the proposed method. To illustrate more the effective use of the approach, model solution is compared with solutions of EGP approach in a previous study (Inuiguchi, & Kume, 1991).

BACKGROUND

The constructive optimization models for optimal production of crops was deeply studied by Wheeler and Russell (1977), Nix (1979) and others in the past. Here, it is to be noted that irrigation water supply is a complicated issue (Molden, 2007; Chartres, & Varma, 2010) owing to its various needs in society, and it has now become a great challenge to obtain adequate irrigable water in cropping seasons in a planning period (Slowinski, Urbaniak, & Weglarz, 1983; Yeh, 1985; Slowinski, 1986). Although, water resource planning models were studied in the past, deep study in the area of irrigation water supply for farming in an uncertain environment is very thin in literature.

Now, concerning the use interval programming (Bitran, 1980) method to MODM problems, it may be mentioned that the values of model parameters are required in certain specified ranges and there is no need to know probability distributions or fuzziness of them in the domain of interest. Although, the potential use of interval programming approach has been implemented to robot path planning (Ida, 2000), portfolio selection (Ida, 2003), thermal power generation and despatch (Pal, & Kumar, 2003) and other problems, implementation of such an approach to crop production problems is yet appear widely in literature.

In this chapter, an EGP model for farming is considered, where interval data for measuring performances against crop production criteria and certain nonlinear probabilistic constraints against socio-economic objectives are taken into account in the formulated model.

Now, the general framework of IVGP problem is discussed in the following section.

CHANCE CONSTRAINED IVGP PROBLEM FORMULATION

In the field of IVGP, the objectives with interval parameters of a MODM problem are converted into interval goals by means of assigning target intervals, instead of fixed target values of achieving objectives, whereas the resource constraints and other structural constraints are considered inexact / crisp depending on the characteristics of model parameters of the problem.

The general structure of an IVGP problem having both linear and fractional objectives and a set of chance constraints can be presented as (Jiang et al., 2008):

Find $\boldsymbol{X}$ so as to:

$$\text{satisfy } Z_k : [c_k^L,\ c_k^U]\mathbf{X} + [\alpha_k^L,\ \alpha_k^U] = [t_k^L, t_k^U],\ k \in K_1 \tag{1}$$

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$$\text{and } Z_k : \frac{[c_k^L, c_k^U]\,\mathbf{X} + [\mu_k^L, \mu_k^U]}{[b_k^L, b_k^U]\mathbf{X} + [\rho_k^L, \rho_k^U]} = [t_k^L, t_k^U],\ k \in K_2 \tag{2}$$

subject to,

$$\mathbf{X} \in S\{\mathbf{X} \in R^n \mid Pr[F(\mathbf{X}) \begin{pmatrix} \geq \\ \leq \end{pmatrix} b] \geq p,\ \ \mathbf{X} \geq 0\ ,\ \mathrm{b} \in \mathrm{R}^{\mathrm{m}}\}, \tag{3}$$

where Z_k represents *k-th* objective, *k=1, 2,..., K* and ***X*** designates the vector of decision variables, and where $[c_k^L, c_k^U], \forall k$, and $[b_k^L, b_k^U], k \in K_2,$ are the vectors of interval coefficients, $[t_k^L, t_k^U], \forall k$, denote target intervals. $[\alpha_k^L, \alpha_k^U], k \in K_1$, and $[\mu_k^L, \mu_k^U]$, $[\rho_k^L, \rho_k^U]$, $k \in K_2$, are constant intervals associated with the respective interval goals, where superscripts *L* and *U* indicate for lower- and upper-bounds, respectively.

It is assumed that the feasible region $S(\neq \varphi)$ is bounded, and $K_1 \cup K_2 = \{1, 2, ..., K\}$ with $K_1 \cap K_2 = \varphi$. Also, in case of the fractional goal expression in (2), $([b_k^L, b_k^U]\mathbf{X} + [\rho_k^L, \rho_k^U]) > 0$ is assumed to avoid any undefined situation and to preserve the feasibility of solution. '*Pr*' indicates probabilistic constraints, *F*(***X***) is (linear or nonlinear) function to represent constraints set, *b* is resource vector, and *p* (*0 < p <1*) is used to indicate probability levels for random model parameters. Here, if *p=1* is considered for a chance constraint, then that would be deterministic one as in the conventional case of optimization problems.

In the above formulation, the parameters with defined intervals represent the respective bounded regions within which the values they possibly take. In IVGP approach, goals in (1) and (2) are converted into planned-interval goals by expressing the objectives as planned value objectives by using interval arithmetic rules (Moore, 1979).

Now, basic operational rules in interval arithmetic are discussed as follows.

Basic Interval Arithmetic Operational Rules

Let *A* be a closed interval which is defined by an ordered pair of real numbers as

$$A = [a^L, a^U] = \{a : a^L \leq a \leq a^U;\ a \in \Re\}, \tag{4}$$

where a^L and a^U are left- and right-limits, respectively, of the real number *a* on the real line $\Re$.

Here, for a particular case, if $a^L = a^U = a$, then A = [*a, a*] represents a real number *a*.

Now, some useful arithmetic operations on interval numbers are discussed as follows:

- The midpoint *m*[*A*] and the width *w*[*A*] of an interval A can be defined as

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$$m[A] = \frac{1}{2}(a^L + a^U) \text{ and } w[A] = (a^U - a^L), \text{ respectively.} \tag{5}$$

- The scalar multiplication of *A* is defined as

$$\lambda A = \begin{cases} [\lambda a^L, \lambda a^U], & \lambda \geq 0 \\ [\lambda a^U, \lambda a^L], & \lambda < 0 \end{cases} \tag{6}$$

The arithmetic operations, possible addition and possible subtraction, on intervals $A = [a^L, a^U]$ and $B = [b^L, b^U]$ are defined as

$$A(+)B = [a^L + b^L, a^U + b^U], \text{ and } A(-)B = [a^L - b^U, a^U - b^L] \tag{7}$$

- The multiplication between interval numbers is defined as

$$A.B = [min(a^L.b^L, a^L.b^U, a^U.b^L, a^U.b^U), max(a^L.b^L, a^L.b^U, a^U.b^L, a^U.b^U)] \tag{8}$$

- The variable multiplication of A is defined as

$$x[a^L, a^U] = [a^L x, a^U x], \text{ where } x \in \Re \text{ is a variable.} \tag{9}$$

If $\{A_j = [a_j^L, a_j^U],\ j = 1,2,...,n\}$ be a collection of intervals and $\{x_j(\geq 0);\ j = 1,2,...,n\}$ be a set of real variables, then the possible sum of *n* intervals is given by:

$$(\overset{n}{\underset{j=1}{+}})A_j x_j = [\sum_{j=1}^{n} a_j^L x_j, \sum_{j=1}^{n} a_j^U x_j] \tag{10}$$

Now, conversions of interval goals in (1) and (2) into planned-interval goals are discussed in the next section.

Planned-Interval Goals

The planned-interval actually signifies an interval planned for obtaining possible values of an objective, called planned values, in inexact environment.

Following operation rule on interval defined in (10), the planned-interval goals corresponding to goal expressions in (1) can be obtained as (Pal et al., 2012):

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$$\left[\sum_{j=1}^{n} c_{kj}^{L} x_j + \alpha_k^{L}, \sum_{j=1}^{n} c_{kj}^{U} x_j + \alpha_k^{U}\right] = \left[t_k^{L}, t_k^{U}\right],\ k \in K_1 \tag{11}$$

Again, the fractional interval goal expression in (2) takes the form:

$$\frac{\left[\sum_{j=1}^{n} c_{kj}^{L} x_j + \mu_k^{L}, \sum_{j=1}^{n} c_{kj}^{U} x_j + \mu_k^{U}\right]}{\left[\sum_{j=1}^{n} b_{kj}^{L} x_j + \rho_k^{L}, \sum_{j=1}^{n} b_{kj}^{U} x_j + \rho_k^{U}\right]} = \left[t_k^{L}, t_k^{U}\right], k \in K_2 \tag{12}$$

The expressions in (11) and (12) indicate the possible achievement of objective values within their respective planned regions.

Then, linear form of the expression in (12) can be obtained by using operational rules in interval arithmetic as follows:

$$\left[\sum_{j=1}^{n}\left(c_{kj}^{L} - t_k^{L} b_{kj}^{U}\right) x_j + \left(\mu_k^{L} - t_k^{U} \rho_k^{U}\right), \sum_{j=1}^{n}\left(c_{kj}^{U} - t_k^{U} b_{kj}^{L}\right) x_j + \left(\mu_k^{U} - t_k^{L} \rho_k^{U}\right)\right] = \left[0, 0\right], k \in K_2 \tag{13}$$

Then, in the sequel of model formulation, the defined goals in (11) and (13) are transformed into standard goals in an analogous to GP by using interval arithmetic technique and introducing under- and over-deviational variables to each of them.

Transformation of Planned-Interval Goals Into Standard Goals

It may be noted that, as in the case of conventional GP, deviations from planned values concerning achievement of objective values are inherent there owing to inexactness of setting parameter values of the problem.

The interval of possible deviation $D_k = [d_k^{L}, d_k^{U}]$ associated with *k-th* planned-interval goal can be represented as (Inuguchi, & Kume, 1991):

$$D_k = \left| \left[t_k^{L} - C_k^{U}(\mathbf{X}), t_k^{U} - C_k^{L}(\mathbf{X})\right] \right| , \tag{14}$$

where,

$$C_k^{U}(\mathbf{X}) = \begin{cases} \sum_{j=1}^{n} c_{kj}^{U} x_j + \alpha_k^{U}, & \text{for } k \in K_1 \\ \sum_{j=1}^{n}\left(c_{kj}^{U} - t_k^{U} b_{kj}^{L}\right) x_j + \left(\mu_k^{U} - t_k^{L} \rho_k^{U}\right), & \text{for } k \in K_2 \end{cases}$$

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and

$$C_k^L(\mathbf{X}) = \begin{cases} \sum_{j=1}^{n} c_{kj}^L x_j + \alpha_k^L, & \text{for } k \in K_1 \\ \sum_{j=1}^{n} \left(c_{kj}^L - t_k^L b_{kj}^U\right) x_j + \left(\mu_k^L - t_k^U \rho_k^U\right), & \text{for } k \in K_2 \end{cases}$$

where $C_k^U(X)$ and $C_k^L(X)$ designate the upper- and lower-bounds of the planned-intervals in (11) and (13), respectively, defined for objective goals of the problem.

Now, it is worth mentioning that occurrence of zero deviational interval, i.e., $D_k = [0, 0]$, is a trivial case in actual practice, because goals are generally incommensurable and often conflict among themselves regarding achievement of values in a decision situation. Eventually, regret arising out of D_k need have to be minimized to the possible extent to obtain optimal solution.

In the above context, a regret function is designed to estimate actual goal achievements as well as occurrence of possible deviations of objective goals from the target intervals. In such a case, the planned-interval goals are to be converted into each of their equivalent two standard goals in executable model of the problem.

The standard goals of goal expressions in (11) and (13) are obtained as (Inuiguchi, & Kume, 1991):

$$\sum_{j=1}^{n} c_{kj}^U x_j + \alpha_k^U + d_{kL}^- - d_{kL}^+ = t_k^L, \tag{15}$$

$$\sum_{j=1}^{n} c_{kj}^L x_j + \alpha_k^L + d_{kU}^- - d_{kU}^+ = t_k^U; k \in K_1 \tag{16}$$

$$\sum_{j=1}^{n} \left(c_{kj}^U - t_k^U b_{kj}^L\right) x_j + \left(\mu_k^U - t_k^L \rho_k^U\right) + d_{kL}^- - d_{kL}^+ = 0, \tag{17}$$

$$\sum_{j=1}^{n} \left(c_{kj}^L - t_k^L b_{kj}^U\right) x_j + \left(\mu_k^L - t_k^U \rho_k^U\right) + d_{kU}^- - d_{kU}^+ = 0; k \in K_2 \tag{18}$$

where (d_{kL}^-, d_{kU}^-) and $(d_{kL}^+, d_{kU}^+) \geq 0$ with $d_{kL}^-.d_{kL}^+ = 0$ and $d_{kU}^-.d_{kU}^+ = 0$, $(k = 1, 2, \ldots, K)$, indicates under- and over-deviational variables, respectively.

Here, three possible cases arise concerning involvement of deviational variables to the goals in (15)-(18). Consequently, possible regret interval D_k takes the form (Inuiguchi, & Kume, 1991):

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$D_k = [d_{kL}^- + d_{kU}^+,\ d_{kL}^+ \vee d_{kU}^-]$ for both types of the defined goals, ($k \in K_1$ and K_2), where $\vee$ indicates *max* operator.

It is to be followed that there are two kinds of possible regrets, which are associated with lower- and upper bounds of D_k for involvement of two different types of possible deviational variables regarding achievement of goal values. In IVGP approach, the regret function is designed to minimizing either $(d_{kL}^- + d_{kU}^+)$ in optimistic decision system or $(d_{kL}^+ \vee d_{kU}^-)$ in pessimistic decision system in the decision search process.

However, from the optimistic point of DM, minimization of $(d_{kL}^- + d_{kU}^+)$ concerning achievement a planned value of the *k-th* goal is generally used MODM problems (Pal et al., 2012) in an inexact environment.

Then, deterministic equivalents (Blumenfeld, 2010) of chance constraints in (3) are obtained below.

Deterministic Equivalent of Chance Constraint

It is assumed that the probabilistic parameters in (3) follow independent normal distribution.

Then, the chance constraints in (3) with ≤ type restriction appear explicitly as:

$$Pr[\sum_{j=1}^{n} a_{ij} x_j \leq \ b_i] \geq p_i,\ \mathrm{i} = 1,2,...,m_1 \text{(say)} \tag{19}$$

where, a_{ij} and $b_i\,(i = 1,2,...,m_1\,; j = 1,2,...,n)$ are coefficient and resource parameters, respectively, and p_i is probability level of *i-th* constraint.

Using the standard probability rules, the deterministic equivalent of the expression in (19) appears as (Hulsurkar, Biswal, & Sinha, 1997):

$$E(v_i) + F_i^{-1}(1 - p_i)\sqrt{\{\mathrm{var}\ \ (v_i)\}} \leq 0,\ i = 1,2,...,m_1 \tag{20}$$

where $v_i = (\sum_{j=1}^{n} a_{ij} x_j - b_i)$ designates random variate and $F_i^{-1}(.)$ represents the inverse of the probability distribution function *F*(.), and where *E*(v_i) and *var*(v_i) represent mean and variance, respectively.

In an analogous way, the deterministic equivalents of constraints in (3) with ≥ type restriction are obtained as:

$$E(v_i) + F_i^{-1}(1 - p_i)\sqrt{\{\mathrm{var}\ \ (v_i)\}} \geq 0,\ i = m_1 + 1,\ m_1 + 2,...,m. \tag{21}$$

Then, formulation of EGP model is described in the following section.

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FORMULATION OF EGP MODEL

In conventional GP formulation, simultaneous minimization of under- and over-deviational variables of the defined model goals is considered for achievement of goal values. In GP, two widely used approaches are *minsum* GP (Ignozio, 1976) and *minmax* GP (Romero, 1991) In the former case, minimization of sum of weighted under- and over-deviational variables are considered in achievement function, whereas minimization of maximum of sum of under- and over-deviational variables associated with all goals is taken into account in later one. Here, an intuitive idea of taking the convex combination of both approaches (termed extended GP (EGP) (Romero, 2004)) is considered to make an aggregate achievement of possible goal values that arises in the decision-making horizon.

Then, the general structure of a regret function can be presented as (Iniguchi, & Kume, 1991):

$$\text{Minimize: } \{\lambda \sum_{k=1}^{K} w_k (d_{kL}^- + d_{kU}^+) + (1-\lambda)V\} \tag{22}$$

In a MODM environment, it is to be noted that the model goals are incommensurable in nature and they often conflict each other to achieve the individual goal values in the decision making situation. In such a situation, DM is often faced with the difficulty of using conventional GP approach to reach a proper decision for goal achievement on the basis of needs and desires in the decision making horizon. To overcome the difficulty, EGP model under a pre-emptive priority structure (Ogryczak, 1997) is considered with view to minimizing total possible regrets from the optimistic point of view of DM towards achieving the planned values of objectives within the respective target intervals.

The *priority based* EGP model can be stated as follows.

Find ***X*** so as to:

$$\text{Minimize } Z = [P_1(\bar{d}), P_2(\bar{d}), ..., P_r(\bar{d}), ..., P_R(\bar{d})],$$

and satisfy the goal expressions in (15-18), subject to the constraints in (21), and

$$d_{rkL}^- + d_{rkU}^+ - V_r \leq 0, \quad k \in I_r, r \in \{1, 2, ..., R\},$$

where

$$V_r = [\max_{k \in I_r}(d_{rkL}^- + d_{rkU}^+)], \; r \in \{1, 2, ..., R\} \tag{23}$$

In the model, Z is a vector of *R* priority achievement functions, *max* stands for maximum.

$P_r(\bar{d})$ represents the regret function for minimizing the vector $\bar{d}$ of under- and over-deviational variables of goals included at *r-th* priority level.

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Again, $P_r(\bar{d})$ is of the form:

$$P_r(\bar{d}) = \{\sum_{k\in I_r} \lambda_r w_{rk}(d^-_{rkL} + d^+_{rkU}) + (1-\lambda_r)V_r\},\ 0 < \lambda_r < 1 \text{ with } \sum_{r\in I_r} \lambda_r = 1 \text{ and } \sum_{k\in I_r} w_{rk} = 1 \tag{24}$$

where I_r designates the set of model goals, *r = 1,2,...,R*, and where $\bigcup_{r=1}^{R} I_r = K$ and $I_q \cap I_s = \varphi$; *q* ≠ *s* and *q, s* ∈{*1,2,...,R*}. w_{rk} (>0), $k \in I_r$ represent numerical weights of achieving the goals, and where d^-_{rkL}, d^+_{rkU} are renamed for d^-_{kL}, d^+_{kU}, respectively, to represent them at *r-th* priority level.

The priority factors have the following relationship:

$$P_1 >>> P_2 >>> ... >>> P_r >>> ... >>> P_R,$$

which means that achievement of goals under the priority factor P_r is preferred most to the next priority factor P_{r+1}, $r = 1, 2, ..., R-1,$ where >>> stands for 'much greater than'.

Now, in actual practice, DM is confused in most of the times to assign proper priorities to goals with regard to their achievements. Therefore, sensitivity analysis of solutions with changes of priorities of model goals is made and *Euclidean distance function* is used to determine the optimal solution.

Use of Euclidean Distance Function for Priority Structure Selection

Let, *P* be the total number of possible priority structures with regard to generation of different solutions.

Then, let $\{x_j^p;\ j = 1,2,...,n\}$ be the optimal solution obtained with the selection of *p-th* priority structure, $p = 1, 2, ..., P$.

Consequently, the ideal solution can be recognized as $\{x_j^*;\ j = 1,2,...,n\}$, where $x_j^* = \max_{p=1}^{P} \{x_j^p\}$, *j=1,2,...,n*.

Using the *Euclidean distance function*, the distance of *p-th* solution from ideal point can be obtained as

$$D^{(p)} = [\sum_{j=1}^{n} (x_j^* - x_j^p)^2]^{1/2}, \tag{25}$$

where $D^{(p)}$ denotes distance function to measure distance between the solution achieved under *p*-th priority structure and ideal solution.

Now, from the viewpoint of closeness of a solution to ideal point, the minimum distance always provides optimal decision.

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$$\text{Let, } D^{(t)} = min\{D^{(p)}; p = 1,2,...,P\}, \tag{26}$$

where, '*min*' stands for minimum.

Then, *t*-th priority structure is selected as appropriate one to obtain optimal solution in inexact environment.

Now, it is to be noted that computational complexity arises for solving MODM problems with nonlinear objectives with the use of traditional approximation techniques, and solution of a problem often leads to a local optimum rather than global one. Further, computational load due to linearization (Pal et al., 2003) as well as approximation error frequently occurs for use of traditional optimization methods.

To avoid the shortcomings, GA method (Michalewicz, 1996) is used to EGP model in (23) to obtain satisfactory solution.

GA SCHEME FOR EGP MODEL

In GA (Holland, 1973; Goldberg, 1989), generation of new population is made by adopting the operators, *selection*, *crossover* and *mutation.* The real value coded chromosomes are considered here in the evolutionary process of solving the problem. The simple roulette-wheel selection (Deb, 2002), arithmetic crossover (Hasan, & Saleh, 2011) for exploration of the promising regions of search space and uniform mutation (Craenen, Eiben, & Marchiori, 2001) for exploitation of best candidate solution in the domain of interest are considered in the process of executing the problem.

Now, the functions *Z* in (23) appears as evaluation function in the proposed genetic scheme.

The evaluation function is expressed as:

$$eval\left(E_v\right)_r = \left(Z_v\right)_r = \left\{\sum_{k=1}^{K} w_{rk}^{-} d_{rk}^{-}\right\}_v, \; v = 1,2,..., \text{ pop_size}, \tag{27}$$

where, $\left(Z_v\right)_r$ is actually renamed for *Z* in (23) to measure fitness value of *v-th* chromosome, when evaluation for achievement goals at *r-th* priority level $\left(P_r\right)$ is considered in execution process.

The best value (Z_k*) for fittest chromosome at a generation is determined as:

$$Z_k^* = min\ \{evel(E_v)_k \mid v = 1,2,..., \text{ pop_size}\},\ k = 1, 2, ..., K \tag{28}$$

The execution of the problem step-by-step for achievement of model goals has been well presented in (Pal, & Chakraborty, 2013).

Now, different types of decision variables and parameters involved in crop production planning are introduced below.

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DEFINITIONS OF VARIABLES AND PARAMETERS

1. Definition of Variables

Two types of variables, decision variables associated with arable land utilization for cultivation of seasonal crops and constrained variables associated with irrigation water supply system, are involved with the problem.

1. Decision variables:

x_{cs} = Allocation of land for cultivation of crop *c* during season *s*, $c = 1, 2, ..., C$; $s = 1, 2, ..., S$.

2.. Constrained variables:

CW_s = Supply of canal-water during season *s,* $s = 1, 2, ..., S$.

GW_s = Supply of groundwater during season *s,* $s = 1, 2, ..., S$.

2. Definition of Parameters

Two types of parameters, farm input and output parameters, are involved with the problem. The input parameters are associated with utilization of farming resources, and output parameters are associated with crop production and revenue achievement decisions in an agricultural planning system.

1. Farm input Parameters:
   a. Interval Coefficient.

$[mh_{cs}^L, mh_{cs}^U]$ = Interval of machine-hour (in hours (*hrs*)) requirement for tillage per hectare (*ha*) of land for cultivating crop *c* during season *s*.

$[md_{cs}^L, md_{cs}^U]$ = Interval of manpower (in days) requirement for cultivation of crop c during season *s*.

$[fr_{csf}^L, fr_{csf}^U]$ = Interval of fertilizer f $(f = 1, 2, ..., F)$ utilization per *ha* of land for cultivating crop *c* during season *s*.

$[P_{cs}^L, P_{cs}^U]$ = Interval of production of crop *c* during season *s*.

$[A_{cs}^L, A_{cs}^U]$ = Interval of cash requirement for purchase of various farming materials per *ha* of land for crop *c* cultivated during season *s*.

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b. Target Intervals.

$[D_s^L, D_s^U]$ = Interval of arable land (in *ha*) utilization for cultivating the crops in season *s*.

$[MH^L, MH^U]$ = Interval of total machine-hour (in *hrs*) required for all -seasons of a plan period.

$[MD^L, MD^U]$ = Interval of total manpower (in days) required for all seasons of plan a period.

$[FR_f^L, FR_f^U]$ = Interval of total amount of fertilizer f $(f = 1, 2, \ldots, F)$ (in quintals (*qtls*)) required for yielding all the crops in a plan period.

$[CR^L, CR^U]$ = Interval of budget allocation for purchase of different resources.

$[CW^L, CW^U]$ = Interval of the supply of canal-water (in million cubic meters (*MCM*)) for cultivation in a plan period.

$[GW^L, GW^U]$ = Interval of possible evacuation of groundwater (in *MCM*) for cultivation of all varieties of crops throughout the seasons in a plan period.

c. Random coefficient:

wu_{cs} = Estimated amount of water consumed (in cubic meter (*CM*)) per ha of land for cultivation of crop *c* during season *s*, *s= 1,2,…,S*.

d. Probabilistic parameter:

RW_s = Expected amount of rainwater (in millimeter (*mm*)) precipitated during season *s*,

s= 1,2,…,*S*.

2. Farm output parameters
   a. Interval coefficient

$[mp_{cs}^L, mp_{cs}^U]$ = Interval of possible market price (Rupees/quintal (*Rs./qtl*)) of yielding crop *c* cultivated during season *s*, *s= 1,2,…,S*.

b. Target intervals

$[AP_c^L, AP_c^U]$ = Interval of annual production (in qtls) of all varieties of crop *c* cultivated during all seasons of a plan period.

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$[MP^L, MP^U]$ = Interval of market price of all the yielding crops cultivated in different seasons of a plan period.

$[FG^L, FG^U]$ = Interval of annual production of all major food-grain crops cultivated during all seasons of a plan period.

c. Farm output ratio interval

$[R^L_{yzs}, R^U_{yzs}]$ = Interval of production ratio of y-th and z-*th* crops cultivated in season s $(y, z = 1, 2, ..., C; y \neq z)$.

Now, following the expressions in (1) and (2), the algebraic structures of interval goals of the problem can easily be obtained. Then, the associated planed-interval goals can be determined by the expressions in (11) and (13).

PLANED-INTERVAL GOALS

The planed-interval goals are actually basic structural forms of objective goals to design the model of the problem. Planed-interval goals are discussed as follows.

1. *Land utilization goal.* The goals for utilization of total cultivable land for production of various seasons during a plan period take the form:

$$\sum_{c=1}^{C} x_{cs} = [D^L_s, D^U_s], \quad s = 1, 2, ..., S \tag{29}$$

2. Productive resource goals:
   2. a. *Machine-hour goal.* Total machine hour within a specified interval need be provided to tillage land in different seasons. The goal appears as:

$$\sum_{s=1}^{S}\sum_{c=1}^{C} [mh^L_{cs}.\ x_{cs}, mh^U_{cs}.\ x_{cs}] = [MH^L, MH^U] \tag{30}$$

   2. b. *Manpower requirement goal*. Requirement of manpower within a specified interval must be considered for smooth functioning of various activities throughout a plan period. The planned interval goal takes the form:

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$$\sum_{s=1}^{S}\ \sum_{c=1}^{C}[md_{cs}^{L}.\ x_{cs},\ md_{cs}^{U}.\ x_{cs}]\ =[MD^{L},\ MD^{U}] \tag{31}$$

2. c. *Fertilizer requirement goal*. To maintain the fertility of soil, different types of fertilizers in essence are utilized to yield seasonal crops. The planned-interval goals for fertilizer requirement take the form:

$$\sum_{s=1}^{S}\ \sum_{c=1}^{C}[\ fr_{csf}^{L}.\ x_{cs},fr_{csf}^{U}.\ x_{cs}]\ =[FR_{f}^{L},\ FR_{f}^{U}],\ f=1,2,...,F \tag{32}$$

3. *Budget allocation goal.* An estimated budget for miscellaneous expenditure would have to be allocated for the purpose of purchase of seeds, fertilizers and other productive resources. The goal appears as:

$$\sum_{s=1}^{S}\ \sum_{c=1}^{C}[\ A_{cs}^{L}.\ x_{cs},A_{cs}^{U}.\ x_{cs}]\ =[CR^{L},CR^{U}] \tag{33}$$

4. Crop production goal.

4. a. *Total seasonal crop production goal.* To meet the demand of agricultural products in society, crop production within a specified interval is highly expected by farm manager. The goal expressions is stated as:

$$\sum_{s=1}^{S}[P_{cs}^{L}.x_{cs},P_{cs}^{U}.x_{cs}]\ =[P_{c}^{L},\ P_{c}^{U}],\ c=1,2,...,C \tag{34}$$

4. b. *Major food-grain crop production goal*. Some of the seasonal crops are taken in a group as main sources of major food-grains, where one of which can be consumed as an alternative to other ones in a same group to meet the need of main food products. Therefore, cultivation of major food-grain crops in different seasons would have to be considered as a convex combination of them in a plan period. The major food-grain crop production goal with target interval appears as:

$$\sum_{s=1}^{S}\sum_{g=1}^{C_{1}}\beta_{g}x_{gs}[P_{gs}^{L}.x_{gs},\ P_{gs}^{U}.x_{gs}]\ =\sum_{g=1}^{S}[FG^{L},\ FG^{U}], \tag{35}$$

where, $\sum_{g=1}^{C_{1}}\beta_{g}=1,\ 0<\beta_{g}<1,$ and where g is used as a rename of the crop c to indicate its inclusion in the set of major food-grain crops C_{1} ($C_{1}<C$).

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5. *Crop production ratio goal.* Since total arable land is limited, allocation of land (in *ha*) in certain seasons would have to be made in such a way that some principal crops could be yielded for civil utility purposes, beyond of satisficing different food-grain demands in society. In such a case, pair-wise ratio of production of crops cultivated during a season can reasonably be taken into account in a crop production decision situation. The planned-interval goal expression in linear form appears as:

$$\left[\sum_{s=1}^{S}\left(P_{ys}^{L}x_{ys}-R_{yz}^{U}\,P_{zs}^{U}.x_{zs}\right),\sum_{s=1}^{S}\left(P_{ys}^{U}x_{ys}-R_{yz}^{L}\,P_{zs}^{L}\right)\right] = \left[0,0\right],\quad y,z\in\{1,2,...,C\};\ y\neq z \tag{36}$$

6. *Annual profit goal.* The annual profit depends upon market price of individual yield crops. Therefore, planned-interval goal is considered for profit achievement.

The goal expression appears as:

$$\sum_{s=1}^{S}\ \sum_{c=1}^{C}[(P_{cs}^{\mathrm{L}}m\mathrm{p}_{cs}^{L}.x_{cs}-A_{cs}^{U}.x_{cs}),(P_{\mathrm{cs}}^{\mathrm{U}}m\mathrm{p}_{cs}^{U}.x_{cs}-A_{cs}^{L}.x_{cs})]\ =[MP^{\mathrm{L}},MP^{U}] \tag{37}$$

7. Water supply goals:
   a. *Canal-water supply goal.* The supply of canal-water from a River-barrage is the major source of irrigation water, which is inexact in nature owing to capacity limitation of barrage as well as constraints on the release of water up to a certain level to preserve ecosystem on earth. The planned-interval goal appears as:

$$\sum_{s=1}^{S}CW_{\mathrm{s}}=[CW^{\mathrm{L}},CW^{U}] \tag{38}$$

   b. *Groundwater supply goal.* Groundwater is always scarce in nature and abstraction of it cannot be made after a certain level to preserve biodiversity as well to make protection against water contamination with mixing of harmful minerals that lie in deep groundwater level. The planned- interval goal takes the form:

$$\sum_{\mathrm{s}=1}^{\mathrm{S}}GW_{\mathrm{s}}=[GW^{L},\ GW^{U}] \tag{39}$$

Now, the system constraints, which are inherently inflexible (rigid) in nature, are discussed in the following section.

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System Constraints

Water Supply Constraints

The adequate supply of water for cultivation is a major input in an agricultural production system. But, a water supply form reserve-water source is very limited owing to capacity limitations of them as well as to serve the other purposes in society including preservation of bio-diversity.

The two types of water utilization constraints are discussed as follows.

1. Water utilization constraints

The utilization of both the canal-water and groundwater need essentially be considered with great care, because they are always constrained for allocation to agricultural system.

The water utilization constraints can be deterministically obtained as:

$$CW_s \le y_s \sum_{s=1}^{S} CW_s, \quad s = 1,2,...,S; \qquad GW_s \le z_s \sum_{s=1}^{S} GW_s, \quad s = 1,2,...,S \tag{40}$$

where, y_s and z_s designate the percentages of utilizing the total allocation of canal-water and groundwater, respectively, to *s-th* cropping season of the plan period.

2. Total water utilization constraints.

A large part of the total demand of irrigation water depends solely on seasonal rainfall, which is highly uncertain as a natural phenomenon. As a matter of fact, adequacy of supplying total irrigation water in a cropping season is always probabilistic.

The seasonal water utilization constraints appear as:

$$Pr[\sum_{c=1}^{C} wu_{cs}.x_{cs} - (CW_s + GW_s) \le \ RW_s] \ge p_s, \ \ s = 1,2,...,S \tag{41}$$

Now, executable EGP model of the problem is demonstrated through a case example.

CASE EXAMPLE

The agricultural planning problem of Hooghly district in WB of the tropical country India is considered to demonstrate the proposed method. Hooghly district is typically known for its fertile soil to cultivate various season based principal crops throughout a planning year. Actually, the regional topography of Hooghly district is with average elevation of 19 meters from sea level and drained by the rivers, Hooghly river (i.e., the end part of Ganga river) and Damodar river. As such, it is an ideal landscape for agricultural industry in India.

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Location Map of Hooghly District is presented in Figure 1.

The data were collected from various agricultural planning units: District Statistical Hand Book (2011), Economic Review (2011), Department of Agri-Irrigation of Hooghly District, Basak (2000).

Three prominent cropping seasons: Summer, Rainy and Winter, successively appear in WB in a planning year, and the patterns of seasonal crops cultivated in the sequential seasons are Pre-kharif, Kharif and Rabi, respectively. The major crops are: Jute, a variety of Paddy, Groundnut, Wheat, Mustard, Potato and Sesame. Again, season based cultivation of crops are: Jute and Aus-paddy in Summer, Aman-paddy and Groundnut in Rainy, and Boro-paddy, Wheat, Mustard, Potato and Sesame in Winter. In model formulation, the seasons are sequentially denoted as: 1, 2, 3, and crops are successively numbered: 1, 2, 3, 4, 5, 6, 7. Then, the decision variables to represent seasonal crops are defined as:

(Jute, Aus-paddy, Aman-paddy, Groundnut, Boro-paddy, wheat, Mustard, Potato, Sesame)

$$= (x_{11}, x_{21}, x_{22}, x_{32}, x_{23}, x_{43}, x_{53}, x_{63}, x_{73}).$$

In sequel of model formulation, five years' (2007-2011) rainfall data were taken into account to accommodate probabilistic constraints of the problem. The various types of data associated with objectives and constraints of the model are summarized in Table 1, Table 2, and Table 3, respectively.

Now, following the expressions in (15)-(18), the model goals are constructed by using data presented in Table 1 and Table 3.

Construction of Model Goals

1. Land utilization goals:

$$x_{11} + x_{21} + d_{1L}^{-} - d_{1L}^{+} = 198650,\ x_{11} + x_{21} + d_{1U}^{-} - d_{1U}^{+} = 228776;\text{(Summer)}$$

$$x_{22} + x_{32} + d_{2L}^{-} - d_{2L}^{+} = 197550,\ x_{22} + x_{32} + d_{2U}^{-} - d_{2U}^{+} = 228776;\text{(Rainy)}$$

Figure 1. Location map of Hooghly district

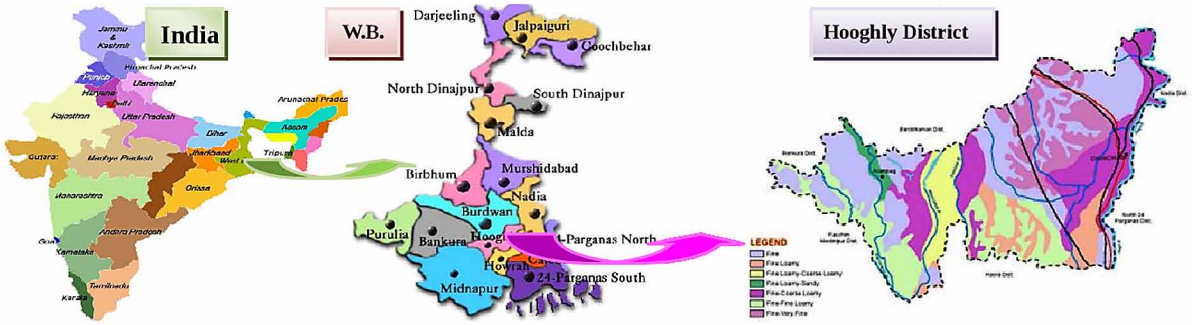

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Table 1. Data description of target intervals of goals

Goal	Target Interval
1. Land Utilization ('000 *ha*):	
(a) Pre-kharif	[198.650, 228.776]
(b) Kharif	[197.550, 228.776]
(c) Rabi	[197.950, 228.776]
2. Machine-hour requirement (in '000 *hrs*):	[48650, 49776]
3. Manpower requirement (in '000 *man-days*):	[86395, 90177]
4. Fertilizer requirement (in *metric ton*):	
(a) Nitrogen	[35.00, 38.59]
(b) Phosphate	[19.80, 20.67]
(c) Potash	[15.00, 16.56]
5. Budget allocation (in *Rs. Lac*)	[154550.30. 169784.54]
6. Crop production (in '000 *metric ton*):	
(a) Jute	[45.06, 46.12]
(b) Aus-paddy	[279.56, 300.25]
(c) Aman-paddy	[715.33, 735.45]
(d) Groundnut	[23.72, 25.76]
(e) Boro-paddy	[359.72, 372.67]
(f) Wheat	[6.14, 6.94]
(g)Mustard	[9.50, 10.17]
(h) Potato	[3218.73, 3247.50]
7. Total production (in '000 *metric ton*) of major food-grain crops (Paddy and Wheat):	[1356.814, 1377.140]
8. Annual profit (in *Rs. Lac*):	[145175.80, 145326.70]
9. Production ratio (Jute and Aus-paddy):	[1.20, 1.25]
10. Water supply (in *MCM)*:	
(a) Canal-water	[1555.5, 1635.37]
(b) Groundwater	[1355.45, 1443.33]

Note: Rs. = Rupees in Indian currency.

Table 2. Data description of rainfall

Year	Rainfall (RW_s) (in mm)		
	Pre-Kharif	Kharif	Rabi
2007	437	1264.11	58.8
2008	505.25	833.23	86.2
2009	273.94	855.67	25.4
2010	683.04	603.88	53.4
2011	375.75	930.34	44.4

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Table 3. Data description of interval coefficients and random coefficients

Crop	$[mh_{cs}^L, mh_{cs}^U]$	$[md_{cs}^L, md_{cs}^U]$	$[fr_{csf}^L, fr_{csf}^U]$			$[P_{cs}^L, P_{cs}^U]$	$[A_{cs}^L, A_{cs}^U]$	$[mp_{cs}^L, mp_{cs}^U]$	wu_{cs}
			N	P	K				
Jute	[198, 210]	[86, 94]	[45, 56]	[19, 22]	[18, 20]	[2731, 2755]	[18655, 18845]	[870, 1050]	520
Aus-paddy	[420, 430]	[57, 64]	[58, 63]	[26, 33]	[22, 28]	[4324, 4401]	[21050, 21350]	[925, 1150]	864
Aman-paddy	[200, 210]	[56, 63]	[75, 85]	[30, 34]	[30, 34]	[4323, 4365]	[22250, 22750]	[920, 1000]	1270
Groundnut	[102, 119]	[28, 31]	[48, 52]	[24, 30]	[18, 24]	[2198, 2236]	[19250, 19750]	[720, 800]	255
Boro-paddy	[805, 822]	[55, 65]	[145, 155]	[78, 82]	[78, 82]	[5115, 5148]	[36430, 36970]	[950, 1105]	1787
Wheat	[200, 210]	[36, 43]	[105, 115]	[52, 58]	[47, 53]	[2380, 2432]	[24965, 25035]	[1350, 1475]	382
Mustard	[98, 105]	[27, 34]	[75, 85]	[35, 45]	[25, 35]	[1025, 1078]	[18520, 18786]	[2965, 3065]	255
Potato	[332, 345]	[66, 74]	[260, 290]	[165, 190]	[165, 190]	[27490, 27537]	[59245, 61390]	[500, 600]	457
Sesame	[95,105]	[26, 34]	[45, 55]	[22, 28]	[12, 18]	[813, 835]	[14170, 14595]	[2920, 3160]	286

Note: N = Nitrogen, P = Phosphate, K = Potash.

$$x_{23} + x_{43} + x_{53} + x_{63} + x_{73} + d_{3L}^- - d_{3L}^+ = 197950,$$

$$x_{23} + x_{43} + x_{53} + x_{63} + x_{73} + d_{3U}^- - d_{3U}^+ = 228776 \text{ (Winter)} \tag{43}$$

2. Productive resource goals:
   a. Machine-hour requirement goals:

$$210x_{11} + 430x_{21} + 210x_{22} + 119x_{32} + 822x_{23} + 210x_{43} + 105x_{53} + 345x_{63} + 105x_{73} + d_{4L}^- - d_{4L}^+ = 4865000,$$

$$198x_{11} + 420x_{21} + 200x_{22} + 102x_{32} + 805x_{23} + 200x_{43} + 98x_{53} + 332x_{63} + 95x_{73} + d_{4U}^- - d_{4U}^+ = 49776000 \tag{44}$$

   b. Man-power requirement goals

$$94x_{11} + 64x_{21} + 63x_{22} + 31x_{32} + 65x_{23} +$$

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$$43x_{43} + 34x_{53} + 74x_{63} + 34x_{73} + d_{5L}^{-} - d_{5L}^{+} = 16395000,$$

$$86x_{11} + 57x_{21} + 56x_{22} + 28x_{32} + 55x_{23} + 36x_{43} + 27x_{53} + 66x_{63} + 26x_{73} + d_{5U}^{-} - d_{5U}^{+} = 17177000 \quad (45)$$

c. Fertilizer requirement goals:

$$56x_{11} + 63x_{21} + 85x_{22} + 52x_{32} + 155x_{23} + 115x_{43} + 85x_{53} + 290x_{63} + 55x_{73} + d_{6L}^{-} - d_{6L}^{+} = 35000000,$$

$$45x_{11} + 58x_{21} + 75x_{22} + 48x_{32} + 145x_{23} + 105x_{43} + 75x_{53} + 260x_{63} + 45x_{73} + d_{6U}^{-} - d_{6U}^{+} = 38590000 \text{ (Fertilizer } N\text{)}$$

$$22x_{11} + 33x_{21} + 34x_{22} + 30x_{32} + 82x_{23} + 58x_{43} + 45x_{53} + 190x_{63} + 28x_{73} + d_{7L}^{-} - d_{7L}^{+} = 19800000,$$

$$19x_{11} + 26x_{21} + 30x_{22} + 24x_{32} + 78x_{23} + 52x_{43} + 35x_{53} + 165x_{63} + 22x_{73} + d_{7U}^{-} - d_{7U}^{+} = 20670000 \text{ (Fertilizer P)}$$

$$20x_{11} + 28x_{21} + 34x_{22} + 24x_{32} + 82x_{23} + 53x_{43} + 35x_{53} + 190x_{63} + 18x_{73} + d_{8L}^{-} - d_{8L}^{+} = 18000000,$$

$$18x_{11} + 22x_{21} + 30x_{22} + 18x_{32} + 78x_{23} + 47x_{53} + 25x_{53} + 165x_{63} + 12x_{73} + d_{8U}^{-} - d_{8U}^{+} = 18980000 \text{ (Fertilizer } K\text{)} \quad (46)$$

3. Budget allocation goals:

$$18.85x_{11} + 21.35x_{21} + 22.75x_{22} + 19.75x_{32} + 36.97x_{23} + 25.04x_{43} + 18.79x_{53} + 61.39x_{63} + 14.59x_{73} + d_{9L}^{-} - d_{9L}^{+} = 15455030,$$

$$18.66x_{11} + 21.05x_{21} + 22.25x_{22} + 19.25x_{32} + 36.43x_{23} + 24.97x_{43} + 18.52x_{53} + 59.25x_{63} + 14.17x_{73} + d_{9U}^{-} - d_{9U}^{+} = 16978454 \quad (47)$$

4. Crop production goals
   a. *Total seasonal crop production goals.*

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$$2755x_{11} + d_{10L}^{-} - d_{10L}^{+} = 45060000,\ 2731x_{11} + d_{10U}^{-} - d_{10U}^{+} = 46120000;\ \text{(Jute)}$$

$$4401x_{21} + d_{11L}^{-} - d_{11L}^{+} = 279560000,\ 4324x_{21} + d_{11U}^{-} - d_{11U}^{+} = 300250000;\ \text{(Aus-paddy)}$$

$$4365x_{22} + d_{12L}^{-} - d_{12L}^{+} = 710330000,\ 4323x_{22} + d_{12U}^{-} - d_{12U}^{+} = 735450000;\ \text{(Aman-paddy)}$$

$$2236x_{32} + d_{14L}^{-} - d_{14L}^{+} = 23720000,\ 2198x_{32} + d_{14U}^{-} - d_{14U}^{+} = 25760000;\ \text{(Groundnut)}$$

$$5148x_{23} + d_{13L}^{-} - d_{13L}^{+} = 357720000,\ 5115x_{23} + d_{13U}^{-} - d_{13U}^{+} = 372670000;\ \text{(Boro-paddy)}$$

$$2432x_{43} + d_{15L}^{-} - d_{15L}^{+} = 6140000,\ 2380x_{43} + d_{15U}^{-} - d_{15U}^{+} = 6940000;\ \text{(Wheat)}$$

$$1078x_{53} + d_{16L}^{-} - d_{16L}^{+} = 9500000,\ 1025x_{53} + d_{16U}^{-} - d_{16U}^{+} = 10170000;\ \text{(Mustard)}$$

$$27537x_{63} + d_{17L}^{-} - d_{17L}^{+} = 3218730000,\ 27490x_{63} + d_{17U}^{-} - d_{17U}^{+} = 32500000\ \text{(Potato)} \tag{48}$$

b. *Major food-grain crop production goals.* The crops Paddy and Wheat are the major food-grain sources across the countries. Therefore, a convex combination of annual production of Paddy and Wheat with certain target interval is considered to supply the demand of major food-grains. The model goals associated with the defined interval goals appear as:

$$\begin{aligned}&\beta_2(4.401.x_{21} + 4.365.x_{22} + 5.148x_{23}) + 2.432\beta_4 x_{43} + d_{19L}^{-} - d_{19L}^{+} = 1356.814,\\ &\beta_2(4.324.x_{21} + 4.323.x_{22} + 5.115x_{23}) + 2.380\beta_4.x_{43} + d_{19U}^{-} - d_{19U}^{+} = 1377.140\end{aligned} \tag{49}$$

5. *Crop production ratio goals.* In the crop production system, it is to be noted that Jute is a single season based crop and it is only used as raw material for textile product. Therefore, ratio of production of Pre-khariff crops, i.e., ratio of Jute and Aus-paddy would have to be maintained with a view to make adequate production of Jute depending on the needs in society. The model goals for the defined ratio appear as:

$$2.73x_{11} - 5.501x_{21} + d_{21L}^{-} - d_{21L}^{+} = 0,\ 2.755x_{11} - 5.189x_{21} + d_{21U}^{-} - d_{21U}^{+} = 0\ \text{(Jute and Aus Paddy)} \tag{50}$$

6. Annual profit goals:

$$\begin{aligned}&10272.50x_{11} + 29561.5x_{21} + 21400x_{22} + 8638x_{32} + 20455.40x_{23} +\\ &10970x_{43} + 14520.70x_{53} + 73832x_{63} + 12216x_{73} + d_{20L}^{-} - d_{20L}^{+} = 1451758000,\end{aligned}$$

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$$4914.7x_{11} + 18647x_{21} + 17021.60x_{22} + 6075x_{32} + 11525.50x_{23} + 7095x_{43} + 11513x_{53} + 48205x_{63} + 9569x_{73} + d^{-}_{20U} - d^{+}_{20U} = 1453267000 \tag{51}$$

7. Water supply goals:
   a. Canal-water supply goals

$$\sum_{s=1}^{3} CW_s + d^{-}_{22L} + d^{-}_{22L} = 1555.5, \sum_{s=1}^{3} CW_s + d^{-}_{22U} + d^{-}_{22U} = 1635.37 \tag{52}$$

   b. Groundwater supply goals

$$\sum_{s=1}^{3} GW_s + d^{-}_{23L} + d^{-}_{23L} = 1355.45, \sum_{s=1}^{3} GW_s + d^{-}_{23U} + d^{-}_{23U} = 1443.33 \tag{53}$$

Now, the constraints in crop production system are discussed as follows.

Construction of Constraints

Water Supply Constraints

1. Reserve-Water Utilization Constraints

It is to be noted that the chance of regular rainfall is very low during Summer season, and cultivation mainly depends on supply of water from reserve-water sources. Again, although Rainy and Winter are the major cropping seasons, the chance of precipitation in rainy season is very high and water consumption in winter is lower than the other two seasons. As such, utilization of cannel-water and groundwater for production of Pre-khariff crops are considered 60% and 50%, respectively, of their total amounts earmarked for supply to agriculture sector all over the seasons of the plan period.

Following the expression in (38), the affinity constraints can be presented as:

$$CW_1 \leq 0.60 \sum_{s=1}^{3} CW_s \, , \, GW_1 \leq 0.50 \sum_{s=1}^{3} GW_s \tag{54}$$

2. Total Water Utilization Constraints

The optimal yields of all the seasonal crops depend on how the probability levels of total water utilization constraints are satisfied during the cropping seasons. The satisficing levels of probabilities in the three successive cropping seasons, Pre-kharif, Kharif and Rabi, are considered 0.90, 0.85 and 0.65, respectively, which are depended on the needs of watering during the respective seasons.

Following the procedure and using the data in Table 2, the mean and variance pairs

$(E(RW_s), Var(RW_s))$, $s = 1, 2, 3,$

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associated with the successive seasons are obtained as (455.00, 18782.92), (897.45, 45514.89), (53.64, 393.94).

Then, following the expression in (39), the deterministic equivalents of probabilistic constraints for three cropping seasons are obtained as:

$$5.02x_{11} + 8.64x_{21} - (CW_1 + GW_1) \leq 331.65 \text{ (Summer)}$$

$$12.70x_{32} + 2.55x_{42} - (CW_2 + GW_2) \leq 715.66 \text{ (Rainy)}$$

$$17.87x_{53} + 3.82x_{63} + 2.55x_{73} + 4.57x_{83} + 2.86x_{93} - (CW_3 + GW_3) \leq 40.10 \text{ (Winter)} \quad (55)$$

Then, *priority based* EGP model can be constructed by using the expressions in (23) and (24).

In the execution process, five priority factors P_1, P_2, P_3, P_4 and P_5 are defined to include the model goals in (43)-(53). Three priority structures are considered to execute the problem under three successive Runs and then to perform sensitivity analysis on model solution.

Now, the general executable EGP model is obtained as follows.

Find $\{x_{11}, x_{21}, x_{22}, x_{32}, x_{23}, x_{43}, x_{53}, x_{63}, x_{73}\}$ so as to:

Minimize Z_p

and satisfy the goal expressions in (43) - (53), subject to the constraints in (54) and (55) with $0 < \beta_2, \beta_4 < 1,\ \beta_2 + \beta_4 = 1,$ and

$$d^-_{rkL} + d^+_{rkU} - V_r \leq 0,\ \ r \in \{1,2,3,4,5\};\ k \in \{1,2,\ldots,24\}$$

$$0 < \lambda_r < 1,\ r = 1,2,3,4,5. \quad (56)$$

where, β_2 and β_4 are associated with the goal expressions in (49).

The three priority achievement functions Z_p, $p = 1, 2, 3$, defined for the three successive Runs are presented in Table 4.

Now, for model simplification, $\lambda_r = 0.5, \forall r$, and $\beta_1 = \beta_2 = 0.5$ are taken into account for executions of problems under the three Runs, where equal weights are also given to goals included at the same priority level for achievement of their aspired levels.

Then, in course of solving the problem in (56), evaluation of the function $Z_p, (p = 1,2,3)$, is considered the fitness function in GA and execution is made step-by-step according to assigned priorities of model goals of the problem. Generation numbers = 300 is initially taken into account to conduct the experiment.

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Table 4. Priority achievement functions under the three Runs

Run	Priority Achievement Function (Z_p)
1	$Z_1 = \begin{bmatrix} P_1\left(\lambda_1 \sum_{k=18}^{20} w_{1k}(d_{1kL}^- + d_{1kU}^+) + (1-\lambda_1)V_1\right), P_2\left(\lambda_2 \sum_{k=10}^{16} w_{2k}(d_{2kL}^- + d_{2kU}^+) + (1-\lambda_2)V_2\right), \\ P_3\left(\lambda_3 \sum_{k=1}^{3} w_{3k}(d_{3kL}^- + d_{3kU}^+) + \lambda_3 \sum_{k=21}^{22} w_{3k}(d_{3kL}^- + d_{3kU}^+) + (1-\lambda_3)V_3\right), \\ P_4\left(\lambda_4(w_{49}(d_{49L}^- + d_{49U}^+) + \lambda_4 w_{4,17}(d_{4,17L}^- + d_{4,17U}^+)) + (1-\lambda_4)V_4\right), \\ P_5\left(\lambda_5 \sum_{k=4}^{8} w_{5k}(d_{5kL}^- + d_{5kU}^+) + (1-\lambda_5)V_5\right) \end{bmatrix}$
2	$Z_2 = \begin{bmatrix} P_1\left(\lambda_1 \sum_{k=1}^{3} w_{1k}(d_{1kL}^- + d_{1kU}^+) + \lambda_1 \sum_{k=21}^{22} w_{1k}(d_{1kL}^- + d_{1kU}^+) + (1-\lambda_1)V_1\right), \\ P_2\left(\lambda_2 \sum_{k=10}^{16} w_{2k}(d_{2kL}^- + d_{2kU}^+) + (1-\lambda_2)V_2\right), P_3\left(\lambda_3 \sum_{k=18}^{20} w_{3k}(d_{3kL}^- + d_{3kU}^+) + (1-\lambda_3)V_3\right), \\ P_4\left(\lambda_4(w_{49}(d_{49L}^- + d_{49U}^+) + \lambda_4 w_{4,17}(d_{4,17L}^- + d_{4,17U}^+)) + (1-\lambda_4)V_4\right), \\ P_5\left(\lambda_5 \sum_{k=4}^{8} w_{5k}(d_{5kL}^- + d_{5kU}^+) + (1-\lambda_5)V_5\right) \end{bmatrix}$
3	$Z_3 = \begin{bmatrix} P_1\left(\lambda_1 \sum_{k=10}^{16} w_{1k}(d_{1kL}^- + d_{1kU}^+) + (1-\lambda_1)V_1\right), P_2\left(\lambda_2 \sum_{k=18}^{20} w_{2k}(d_{2kL}^- + d_{2kU}^+) + (1-\lambda_2)V_2\right), \\ P_3\left(\lambda_3(w_{39}(d_{39L}^- + d_{39U}^+) + \lambda_3 w_{3,17}(d_{3,17L}^- + d_{3,17U}^+)) + (1-\lambda_3)V_3\right), \\ P_4\left(\lambda_4 \sum_{k=1}^{3} w_{4k}(d_{4kL}^- + d_{4kU}^+) + \lambda_4 \sum_{k=21}^{22} w_{4k}(d_{4kL}^- + d_{4kU}^+) + (1-\lambda_4)V_4\right), \\ P_5\left(\lambda_5 \sum_{k=4}^{8} w_{5k}(d_{5kL}^- + d_{5kU}^+) + (1-\lambda_5)V_5\right) \end{bmatrix}$

The genetic parameter values are considered as:

Probability of crossover $p_c = 0.8$

Probability of mutation $p_m = 0.08$

- Population size =100
- Chromosome length =150.

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The GA is implemented using the GA-Toolbox under MATLAB Optimization Tool (MATLAB-Ver. R2010a) to execute the problem. The execution is performed in Intel Pentium IV with 2.66 GHz, Clock-pulse and 4 GB RAM.

The land utilization decisions under three Runs are displayed in Table 5.

From the results displayed in Table 5, the ideal solution point, the elements of which correspond to the maximum of individual variable values achieved under the three Runs, is found as:

$(x_{11}, x_{21}, x_{22}, x_{32}, x_{23}, x_{43}, x_{53}, x_{63}, x_{73})$

= (16.500, 62.621, 163.878, 11.179, 69.557, 2.936, 8.812, 116.911, 29.374).

Then, the *Euclidean distances* of individual solutions of the successive three Runs from ideal solution are determined as:

$$D^{(1)} = 0.963, \qquad D^{(2)} = 23.839, \qquad D^{(3)} = 0.961.$$

The result shows that the minimum distance corresponds to $D^{(3)} = 0.961$.

Thus, the priority structure under Run 3 is acceptable one for optimal land allocation decision in the farm management system.

The resulting land allocation (in '000 *ha*) decision is obtained as:

$(x_{11}, x_{21}, x_{22}, x_{32}, x_{23}, x_{43}, x_{53}, x_{63}, x_{73})$

= (16.500, 62.621, 163.878, 10.608, 69.557, 2.935, 8.812, 116.911, 28.611).

The production of crops (in '000 *metric ton*) in interval forms are found as:

Jute = [45.46, 45.95], Aus-paddy = [270.812, 275.453], Aman-paddy = [706.257, 715.027],

Groundnut = [23.816, 24.719], Boro-paddy = [365.784, 378.079], Wheat = [6.985, 7.138],

Mustard = [9.032, 9.500], Potato = [3211.883, 3219.378], Sesame = [23.219, 23.576].

Table 5. Land allocation decisions under the three Runs

Land Allocation ('000 ha) Run	x_{11}	x_{21}	x_{22}	x_{32}	x_{23}	x_{43}	x_{53}	x_{63}	x_{73}
1	16.500	62.621	163.878	10.608	69.557	2.936	8.812	116.818	28.611
2	16.500	62.621	163.878	11.179	54.399	2.936	8.812	98.427	29.374
3	16.500	62.621	163.878	10.608	69.557	2.936	8.812	116.911	28.611

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Here, using the additive rule of interval arithmetic, the production of total Paddy in interval form is obtained as [1342.853, 1368.559].

In the context of above crop production achievements, it is to be noted that the utilization of canal-water and groundwater during all the seasons are 97.96% and 75.23%, respectively.

The interval of profit achievement (in *Rs. Lac*) = [145115.331, 145338.432].

The result indicates that the obtained solution is most satisfactory for crop production decision in inexact environment.

To illustrate more the effectiveness of the proposed method, the modelling aspect without considering any priority structure is considered.

EGP Model Without Priority Structure

If priorities are not considered, the model would be the conventional EGP model proposed by Inuiguchi, & Kume (1991).

Here, the executable model appears as follows.

Find $\{x_{11}, x_{21}, x_{22}, x_{32}, x_{23}, x_{43}, x_{53}, x_{63}, x_{73}\}$ so as to:

$$\text{Minimize } Z' = \{\lambda \sum_{k=1}^{K} w_k (d_{kL}^- + d_{kU}^+) + (1-\lambda)V\}$$

and satisfy the goal expressions in (43) - (53), subject to the constraints in (54) and (55) with $0 < \beta_2, \beta_4 < 1,\ \beta_2 + \beta_4 = 1,$ and

$$d_{kL}^- + d_{kU}^+ - V \leq 0\,,\ k=1, 2,\ldots, K \tag{57}$$

where, $V = [\max_{k=1}^{K}(d_{kL}^- + d_{kU}^+)]$,

Here, equal weights are also given to the model goals, that is, $w_k = 1/23, \forall k$, and $\beta_1 = \beta_2 = 0.5$ are considered in the executable model of the problem.

Then, the achieved land allocation (in '000 *ha*) decision is

$$(x_{11}, x_{21}, x_{22}, x_{32}, x_{23}, x_{43}, x_{53}, x_{63}, x_{73})$$

= (16.500, 62.621, 163.878, 10.608, 69.557, 2.936, 8.812, 116.911, 10.107)

The production of crops (in '000 *metric ton*) in interval form are obtained as:

Jute = [45.46, 45.95], Aus-paddy = [270.812, 275.453], Aman-paddy = [706.257, 715.027],

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Groundnut = [23.816, 24.719], Boro-paddy = [365.784, 378.079], Wheat = [6.985, 7.138],

Mustard = [9.032, 9.500], Potato = [3211.883, 3219.378], Sesame = [8.217, 8.492].

Here, the interval of total production of Paddy is found [1342.853, 1368.559].

The result shows that production achievement of Sesame is quite dissatisfactory in terms of the specified interval of demand, where the intervals for achievement of other crops are found acceptable with regard to meeting the need in society. Here, utilization of groundwater is found 8.32% more than that of the result obtained under the proposed method.

The interval of profit achievement (in *Rs. Lac*) = [145101.023, 145237.453], which is an inferior one in contrast to the result achieved by employing the *priority-based* IVGP method.

Therefore, it may be said that the EGP method is better than that of conventional IVGP method studied previously concerning achievement of pragmatic solution in inexact environment. However, to make a precise interpretation of using the proposed method, a performance comparison is made with possible crisp solutions of the results discussed under the above two approaches along with existing cropping plan of Hooghly district in the next section.

Illustration for Solution Comparison

The crisp version of the solutions for crop production and profit achievement obtained under the different approaches are presented as follows.

- Using the midpoint arithmetic rule of interval analysis, the achievement levels of production (in ’000 *metric ton*) of crops obtained under the proposed approach are as follows.

(Jute, paddy, Groundnut, Wheat, Mustard, Potato, Sesame)

= (45.705, 1355.706, 24.267, 7.062, 9.266, 3215.604, 23.60).

The achievement profit = *Rs.* 145226.283 *Lac.*

- If the crisp definitions of model parameters are considered by using the midpoint arithmetic rule, then the production levels (in ’000 *metric ton*) of crops are found as:

(Jute, paddy, Groundnut, Wheat, Mustard, Potato, Sesame)

= (45.705, 1355.706, 24.267, 7.062, 9.266, 3215.604, 8.354).

The achievement of profit = Rs. 145169.238 *Lac.*

- In a precise decision environment, the existing land utilization (in ’000 *ha*) decision for seasonal crops in the planning year (2011-2012) is

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(Jute, paddy, Groundnut, Wheat, Mustard, Potato, Sesame)

= (9.12, 203.42, 2.87, 1.96, 7.68, 72.45, 16.18).

The crop production (in '000 *metric ton*) decision is

(Jute, paddy, Groundnut, Wheat, Mustard, Potato, Sesame)

= (25.89, 879.24, 7.09, 3.42, 15.97, 1960.34, 15.56).

The achieved profit = *Rs*. 98673.59 *Lac*.

It may be mentioned here that the existing land allocation pattern for cropping plan is mostly adopted on the general prediction of demands of crops in society and not based on any planning model.

Now, the graphical representations of the above crisply defined solutions against crop production decision are displayed in Figure 2.

Similarly, the schematic presentations of crisply defined solutions against profit achievement decision are displayed in Figure 3.

Figure 2. Comparison of crop production under the two approaches and existing plan

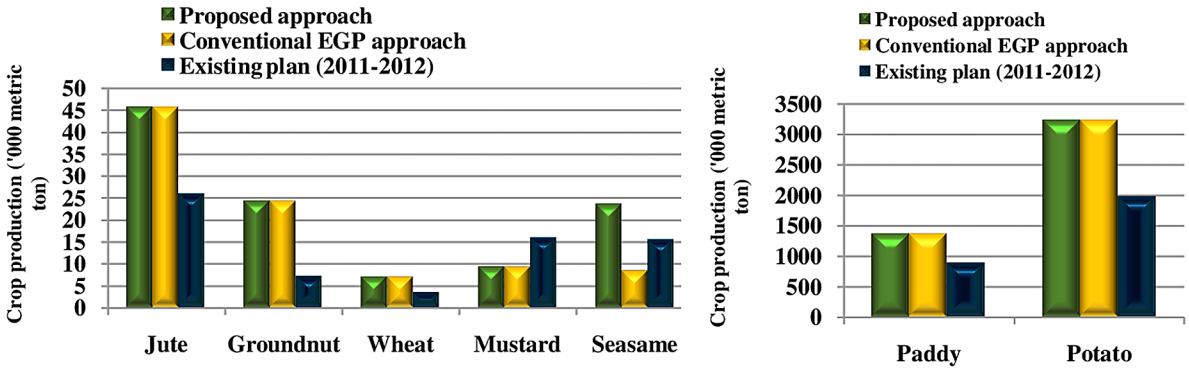
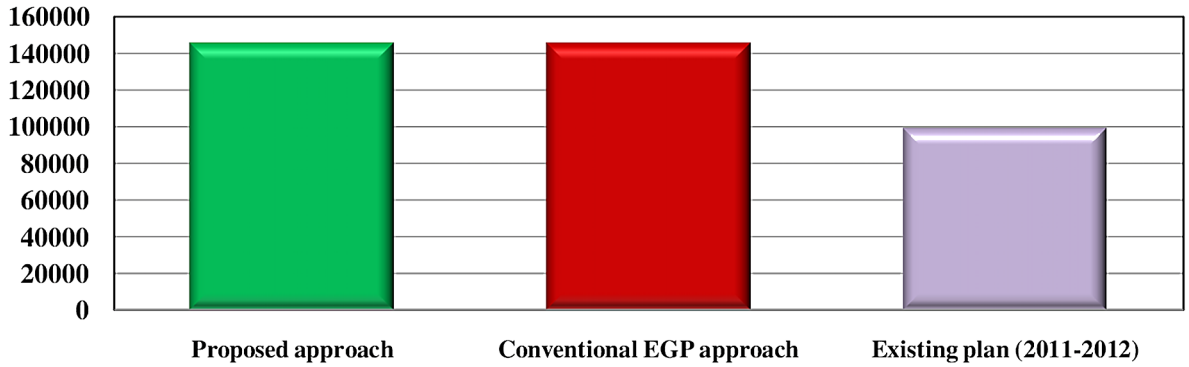


Figure 3. Comparison of profit achievement under the two approaches and existing plan



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The graphical comparisons indicate that the proposed approach is superior over other ones with regard to acceptable crop production decision.

Remark 1: It may be mentioned that, if any change of decision with regard to resource utilization as well as crop production is needed there in inexact environment, then that can be considered in the model with possible changes of interval parameters as well rearrangement of priorities of model goals of the problem.

Remark 2: With regard to implementation of the proposed model, the problem with involvement of computational load with rearrangement of priorities in different ways in solution search process may generally be raised in the context of management of farm. Because, if R be the total number of priorities, $R!$ priority structures may have to be considered there to search optimal solution. But, it is worth mentioning here that at most 'five' priority levels are typically involved (Ignizio, 1976) and the conflict to assign priorities occurs up to 'three' priority levels in actual practice in a decision environment.

FUTURE RESEARCH DIRECTIONS

In future study, the proposed approach can be extended to cropping plan for fuzzy description on bounds of interval data of model parameters with a view to further relaxation on resource utilization plan towards arriving at more effective crop production decision. Again, the possible extension of land under cultivation along with investment in rain-fed agriculture to improve environmental sustainability, agricultural waste-water management and other crop yielding criteria may be introduced in the model presented here, that are the emerging research problems with regard to take challenges for elimination of hunger and poverty in society. However, may be said that the study made in this chapter leads to open up new avenues to modeling agricultural problems in the current scenario of increasing demands of food grains in society.

CONCLUSION

In this chapter, a GA based EGP formulation of agricultural problems with interval model data under a set of chance constraints is presented. The study provides a new way of modeling and solving farm management problems in uncertain environment. Further, other different types of parameters and environmental constraints can be accommodated in the proposed model to make cropping plan towards meeting the demand of various food products in modern society.

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REFERENCES

Assavapokee, T., Realff, M. J., & Ammons, J. C. (2008). Min-max regret robust optimization approach on interval data uncertainty. *Journal of Optimization Theory and Applications*, *137*(2), 297–316. doi:10.100710957-007-9334-6

Basak, R. K. (2000). *Soil testing and fertilizer recommendation*. New Delhi: Kalyani Publishers.

Biswas, A., & Pal, B. B. (2005). Application of fuzzy goal programming technique to land use planning in agricultural system. *Omega*, *33*(5), 391–398. doi:10.1016/j.omega.2004.07.003

Bitran, G. R. (1980). Linear multiobjective problems with interval coefficients. *Management Science*, *26*(7), 694–706. doi:10.1287/mnsc.26.7.694

Blumenfeld, D. (2010). *Operations research calculations handbook*. New York: CRC Press.

Bravo, M., & Ganzalez, I. (2009). Applying stochastic goal programming: A case study on water use planning. *European Journal of Operational Research*, *196*(3), 1123–1129. doi:10.1016/j.ejor.2008.04.034

Campbell, B. M. S., & Overton, M. (1993). A new perspective on medieval and early modern agriculture: six centuries of Norfolk Farming, c.1250-c.1850. *Past and Present, 141*(Nov), 38-105. doi:.org/stable/651030

Charnes, A., & Cooper, W. W. (1959). Chance-constrained programming. *Management Science*, *6*(1), 73–79. doi:10.1287/mnsc.6.1.73

Charnes, A., Cooper, W. W., & Ferguson, R. (1955). Optimal estimation of executive compensation by linear programming. *Management Science, 1*(2), 138-151. doi:.org/stable/2627315

Chartres, C., & Varma, S. (2010). *Out of water. From Abundance to Scarcity and How to Solve the World's Water Problems*. FT Press.

Craenen, B. C. W., Eiben, A. E., & Marchiori, E. (2001). How to handle constraint with evolutionary algorithms. In L. Chambers (Ed.), The Practical Handbook of genetic algorithms applications (2nd ed.). Chapman & Hall/CRC.

Deb, K. (2002). *Multi-objective Optimization using Evolutionary Algorithm*. John Wiley & Sons Ltd.

District Statistical Hand Book. (2011). *Hooghly, Department of Bureau of Applied Economics and Statistic*. Govt. of West Bengal, India. Retrieved from http://hooghly.nic.in/agri/agriculture.htm

Glen, J. (1987). Mathematical models in farm planning: a survey. *Operations Research, 35*(5), 641-666. doi; doi:10.1287/opre.35.5.641

Goldberg, D. E. (1989). *Genetic algorithms in search, optimization, and machine learning.* Addison-Wesley.

Hansen, E. R. (2003). *Global optimization using interval analysis*. New York: Marcel Dekker Inc. and Sun Micro system Inc.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Hasan, B. H. F., & Saleh, M. S. M. (2011). Evaluating the effectiveness of mutation operators on the behaviour of genetic algorithms applied to non-deterministic polynomial problems. *Informatica*, *35*(4), 513–518.

Heady, E. O. (1954). Simplified presentation and logical aspects of linear programming technique. *Journal of Farm Economics, 36*(5), 1035-1054. doi:.org/stable/1234313

Holland, J.H. (1973). Genetic algorithms and optimal allocation of trials. *SIAM Journal of Computing, 2*(2), 88-105. doi:10.1137/0202009

Hulsurkar, S., Biswal, M. P., & Sinha, S. B. (1997). Fuzzy programming approach to multi-objective stochastic linear programming problems. *Fuzzy Sets and Systems*, *88*(3), 173–181. doi:10.1016/S0165-0114(96)00056-5

Ida, M. (2000). Interval multiobjective programming and mobile robot path planning. In New Frontiers in Computational Intelligence and its Applications. IOS Press.

Ida, M. (2003). Portfolio selection problem interval coefficients. *Applied Mathematics Letters*, *16*(5), 709–713. doi:10.1016/S0893-9659(03)00071-5

Ignizio, J. P. (1976). *Goal programming and extensions*. Lexington Books.

Ignizio, J. P. (1982). *Linear programming in single- and multiple-objective systems*. Englewood Cliffs, NJ: Prentice-Hall.

Inuiguchi, M., & Kume, Y. (1991). Goal programming problems with interval coefficients and target intervals. *European Journal of Operational Research*, *52*(3), 345–360. doi:10.1016/0377-2217(91)90169-V

Israel, B. A., & Robers, P. D. (1970). A decomposition method for interval linear programming. *Management Science*, *16*(5), 374–387. doi:10.1287/mnsc.16.5.374

Jiang, C., Han, X., Liu, G. R., & Liu, G. P. (2008). A nonlinear interval number programming method for uncertain optimization problems. *European Journal of Operational Research*, *188*(1), 1–13. doi:10.1016/j.ejor.2007.03.031

Kall, P., & Wallace, S. W. (1994). *Stochastic programming*. Chichester, UK: John Wiley.

Liu, B. (2003). *Theory and practice of uncertain programming*. Heidelberg, Germany: Physica-Verlag.

Mazoyer, M., & Roudart, L. (2006). *A history of World agriculture: From the Neolithic age to the current crisis*. New York: New York University Press.

Michalewicz, Z. (1996). *Genetic Algorithms + Data Structures = Evolution Programs* (3rd ed.). Berlin: Spriger-Verlag. doi:10.1007/978-3-662-03315-9

Molden, D. (Ed.). (2007). *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture*. London, UK: Earthscan.

Moore, R. E. (1966). *Interval analysis*. Prentice-Hall.

Moore, R. E. (1979). *Methods and applications of interval analysis*. Philadelphia: SIAM. doi:10.1137/1.9781611970906

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Nix, J. S. (1979). Farm management, the state of the art (or science). *Journal of Agricultural Economics*, *30*(3), 277–292. doi:10.1111/j.1477-9552.1979.tb02143.x

Norton, R. D., & Schiefer, G. W. (1980). Agricultural sector programming models: A review. *European Review of Agriculture Economics*, *7*(3), 229–264. doi:10.1093/erae/7.3.229

Ogryczak, W. (1997). Preemptive reference point method. In J. Climacao (Ed.), *Multicriteria Analysis* (pp. 156–157). New York: Spinger-verlag. doi:10.1007/978-3-642-60667-0_16

Olivera, C., & Antunes, C. H. (2007). Multiple objective linear programming models with interval coefficients –an illustrated overview. *European Journal of Operational Research*, *181*(3), 1434–1463. doi:10.1016/j.ejor.2005.12.042

Pal, B. B., & Chakraborti, D. (2013). Using genetic algorithm for solving quadratic bilevel programming problems via fuzzy goal programming. *International Journal of Applied Management Science*, *5*(2), 172–195. doi:10.1504/IJAMS.2013.053690

Pal, B. B., Chakraborti D., & Biswas, P., 2009. A genetic algorithm based hybrid goal programming approach to land allocation problem for optimal cropping plan in agricultural system. *IEEE Xplore Digital Library*, 181-186. doi:10.1109/ ICIINFS.2009.5429867

Pal, B. B., Gupta, S., & Chakraborti, D. (2010). A genetic algorithm based stochastic simulation approach to chance constrained interval valued multiobjective decision making problems. *IEEE Xplore Digital Library*, 1-7. doi:10.1109/ICCCNT.2010.5591826

Pal, B. B., & Kumar, M. (2013). Interval goal programming for economic - environmental Power generation-dispatch problems. *IEEE Xplore Digital Library*, 1-8. doi:10.1109/FUZZ-IEEE.2013.6622446

Pal, B. B., Kumar, M., & Sen S. (2012). Management decision making for proper academic personnel planning in university system - an intervalvalued goal programming approach. *International Journal of Applied Management Science, 4*(3), 284-310. doi:.2012.047678 doi:10.1504/IJAMS

Pal, B. B., & Moitra, B. N. (2003). A goal programming procedure for solving problems with multiple fuzzy goals using dynamic programming. *European Journal of Operational Research*, *144*(3), 480–491. doi:10.1016/S0377-2217(01)00384-8

Ravindran, A., Ragsdell, K. M., & Reklaitis, G. V. (2007). Linear Programming Engineering optimization: method and applications (2nd ed.). Academic Press.

Review, E. (2012). *Department of Bureau of Applied Economics and Statistic*. Govt. of West Bengal.

Romero, C. (1991). *Handbook of critical Issues in goal programming*. Oxford, UK: Pergamon Press.

Romero, C. (2004). A general structure of achievement functions for goal programming model. *European Journal of Operational Research*, *153*(3), 675–686. doi:10.1016/S0377-2217(02)00793-2

Sahinidis, N. V. (2004). Optimization under uncertainty: state-of- the- art and opportunities. *Computers and Chemical Engineering, 28*(6-7), 971-983. doi:.09.017 doi:10.1016/j.compchemeng.2003

Simon, H. A. (1945). *Administrative behaviour*. New York: The Free Press.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Slowinski, R. (1986). A multicriteria fuzzy linear programming method for water supply system development planning. *Fuzzy Sets and Systems*, *19*(3), 217–237. doi:10.1016/0165-0114(86)90052-7

Slowinski, R., Urbaniak, A., & Weglarz, J. (1983). Bicriterion capacity expansion planning of a water supply system. *Mathematics of Operations Research*, *46*, 733–744.

Taguchi, T., Ida, K., & Gen, M. (1998). A Genetic Algorithm for Optimal Flow Assignment in Computer Network. *Computers & Industrial Engineering*, *35*(3-4), 535–538. doi:10.1016/S0360-8352(98)00152-1

Wheeler, B. M., & Russell, J. R. M. (1977). Goal programming and agricultural planning. *Operational Research Quarterly, 28*(1), 21-32. doi: jstor.org/stable/3008887

Yeh, W. W. G. (1985). Reservoir management and operations models: a state-of-the-art review. *Water Resources Research, 21*(12), 1797-1818. doi: 021i012p01797 doi:10.1029/WR

Yu, P. L. (1973). A class of solutions for group decision problems. *Management Science*, *19*(8), 936–946. doi:10.1287/mnsc.19.8.936

Zadeh, L. A. (1965). Fuzzy Sets. *Information and Control*, *8*(3), 338–353. doi:10.1016/S0019-9958(65)90241-X

Zimmermann, H.-J. (1987). *Fuzzy Sets, Decision Making and Expert Systems*. Boston: Kluwer Academic. doi:10.1007/978-94-009-3249-4

ADDITIONAL READING

Askew, A. J. (1974). Chance-constrained dynamic programming and the optimization of water resource systems. *Water Resources Research, 10*(6), 1099-1106. doi: p01099 doi:10.1029/WR010i006

Cullather, N. (2010). *The hungry world: America's cold war battle against poverty in Asia. America*. Harvard University Press.

Pal, B. B., & Basu, I. (1996). Selection of appropriate priority structure for optimal land allocation in agricultural planning through goal programming. *Indian Journal of Agricultural Economics*, *51*, 342–354.

Pal, B. B., & Kumar, M. (2013). Interval goal Programming for economic - environmental power generation-dispatch problems. *IEEE Xplore Digital Library,* 1-8. doi:10.1109/FUZZ-IEEE.2013.6622446

KEY TERMS AND DEFINITIONS

Farm Planning: Proper allocation of cultivable land for optimal production of several seasonal crops by utilizing different productive resources.

Fractional Programming: Special field of study in the area of mathematical programming, where certain objective functions appear in the form of ratios for optimizing them in the decision environment.

Genetic Algorithm: Genetic algorithm is an adaptive heuristic search algorithm based on the evolutionary ideas of natural selection and genetics in living system.

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Goal Programming: Goal programming is a goal-oriented optimization technique to solve decision problems with multiplicity of objectives in crisp environment.

Interval Programming: Interval programming is the modelling aspects of optimization problems in which model parameters are defined in the form of bounded intervals.

Stochastic Programming: Stochastic programming is an optimization technique for solving problems with probabilistically defined data in uncertain environment.

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Chapter 34
Mobile Vision for Plant Biometric System

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ABSTRACT

In human's life plant plays an important part to balance the nature and supply food-&-medicine. The traditional manual plant species identification method is tedious and time-consuming process and requires expert knowledge. The rapid developments of mobile and ubiquitous computing make automated plant biometric system really feasible and accessible for anyone-anywhere-anytime. More and more research are ongoing to make it a more realistic tool for common man to access the agro-information by just a click. Based on this, the chapter highlights the significant growth of plant identification and leaf disease recognition over past few years. A wide range of research analysis is shown in this chapter in this context. Finally, the chapter showed the future scope and applications of AaaS and similar systems in agro-field.

INTRODUCTION[1]

At the beginning of this century, there was a tremendous technological revolution in the field of wireless communication and mobile technology. Mobile and ubiquitous computers are increasing their magnitude in every small, portable, wireless computing and communication fields. The technological omnipresence of ubiquitous devices invisibly activates the world by providing accessibility *anywhere-anytime* computing. However, this revolution is still slow in the agricultural sphere, despite the advancements in technologies making it possible to build and deploy wireless sensor networks (WSN) in fields that would radically improves the farming efficiencies. This is because the current wireless technologies are too expensive and complicated for farmers to use especially in the developing countries like India. Two-way radios have long been used by farmers in many such developed countries with large farmlands to contact their employees, farm suppliers, equipment dealers, agents, buyers and farm awareness. Today, world-wide availability of smartphones and cellular networks, the use of mobile phones in agricultural sector is popularly, replacing the use of two-way radios (Wang, Li, Zhu, & Xu, 2016). The advantage of using two-way radios and mobile phones is that these wireless tools are relatively cheap and very simple

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to use. Additionally, smartphones have several important advantages such as all the brands of mobile phones are generally compatible for running various types of application software, and are equipped with Wi-Fi, Bluetooth, camera(s) and GPS capabilities.

In Asia-Pacific region, India has outscored the other nations in terms of the number of mobile users. With such rapidly increasing tele-density, mobile penetration in rural areas is also growing strongly. These days, mobile phones are available to people even in rural India, especially among the agrarian community. Motivated by the advancement in mobile technology and the wide-spread use of phones in India, as discussed above, researchers are aiming to help the illiterate agrarian community to improve their agricultural activities through the use of mobile phones. Thus, a new agro-information technology needs to be introduced in order to bridge the gaps between the real and digital objects via mobile computing (MC) and augmented reality (AR).

Agricultural Scenario

In developing countries, agriculture accounts the major role of rural employment and holds the promise for socio-economic growth. In fact, agro-community is roughly five-times more effective in raising the income of poor farmers compared to any other sector. Agricultural improvement also directly impacts on the hunger and malnutrition and thus plays a significant role in decreasing the occurrences of famine. However, the growing global population has heightened the demand for foods. Due to the lack of infrastructure in rural areas, raising the food prices and the climatic change and the real effective and "smart" agriculture is essential. Together with geographic information systems (GIS) and virtual reality (VR) smartphones can play an important role in precision agriculture environment (Bakhsh, Colvin, Jaynes, Kanwar, & Tim, 2000; Jain, Tim, & Jolly, 1995; Tim, 1995). Some of the uses of on-farm wireless network technologies in improving the agricultural productions are discussed in (Vellidis et al. 2007; Izzat, Ismail, Mehat, & Haroon, 2009; Revenaz, Ruggeri, & Martelli, 2010).

Mobile-Based Agriculture

Information and Communication Technology (ICT), particularly mobile technologies, are often seen as the 'game changer' in agro-community. The already existing *m*-Agricultural information system provides a giant leap in agriculture that offers a plethora of services, serving as a tool for information dissemination (Brugger, 2011). Various mobile-based services such as Internet-based, SMS-based information services (Gore, Lobo, & Doke, 2012), voice-based agro-advisory services like mKRISHI -(Shinde et al. 2014), and videos over mobile networks (Pande, Jagyasi, & Choudhuri, 2009) are utilized for transferring general knowledge about the farming techniques and trends, information of the plants and their varieties regarding how to keep them disease free. The general awareness in India by using *m*-Agriculture techniques since last decade are listed in Figure 1. But due to the limited and disconnected services they did not server the real needy.

Specifically, *m*-Agriculture refers to the delivery of agriculture-related services via mobile communication technology (Brugger, 2011). In order to make decisions on agricultural measures, it provides an individual decision support systems and services. These decision are based on the local contextual information, *i.e.*, delivering location-specific information like climatic patterns, soil and water conditions. Here, *m*-Agricultural termed to involve gathering of related information through mobile technologies like automated weather stations or sensors used in mobile. Thus, *m*-Agriculture involves a two-way advisory

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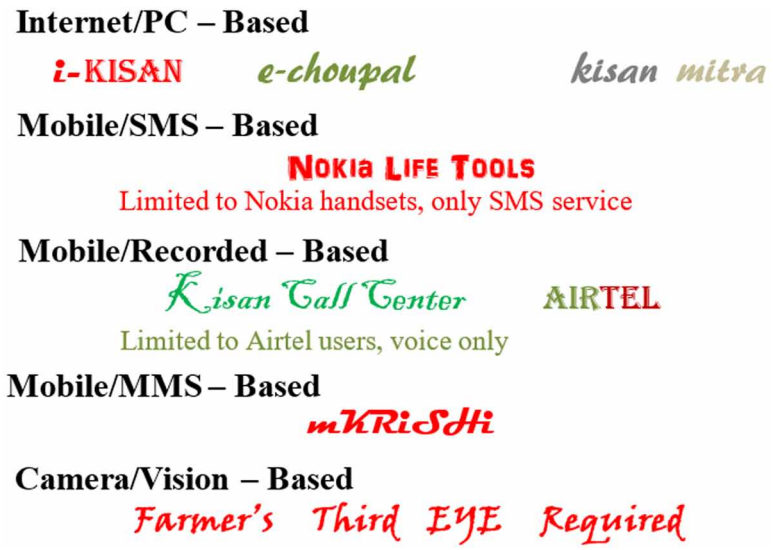
Figure 1. Mobile-based ICT agro-services launched in India



systems that provides individual feedbacks and advices like remote diagnosis of diseases by experts using some fertilizers/chemicals. These advisory systems typically include smartphones and intermediaries for wireless communication with the farmers and require remote sensing instruments like GIS.

m-Agriculture projects are built on the opportunities to increase the use of mobile/ubiquitous devices by farmers in the developing countries. Therefore, the primary objective of this chapter is to project such mobile-based vision systems for plant species identification and disease diagnosis using plant leaf imaging. Why an agro-vision system? Because famers or the other illiterate (non-botanical) person may not be able to explain the exact visual symptoms occurred on the crop to the expert to get a proper solution for the problem(s).

Motivation

The biodiversity is rapidly disappearing and we are losing the opportunities to know and understand the complexity of our mother-nature. Smart technologies are indispensable in order to rapidly identify the species and access the biodiversity information. If possible, it also develops the eco-informatics expert systems. Thus, mobile-based automated plant biometric system to automatically segment leaf from a complex background, followed by leaf analysis to identify the plant species, and diagnose the diseases on the leaf, is a need.

Currently, there are several plant classification methods such as plant genetics method, cytotaxonomy method and chemotaxonomy method. Plant species classification is not only botanic, but also is the foundation of ecology, medicine and life science (Wang, Li, Zhu, & Xu, 2016). According to a survey conducted in 2003, botanists claimed that to identify more than 3,15,000 plant species the key features used are fruits, flowers, stems, roots and leaves (Scotland & Wortley, 2003). Different types of plant leaves are shown in Figure 2. However, fruits and flowers are seasonal and may not be available throughout a year for identification purpose, while roots and stems are difficult to analyze. This is not the case with a plant leaf. It is available throughout the year and can easily be photographed; containing

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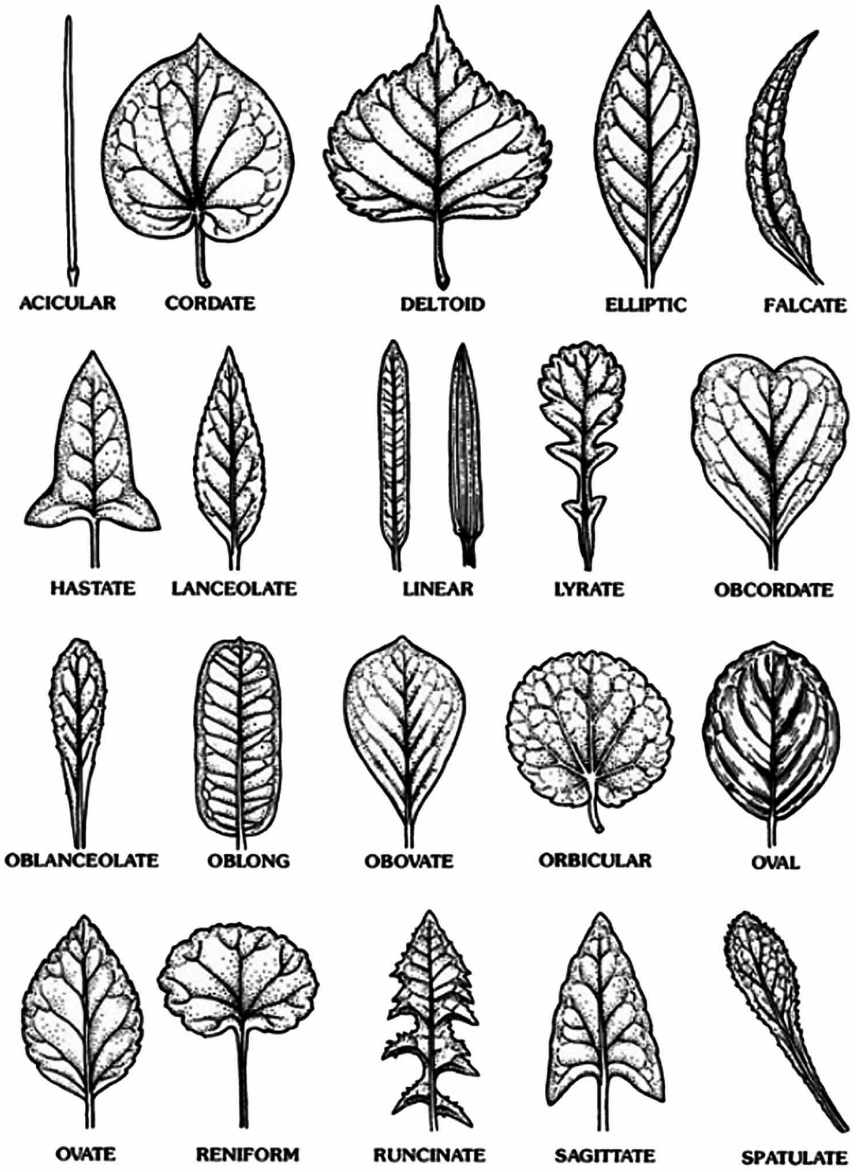
Figure 2. The common shapes of simple leaves (Plant Glossary, 2009)



sufficient information for species analysis. As a result, majority of the existing techniques are based on plant leaf features such as leaf shape, leaf margin, leaf vein and leaf texture (Cope, Corney, Clark, Remagnino, & Wilkin, 2012).

Some of the basic plant leaf shapes with their venation details are shown in Figure 2. These features are well explanatory in real world but for virtual or digital world they are mathematically represented using various transforms in both spatial and frequency domain (Cope et al., 2012). In this chapter, both spatial and frequency domain representations of plant leaf features are highlighted for further analysis (specie or disease recognition).

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The chapter, especially focus on the novel techniques used for plant identification and disease diagnosis. The graphical abstract of the proposed system is shown in Figure 3 where the crop leaf (object) is photographed via mobile/ubiquitous device, and subsequently represented mathematically in feature space which is then projected for classification using an optimal classifier.

The next few sections describe the existing automated plant biometric systems and their limits with their comparison and results.

BACKGROUND

As discussed, the manual monitoring and experimenting involves human expertise which is a tedious, time consuming, brittle and frustrating practice. Users need to traverse a decision tree manually to make a decision related to species, as shown in Figure 4(a). Botanists collect the specimens and preserve them in herbaria like Royal Botanical Gardens, Kew in London[2] (Kumar et al. 2012), as shown in Figure 4(b). The herbarium can be seen as a major collection of experts' knowledge in form of a structured repository and thus, to facilitate the access they are being digitized with images of species, dates, locations and so on.

In computer vision (CV) and pattern recognition (PR), feature representation and feature selection are the most important aspect of research since many decades. Various image processing and machine learning algorithms such as neural network (NN), support vector machine (SVM), and *k*-nearest neighbor (*k*-NN)

Figure 3. The graphical abstract of the proposed system

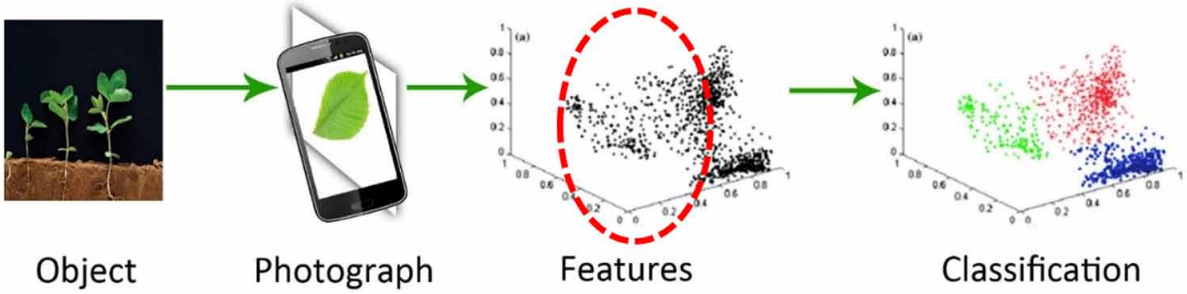
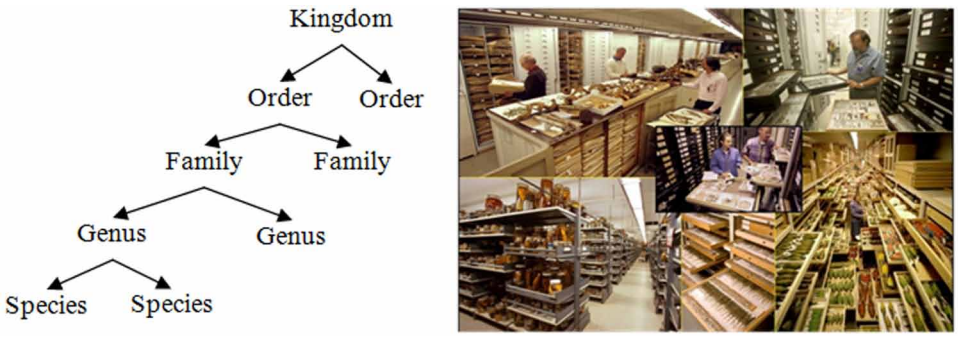


Figure 4. (a) Hierarchy of biodiversity classification and (b) bio-specimens herbaria



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are used in different domains like medical imaging (Orr, Peersson, Marquand, Sartori, & Mechelli, 2012), surveillance (Pogorelc, Bosni, & Gams, 2012), object recognition, species identification (Kumar et al. 2012) and designing automated defence systems (Heinze, Goss, & Pearce, 1999). The development and ubiquity of technologies like mobile cameras and mobile processors in related fields have brought such ideas close to the reality (MacLeod, Benfield, & Culverhouse, 2010). Therefore, various CV systems have been proposed for plant identification using their fruits, flowers or leaves[3], especially morphological studies, e.g., Tilia (Schneider, 1912), Ulmus (Melville, 1937), Betula (Natho, 1959) and many more.

There are many aspects of plants that are used by botanists in identification such as the 2-dimensional outlines of leaf, veins of leaf, margin of leaf and texture of leaf. Among these, leaf shape information is the mostly exposed and popular method among CV researchers. The two well know mobile applications launched in market for species identification are *LeafSnap* and *Leafview*. Both uses the leaf shape information for plant leaf identification via iPhone, as shown in Figure 5(a-b). *LeafZone*[4] (Figure 5c) is another app that not only identifies the plant species but also provides information about the effect of ozone on them making it more exciting for people to know their nature.

Leaf-Shape-Based Identification

Leaf shape has the maximum discriminative power among all the other parts of a plant. At the same time, leaves of the same plant may have different shapes and size. Over it, leaves of different species may have similar characteristic shape. As discussed above, the existing algorithms used to extract shape information in the frequency domain from a leaf I^3_{leaf} are Fourier analysis (McLellan & Endler, 1998), elliptic Fourier descriptors (EFDs) (Neto, Meyer, Jones, & Samal, 2006) and Fourier harmonics (Hearn, 2009). Following this, Principal Component Analysis (PCA) was also applied to reduce the dimensionality of the feature-space for efficient classification. The advantage of using such methods is that the shape can be reconstructed from its descriptors and are rotation invariant. Recently, EFDs was also used by different authors for leaf shape analysis (Andrade, Mayo, Kirkup, & Van-Den-Berg, 2008; Lexer et al. 2009; Neto et al. 2006). Next, a number of approach uses contour signatures for leaf shape classifica-

Figure 5. (a) LeafSnap, (b) LeafView, and (c) Leafzone are the popular electronic plant information systems

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tion such as the morphological description (Cope et al. 2012) and the centroid-contour distance (CCD) (Wang, Chi, & Feng, 2003). CCD is a sequence of distances between the center pixel to the contour of the object and hence, suffers from orientation problem. The other signatures include centroid-angle and tangents of the leaf outline. Meade and Parnell (2003) and Wang, Chi, and Feng (2003) attempted to increase the CCD accuracy when applied on leaf shape identification. A new time-series shapelets approach to calculate local features was proposed by Ye and Keogh (2009) and Prasad, Kumar, and Ghosh (2016). But a major difficulty with these contour based signatures is that they are sensitive to self-intersection which occurs quite often with multiple lobe leaves and in compound leaves. Prasad, Kumar, and Ghosh (2016) overcomes with this limitation to some extent. Another common approach for shape extraction is the use of movement invariant (MI) features (Zulkifli, Saad, & Mohtar, 2011), region-based features (Lee & Chen, 2006), and others. Warren (1997) proposed an automated system to recognize plant genus "Chrysanthemum" with thirty species. In Warren (1997), three basic mathematical descriptors such as the shape, color and size of leaf, flower and petal were used to identify the species. Similarly, authors (White, Marino, & Feiner, 2006 & 2007; White, Feiner, & Kopylec, 2007), used a morphological descriptor for shape information extraction from a complete leaf image. They designed a mobile vision Tablet-PC-based electronic field guide to identify plant leaves for the use of botanists and others to make their work much easier. Since *LeafSnap* is designed for iOS, Zhao et al. (2015), proposed *ApLeaf*, an Android based replica of *LeafSnap* with few pros-and-cons. Thus, Multiscale-ARCH-height (MARCH) a shape-based algorithm for mobile devices to retrieve plant leaf image was introduced in Wang, Brown, Gao, and Salle (2015).

In Prasad, Kumar, and Ghosh (2013b), the authors proposed a mobile plant identification system with a statistical leaf shape information. Here, they used the reduced shape and color mean information where the leaf image was down sampled to an acceptable and feasible limit which is optimal for mobile-level computing. The first step in this was to capture an isolated constant background plant leaf image I^3_{leaf} using mobile camera. The pre-processing step is minimal or negligible due to the above pre-segmented input leaf. The shape and color features are extracted and used for classification after limiting I^3_{leaf} to a fixed window size to make the approach translation and scale invariant.

Since shape or color cannot be used individually for a reliable leaf classification, as they may vary with different conditions and locations, researchers applied a decision level fusion to avoid such problem(s). The first level decision is based on shape information which is subsequently verified in the second level using color features (Prasad, Kumar, & Ghosh, 2013b). For the purpose of shape feature extraction, geometric features (elongation, roundness, circularity and porosity) and polar Fourier transform features were used. On the other hand, for color features, the mean, standard deviation, skewness and kurtosis were derived (Prasad, Kumar, & Ghosh, 2013b). To test the functionality two different datasets were used: Flavia dataset[5] and a set of hundred plant species dataset (Wu et al. 2007) with an accuracy of 91.34% and 76.21%, respectively. Other than this, few other authors have used some very specific leaf features to identify plant species, such as the leaf lobedness (Pauwels, Zeeuw, & Ranguelova, 2009) and fractal combined with Linear Discriminant Analysis (LDA) (Bruno, deOliveira Plotze, Falvo, & deCastro, 2008). It is found that fractal features are significant only if used with the combination of other features. In 2006, Du, Huang, Wang, and Gu proposed a polygonal representation of plant leaves for comparison limiting the method to a more generic tasks.

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Leaf Veins and Margin-Based Identification

The second commonly used leaf information is its vein pattern. The common leaf vein structure are shown in Figure 2. The veins provides structure to a leaf and thus, the vein pattern of a leaf can serve as a measure for its identification. The algorithms proposed in these are Independent Component Analysis (ICA) (Li, Chi, & Feng, 2006) and Artificial Ant Swarm Intelligence (AASI) (Mullen, Monekosso, Barman, Remagnino, & Wilkin, 2008) to extract leaf edge and leaf vein patterns for species recognition. Cope, Remagnino, Barman, and Wilkin (2010) used Genetic Algorithm (GA) to identify vein pixels and non-vein pixels. Whereas, vein extraction is best achieved by using threshold and neural network approach, as claimed by Fu and Chi (2006). Some other similar methods are discussed by Nam, Hwang, and Kim (2008) and Park, Hwang, and Nam (2008).

The third information used to classify a plant species is by its leaf margin. However, it is not a perfect feature and, therefore, generally used only in combination with other features. The leaf margin often consists of teeth pattern, as shown in Figure 1, which offers a small contribution in automated plant species recognition. Clark (2004) used multi-layer perceptron for identifying species and in Clark (2009), he used a hair descriptor as one of the features in self-organizing map (SOM) for Tilia classification. Rumpunen and Bartish (2002) used a manual measure to calculate the angle and length of the leaf tooth. If undamaged leaves are available, then leaf margin may be a good option for the purpose. On the other hand, leaf vein combined with leaf margin may perform well in damaged leaf cases. But for taxa that do not have teeth, it may fail.

Leaf-Texture-Based Identification

Last but the most important information of a plant leaf is its texture and so many novel techniques have been proposed using it. The size and color of plant leaf varies arbitrarily and even in a single plant two leaves may have different sizes. Thus, the algorithm needs to be translation, scale and rotational invariant, as in case of Curvelet transform (CT) (Prasad, Kumar, & Tripathi, 2011). Image texture quantifies the perceived texture of an image and can be calculated using either structural approach or statistical approach. Backes, Gonalves, Martinez, and Bruno (2010) proposed multi-scale fractal approach to represent the texture of leaf and used neural network for classification. Other methods based on Gabor transform (GT) (Casanova, de Mesquita, & Brun, 2009; Cope et al. 2010, 2012), wavelet transform (Liu et al., 2009) and Relative sub-Image Coefficient (RSC) feature (Prasad, Kundiri, & Tripathi, 2011a) were proposed to extract leaf texture for species recognition.

In 2014, Yanikoglu, Aptoula, and Tirkaz used shape-texture-color features to identify plant species from photographed images with a maximum accuracy of 81% in various lighting, poses, and orientation conditions. Finally, each method has its own pros and cons. It is conjectured that texture combined with contour-based shape analysis may be the best solution in the present context.

The plant biometric also entered into the deep learning and come up with several convolutional approaches for plant leaf species classification (Lee, Chan, Wilkin, & Remagnino, 2015; Sünderhauf, McCool, Upcroft, & Perez, 2014; Reyes, Caicedo, & Camargo, 2015; Jassmann, 2015).

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Based on Flowers and Other Parts of Plants

In the literature, there is a dearth of research done on leaf lamina feature extraction using wavelet and Gaussian interpolation (Gu, Du, & Wang, 2005). To other extent, 3D image processing has also been proposed for leaf feature extraction (Ma et al. 2008). They combined 2D leaf images to extract 3D leaf structure and together with 2D and 3D information, leaf boundary segmentation is achieved by applying normalized-cuts. They applied CCD for classifying leaf into palmate and cordate. Similarly, Teng, Kuo, and Chen (2009) used stereo imaging and stereo matching for the same purpose.

A number of approaches have also been proposed that use flower as a key to identify plant[6]. In case of flower, color is the most common and significant feature. Nilsback & Zisserman, (2010) combined petal shape and color information to design flower segmentation algorithm. Hong, Gang, Jun-li, Chi, and Zhang (2004) used the same color-histogram with CCD and angle-code histogram to classify a set of fourteen species. Yoshioka, Iwata, Ohsawa, and Ninomiya (2004) used Elliptic Fourier Analysis (EFA) for shape analysis of petals in case of Primula sieboldii while Gage and Wilkin (2008) used EFA for outline analysis of tepals (such as petals and sepals) of three species of Sternbergia to validate whether they actually have distinct morphology. Huang, Huang, Du, Quan, and Gua (2006) used Gabor transform (GT) and radial Probabilistic Neural Network (PNN) for bark texture analysis. Lastly, few of the researchers used digital imaging on plant root to analyze root shapes and structures via polynomial curve fitting (Huang, Jain, Stockman, & Smucker, 1992; Zeng, Birchfield, & Wells, 2010). Recently, Mzoughi, Yahiaoui, Boujemaa, and Zagrouba (2015) proposed a hybrid approach for plant species identification. They used leaf arrangement, leaf lobation and leaf partition information to form the feature space necessary for classification. But again, this novel retrieval strategy lacks proper feature representation and selection for ImageCLEF 2011 leaf dataset[7]. Majority of them are content-based image retrieval which needs to be replaced by semantic and cognition based resulting higher level of accuracy in very small time of response (Candan, Kim, Nagarkar, Nagendra, & Yu, 2011; Li et al., 1997, 1998).

Mobile-Based Plant Species Identification System

On the other side of the coin, MC can aid timely access to agriculture related information such as production monitoring, bank policies, *m*-agriculture commerce, and so on, as claimed by Prasad, Kumar, and Ghosh (2013a). Other than Kumar et al. (2012), White et al. (2006), Zhao et al. (2015), Prasad, Kumar, and Ghosh (2013b), Prasad, Kumar, and Ghosh (2015) presented an *Agriculture-as-a-Service* (*AaaS*) framework combining MC, AR and wireless communication technologies with cloud computing (CC) to better serve the agricultural community (agro-community). As the *third eye* of farmer, *AaaS* automatically assists in monitoring their crop fields by a smart remote expert's eye. As discussed above, majority of works were desktop driven and limited to laboratory only. Few approaches are executed on mobile device as an interface such as the *LeafSnap*, *Apleaf,* and *AgroMobile*. Nonetheless, the mobile applications are very popular among the mass communities compared to other desktop-based systems. In addition to this, Mobile Cloud Computing (MC2) manages the energy consumption of a mobile phone supporting an off-line accessibility of plant information and pathological data, as shown in Figure 6. Accordingly, Kim et al. (2013) proposed a self-growing agriculture knowledge using CC services assisting farmers to make smart decisions. The detailed MC2 in agriculture is discussed in Prasad, Kumar, and Ghosh (2013a, 2015).

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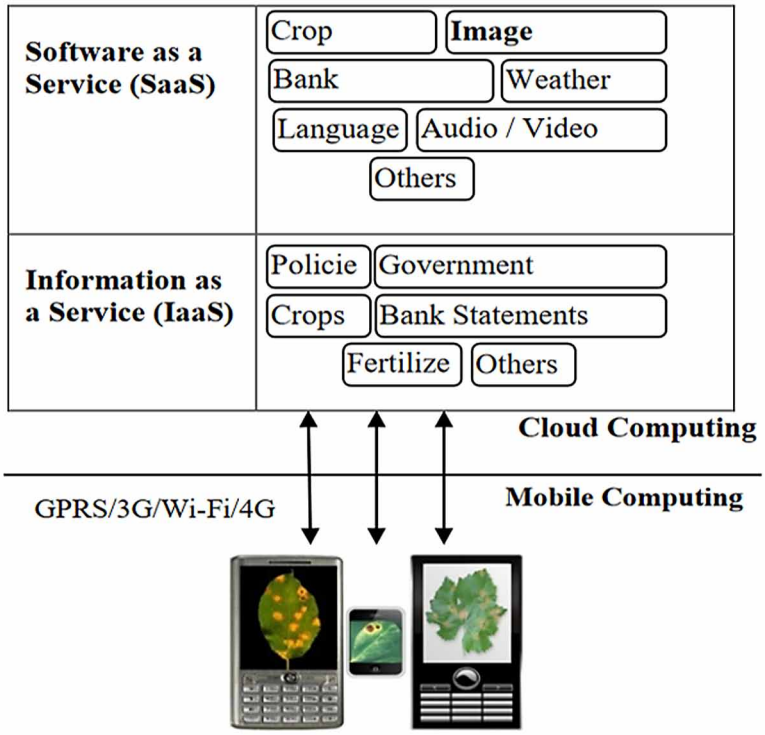
Figure 6. AgroMobile framework (Prasad, Kumar, & Ghosh, 2013a)



Disease

With recent advances in technology, Prasad, Kumar, and Ghosh (2016a) proposed a system that can recognize plant leaf disease using efficient CV algorithms. The author used Gabor Wavelet transform (GWT) over GLCM for disease patch pattern computation which is further used for classification using *k*-NN. The dataset used was a diseased leaf dataset with 5 different pathogen attacks on 4 different species. The system proposed is an Android-based mobile client-server architecture which even an illiterate farmer can operate. The server performs feature extraction followed by classification of the disease and inform the farmer in the field via a fax-back system. The accuracy reported by the author is 93% for diseased identification. In this paper, author have also mentioned an unsupervised leaf diseased patch segmentation in *L*a*b** color space which is quite acceptable (Prasad, Kumar, & Ghosh, 2016a). Such system in future may be used to monitor, control and manage the agricultural productions automatically without any manual expert via MC2 (Prasad, Kumar, & Ghosh, 2013a, 2015). The tremendous growth in MC2 and its rising popularity among people all over the globe have motivated researchers to develop ubiquitous plant disease diagnosis system.

DATASETS

For plant biometric system, several plant leaf datasets are introduces with different challenges like the first dataset which is mostly used by researchers is the Flavia Leaf dataset (Wu et al. 2007) having 32

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different species and 1900+ high quality image samples. Secondly, ICL (Intelligent Computing Laboratory) Leaf dataset (ICL) with 220 species, third is 100 plant leaf dataset (Mallah, Cope, & Orwell, 2013), and fourth is Swedish leaf dataset 11 (Sderkvist, 2001). All these leaf datasets are semi-segmented and so pre-processing is reduced. While there is another big dataset called PlantCLEF 2015 dataset[8] which is composed of 113,205 plant images of 1000 different species (trees, herbs and ferns) in Western European regions (Goeau, 2015). A diseased leaf dataset collected from Indian Institute of Technology (IIT) Roorkee and Forest Research Institute (FIR) Dehradun campuses (Prasad, Kumar, & Ghosh, 2014, 2016a) is also available for plant leaf disease identification. More details related plant leaf datasets and research papers can be found on http://www.visionbib.com/bibliography/applicat842l1.html.

COMPARISON EVALUATION

The contribution of automated plant biometric system since 2000 is shown using a graph (Figure 7), where y-axis shows the number of good related articles published in respective year on current topic (Wang et al., 2016). The increasing number shows the dedication of CV researchers in agriculture field. For comparison, several datasets are compared with different approaches proposed, as mentioned in this chapter, is shown in Table 1. The first column is for Flavia dataset and second for ICL leaf dataset. The third column is a mixed dataset highlighted only to compare the highest accuracy achieved by various researchers in recent years in plant species identification. From Table 1, it is seen that CNN is currently the best feature map to represent plant leaves for accurate classification. The problem with CNN is it needs a proper training with large datasets which requires huge number of resources.

AaaS framework in reality may server agro-community in all sectors with high accuracy assisting famers when, what and how to plant with what fertility rate and chemical/natural controls. It even aware one remote farmer working in other end of world with the situations of other farmer's failures while cultivation.

CONCLUSION

In this chapter, a brief survey of automated plant biometric systems since decades is presented highlighting the current state-of-the-art. According to several authors, plant leaf patterns are represented mathemati-

Figure 7. Distribution of standard publications in field of plant species identification

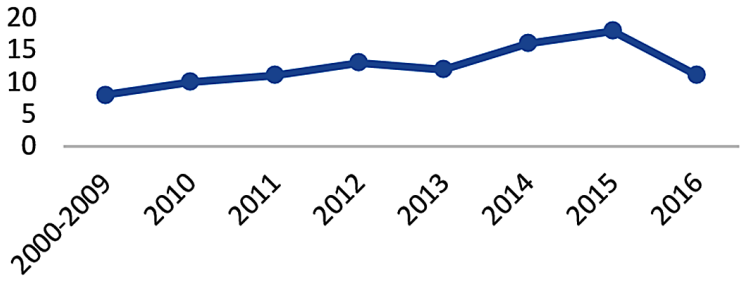

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Table 1. State-of-the-art in plant biometric system

Flavia Dataset		ICL Dataset		Other Datasets	
Methods	**Accuracy (%)**	**Methods**	**Accuracy (%)**	**Methods**	**Accuracy (%)**
MCC (Adamek & Connor, 2004)	84.93	IDCS (Ling, Member, & Jacobs, 2007)	81.39	Wang et al., 2016	93.00
TAR (Alajlan, Kamel, & Freeman, 2007)	85.03	MCC (Adamek & Connor, 2004)	73.17	**Lee, Chan, Wilkin, & Remagnino, 2015**	**99.50**
IDSC (Ling, Member, & Jacobs, 2007)	88.11	TAR (Alajlan, Kamel, & Freeman, 2007)	78.25	Jassmann, 2015	81.60
TSLA (Mouine, Yahiaoui, & Verroust-Blondet, 2013)	93.53	Fourier (Wang et al. 2015)	60.08	Kruse et al., 2014	95.00
MARCH (Wang et al. 2015)	96.15	MARCH (Wang et al. 2015)	85.31	Arunpriya & Thanamani, 2014	88.60
Prasad, Kumar, & Ghosh, 2016	**97. 96**	**Prasad, Kumar, & Ghosh, 2016**	**96.50**	Priyankara & Withanage, 2015	96.48

cally using various transforms including both spatial and frequency domain. More than fifty feature spaces for ten different plant datasets are discussed using different classifiers. Based on this survey, we find out the pros and cons of different feature spaces and classifiers. The future scopes and applications of such systems in agro-communities also motivate researchers to work in this field.

REFERENCES

Adamek, T., & Connor, N. E. O. (2004). A Multiscale Representation Method for Nonrigid Shapes with a Single Closed Contour. *IEEE Transactions on Circuits and Systems for Video Technology*, *14*(5), 742–753. doi:10.1109/TCSVT.2004.826776

Alajlan, N., El, I., Kamel, M. S., & Freeman, G. (2007). Shape retrieval using triangle-area representation and dynamic space warping. *Pattern Recognition*, *40*(7), 1911–1920. doi:10.1016/j.patcog.2006.12.005

Andrade, I. M., Mayo, S. J., Kirkup, D., & Van Den Berg, C. (2008). Comparative morphology of populations of Monstera Adans. (Araceae) from natural forest fragments in Northeast Brazil using elliptic Fourier analysis of leaf outlines. *Kew Bulletin*, *63*(2), 193–211. doi:10.100712225-008-9032-z

Arunpriya, C., & Thanamani, A. S. (2014). A novel leaf recognition technique for plant classification. *Int J Comput Eng Appl*, *4*, 42–55.

Backes, A. R., Gonalves, W. N., Martinez, A. S., & Bruno, O. M. (2010). Texture analysis and classification using deterministic tourist walk. *Pattern Recognition*, *43*(3), 685–694. doi:10.1016/j.patcog.2009.07.017

Bakhsh, A., Colvin, T. S., Jaynes, D. B., Kanwar, R. S., & Tim, U. (2000). Using Soil Attributes and GIS for Interpretation of Spatial Variability in Yield. *Transactions of the ASAE. American Society of Agricultural Engineers*, *43*(3), 819–828. doi:10.13031/2013.2976

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Brugger, F. (2011). *Mobile Applications in Agriculture*. Retrieved from http://www.gsma.com/mobilefordevelopment/wpcontent/uploads/2011/12/SyngentaReporton*m*-Agricultureabridgedwebversion.pdf

Bruno, O. M., deOliveira Plotze, R., Falvo, M., & deCastro, M. (2008). Fractal dimension applied to plant identification. *Inform. Sciences*, *178*(12), 2722–2733. doi:10.1016/j.ins.2008.01.023

Candan, K. S., Kim, J. W., Nagarkar, P., Nagendra, M., & Yu, R. (2011). RanKloud: Scalable multimedia data processing in server clusters. *IEEE MultiMedia*, *18*(1), 64–77. doi:10.1109/MMUL.2010.70

Casanova, D., de Mesquita Sa Junior, J. J., & Bruno, O. M. (2009). Plant leaf identification using Gabor wavelets. *International Journal of Imaging Systems and Technology*, *19*(3), 236–243. doi:10.1002/ima.20201

Clark, J. (2004). Identification of botanical specimens using artificial neural networks. *Proc. of the 2004 IEEE Symp. On Computational Intelligence in Bioinformatics and Computational Biology*, 87-94. Retrieved from http://ieeexplore.ieee.org/xpls/abs all.jsp?arnumber=1393938

Clark, J. Y. (2009). Neural networks and cluster analysis for unsupervised classification of cultivated species of Tilia (Malvaceae). *Botanical Journal of the Linnean Society*, *159*(2), 300–314. doi:10.1111/j.1095-8339.2008.00891.x

Cope, J. S., Remagnino, P., Barman, S., & Wilkin, P. (2010). The extraction of venation from leaf images by evolved vein classifiers and ant colony algorithms. In Advanced Concepts for Intelligent Vision Systems (Vol. 6474 LNCS, pp. 135-144). doi:10.1007/978-3-642-17688-3_14

Cope, J. S., Corney, D., Clark, J. Y., Remagnino, P., & Wilkin, P. (2012). Plant species identification using digital morphometrics: A review. *Expert Systems with Applications*, *39*(8), 7562–7573. doi:10.1016/j.eswa.2012.01.073

Du, J. X., Huang, D. S., Wang, X. F., & Gu, X. (2006). Computer-aided plant species identification (CAPSI) based on leaf shape matching technique. *Transactions of the Institute of Measurement and Control*, *28*(3), 275–285. doi:10.1191/0142331206tim176oa

Fu, H., & Chi, Z. (2006). Combined thresholding and neural network approach for vein pattern extraction from leaf images. *IEE Process-Vision*, *Image and Signal Process*, *153*(6), 881–892. doi:10.1049/ip-vis:20060061

Gage, E., & Wilkin, P. (2008). A morphometric study of species delimitation in Sternbergialutea (Alliaceae, Amaryllidoideae) and its allies S. sicula and S. greuteriana. *Botanical Journal of the Linnean Society*, *158*(3), 460–469. doi:10.1111/j.1095-8339.2008.00903.x

Goeau, H., Joly, A., & Bonnet, P. (2015). LifeClef plant identification task 2015. CLEF Working Notes 2015.

Gore, K., Lobo, S., & Doke, P. (2012). *GappaGoshti*: Digital inclusion for rural mass. In *2012 4th Int. Conf. on Communication Systems and Networks, COMSNETS 2012* (pp. 1-6). doi:10.1109/COMSNETS.2012.6151383

Gu, X., Du, J.-X., & Wang, X.-F. (2005). Leaf recognition based on the combination of wavelet transform and Gaussian interpolation. *Advances in Intelligent Computing*, 253-262. doi:27 doi:10.1007/11538059

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Hearn, D. J. (2009). Shape analysis for the automated identification of plants from images of leaves. *Taxon*, *58*(3), 934–954.

Heinze, C., Goss, S., & Pearce, A. (1999). Plant recognition in military simulation: Incorporating machine learning with intelligent agents. *Proc. of IJCAI-99 Workshop on Team Behavior and Plan Recognition*, 53-64.

Hong, A., Gang, C., Jun-li, L., Chi, Z., & Zhang, D. (2004). A flower image retrieval method based on ROI feature. *Journal of Zhejiang University. Science*, *5*(7), 764–772. doi:10.1631/jzus.2004.0764 PMID:15495304

Huang, Q., Jain, A. K., Stockman, G. C., & Smucker, A. J. M. (1992). Automatic Image Analysis of Plant Root Structures. In *11th IEEE IAPR Int. Conf. on Pattern Recognition* (pp. 569-572). 10.1109/ICPR.1992.201842

Huang, Z., Huang, D.-S., Du, J.-X., Quan, Z., & Gua, S.-B. (2006). Bark Classification Based on Contourlet Filter Features. In Intelligent Computing (pp. 1121-1126). Springer Berlin Heidelberg.

Izzat Din Abdul Aziz, M. H. H., Ismail, M. J., Mehat, M., & Haroon, N. S. (2009). Remote monitoring in agricultural greenhouse using wireless. *Int. J. Engg. Techlon*, *9*(9), 35–43.

Jain, D. K., Tim, U., & Jolly, R. W. (1995). A spatial decision support system for livestock production planning and environmental management. *Applied Engineering in Agriculture*, *11*(5), 711–719. doi:10.13031/2013.25795

Jassmann, T. J. (2015). *Mobile Leaf Classification Application Utilizing a Convolutional Neural Network* (Doctoral dissertation). Appalachian State University.

Kim, T., Bae, N.-J., Shin, C.-S., Park, J. W., Park, D., & Cho, Y.-Y. (2013). An Approach for a Self-Growing Agricultural Knowledge Cloud in Smart Agriculture. In *Multimedia and Ubiquitous Eng* (pp. 699–706). Springer. doi:10.1007/978-94-007-6738-6_86

Kruse, O. M. O., Prats-Montalban, J. M., Indahl, U. G., Kvaal, K., Ferrer, A., & Futsaether, C. M. (2014). Pixel classification methods for identifying and quantifying leaf surface injury from digital images. *Computers and Electronics in Agriculture*, *108*, 155–165. doi:10.1016/j.compag.2014.07.010

Kumar, N., Belhumeur, P. N., Biswas, A., Jacobs, D. W., Kress, W. J., Lopez, I. C., & Soares, J. V. B. (2012). Leafsnap: A computer vision system for automatic plant species identification. In Comput. Vision - ECCV 2012 (Vol. 7573 LNCS, pp. 502-516). doi: 36 doi:10.1007/978-3-642-33709-3

Lee, C., & Chen, S. (2006). Classification of leaf images. *International Journal of Imaging Systems and Technology*, *16*(1), 15–23. doi:10.1002/ima.20063

Lee, S. H., Chan, C. S., Wilkin, P., & Remagnino, P. (2015, September). Deep-Plant: Plant Identification with convolutional neural networks. In *Image Processing (ICIP), 2015 IEEE International Conference on* (pp. 452-456). IEEE.

Lexer, C., Joseph, J., van Loo, M., Prenner, G., Heinze, B., Chase, M. W., & Kirkup, D. (2009). The use of digital image-based morphometrics to study the phenotypic mosaic in taxa with porous genomes. *Taxon*, 349–364.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Li, Y., Chi, Z., & Feng, D. D. (2006). Leaf vein extraction using independent component analysis. In *IEEE Int. Conf. on Systems, Man and Cybernetics*, (pp. 3890-3894). 10.1109/ICSMC.2006.384738

Li, W.-S., Candan, K. S., & Hirata, K. (1997). SEMCOG: An Integration of SEMantics and COGnition- based Approaches for Image Retrieval. In *12th Annual Symp. on Applied Computing (SAC-97)*, (pp. 36-43). 10.1145/331697.331727

Li, W.-S., Seluk Candan, K., Hirata, K., & Hara, Y. (1998). Hierarchical image modeling for object-based media retrieval. *Data & Knowledge Engineering*, *27*(2), 139–176. doi:10.1016/S0169-023X(97)00058-X

Ling, H., Member, S., & Jacobs, D. W. (2007). Shape Classification Using the Inner-Distance. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, *29*(2), 286–299. doi:10.1109/TPAMI.2007.41 PMID:17170481

Liu, J., Zhang, S., & Deng, S. (2009). A method of plant classification based on wavelet transforms and support vector machines. In *Emerging Intelligent Computing Technology and Applicat* (pp. 253–260). Springer Berlin Heidelberg.

Ma, W. M. W., Zha, H. Z. H., Liu, J. L. J., Zhang, X. Z. X., & Xiang, B. X. B. (2008). Image-based plant modeling by knowing leaves from their apexes. In *2008 IEEE 19th Int. Conf. on Pattern Recognition,* (pp. 2-5). doi:10.1007/978-3-642-04070-2_29

Mallah, C., Cope, J., & Orwell, J. (2013). Plant leaf classification using probabilistic integration of shape, texture and margin features. Signal Processing. *Pattern Recognition and Applications*, *5*, 1.

MacLeod, N., Benfield, M., & Culverhouse, P. (2010). Time to automate identification. *Nature*, *467*(7312), 154–155. doi:10.1038/467154a PMID:20829777

McLellan, T., & Endler, J. A. (1998). The relative success of some methods for measuring and describing the shape of complex objects. *Systematic Biology*, *47*(2), 264–281. doi:10.1080/106351598260914

Meade, C., & Parnell, J. (2003). Multivariate analysis of leaf shape patterns in Asian species of the Uvaria group (Annonaceae). *Botanical Journal of the Linnean Society*, *143*(3), 231–242. doi:10.1046/j.1095-8339.2003.00223.x

Melville, R. (1937). The accurate definition of leaf shapes by rectangular coordinates. *Annals of Botany*, *1*, 673–679.

Mouine, S., Yahiaoui, I., & Verroust-Blondet, A. (2013). A Shape based Approach for Leaf Classification using Multiscale Triangular Representation. In *Process. of the 3rd ACM Conf. on Int. Conf. on multimedia retrieval*, (pp. 127134). ACM.

Mullen, R. J., Monekosso, D., Barman, S., Remagnino, P., & Wilkin, P. (2008). Artificial ants to extract leaf outlines and primary venation patterns. In Ant Colony Optimization and Swarm Intelligence, (Vol. 5217 LNCS, pp. 251-258). = doi:10.1007/978-3-540-87527-7_24

Mzoughi, O., Yahiaoui, I., Boujemaa, N., & Zagrouba, E. (2015). Semantic-based automatic structuring of leaf images for advanced plant species identification. *Multimedia Tools and Applicat*., 1-32. doi:10.100711042-015-2603-8

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Nam, Y., Hwang, E., & Kim, D. (2008). A similarity-based leaf image retrieval scheme: Joining shape and venation features. *Computer Vision and Image Understanding*, *110*(2), 245–259. doi:10.1016/j.cviu.2007.08.002

Natho, G. (1959). Variationsbreite und Bastardbildung bei mitteleuropischen Birkensippen. *Repertorium Novarum Specierum Regni Vegetabilis*, *61*(3), 211–273. doi:10.1002/fedr.19590610304

Neto, J. C., Meyer, G. E., Jones, D. D., & Samal, A. K. (2006). Plant species identification using Elliptic Fourier leaf shape analysis. *Computers and Electronics in Agriculture*, *50*(2), 121–134. doi:10.1016/j.compag.2005.09.004

Nilsback, M. E., & Zisserman, A. (2010). Delving deeper into the whorl of flower segmentation. *Image and Vision Computing*, *28*(6), 10491062. doi:10.1016/j.imavis.2009.10.001

Orr, G., Pettersson-Yeo, W., Marquand, A. F., Sartori, G., & Mechelli, A. (2012). Using Support Vector Machine to identify imaging biomarkers of neurological and psychiatric disease: A critical review. *Neuroscience and Biobehavioral Reviews*, *36*(4), 1140–1152. doi:10.1016/j.neubiorev.2012.01.004 PMID:22305994

Pande, A., Jagyasi, B. G., & Choudhuri, R. (2009). Late Blight Forecast Using Mobile Phone Based Agro Advisory System. In Pattern Recognition and Machine Intelligence, (pp. 609-614). Springer Berlin Heidelberg. doi:10.1007/978-3-642-11164-8_99

Park, J., Hwang, E., & Nam, Y. (2008). Utilizing venation features for efficient leaf image retrieval. *Journal of Systems and Software*, *81*(1), 71–82. doi:10.1016/j.jss.2007.05.001

Pauwels, E. J., de Zeeuw, P. M., & Ranguelova, E. B. (2009). Computer-assisted tree taxonomy by automated image recognition. Eng. *Applied Artificial Intelligence*, *22*(1), 26–31. doi:10.1016/j.engappai.2008.04.017

Plant Glossary. (2009). Retrieved April 12, 2015, from http://www.vplants.org/plants/glossary/index.html

Pogorelc, B., Bosni, Z., & Gams, M. (2012). Automatic recognition of gait-related health problems in the elderly using machine learning. *Multimedia Tools and Applications*, *58*(2), 333–354. doi:10.100711042-011-0786-1

Prasad, S., Kudiri, K. M., & Tripathi, R. C. (2011). Relative sub-image based features for leaf recognition using support vector machine. In *Proceedings of the 2011 Int. Conf. on Commun., Computing & Security*, (pp. 343-346). Retrieved from10.1145/1947940.1948012

Prasad, S., Kumar, P., & Tripathi, R. C. (2011). Plant leaf species identification using curvelet transform. In *2011 2nd Int. Conf. on Comput. and Communication Technology (ICCCT),* (pp. 646-652). IEEE. 10.1109/ICCCT.2011.6075212

Prasad, S., Kumar, P. S., & Ghosh, D. (2013a). *AgroMobile*: A Cloud-Based Framework for Agriculturists on Mobile Platform. *Int. J. of Advanced Sci. and Technology*, *59*, 41–52. doi:10.14257/ijast.2013.59.04

Prasad, S., Kumar, P. S., & Ghosh, D. (2013b). Mobile Plant Species Classification: A Low Computational Approach. In *Process. of the 2013 IEEE Second Int. Conf. on Image Inform. Process.,* (pp. 405-409). 10.1109/ICIIP.2013.6707624

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Prasad, S., Kumar, S. P., & Ghosh, D. (2014). Energy Efficient Mobile Vision System for Plant Leaf Disease Identification. In *IEEE Wireless Commun. and Networking Conf. (WCNC)*, (pp. 3356-3361). 10.1109/WCNC.2014.6953083

Prasad, S., Kumar, P. S., & Ghosh, D. (2015). Agriculture-as-a-Service. *IEEE Potentials*.

Prasad, S., Kumar, P. S., & Ghosh, D. (2016a). An efficient low vision plant leaf shape identification system for smart phones. *Multimedia Tools and Applications*, 1–25.

Prasad, S., Peddoju, S. K., & Ghosh, D. (2016b). Multi-resolution mobile vision system for plant leaf disease diagnosis. Signal. *Image and Video Processing*, *10*(2), 379–388. doi:10.100711760-015-0751-y

Chathura, H. A., & Withanage, D. K. (2015) Computer assisted plant identification system for Android. Moratuwa engineering research conference, 148–153.

Revenaz, A., Ruggeri, M., & Martelli, M. (2010). Wireless communication protocol for agricultural machines synchronization and fleet management. In *IEEE Int. Symp. on Industrial Electron*, (pp. 3498-3504). 10.1109/ISIE.2010.5637476

Reyes, A. K., Caicedo, J. C., & Camargo, J. E. (2015). Fine-tuning deep convolutional networks for plant recognition. Working notes of CLEF 2015 conference.

Rumpunen, K., & Bartish, I. V. (2002). Comparison of differentiation estimates based on morphometric and molecular data, exemplified by various leaf shape descriptors and RAPDs in the genus Chaenomeles (Rosaceae). *Taxon*, *51*(1), 69–82. doi:10.2307/1554964

Schneider, C. K. (1912). *Illustriertes Handbuchder Laubholzkunde*. Ripol Klassik.

Scotland, R. W., & Wortley, A. H. (2003). How many species of seed plants are there? *Taxon*, *52*(1), 101–104. doi:10.2307/3647306

Sderkvist, O. J. O. (2001). *Computer Vision Classification of Leaves from Swedish Trees*. Academic Press.

Shinde, S., Piplani, D., Srinivasan, K., Singh, D., Sharma, R., & Mohnaty, P. (2014). *mKRISHI* Simplification Of IVR Based Services For Rural Community. In *Process. of the India HCI2014 Conf. on Human Comput. Interaction* (p. 154). ACM.

Sünderhauf, N., McCool, C., Upcroft, B., & Perez, T. (2014). Fine-Grained Plant Classification Using Convolutional Neural Networks for Feature Extraction. In CLEF (Working Notes) (pp. 756-762).

Teng, C. H., Kuo, Y. T., & Chen, Y. S. (2009). Leaf segmentation, its 3D position estimation and leaf classification from a few images with very close viewpoints. In *Image Analysis and Recognition* (pp. 937–946). Springer Berlin Heidelberg. doi:10.1007/978-3-642-02611-9_92

Tim, U. S. (1995). The application of GIS in environmental health sciences: Opportunities and limitations. *Environmental Research*, *71*(2), 75–88. doi:10.1006/enrs.1995.1069 PMID:8977616

Vellidis, G., Garrick, V., Pocknee, S., Perry, C., Kvien, C., & Tucker, M. (2007). How Wireless Will Change Agriculture. *Precision Agriculture*, *7*, 57–67.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Wang, Z., Chi, Z., & Feng, D. (2003). Shape based leaf image retrieval. IEE Process. -. *Vision, Image, and Signal Process.*, *150*(1), 34. doi:10.1049/ip-vis:20030160

Wang, B., Brown, D., Gao, Y., & La Salle, J. (2015). MARCH: Multiscale-arch-height description for mobile retrieval of leaf images. *Inform. Sciences*, *302*, 132–148. doi:10.1016/j.ins.2014.07.028

Wang, Z., Li, H., Zhu, Y., & Xu, T. (2016). Review of Plant Identification Based on Image Processing. *Archives of Computational Methods in Engineering*, 1–18.

Warren, D. (1997). Automated leaf shape description for variety testing in chrysanthemums. In *IET 6th Int. Conf. on Image Process. and its Applicat.* (pp. 497 - 501). 10.1049/cp:19970943

White, S., Feiner, S., & Kopylec, J. (2006). Virtual vouchers: Prototyping a mobile augmented reality user interface for botanical species identification. In *Process* (p. 133). IEEE Virtual Reality. doi:10.1109/VR.2006.145

White, S. M., Marino, D. M., & Feiner, S. (2006). *LeafView*: A User Interface for Automated Botanical Species Identification and Data Collection. In *ACM UIST 2006 Conf. Companion*, (pp. 1-2). Montreux, Switzerland: ACM.

White, S. M., Marino, D., & Feiner, S. (2007). Designing a mobile user interface for automated species identification. In Human Factors in Computing Systems, CHI'07, (pp. 291-294). doi:10.1145/1240624.1240672

Wu, S. G., Bao, F. S., Xu, E. Y., Wang, Y., Chang, Y., & Xiang, Q. (2007). A Leaf Recognition Algorithm for Plant Classification Using Probabilistic Neural Network. In *Int. Symp. on Signal Process. and Inform. Technology,* (pp. 11-16). 10.1109/ISSPIT.2007.4458016

Wu, S. G., Bao, F. S., Xu, E. Y., Wang, Y., Chang, Y., & Xiang, Q. (2007). A Leaf Recognition Algorithm for Plant Classification Using Probabilistic Neural Network. In *Int. Symp. on Signal Process. and Inform. Technology,* (pp. 11-16). 10.1109/ISSPIT.2007.4458016

Yanikoglu, B., Aptoula, E., & Tirkaz, C. (2014). Automatic plant identification from photographs. *Machine Vision and Applications*, *25*(6), 1369–1383. doi:10.100700138-014-0612-7

Ye, L., & Keogh, E. (2009). Time series shapelets: a new primitive for data mining. *Process. of the 15th ACM SIGKDD Int. Conf. on Knowledge Discovery and Data Mining*, 947-956. 10.1145/1557019.1557122

Yoshioka, Y., Iwata, H., Ohsawa, R., & Ninomiya, S. (2004). Analysis of petal shape variation of Primula sieboldii by elliptic Fourier descriptors and principal component analysis. *Annals of Botany*, *94*(5), 657–664. doi:10.1093/aob/mch190 PMID:15374833

Zeng, G., Birchfield, S. T., & Wells, C. E. (2010). Rapid automated detection of roots in minirhizotron images. *Machine Vision and Applications*, *21*(3), 309–317. doi:10.100700138-008-0179-2

Zhao, Z.-Q., Ma, L.-H., Cheung, Y., Wu, X., Tang, Y., & Chen, C. L. P. (2015). *ApLeaf*: An efficient android-based plant leaf identification system. *Neurocomputing*, *151*, 1112–1119. doi:10.1016/j.neucom.2014.02.077

Zulkifli, Z., Saad, P., & Mohtar, I. A. (2011). Plant leaf identification using moment invariants & General Regression Neural Network. In *2011 11th Int. Conf. on Hybrid Intelligent Systems (HIS)*, (pp. 430-435). 10.1109/HIS.2011.6122144

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ENDNOTES

[1] The author is currently in NTU, Singapore as Research Fellow.

[2] http://apps.kew.org/herbcat/navigator.do

[3] Several research are going on Plants, Leaf Shapes, Leaf Analysis and Leaf Segmentation. http://www.visionbib.com/bibliography/applicat842l1.html#Plants, Leaf Shapes, Leaf Analysis, Leaf Segmentation

[4] http://leafzone.keydown.org/index.html

[5] http://flavia.sourceforge.net/

[6] Several research going on Plants species, Flowers, Flower Shape and Flower Color. http://www.visionbib.com/bibliography/applicat842f1.html#Plants, Flowers, Flower Shape, Flower Color

[7] http://www.imageclef.org/2011/Plants

[8] http://www.imageclef.org/

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Chapter 35
Demand for Food Diversity in Romania

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ABSTRACT

The present research work applied a food diversity measurement tool (Transformed Berry Index) on the 2011 Household Budget Surveys data. The investigation was performed on household purchased based TBI measure and on actual consumption TBI, in order to highlight the errors that one would make if one fails to take into account the production of goods by the household. There are some important differences in the food diversity of the actual food consumption in comparison to the purchased food quantities, the number of food items being higher in the case of actual consumption. However, food diversity does not seem to be influenced by the residence area (urban vs. rural) in any of the two approaches.

INTRODUCTION

In Romania, the transition period was associated to a massive reduction in the population's real incomes, this leading to the increase in the consumption of products considered inferior from a nutritional point of view, such as potatoes and cereal-based products, together with the decrease in consumption of the products that are more valuable in nutritional terms, such as meat and dairy products. Food substitutions took place not only inside certain groups of products, but also between groups of products (meat with cereals, for instance), out of the households' need to adjust their food expenditures in the situation of real incomes diminution (Petrovici and Ritson, 2000).

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Subsequently, in the period of accession preparation to the European Union, and in the post-accession period, meat and dairy consumption increased, but the still low incomes resulted in a very high share of food expenditures in the household budget, in parallel with the relatively low dietary diversity, low consumption of fresh fruit and vegetables and high consumption of animal fat. An important part of the food consumed by households comes from the own produced food and this is especially true for rural households. The difficult situation from an household economic point of view due to the severe reduction in incomes, led to the increase in the share of consumption from own resources. The transfers of products from the rural to the urban households from the same family continue to represent a cultural pattern, and in the situations of crisis even a survival strategy for extended families.

Due to this reason, the investigation of food diversity in Romania cannot be made by exclusively applying the methodology specific to the developed countries, where most food products are bought, as this would exclude the food consumption from own resources, the contribution of which is quite significant for certain households. The present research work applied food diversity measurement tools for a data set obtained from the Household Budget Surveys for the first quarter of the year 2011, both for the amount of products bought by the households and separately for the amount of products effectively consumed on the households, in order to highlight the differences between the results of the two approaches.

Numerous approaches link dietary diversity to the level of incomes (Jackson, 1984). Thus, in the situation when the level of incomes is low, only a subset of available foodstuffs is bought. This pattern is known as the hierarchic demand system. The higher the level of consumption, the larger the number of products that go to the consumer's basket.Most studies dedicated to the developed countries reveal the positive correlation between diversity (measured by the Herfindahlindex or the entropy index) and the level of incomes, measured by the real income per capita. One of these studies (Lee and Brown, 1989), where consumer demand for food diversity is measured by the entropy and Simpson indices for budget share, show that consumer demand for food diversity is related to total food expenditures and household size and composition.

The econometric models by which the dietary diversity in the developed countries was investigated, for instance in Germany (Thiele and Weiss, 2003), reveal that dietary diversity is influenced by the household socio-economic characteristics, by income in the first place, then by the household size and composition, mainly the number of children 7 – 17 years old, the residence area and the size of the locality where the household is located. Dietary diversity decreases with the age of household members (up to 46 years), to moderately increase afterwards, in general the relationship being non-linear. The farmer households feature lower diversity for the purchased products, as certain foodstuffs are produced on their own households.

While in the consumption pattern of developed countries, in nutritional terms, it is not the variety between the groups of products that is mostly important, but rather the variety between the individual products, in the less developed countries the diversity between groups of food products can be more important than the diversity of products as such, which could belong to the same group (Swindale and Bilinsky, 2006). At the same time, in the case of subsistence economies, a positive influence upon food diversity on the rural households is brought by the household's access to the agricultural resources (Taruvinga et al., 2013).

Recent studies in the New Member States of EU, including Romania, dedicated to dietary diversity, measured by the Count Measure and the Transformed Berry Index, indicates that food diversity is income elastic (Cockx et al., 2015; Cupak et al., 2014; Alexandri and Pauna, 2015, Alexandri and Kevorchian, 2015). The gender and occupational status of the household head play an important role, as female-

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headed households have significantly higher levels of food diversity and self-employment in agriculture decreases diversity measured by food expenditures. The results further indicate a significantly positive effect for the presence of young children.

METHODOLOGY

Romania has some particularities in terms of consumption when compared to other similar countries. Almost half of the population live in rural areas, and a large percentage of them are self-employed in subsistence agriculture. Besides the obvious poverty aspects of this occupation, it means that a large share of the households' food consumption is not transacted on the market but is produced in-house. The effect of self-consumption on diversity is not very easy to assess, households might use the additional resources available to them for buying other food products (ambiguous effect on diversity), but they could equally buy non-food products (diversity decreases). This is why authors are interested to see how the determinants of diversity vary when the purchased food quantities are considered and when the actual food consumption are considered, and in order to do so, it was estimated the same diversity function for both data sets.

The diversity measure that we have used in the paper is the Transformed Berry Index (TBI) which is computed using the share of expenditure for all purchased food products. We have computed two indices one based on the actual food purchased by the household and the second based on the actual household consumption. In the case of actual consumption, for each food product which originates from own production a price was imputed, equal tothe price of the purchased product in the same household if available, or the average sample price for that product if that food item was not purchased by the household.

The Berry Index (BI) is constructed by adding the square of the share of expenditure for all food products:

$$BI = 1 - \sum_{i=1}^{n} \left(\frac{x_i}{X} \right)^2$$

where: x_i is the expenditure on the i product and X is the total food expenditure. Typically, the dependent variable in a regression is the transformed Berry Index (TBI) which is computed from the BI as follows:

$$TBI = \ln \left(\frac{BI}{1 - BI} \right)$$

DATA AND ESTIMATION RESULTS

We use the Household Budget Survey for first quarter of the 2011 (7843 households). The survey contains detailed information on the composition of the household like the age of the members, education level, occupational status, etc. as well as information on the consumption and income in the month of the interview. The survey includes 106 records for food expenditure/consumption, and this is the information

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that is used for computing the diversity measures described above. Table 1 presents the values of TBI for the two approaches, purchased quantities and actual consumption.

The importance of taking into consideration the consumption of food coming from own resources of the household is revealed by the higher diversity in the case of estimating the demand on the basis of actual food consumption compared to the results for the purchased food quantities. Thus, the average number of effectively consumed food items is 36.2, while the number of purchased food items is 22.5. There are also relevant differences in the case of BI (0.93 versus 0.88) and TBI (2.72 versus 2.22), with higher values for actual food consumption compared to purchased food quantities.

The graphs in Appendix A plot the relationship between TBI and the age of the household head in the case of the expenditure based TBI (Figure 1) and actual consumption based TBI (Figure 2). The graphs indicate the importance of selecting the appropriate measure of diversity. Since the importance of own produced goods in total consumption differs from urban to rural households, the diversity gap between urban and rural households is greatly diminished when appropriately defining the household consumption. On the other hand, it does not appear that the age of the household is an important determinant of the food diversity for a given household.

The other graphs in the same Appendix A present the dependence of the expenditure based TBI (Figure 3) and actual consumption based TBI (Figure 4) as a function of the total household income. The graphs use nonparametric methods and their shortcomings are evident on the graph, due to the scarcity of the data, the method is not very reliable at both ends of the data. As expected there is some increase in diversity due to the increase in household income both in the case of urban and rural households. Again, the gap between the rural and urban household diversity diminishes significantly when the diversity measure based on actual consumption is employed. There seems that the relationship between income and food diversity is less elastic when using actual consumption measures in comparison to expenditure measures.

The equations estimated have as dependent variable the Transformed Berry Index (TBI) measured based on the purchased goods and on the effective consumption. The explanatory variables used are: the logarithm of the household income, in order to assess the elasticity of the diversity with respect to income, information on the household composition, the characteristics of the household head, and information on the residence area. The household composition variables are the number of household members and the number of children. The household characteristics that are included in the equation are age, education, occupational status. In terms of residence, we have included a dummy for the urban households, the county of residence. In addition, the education of the household head was interacted with the residence area (urban/rural) in order to assess whether the educated/uneducated urban households made different choices in terms of diversity in comparison to the educated/ uneducated rural households.

Table 1. Statistics of the Transformed Berry Index

Variable	Obs.	Mean	Std. Dev.	Min	Max
Actual food consumption					
TBI	7843	2.724478	0.38573	0.09713	3.708334
Purchased food quantities					
TBI	7835	2.2217	0.607214	-1.17966	3.531456

Source: authors' computations

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By estimating the two regressions the goal was to understand how distorted the results would be if one fail to take into account the fact that numerous households are able to consumed foods which are produced internally. The output results for the two TBI computed as explained above are presented in Appendix B (see Table 2).

REGRESSION ON TRANSFORMED BERRY INDEX

A very important determinant of diversity is household income. As expected, in both regressions the food diversity increases with the increase in income, but the TBI based on actual food consumption is less elastic than the TBI based on purchased food quantities, indicating that one might arrive to misleading results if one does not take into account the actual food consumption and looks only at the purchased food consumption.

The education level in the case of the urban households is important in the determination of TBI diversity. In both regressions, any education means higher diversity in comparison to the omitted category which is no education, but again the importance of education on diversity is misleading if one analysis the diversity computed based on the purchased foods. This time the coefficients are five times as big as the correct ones, falsely indicating that higher educated urban households are opting for a more diverse diet. The rural education level is not significantly affecting the diversity level of the household. It appears that no education for the household heads means less diversity. There are certain levels of education that seem to be associated with higher TBI diversity (before university studies).

As regards the occupational status of the household head, housewives are associated with lower diversity of food. The age of the household head does not appear to have a significant effect on the food diversity of the household, ceteris paribus. A female household head has a positive influence on the TBI measure, both in the case of purchases and of actual consumption.

Household composition greatly affects the TBI diversity, the increase in the number of members decreases diversity, but if the household has children the diversity is increased. As before, the effect on diversity of household size is overvalued by the TBI based on purchased goods.

There is some indication that cultural differences may affect the food diversity of households. There are some counties which appear to be associated with higher or lower food diversity. TBI measure of diversity is higher for the households located in developed counties and lower in less developed counties.

CONCLUSION

Romania has some particularities in terms of consumption when compared to other similar countries. A large percentage of rural population are self-employed in subsistence agriculture. The investigation of food diversity in Romania cannot be made by exclusively applying the methodology specific to the developed countries, where most food products are bought, as this would exclude the food consumption from own resources, the contribution of which is quite significant for certain households.

The present research work applied a food diversity measurement tool, Transformed Berry Index (TBI), on a Household Budget Surveys data set for the first quarter of the year 2011. TBI was computed for the amount of products bought by the households and separately for the amount of products effectively consumed on the households, in order to highlight the differences between the results of the two approaches.

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There are some important differences in the food diversity of the actual food consumption in comparison to the purchased food quantities. The TBI diversity is more elastic with respect to income in the case of purchased food quantities than in the case of actual food consumption, indicating that one obtains misleading results if one is not careful in the definition of the diversity. A female household head has a positive influence on the TBI measure, both in the case of purchases and of consumption. The education level seems to be important in the determination of TBI diversity only in the case of the urban households. Household composition greatly affects the TBI diversity, the increase in the number of members decreases diversity (both for purchases and consumption) but if the members are children, diversity increase. Food diversity does not seem to be influenced by the residence area (urban vs. rural) in any of the two approaches. Yet TBI measure of diversity is higher for the households located in developed counties and lower in less developed counties.

ACKNOWLEDGMENT

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REFERENCES

Alexandri, C., & Kevorchian, C. (2015). Food consumption diversity in Romania. *Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Horticulture*, *72*(1), 243–248.

Alexandri, C., & Pauna, B. (2015). Assessment of food consumption diversity for Romanian households. *LSMAScientific Research. Agricultural Management*, *17*(1), 282-289.

Cockx, L., Francken, N., & Pieters, H. (2015). *Food and nutrition security in the European Union: Overview and case studies*. FOODSECURE Working paper no. 31.

Cupak, A., Pokrivcak, J., & Rizov, M. (2014). *Demand for the Food Diversity in Central and Eastern European Countries: an Evidence from Slovakia.* Paper presented at the 142nd EAAE Seminar, Budapest.

Jackson, L. F. (1984). Hierarchic demand and the Engel curve for variety. *The Review of Economics and Statistics*, *66*(1), 8–15. doi:10.2307/1924690

Lee, J. Y., & Brown, M. G. (1989). Consumer demand for food diversity. *Southern Journal of Agricultural Economics*, *21*(December), 47–54. doi:10.1017/S0081305200001163

NIS. (2012). *Co-ordinates of living standard in Romania. Population income and consumption. The year 2011*. Bucharest, Romania: National Institute of Statistics.

Petrovici, D., & Ritson, C. (2000). Food consumption patterns in Romania. *British Food Journal*, *102*(4), 290–307. doi:10.1108/00070700010327724

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Swindale, A., & Bilinsky, P. (2006). Household Dietary Diversity Score (HDDS) for Measurement of Household Food Access: Indicator Guide (FHI 360/FANTA). Washington, D.C.

Taruvinga, A., Muchenje, V., & Muchenje, A. (2013). Determinants of rural household dietary diversity: The case of Amatole and Nyandeni districts, South Africa. *International Journal of Development and Sustainability*, *2*(4), 2233–2247.

Thiele, S., & Weiss, C. (2003). Consumer demand for food diversity: Evidence for Germany. *Food Policy*, *28*(2), 99–115. doi:10.1016/S0306-9192(02)00068-4

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APPENDIX A

Dependences of Transformed Berry Index (TBI)

Figure 1. The dependence of expenditure based TBI as a function of the age of the household head

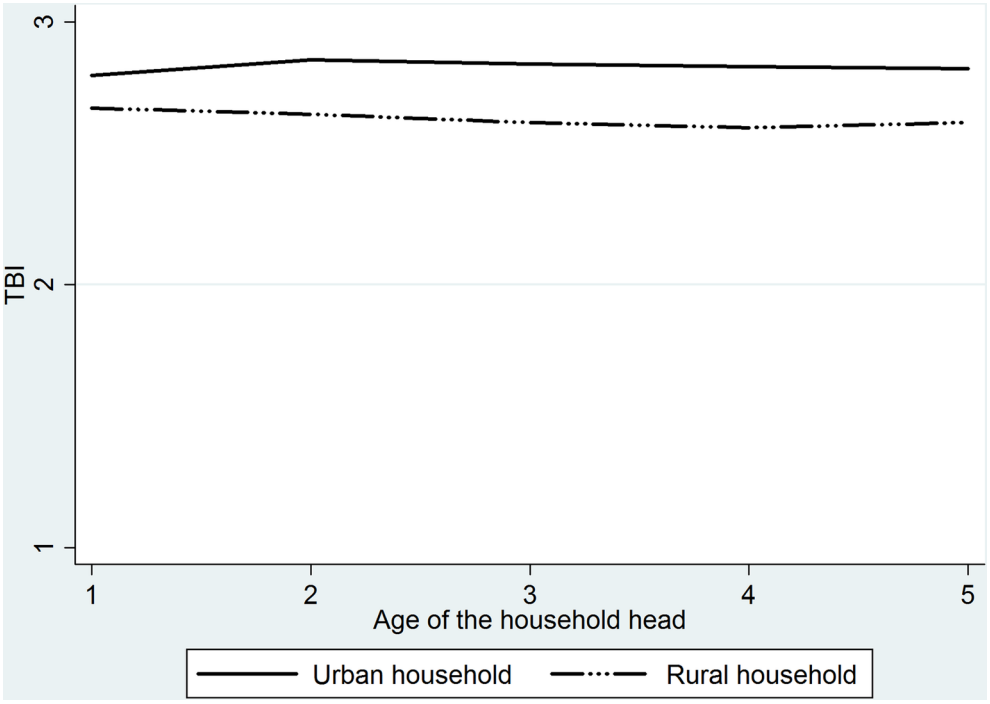

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Figure 2. The dependence of consumption based TBI as a function of the age of the household head

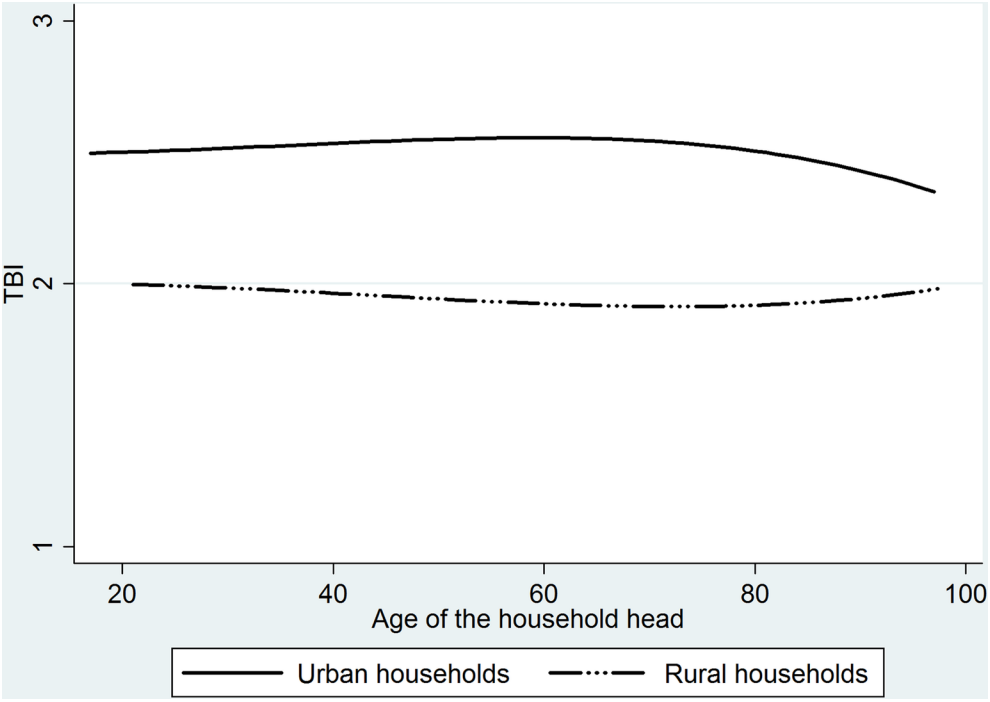

Figure 3. The dependence of expenditure based TBI as a function of the total household income

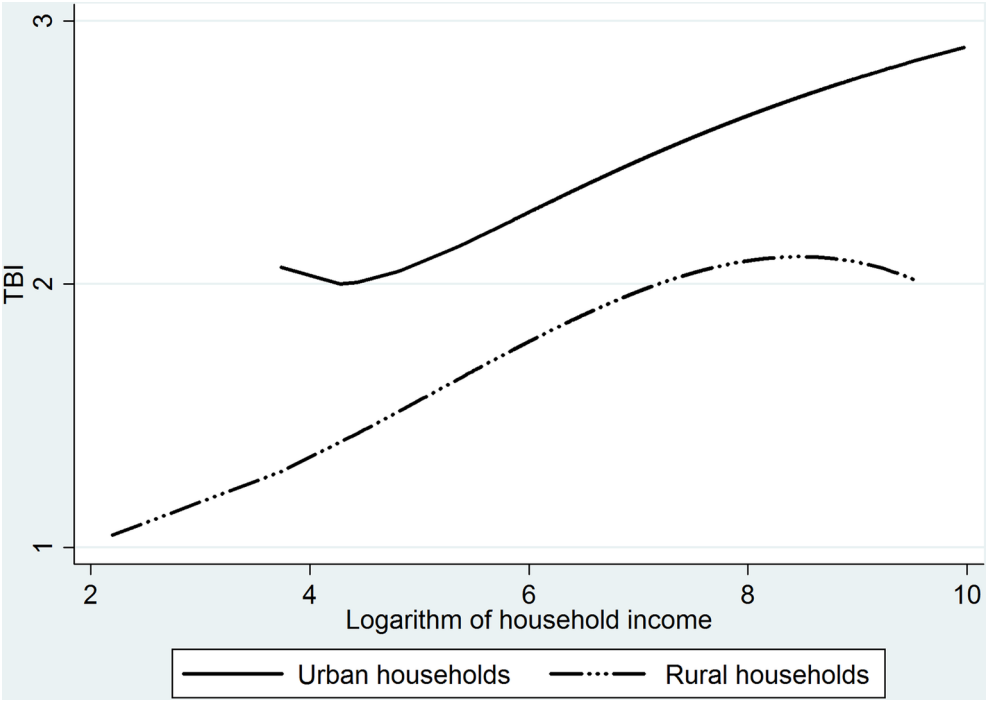

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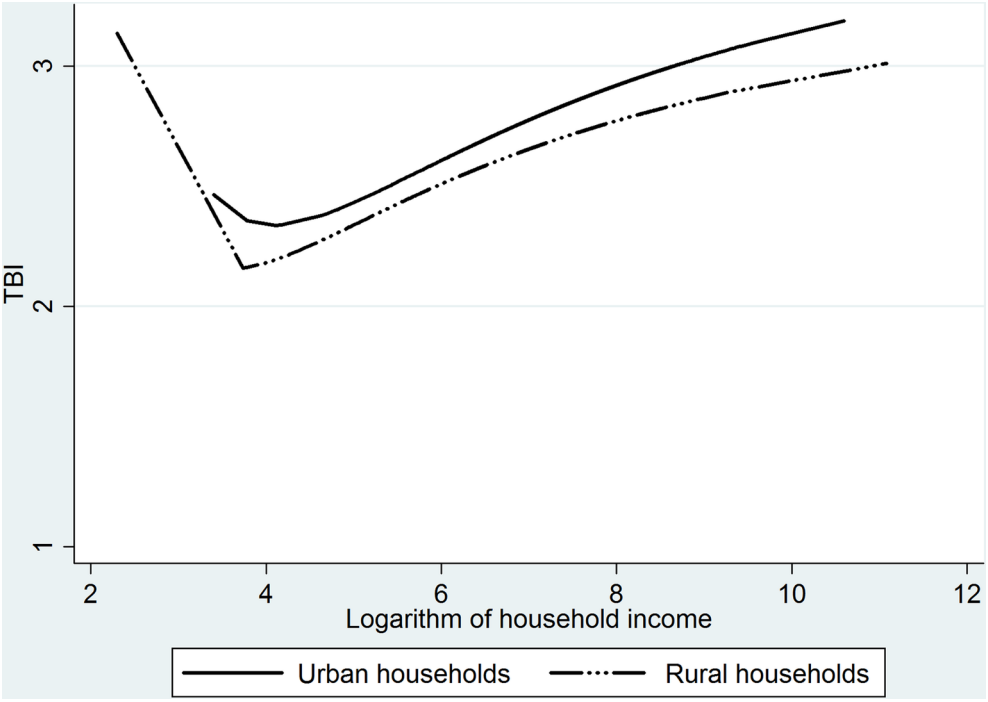
Figure 4. The dependence of consumption based TBI as a function of the total household income



APPENDIX B

Table 2. The estimation regressions of Transformed Berry Index

	Actual Food Consumption		Purchased Food Quantities	
Number of obs	7816		7808	
F(111, 7708)	33.96		47.7	
Prob> F	0		0	
R-squared	0.3204		0.4076	
Adj R-squared	0.311		0.399	
Root MSE	0.31987		0.46941	
	Coef	**Prob**	**Coef**	**Prob**
Logarithm of income	**0.15372**	0	**0.234934**	0
Second month of the quarter	0.012121	0.171	**0.081059**	0
Third month of the quarter	**-0.01891**	0.035	**0.049938**	0
Female	**0.072031**	0	**0.068747**	0
Urban household	-0.21138	0.21	-0.15106	0.54
Education level of the rural household head, omitted category is no education				
Primary school	-0.10581	0.518	-0.06234	0.4
Secondary school	-0.06951	0.67	-0.05021	0.5

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Table 2. Continued

	Actual Food Consumption		Purchased Food Quantities	
Vocational education	-0.03863	0.812	-0.03973	0.6
First two years of highschool	-0.05976	0.723	-0.09088	0.3
High school	-0.01477	0.928	0.039272	0.61
Post high school schooling	-0.00763	0.963	0.008172	0.93
Short term university degree	-0.03911	0.814	0.005787	0.96
University degree	-0.03207	0.844	0.156606	0.11
Doctoral studies	-0.06602	0.752	-0.12009	0.8
Education level of th urban households, omitted category is no education				
Primary school	0.159363	0.349	0.475731	0.06
Secondary school	**0.134853**	0.426	**0.53855**	0.03
Vocational education	**0.110727**	0.513	**0.573263**	0.02
First two years of highschool	**0.085705**	0.628	**0.539452**	0.04
High school	**0.114061**	0.501	**0.497585**	0.05
Post high school schooling	**0.09285**	0.593	**0.516825**	0.04
Short term university degree	0.191115	0.299	0.494392	0.07
University degree	0.192876	0.269	0.385081	0.13
Doctoral studies	0.527302	0.171	0.567561	0.32
Occupational status of the household head, omitted category is wage earner				
Patron	**0.202358**	0.005	0.232364	0.03
Self-employed in non-agricultural activities	-0.02162	0.313	-0.01598	0.61
Member in a non-agricultural cooperative	0.075064	0.642	0.162339	0.49
Self-employed in agricultural activities	0.011712	0.507	-0.02329	0.37
Member in an agricultural cooperative	-0.22113	0.334	-0.09906	0.77
Unemployed	-0.00107	0.958	-0.0412	0.17
Pensioner	0.016125	0.285	0.035886	0.11
Pupil	0.046893	0.669	**-0.38204**	0.02
Student	-0.06337	0.213	**-0.34258**	0
Housewife	-0.08891	0.062	**-0.14902**	0.03
Dependent person	**-0.1805**	0	-0.04948	0.52
The age of the household head, omitted category is less than 30 years				
between 30 and 39	0.036519	0.115	0.053812	0.16
between 40 and 49	0.004575	0.837	-0.00039	0.99
between 50 and 59	0.006842	0.76	-0.00828	0.83
over 60	0.0149	0.548	-0.04141	0.26
Number of household members, omitted category is one member				
2 members	**-0.02846**	0.009	**-0.10233**	0
3 members	**-0.11116**	0	**-0.22185**	0
4 members	**-0.17356**	0	**-0.29489**	0
5 members	**-0.20803**	0	**-0.33321**	0

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Table 2. Continued

	Actual Food Consumption		Purchased Food Quantities	
6 members	**-0.3206**	0	**-0.40882**	0
7 members	**-0.42802**	0	**-0.58347**	0
Number of children, omitted category is no child				
1 child	**0.070138**	0	**0.146454**	0
2 children	**0.133468**	0	**0.193642**	0
3 children	**0.128**	0.003	**0.282483**	0
4 children	**0.173756**	0.024	**0.338271**	0
5 children	**0.234619**	0.02	**0.388104**	0.01
County, omitted category is Alba				
Arad	-0.04143	0.239	**0.165858**	0
Arges	-0.02847	0.418	0.054178	0.29
Bacau	**0.167189**	0	**0.332162**	0
Bihor	**0.207654**	0	**0.266073**	0
BistritaNasaud	0.035482	0.362	**0.173195**	0
Botosani	0.047578	0.179	0.083837	0.11
Brasov	0.050322	0.129	**0.288045**	0
Braila	**0.133885**	0.001	**0.380932**	0
Buzau	0.052015	0.144	**0.321964**	0
Caras-Severin	**0.145652**	0	**0.233873**	0
Cluj	**0.089038**	0.007	-0.08739	0.07
Constanta	**-0.1063**	0.002	**0.114265**	0.02
Covasna	**0.229402**	0	0.093961	0.11
Dambovita	**-0.10683**	0.002	**0.147829**	0
Dolj	**-0.06945**	0.037	**0.170133**	0
Galati	**-0.23205**	0	**-0.14144**	0.01
Gorj	**-0.10794**	0.005	-0.10872	0.06
Harghita	-0.02796	0.471	0.058356	0.31
Hunedoara	**0.113388**	0.001	**0.262106**	0
Ialomita	-0.00678	0.861	**0.24962**	0
Iasi	**0.109898**	0.001	**0.325117**	0
Ilfov	**0.173466**	0	**0.478951**	0
Maramures	0.029661	0.421	0.096954	0.07
Mehedinti	**-0.34734**	0	**-0.2433**	0
Mures	**0.069689**	0.042	0.00325	0.95
Neamt	0.001972	0.957	**0.16821**	0
Olt	-0.21143	0	-0.05381	0.31
Prahova	0.042886	0.198	**0.303305**	0
Satu Mare	**-0.17011**	0	**-0.13255**	0.02
Salaj	0.014234	0.722	0.029865	0.61

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Table 2. Continued

	Actual Food Consumption		Purchased Food Quantities	
Sibiu	**0.1096**	0.002	0.052334	0.31
Suceava	**0.255623**	0	**0.433883**	0
Teleorman	**-0.44748**	0	**-0.18834**	0
Timis	**-0.08138**	0.013	0.081765	0.09
Tulcea	**0.05227**	0.204	**0.135762**	0.03
Vaslui	**-0.08767**	0.018	0.086875	0.11
Valcea	**-0.20064**	0	**-0.3434**	0
Vrancea	**-0.15821**	0	0.03135	0.56
Bucharest, s1	-0.05555	0.254	**0.220799**	0
Bucharest, s2	**-0.09287**	0.028	**0.243482**	0
Bucharest, s3	-0.02204	0.619	**0.237548**	0
Bucharest, s4	**0.146235**	0	**0.354457**	0
Bucharest, s5	**0.110701**	0.018	**0.417674**	0
Bucharest, s6	**0.064074**	0.123	**0.383846**	0
Calarasi	**-0.14633**	0	-0.06042	0.28
Giurgiu	-0.07481	0.056	**0.15741**	0.01
Constant	**1.732855**	0	**0.307566**	0.01

Source: authors' computations

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Chapter 36
Simulation-Based Approaches for Ecological Niche Modelling: A Geospatial Reference

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ABSTRACT

Over recent years, many modelling approaches have been used to map and monitor both present and potential distribution of species in the context of ecological niche-based conservation, especially in the face of global environmental change. Using different statistical techniques in a built-in geographic information system (GIS), the development of predictive species distribution models has extensively increased. This chapter introduces a geospatial reference to simulation-based approaches of ecological niche models. The chapter discusses various environmental modeling tools and simulation models available in open source domain used by scientific communities. As an effort of this chapter, we focus on the potential of using such experimental models for large-scale ecosystem modelling studies, highlighting opportunities of research, for a variety of bio-geographical applications. It would serve as a basis for beginners in ecology exploring this field of research, who can further contribute and develop such models to better understand the complex field of ecosystem studies.

INTRODUCTION

The knowledge of spatial distribution of species is essential, especially to investigate the species' realized and fundamental niches. The understanding of this species-environment relationship is central for many current research programmes in ecology and conservation under global change (climatic and environmental) and it is of great scientific and societal relevance. This realization of the importance of predictive modelling of species is crucial in the field of both conventional as well as applied ecological research. Over past few years, species distribution models have seen an impressive growth in its mod-

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elling approaches in studies of biogeography, conservation biology, ecology, palaeo-ecology, wildlife management, and more recently, studying the effects of climate change (Table 1). Such an experimental modeling approach allows us to estimate species' ecological requirements (Araújo and Guisan, 2006), generally based on various hypothesis (Guisan and Zimmermann, 2000). The idea is to quantify correlation between known occurrence of species and features of the ecological and environmental landscape (Miller, 2010). These models are often termed as *species distribution models*, *climatic envelope models*, or, most commonly known as, *ecological niche-based models*. The aim of such models is to reconstruct empirically derived 'environmental profile' which can be used to estimate the *ecological space* of species and/or predict the geographical distribution of species (Peterson, 2006). This sort of useful predictive modelling technique has had overwhelming success in the recent past (Austin, 2007, 2002; Elith et al., 2006, 2002; Guisan and Thuiller, 2005; Guisan and Zimmermann, 2000; Peterson, 2006; Sinclair et al., 2010). However, despite widespread use of these models, conceptual ambiguities and the biotic as well as abiotic limiting constraints need to be clearly addressed before any practical application of these modeling results are made available (Araújo and Guisan, 2006; Dormann, 2007).

The predictive modelling of species is one of the vital components of applied research (geography and ecology). With the advancement in geographic information system (GIS) and other related technologies, increased availability of satellite-based remotely sensed data and myriad number of open source tools that have developed; this enables scientists to employ powerful and sophisticated means of species' distribution modelling. As a result of simultaneous development of parallel applications with considerably different objectives, this process referred here as 'ecological niche-based modelling' has been previously described as 'predictive vegetation mapping' (Franklin, 1995; Miller et al., 2007), 'predictive habitat distribution modeling' (Guisan and Zimmermann, 2000), 'bioclimatic envelope modeling' (Heikkinen et al., 2006; Pearson and Dawson, 2003), 'habitat suitability index mapping' (Brown et al., 2000; Roloff and Kernohan, 1999), 'habitat suitability modeling' (Hirzel et al., 2006, 2002), and 'niche modeling'

Table 1. Some of the uses of ecological niche-based models

Quantifying the environmental niche of species	Austin et al., 1990; Vetaas, 2002
Testing biogeographical, ecological and evolutionary hypotheses	Anderson et al., 2002; Graham et al., 2004; Leathwick, 1998
Supporting appropriate management plans for species recovery and mapping suitable sites for species reintroduction	Pearce and Lindenmayer, 1998
Assessing species invasion and proliferation	Beerling et al., 1995; Peterson, 2003
Supporting conservation planning and reserve selection	Araújo et al., 2004; Ferrier, 2002
Suggesting unsurveyed sites of high potential of occurrence for rare species	Engler et al., 2004; Raxworthy et al., 2003
Modelling species assemblages (biodiversity, composition) from individual species predictions	Ferrier et al., 2002a; Guisan and Theurillat, 2000; Leathwick, 1998
Assessing the impact of climate, land use and other environmental changes on species distributions	Thomas et al., 2004; Thuiller, 2004
Building bio- or ecogeographic regions	No published example found
Improving calculation of ecological distance between patches in landscape meta-population dynamic and gene flow models	No published example found

Source: Guisan and Thuiller (2005).

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(Peterson, 2006; Stockwell, 2006), among other terms. The ecological niche-based models, for instance, have been used to study relationships between environmental factors and species richness (Nally and Fleishman, 2004), presence of species in landscape influenced by characteristics and spatial configuration of habitats (Araújo and Williams, 2000; Dormann et al., 2007; Ferrier et al., 2002b; Scotts and Drielsma, 2002), potential of invasive non-native species (Peterson, 2003), historical species' distributions (Hugall et al., 2002; Peterson et al., 2004) or species' distributions in future climates (Araújo et al., 2004; Bakkenes et al., 2002; Thomas et al., 2004; Thuiller et al., 2005; Woodin et al., 2013), and ecological and geographic differentiation of the distributions of closely-related species (Graham et al., 2004).

Another controversial usage of terms relates the concepts of 'habitat' and 'niche', which needs to be clarified by scientific researchers while conducting any predictive modelling studies on spatial distribution of species (Miller, 2010). Hence, what needs to be addressed is the urgency in rigorous assessments in this field of science to move forward with much transparency in the usage of terms (Kearney, 2006). Unambiguous interpretation of the aforementioned concepts requires explicit chosen assumptions and hypothesis about the spatial extent and spatial resolution of the areas that are measured; the types, mechanisms and effects of the biotic and abiotic interactions that may affect the distributions; the different roles that environmental and climate variables that can influence the presence and absence of species, and also the anthropogenic disturbances should be accounted in the niche definitions; and the scope of spatial displacements in ecological and evolutionary time frames.

The correlative ecological niche-based models often require little knowledge of the mechanistic links between species and its surrounding environment, which acts as an advantage for poorly studied taxa (Kearney and Porter, 2009). In many circumstances, this can be proven beneficial given the paucity in the amount of data available (Barbet–Massin et al., 2012), but otherwise, scientists employing ecological niche-based models should reflect more on their limitation of these approaches. The key issue in species distribution modeling is the selection of the explanatory variables to create species-environment profile that supposedly predicts the distribution and abundance of organisms (Dormann, 2007). Since the causal mechanism of species distribution is not readily quantifiable, we often resort to substitute and proxies (Minor and Urban, 2007). Table 2 summarizes the shortcomings of ecological niche-based models and species distribution projections. The most basic and fundamental constraint of the usage of such models is the understanding of physiological limitations of the species. Although, the field of physiological ecology is developing ever so quickly (Buckley et al., 2010; Helmuth et al., 2004), much still needs to be done to overcome the barrier of limiting behavioral, morphological, and physiological traits of species with GIS datasets (Kearney and Porter, 2009). In correlative modelling approaches, species occurrences information is linked with GIS built-in environment through different statistical techniques. In mechanistic modeling approaches, information on the functional traits of species is linked with GIS built-in environment through different models that explicitly capture key processes by which traits and habitat features interact to determine species-environment relationship.

In this chapter, we aim to review the various steps involved in predictive modeling of species, from the conceptual model formulation to species prediction and its application. After highlighting the major concerns on using such predictive models, we provide a basis for further developing the current existing ecological niche-based models. This state of the art technology, even though has been used considerably, with spectacular progress in dealing with the challenge of impacts of climate change; a better integration of these models with ecological theory can help to avoid the precluding use of these models in many theoretical and practical applications. We first define the concept of the term used from here on, *ecological niche-based models*, and provide an overview of the basic ecological theory and major assumptions

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Table 2. Overview of problems associated with ecological niche-based models

General Species Distribution Model Issues
Causal drivers are rarely quantifiable.
Species may not be at equilibrium with environmental drivers
Limiting factors may differ throughout a species' range
Distribution patterns are governed by processes at multiple spatial scales
Extrapolation Issues
Identity of limiting factors may change with environmental change
Biotic interactions are probably affected by environmental changes
Genetic structure of species is likely to be affected by environmental changes
Trends may not be valid beyond the range of present data
Environmental change scenarios are spatially uncertain
Statistical Issues
Drivers have non-linear effects on species distribution patterns
Drivers interact in their effects
Causal drivers may be correlated with each other
Data points in space are non-independent (spatial autocorrelation)
Presence-absence data have low information content
Low sample size and parsimony may lead to inadequately simple models

Source: Dormann (2007).

used in the predictive modelling process. We outline the steps involved in making a niche-based model used in the field of applied ecology, and we identify issues and applications associated with new developments in this field. We then discuss some methodological issues involved, and the decisions that are made during the process of developing a model and its calibration, and the implications of such results in ecological conservation and management. We summarize this chapter by addressing the challenges that should be overcome keeping in mind the limitations of these models. To add to this, we also discuss niche conservatism across different time scales and spatial scales in order to suggest future direction of species distribution modelling.

BACKGROUND

The ecological niche-based models attempts to provide detailed prediction of the distribution of species which is trained on its presence or abundance or absence or may be both, by relating it to environmental variables. For instance, the major concept central to predictive modelling is the distinction between geographic and ecological space, where geographic space is defined by either two-dimensional or three-dimensional space having information on species (such as occurrence records), and ecological space is a hypothetical multi-dimensional space which can be defined by sets of environmental layers (Figure 1).

In the field of ecology, any framework will have three basic major components for the statistical modelling process; namely,

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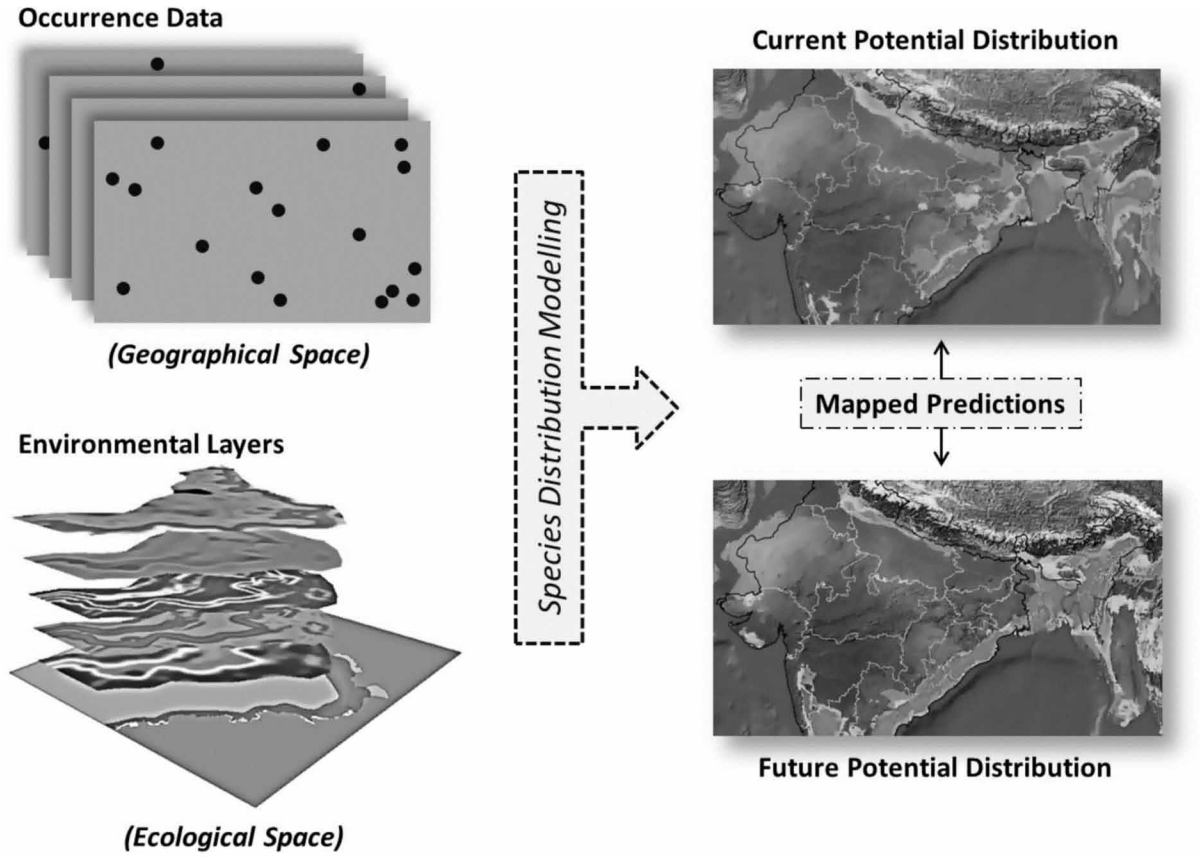
Figure 1. An example showing relationship between species and environmental data, and predictive modelling (current and future) of species using any set environmental variables



1. Ecological model,
2. Data model, and
3. Statistical model (Austin, 2002).

The ecological information to be used or tested in the study would be comprised in the ecological model. The data model would consist of the information regarding data collection and its pre- and post-processing. The statistical model would involve the choices of statistical method being employed, the error basis function and other significant tests to be conducted. The models interact with each other and determine the success or failure of any statistical predictive species distribution modelling process.

The ecological niche-based models are empirical models which mainly relate field observations with environmental variables; based on statistical or theoretical surfaces (Guisan and Zimmermann, 2000). The information about species data can simply be the presence, presence-absence, absence or abundance observations based on either random or stratified field sampling, or historical observations (Guisan and Thuiller, 2005). The environmental variables, however, can have direct or indirect influence on the species, optimally chosen to reflect the three foremost types of influences on the species, such as,

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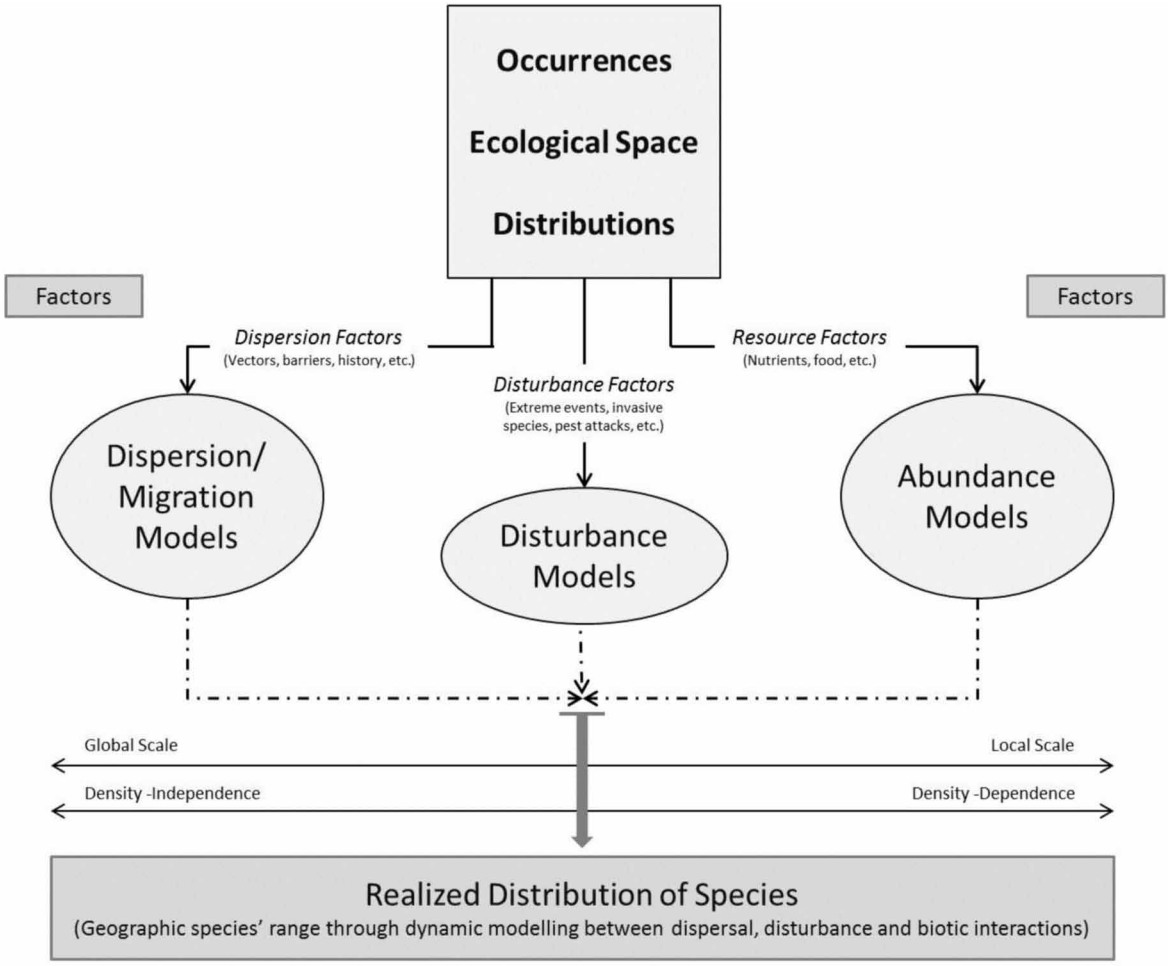
1. Limiting factors (or regulators),
2. Disturbances, and
3. Resources.

These relationships between the species in study and its overall environment can cause different geographical distribution patterns that needs to be observed at different temporal and spatial scales (Figure 1), often in a hierarchical manner (Pearson et al., 2004) (Figure 2).

For robust prediction of distribution of species, the understanding of the elements that can limit geographical range of species is crucial. The different statistical techniques used in the ecological niche-based models analyze organisms and its spatial existence in the ecosystems. These models vary significantly in scope and complexity. The distribution of species is intertwined with myriad number of climatic and environmental factors, which lead to the presence of a species at a particular geographical location. The niche-based modeling involves two fundamental steps; *first*, estimate the relationship among species in a particular area with respect to its biotic and abiotic conditions and *second*, forecast changes in the spe-

Figure 2. General hierarchical ecological niche-based models
Source: Adapted from Guisan and Thuiller (2005).



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cies' distribution in response to any environmental change. Some species distribution models strategies predict changes in the geographical distribution of species by combining factors that relate to niches and suitable environmental surroundings with the presence and abundance of species in a single modeling framework. In contrast to this archetype, a pure niche-based model will first estimate suitability on the basis of current environmental information. This kind of niche model is then applied to predict future conditions to estimate the potential areas suitable for that particular species' growth, which can serve as a critical input for a spatially explicit simulations (Anderson, 2013). The distribution and abundance of any species', however, can be influenced by many ecological and evolutionary processes, which may or may not be limited to a species' niche (Figure 3).

The niche of any species' can be predicted through either correlative or mechanistic models (Table 3); lately, efforts have been attempted to successfully link them (Kearney and Porter, 2009). Mechanistic models are directly on physiological and behavioral tolerances. However, these models can be quite dif-

Figure 3. Major ecological processes can be captured by niche-based models. These processes may or may not include biotic interactions (realized niche vs. fundamental niche).
Source: Adapted from Kearney and Porter (2009).

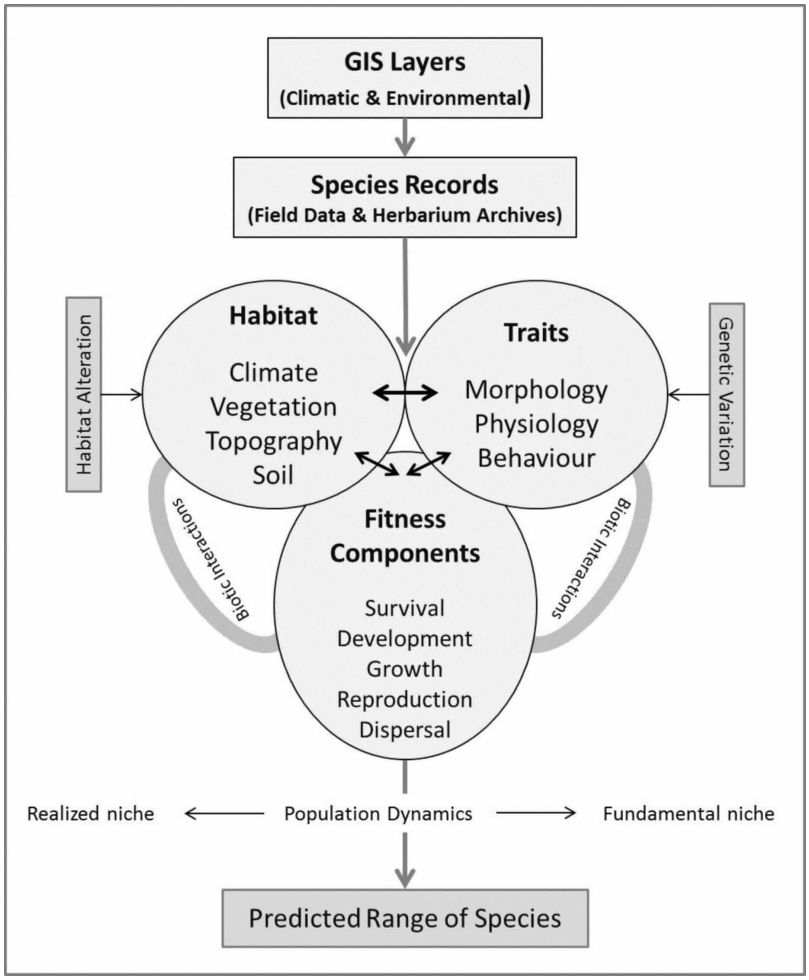

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Table 3. A comparison of mechanistic and correlative approaches to species distribution modelling

	Mechanistic (Physiological) Approaches	Correlative (Statistical) Approaches	Advantages of Mechanistic Approaches	Advantages of Correlative Approaches
Conceptualization				
Theoretical basis	Energy-mass balance, climate space, mechanistic conceptualization of the Hutchinsonian niche	Probability, statistical theory, pattern recognition, often considered in the context of the Hutchinsonian niche or habitat concepts	Grounded in physico-chemical principles, provides mechanistic understanding of underlying processes	Can implicitly incorporate any process, biotic or abiotic, statistically associated with the independent variables, can be used to develop hypotheses about underlying processes
Model selection	Prescribed (variants of an energy balance equation)	Flexible (numerous algorithms and variable selection procedures, e.g. regression, maximum entropy, polynomial ⁄linear terms)	Energy⁄mass balance equation provides a common frame of reference	Can be more easily tailored to fit available data
Generality (transferability) and precision	High generality across environments but potentially low precision	Local analysis often with high precision, although choice of variables and fitting strategy can be tailored for emphasizing generality or precision	Scope of applications extends to non-equilibrium/novel circumstances	More likely to capture a limiting processes, less likely to overestimate potential range
Data Requirements				
Species data	Functional traits, (morphology physiological and behavioural responses)	Occurrence data (presence only, presence⁄absence or abundance records)	Directly applies physiological understanding to range prediction. Can be applied when occurrence data is limited or in non-equilibrium⁄novel circumstances	Exploits a more commonly available data source
Spatial data	Prescribed – energy balance equations demand specific independent variables	Flexible	Less subjectivity in variable selection	While directly related (proximal) environmental variables are preferable, can exploit a wider range of proxy spatial data types
Scale	Prescribed – highly proximal (scale of an individual organism)	Flexible	Less subjectivity in variable selection	Can use data sets of a wider range of scales, can capture processes at different scales within a single model
Model Fitting				
Parameters	Trait values, enegry/mass transfer coefficients, physiological response curves (may themselves be parameterized statistically)	Dimensionless coefficients	Robust because parameters are estimated independently of the (geographical range⁄abundance) data	Pragmatic because parameters are estimated from a single dataset within a single analytical framework
Geographical variation (plastic and genetic)	Explicit	Implicit	Permits assessments of the degree of geographical variation and inference on its adaptive significance	Easier to incorporate geographical variation because it is indirectly represented in the occurrence data
Evolutionary change	Explicit	Implicit	Permits explicit consideration of evolution, avoids confounding with other processes that may alter environmental associations through time	Can exploit readily available datasets to set up testable hypotheses about the past evolution of traits
Inference				
Output	Fitness components (survival, performance, development, growth and reproductive capacity)	Dimensionless habitat suitability indices or estimates of probability of occurrence or abundance	Highly interpretable ecologically, may serve as input into other process models (e.g. dispersal)	Provides a simple output indirectly representing many different processes
Validation and evaluation	Validation through independent empirical studies (field and laboratory), e.g. of behaviour, body temperature, energy and water turnover, evaluation against independently observed occurrence	Fit evaluated against original occurrence input data, subsets of original data left aside for validation, or (rarely) independent data on distribution and abundance	Biologically grounded and independent of the data used to derive the model	Often easier because model construction and validation⁄evaluation uses a single, readily available dataset and analytical framework

Source: Kearney and Porter (2009).

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ficult to be implemented give the amount of extensive data it requires, along with cost factors. Hence, for most studies related to distribution mapping of species, correlative approaches are used. This can be conducted due to relatively easily available and accessible online and offline data sources regarding species occurrences and environmental conditions. Nonetheless, the challenges for building an ecological niche-based model differ substantially between mechanistic and correlative approaches; however, many relevant principles hold true for both the approaches (Anderson, 2013).

In this chapter, we aim to sketch a conceptual overview of niche and niche-based models in the field of ecological modelling. In order to do so, the theoretical paradigm of the selection criteria of the niche-based models while considering the methodological constraints is highlighted in the upcoming sections.

Niche Concept and Niche-Based Models

The notion of 'ecological niche' is central to ecology of an organism, where the ecological properties of species and area of geographical distribution is related (Grinnell, 1917; James et al., 1984). Over the years, scientists are trying to estimate distributional area of species, by calculating 'environmental' or 'ecological' niches (Guisan and Zimmermann, 2000; Peterson, 2006). The foundation of niche modeling may vary depending on the application of niche concept being applied, namely, Grinnellian concept, Eltonian concept and Hutchinsonian concept of ecological niches (Table 4).

The term 'niche' is used interchangeably by the modelers; although, much has been written about its different interpretations, both in general (Chase and Leibold, 2003; Pulliam, 2000) and as applied to ecological niche-based models in particular (Araújo and Guisan, 2006; Austin, 2002; Franklin, 2010; Guisan and Zimmermann, 2000; Kearney, 2006; Soberón and Peterson, 2005). It is, therefore, important to clarify which ecological niche concepts are being translated in the species distribution modeling process.

Model Selection and Methodological Considerations

There can be many modeling approaches, consequently, resulting in different outputs, depending upon the selection of the constructed ecological niche-based model. These modeling approaches could vary

Table 4. Summary of division of niche concepts

Niche Perspective	Relevant Environmental Variables	Generalities Regarding Scale	Nature of Driving Factors	Relationship to Population Growth Rate	Relevant Modeling Approach
Grinnellian niche	Variables not affected by the presence of the focal species	Coarser grains; geographic extents	Density-independent	Related to intrinsic population growth rate	Static models
Eltonian niche	Variables affected by the presence of the focal species	Finer grains; local extents	Density-dependent	Related to instantaneous population growth rate	Dynamic models
Hutchinsonian niche	Variables affected by the presence of the focal species	Spatial grains; regional to continental extents	Density-dependent	Related to instantaneous population growth rate	Static models

Source: Adapted from Anderson (2013).

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from the input sources itself, depending on the amount of data available. For instance, the model may be constructed from species occurrence points (presence; or presence/absence information) which acts as the dependent variable, and along with the required available environmental data of the same or approximately same region, which act as the independent variables. This kind of approach will lead to two types of common outputs: binary classification of geographical region as being within or outside the species distribution, and continuous or probabilistic distribution of species. The parameters can be further projected using future climate scenarios to develop and map the predicted future distribution of the species.

Predicting the distribution of species has gone through different phases in history:

1. Based on empirical data, non-spatial statistical quantification of the species–environment relationship,
2. Expert-based spatial modelling of distribution of species (non-statistical, non-empirical), and
3. Modelling of distribution of species through spatially explicit statistical and empirical models (Guisan and Thuiller, 2005).

With the evolvement of this field, it can be seen that there is little agreement on appropriate data, methodology or even interpretation, and mostly, there is little discussion behind the conceptual framework on which the predictive ecological niche-based model is based.

Even for comparison, the different methods of modeling approaches rarely use the same type of data (whether it is the abundance or presence/absence information), or type of the regression method being applied (for example, multiple linear versus curvi-linear), or even the usage of common set of predictor variables. Most of the evaluation of comparisons among the different set of modeling approaches by scientists lies in how the methods are being applied, i.e. model parameterization (Austin, 2007). Although, the basic paradigm for any modelling approach consists of commonly agreed set of evidences (that is, presence or absence data on species), a conceptual framework (viz. the niche theory to be considered), set number of variable that can be considered (climate and environmental condition of species distribution) and method of modeling the distribution (for example, logistic regression) (Guisan and Zimmermann, 2000).

Nonetheless, the ecological niche-based models, even with different levels of complexity fit within a basic framework. For instance, it either is using only climate as independent variables or/along with the usage of biophysical variables. The least common used models generally include the models that are constructed from physiological needs of different species (Kearney and Porter, 2009), rather than more commonly used species–climate models that are based on the distributional data.

Selecting the model best or most appropriate using the most influential predictors is crucial. Shortcomings in the selection procedure have been recognized and in response, newer approaches have been implemented to better predict species distributions (Guisan and Thuiller, 2005). These ecological niche-based distribution models can be developed using a variety of algorithms, including heuristic models (for example, BIOCLIM—Busby, 1991), statistical models (such as, generalized additive models, i.e., GAMs—Guisan et al., 2002), combinatorial optimization (e.g., genetic algorithm for rule set production, i.e., GARP—Stockwell, 1999) and machine learning (for instance, artificial neural network, ANN—Hilbert and Ostendorf, 2001; or, maximum entropy, MAXENT—Phillips et al., 2006). Studies have used multiple models to extrapolate global extinction rates from climate change (Thomas et al., 2004; Woodin et al., 2013). Table 5 lists the most of different published predictive models for studying species-specific information. One can conclude that each modeling approach has its own merits and demerits,

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Table 5. List of ecological niche-based models

	Type of Models	Data Type	Reference(s)
ANUCLIM	Envelope model	P	Xu and Hutchinson, 2011
BIOCLIM	Envelope model	P	Busby, 1991
BAYES	Predictive statistical model	P	Aspinall, 1992; Ellison, 2004
BIOMAPPER	Envelope model	P	Hirzel et al., 2007
BIOMOD	Envelope model	P, A	Thuiller et al., 2009
BRUTU	Regression, a fast implementation of a GAM	P, A	Hastie et al., 2009
DOMAIN	Multivariate distance	P, A	Carpenter et al., 1993
ENFA	Ecological niche factor analysis	P	Hengl et al., 2009
LIVES	Multivariate distance	P, A	Elith et al., 2006
GAMs	Generalized additive models	P, A	Guisan et al., 2002
GBMs	Boosted decision trees	P, A	Friedman et al., 2000
GLMS	Generalized linear models (logistic regression, auto-logistic regression, regression and others)		Guisan et al., 2002
GARP	Genetic algorithm for rule set prediction	P, A	Stockwell, 1999
GDM	Generalized dissimilarity model	P, A	Ferrier et al., 2002b
GRASP	Generalized regression analysis and spatial prediction	P, A	Lehmann et al., 2002
MARS	Regression; multivariate adaptive regression splines	P, A	Moisen and Frescino, 2002
MAXENT	Maximum Entropy	P, A	Phillips et al., 2006
ModEco	Envelope model	P, A	Guo and Liu, 2010
NPMR	Non-parametric multiplicative regression	P, A	Yost, 2008
OM-GARP	Open modeller-GARP	P, A	Elith et al., 2006
SPECIES	Artificial neural network (ANN)	P	Pearson et al., 2002

Source: Adapted from Guisan and Thuiller (2005) and Wisz et al. (2008).
P – Presence; A – Absence.

and accordingly has its own important strengths and weaknesses. In order to test the performance of any modeling approach, it can be generally evaluated using a test or validation datasets (Elith et al., 2006; Hijmans, 2012; Wisz et al., 2008). What can be achieved, or hoped to be achieved, is the use of different set of modelling approaches, and identification of significant interactions among the species and the environment to better understand the complexity in nature.

Functionalities and Possibilities

At times, bearing in mind the availability of data and the landscape constraints, as researchers we also need to delimit the scope and extent of our analysis. While doing so, one needs to also consider the abiotic, biotic and movement factors (‘the BAM diagram’) that may or may not limit the distributions of species in geographical space (Figure 4). This kind of illustration of the scale-dependent relationship is critical for identifying the nature of differences in predicting the distribution of species. These three interacting set of factors,

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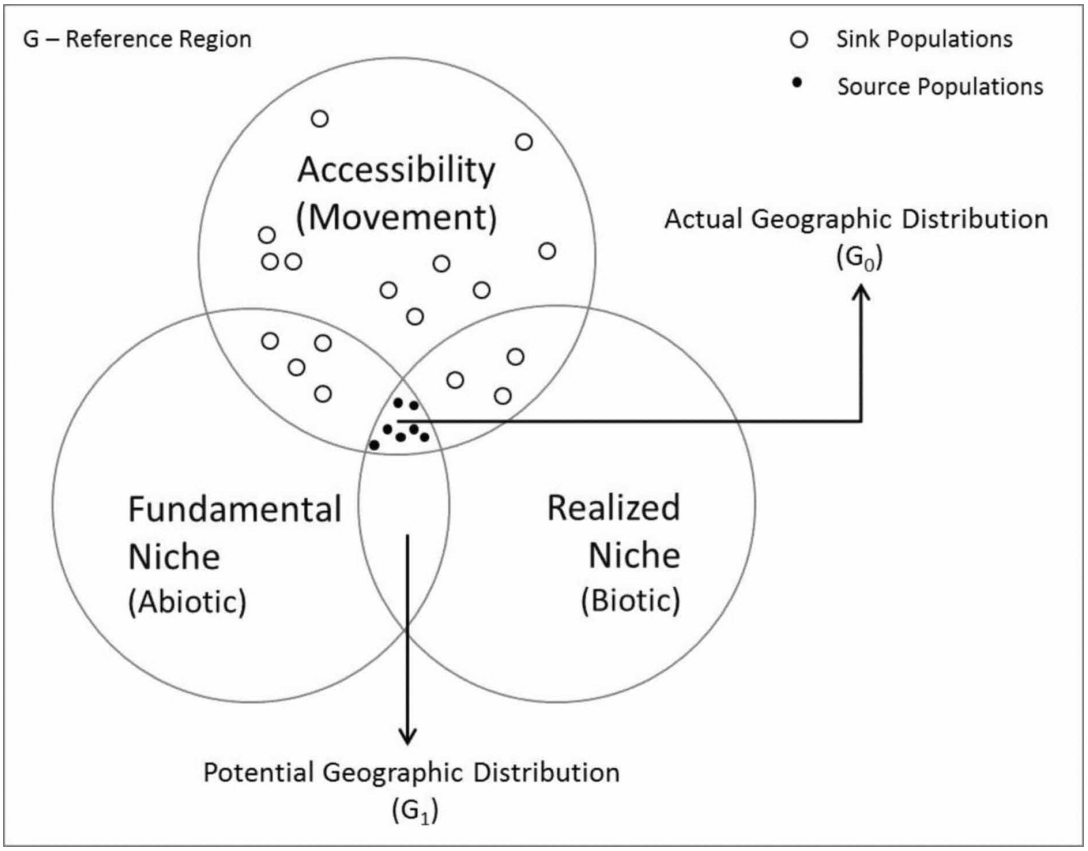
Figure 4. A simplified version of the BAM diagram; the distribution of species corresponds to three sets of factors: abiotic niche (A), biotic niche (B), and, accessibility or movement (M). A and B roughly correspond to the fundamental ecological niche (A) and the realized ecological niche (A ∩ B, here termed the potential geographic distribution). The area corresponding involvement of all the three set of factors (A ∩ B ∩ M) is the actual geographic distribution of species. [Note: The absence of species can be due to incorrect environment, lack of dispersal capacity; and also due to both incorrect conditions and limited dispersal (it can be present anywhere, depending on the condition)].
Source: Adapted from Soberón and Peterson (2005).



1. Abiotic,
2. Biotic, and
3. Movement factors, help us in anticipating the geographical distributions of organisms.

The basic requirements of most of the ecological-niche based models are the same. The set of applications that they have been used for have are summarized in Table 6. The first and foremost step is to understand the ecological requirements of the species by understanding its ecological dimensions relevant to the geographical distribution (Peterson, 2006). The second most important criteria is the knowledge on limiting factors that constitute the geographical space of any species should be clearly understood and categorized before applying any niche-based model for ecological studies. Depending on the availability of the data required, one can then select the appropriate best model for selecting the

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Table 6. Summary of different uses of ecological niche-based models, and their requirements in terms of output and information

Quality of Interest	Understand Ecological Requirements of Species	Understand Biogeography and Dispersal Barriers	Find Unknown Populations	Find New Species	Identify Sites for Translocations and Reintroductions	Conservation Planning and Reserve System Design	Predict Effects of Habitat Loss	Predict Species' Invasions	Predict Climate Change Effects
Form of prediction (e.g., binary, ranked, absolute)	Any	Any	Any	Any	Absolute	Absolute	Any	Any	Any
Grain required	Any	Any	Population	Any	Individual-population	Individual-population	Any	Any	Any, but may be limited by resolution of climate change data sets
Causal variables needed, or surrogates OK?	Causal	Causal	Surrogates	Surrogates OK if within range; causal necessary if extrapolating	Surrogates OK if within range; causal necessary if extrapolating	Surrogates	Causal	Causal	Causal
Need model response curve or parameter retrieval	Yes	Yes	No	No	Useful, to avoid error	Useful, to avoid error	No	No	No
Error needs	Overall low error needed	Overall low error needed	Low omission (don't mind searching extra localities, but don't want to leave anything out)	Low omission (don't mind searching extra localities, but don't want to leave anything out)	Low commission (very high cost of errors)	Low commission (very high cost of errors)	Overall	Overall	Overall
Potential distributional model *versus* realized distribution?	Potential	Potential	Realized	Potential	Realized	Realized	Realized	Potential	Both
Uncertainty estimates needed?	No	No	No	No	Yes	Yes	No	No	No

Source: Peterson (2006).

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distribution model for predictive studies. The third basic requirement of any models would lie in the known and unknown population of species.

The in depth understanding of the ecological niche-based models functions and further possibilities will help in prioritizing areas based on the patterns of species' occurrences. This can help in establishing conservation sites accordingly to the most likely suitable or unsuitable sites for the species in study, depending on the case of management strategy that may be. The relatively easier applicability of the ecological niche-based models helps in identifying the framework that can be applied for conservation of the threatened or likely to be the threatened species in present as well as in future.

Assumptions and Statistical Stumbling Stones

Since the information on both species' occurrences and the environmental as well as climatic data is limited to either time or space, the species-environment relationship that is generated through these ecological niche-based models, it can only provide us a overview of the expected relationship. One of the convenient ways of working around such predictive modelling approaches is to assume that the species modeled would attain if not any complete but partial pseudo-equilibrium with its environment (Guisan and Thuiller, 2005).

The appropriate selection of the models for correlative niche modeling, both regarding records of the species' presence or absence, along with environmental variables assumes certain hypothesis. Much of the information regarding the environment and climatic parameters at the predictive species' site, show disagreement with the correlative niche modelling techniques found at presence records datasets (Anderson, 2013). To add to this, several statistical obstacles are also there when it comes to interpretation of these modelling results. The first and foremost factor that needs to be looked in details is the availability of data. The collection of data at different resolutions, during different time periods, along with collection under different taxonomic concepts and ecological hierarchies creates difficulty, depending on the purpose of niche modeling exercise. To integrate all the data available in one platform itself, is a big challenge and requires more specific dedicated analysis, unlike done otherwise.

The first challenge and the major assumption that is considered in most studies are the linear predictors used for species distribution (Dormann, 2007). For most ecological studies, one can safely accept non-linear effect of species abundance or performance to environmental variables (Austin, 2002). Likewise, few analysis attempt to investigate of species distributions with interactions among environmental drivers (Thuiller et al., 2003). The second most important assumption is disregarding the commonalities among interrelated drivers (Anderson, 2013; Dormann, 2007). Many a times, the predictive modelling approach fails to detect the species in the geographical space (whether or not it occupies those regions). The abiotic conditions that can be found in the species' occupied areas correspond to the species' occupied niche space, which is termed the *realized niche* in the analysis. Even if we assume that all occurrences of species represent demographic sources and the sampling was unbiased, the presence-only records may provide inadequate and/or inaccurate classifications of the species' *fundamental niche* for the examined abiotic variables. Therefore, we can conclude two major issues that contribute to the performance of ecological niche-based models:

1. The limited range of environmental conditions that exist in a study site; and
2. Non-equilibrium distributions of species (Anderson, 2013).

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Another ambiguity that may arise is the purpose of the modeling approach, where the estimates of the fundamental niche require clarity in the niche space assumption, that is, whether it is applicable to the study region (correlative niche modelling) or experiments (mechanistic niche modelling). Moreover, correlative niche models assume that presence records constitute unbiased samples, unlike mechanistic niche models. Table 7 summarizes these assumptions regarding occurrence data as the dispersal/demographic noise assumption, the biotic noise assumption, and the human noise assumption. Each assumption relates to the condition for a particular species in any given study site.

These descriptions clearly leave us a bleak impression on the current state of the art modelling approaches. However, it is known that species' distribution modelling has both potential for science and social science. Since the assumptions lead us to principally selecting the ecological niche-based model to be applied, one must acknowledge them clearly before concluding any solutions. If any such assumption is not clarified in a study, the niche model will automatically start accounting for incomplete or distorted predictive estimate of specie's geographical distribution. Despite the drawbacks, many insightful studies have been attempted to solve the above mentioned problems. Realizing these caveats is essential, as one may take up the endeavor to solve such ecological riddles.

FUTURE RESEARCH DIRECTIONS

Given the current need to improve our knowledge on the distribution of species in the era of global change, we need to address the issues in our modelling approaches. Consideration of few steps is crucial to successfully apply the practical solutions of such predictive modeling experiments. To further develop

Table 7. Four assumptions associated with data used in niche models estimating abiotic suitability for a species, with recommendations for correlative models of Grinnellian niches

Name of Assumption	Assumption	Consequences of Violation	Recommendations
Niche space assumption	The study contains the full range of conditions that the species can inhabit (for the examined abiotic variables)	The existing fundamental niche is smaller than the fundamental niche; the species' response is truncated for one or more abiotic variables	Use presence records from many portions of the species' range and over multiple time periods; examine response curves and detect truncations in calibration region
Dispersal/ demographic noise assumption	Factors related to dispersal, establishment, and persistence do not cause the species to occupy an environmentally biased subset of the abiotically suitable areas	The occupied niche space is smaller than the existing fundamental niche; the species' response is truncated and/or distorted for one or more abiotic variables	Use occurrence data (presence records and comparison data) only from regions where the species is at equilibrium with abiotic variables or where limitations caused by dispersal/ demography, biotic interactions, or human modifications do not cause the species to occupy an environmentally biased subset of the abiotically suitable areas
Biotic noise assumption	Biotic interactions do not cause the species to occupy an environmentally biased subset of the abiotically suitable areas	Same as above	
Human noise assumption	Human modifications of the environment do not cause the species to occupy an environmentally biased subset of the abiotically suitable areas	Same as above	

Source: Anderson (2013).

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these ecological niche-based models, few recommendations should be considered in such experiments and their projections. The first critical step would imply to understand the uncertainties involved with the outputs of predictive modeling of the distribution of species. The identification of the flaws causing major variability should be noted and accepted in the models. These assumptions include the quality of primary and secondary data being collected, the choice and collinearity of explanatory predictor variables, and type of statistical modelling approach considered (Dormann, 2007). The next step would involve efforts to compare the differences in outputs of the distribution models. Consideration of maximum possible abiotic and biotic factors accounting for the ecological processes is also important. Given the data availability, such factors can determine the performance of the niche models. And lastly, the validation of such predictive modeling exercise should be thoroughly conducted before jumping to conclusion on the geographical range of species distribution.

Although many studies have been using predictive ecological niche-based models for impacts studies on climate change and species conservation, recent studies suggest that their uses is in now resurfacing in theoretical ecology and evolution. However, given the pitfalls in this field of study, we need to be reasonable and therefore, further improve the methods. Species which require general environment to survive are preferably better candidates for such modeling studies. While species which require more specific explicit environment of survival, may not be best modeled with such species distribution models.

The future of this field of science lies in further developing the basic biological and ecological research tools. If our understanding and knowledge of the target species' ecology is clear, such predictive models can be very well utilized. We need to improve our modelling algorithms and try to use the best available method. Systematic collection of species distribution records is essential as it represents the basic requirement of any model. Even the collection of absences is valuable, because many modeling routines may require both absence and presence data information about the species. Both the geographic and environmental space should be well-sampled and surveyed for these niche models. The outputs of such studies should be regularly monitored especially while predicting future distribution of species. In this way, the models can be further validated and improved. While addressing the uncertainties explicitly, it should be communicated with other researchers, along with managers and policy makers, so as to put these models to better use. Whether it is the migration process, or the dynamics of species, or the incorporation of biotic interactions while modelling the functional traits and communities, it should be explored more in this field (Guisan and Thuiller, 2005). It would be interesting to see such efforts which can drastically influence the outputs and reliability of such modelling approaches.

CONCLUSION

Although there has been tremendous development that has been made on many aspects related to the building and evaluation of ecological niche-based models, focused future efforts should be considered for developing and standardized more robust modelling frameworks. This chapter points out the critical, but obvious issues that need to addressed. It may be pointed out that, although it may seem obvious, it has been neglected in the past. However, recent efforts have been made to improve such modelling frameworks, while keeping mind the uncertainties.

Many important basic concepts require deeper dwelling and understanding. Some of them are as follows:

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1. To explore the relationship between niche concepts and species distribution;
2. To assess the equilibrium or pseudo-equilibrium stages of modelled species; and
3. To investigate the degree to which competition among species can limit their geographical ranges along environmental gradients (Guisan and Thuiller, 2005).

Both information of time scale and spatial scale should be further enhanced to decrease the errors and uncertainties in ecological niche-based models.

Sources of biological data continue to expand, particularly for presence-only observations; environmental data are available at even finer spatial resolutions; and more complex modeling algorithms are being developed or becoming accessible to the SDM community. Each step taken in the species distribution modeling process involves a combination of assumptions and subjective decisions that propagate to affect the product, which is increasingly used to inform policy decisions. Given their current and potential use in a wide range of applications, these conceptual issues associated with the data and methods used need further study.

With this chapter, we try to highlight issues that can be identified in such simulation experiments of ecological niche-based models, in a geographic built-in environment. Whether it is the spatial autocorrelation, or paucity in the availability of data, there is still considerable debate that needs to be addressed. Although, we try to model scenarios of species' distribution based on simulated data, it can be proven most useful if the assumptions of niche concept and the environmental profile can be further elucidated. If the ecological niche-based models are used in forecasting studies, issues of ecological equilibrium theory and ecological niche conservatism should be answered prior to such exploration.

In conclusion, with this chapter, we critically assess different ecological modeling approaches. We focused on the potential of using such experimental models for large-scale ecosystem modeling studies. This can serve as a basis for the scientist and researcher interested ecological modeling, who can further contribute and develop such models to better understand the complex field of ecosystem studies. We urge the ecologists, geographers, bio-geographers, modelers, and biologists to work in unison and contribute in a much concentrated manner to further develop this field of scientific research. Along with this we also need initiatives to develop interfaces between the scientific interpretation and required generalization for policy analysis.

REFERENCES

Anderson, R. P. (2013). A framework for using niche models to estimate impacts of climate change on species distributions. *Annals of the New York Academy of Sciences*, *1297*, 8–28. PMID:25098379

Anderson, R. P., Peterson, A. T., & Gómez-Laverde, M. (2002). Using niche-based GIS modeling to test geographic predictions of competitive exclusion and competitive release in South American pocket mice. *Oikos*, *98*(1), 3–16. doi:10.1034/j.1600-0706.2002.t01-1-980116.x

Araújo, M. B., Cabeza, M., Thuiller, W., Hannah, L., & Williams, P. H. (2004). Would climate change drive species out of reserves? An assessment of existing reserve-selection methods. *Global Change Biology*, *10*(9), 1618–1626. doi:10.1111/j.1365-2486.2004.00828.x

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Araújo, M. B., & Guisan, A. (2006). Five (or so) challenges for species distribution modelling. *Journal of Biogeography*, *33*(10), 1677–1688. doi:10.1111/j.1365-2699.2006.01584.x

Araújo, M. B., & Williams, P. H. (2000). Selecting areas for species persistence using occurrence data. *Biological Conservation*, *96*(3), 331–345. doi:10.1016/S0006-3207(00)00074-4

Aspinall, R. (1992). An inductive modelling procedure based on Bayes' theorem for analysis of pattern in spatial data. *International Journal of Geographical Information Systems*, *6*(2), 105–121. doi:10.1080/02693799208901899

Austin, M. (2002). Spatial prediction of species distribution: An interface between ecological theory and statistical modelling. *Ecological Modelling*, *157*(2-3), 101–118. doi:10.1016/S0304-3800(02)00205-3

Austin, M. (2007). Species distribution models and ecological theory: A critical assessment and some possible new approaches. *Ecological Modelling*, *200*(1-2), 1–19. doi:10.1016/j.ecolmodel.2006.07.005

Austin, M., Nicholls, A., & Margules, C. R. (1990). Measurement of the realized qualitative niche: Environmental niches of five Eucalyptus species. *Ecological Monographs*, *60*(2), 161–177. doi:10.2307/1943043

Bakkenes, M., Alkemade, J., Ihle, F., Leemans, R., & Latour, J. (2002). Assessing effects of forecasted climate change on the diversity and distribution of European higher plants for 2050. *Global Change Biology*, *8*(4), 390–407. doi:10.1046/j.1354-1013.2001.00467.x

Barbet–Massin, M., Jiguet, F., Albert, C. H., & Thuiller, W. (2012). Selecting pseudo-absences for species distribution models: How, where and how many? *Methods in Ecology and Evolution*, *3*(2), 327–338. doi:10.1111/j.2041-210X.2011.00172.x

Beerling, D. J., Huntley, B., & Bailey, J. P. (1995). Climate and the distribution of Fallopia japonica: Use of an introduced species to test the predictive capacity of response surfaces. *Journal of Vegetation Science*, *6*(2), 269–282. doi:10.2307/3236222

Brown, S. K., Buja, K. R., Jury, S. H., Monaco, M. E., & Banner, A. (2000). Habitat suitability index models for eight fish and invertebrate species in Casco and Sheepscot Bays, Maine. *North American Journal of Fisheries Management*, *20*(2), 408–435. doi:10.1577/1548-8675(2000)020<0408:HSIMFE>2.3.CO;2

Buckley, L. B., Urban, M. C., Angilletta, M. J., Crozier, L. G., Rissler, L. J., & Sears, M. W. (2010). Can mechanism inform species' distribution models? *Ecology Letters*, *13*, 1041–1054. PMID:20482574

Busby, J. R. (1991). *BIOCLIM – a bioclimate analysis and prediction system. Plant Protection Quarterly (Australia)* (pp. 64–68). Melbourne: CSIRO.

Carpenter, G., Gillison, A., & Winter, J. (1993). DOMAIN: A flexible modelling procedure for mapping potential distributions of plants and animals. *Biodiversity and Conservation*, *2*(6), 667–680. doi:10.1007/BF00051966

Chase, J. M., & Leibold, M. A. (2003). *Ecological niches: linking classical and contemporary approaches*. University of Chicago Press. doi:10.7208/chicago/9780226101811.001.0001

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Dormann, C. F. (2007). Promising the future? Global change projections of species distributions. *Basic and Applied Ecology*, *8*(5), 387–397. doi:10.1016/j.baae.2006.11.001

Dormann, C. F., McPherson, J. M., Araujo, M. B., Bivand, R., Bolliger, J., Carl, G., ... Wilson, R. (2007). Methods to account for spatial autocorrelation in the analysis of species distributional data: A review. *Ecography*, *30*, 609–628. doi:10.1111/j.2007.0906-7590.05171.x

Elith, J., Burgman, M. A., & Regan, H. M. (2002). Mapping epistemic uncertainties and vague concepts in predictions of species distribution. *Ecological Modelling*, *157*(2-3), 313–329. doi:10.1016/S0304-3800(02)00202-8

Elith, J., Graham, C., Anderson, R., Dudik, M., Ferrier, S., Guisan, A., ... Zimmermann, N. (2006). Novel methods improve prediction of species' distributions from occurrence data. *Ecography*, *29*, 129–151. doi:10.1111/j.2006.0906-7590.04596.x

Ellison, A. M. (2004). Bayesian inference in ecology. *Ecology Letters*, *7*(6), 509–520. doi:10.1111/j.1461-0248.2004.00603.x

Engler, R., Guisan, A., & Rechsteiner, L. (2004). An improved approach for predicting the distribution of rare and endangered species from occurrence and pseudo-absence data. *Journal of Applied Ecology*, *41*(2), 263–274. doi:10.1111/j.0021-8901.2004.00881.x

Ferrier, S. (2002). Mapping spatial pattern in biodiversity for regional conservation planning: Where to from here? *Systematic Biology*, *51*(2), 331–363. doi:10.1080/10635150252899806 PMID:12028736

Ferrier, S., Drielsma, M., Manion, G., & Watson, G. (2002a). Extended statistical approaches to modelling spatial pattern in biodiversity in northeast New South Wales. II. Community-level modelling. *Biodiversity and Conservation*, *11*(12), 2309–2338. doi:10.1023/A:1021374009951

Ferrier, S., Watson, G., Pearce, J., & Drielsma, M. (2002b). Extended statistical approaches to modelling spatial pattern in biodiversity in northeast New South Wales. I. Species-level modelling. *Biodiversity and Conservation*, *11*(12), 2275–2307. doi:10.1023/A:1021302930424

Franklin, J. (1995). Predictive vegetation mapping: Geographic modelling of biospatial patterns in relation to environmental gradients. *Progress in Physical Geography*, *19*(4), 474–499. doi:10.1177/030913339501900403

Franklin, J. (2010). Moving beyond static species distribution models in support of conservation biogeography. *Diversity & Distributions*, *16*(3), 321–330. doi:10.1111/j.1472-4642.2010.00641.x

Friedman, J., Hastie, T., & Tibshirani, R. (2000). Additive logistic regression: A statistical view of boosting. *Annals of Statistics*, *28*(2), 337–407. doi:10.1214/aos/1016218223

Graham, C. H., Ron, S. R., Santos, J. C., Schneider, C. J., & Moritz, C. (2004). Integrating phylogenetics and environmental niche models to explore speciation mechanisms in dendrobatid frogs. *Evolution; International Journal of Organic Evolution*, *58*(8), 1781–1793. doi:10.1111/j.0014-3820.2004.tb00461.x PMID:15446430

Grinnell, J. (1917). The niche-relationships of the California Thrasher. *The Auk*, *34*(4), 427–433. doi:10.2307/4072271

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Guisan, A., Edwards, T. C. Jr, & Hastie, T. (2002). Generalized linear and generalized additive models in studies of species distributions: Setting the scene. *Ecological Modelling*, *157*(2-3), 89–100. doi:10.1016/S0304-3800(02)00204-1

Guisan, A., & Theurillat, J.-P. (2000). Equilibrium modeling of alpine plant distribution: How far can we go? *Phytocoenologia*, *30*(3-4), 353–384. doi:10.1127/phyto/30/2000/353

Guisan, A., & Thuiller, W. (2005). Predicting species distribution: Offering more than simple habitat models. *Ecology Letters*, *8*(9), 993–1009. doi:10.1111/j.1461-0248.2005.00792.x

Guisan, A., & Zimmermann, N. E. (2000). Predictive habitat distribution models in ecology. *Ecological Modelling*, *135*(2-3), 147–186. doi:10.1016/S0304-3800(00)00354-9

Guo, Q., & Liu, Y. (2010). ModEco: An integrated software package for ecological niche modeling. *Ecography*, *33*(4), 637–642. doi:10.1111/j.1600-0587.2010.06416.x

Hastie, T., Tibshirani, R., Friedman, J., Hastie, T., Friedman, J., & Tibshirani, R. (2009). *The elements of statistical learning*. New York: Springer-Verlag. doi:10.1007/978-0-387-84858-7

Heikkinen, R. K., Luoto, M., Araújo, M. B., Virkkala, R., Thuiller, W., & Sykes, M. T. (2006). Methods and uncertainties in bioclimatic envelope modelling under climate change. *Progress in Physical Geography*, *30*(6), 751–777. doi:10.1177/0309133306071957

Helmuth, B., Kingsolver, J. G., & Carrington, E. (2004). Biophysics, physiological ecology, and climate change: Does mechanism matter? *Annual Review of Physiology*, *67*(1), 177–201. doi:10.1146/annurev.physiol.67.040403.105027 PMID:15709956

Hengl, T., Sierdsema, H., Radović, A., & Dilo, A. (2009). Spatial prediction of species' distributions from occurrence-only records: Combining point pattern analysis, ENFA and regression-kriging. *Ecological Modelling*, *220*(24), 3499–3511. doi:10.1016/j.ecolmodel.2009.06.038

Hijmans, R. J. (2012). Cross-validation of species distribution models: Removing spatial sorting bias and calibration with a null model. *Ecology*, *93*(3), 679–688. doi:10.1890/11-0826.1 PMID:22624221

Hilbert, D. W., & Ostendorf, B. (2001). The utility of artificial neural networks for modelling the distribution of vegetation in past, present and future climates. *Ecological Modelling*, *146*(1-3), 311–327. doi:10.1016/S0304-3800(01)00323-4

Hirzel, A., Hausser, J., & Perrin, N. (2007). *Biomapper 4.0*. Switzerland: Laboratory for Conservation Biology, Department of Ecology and Evolution, University of Lausanne. Retrieved from http://www2.unil.ch/biomapper

Hirzel, A. H., Hausser, J., Chessel, D., & Perrin, N. (2002). Ecological-niche factor analysis: How to compute habitat-suitability maps without absence data? *Ecology*, *83*(7), 2027–2036. doi:10.1890/0012-9658(2002)083[2027:ENFAHT]2.0.CO;2

Hirzel, A.H., Le Lay, G., Helfer, V., Randin, C., Guisan, A., (2006). Evaluating the ability of habitat suitability models to predict species presences. *Ecological Modelling*, 199(2), 142–152.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Hugall, A., Moritz, C., Moussalli, A., & Stanisic, J. (2002). Reconciling paleodistribution models and comparative phylogeography in the Wet Tropics rainforest land snail Gnarosophia bellendenkerensis (Brazier 1875). *Proceedings of the National Academy of Sciences of the United States of America*, *99*(9), 6112–6117. doi:10.1073/pnas.092538699 PMID:11972064

James, F. C., Johnston, R. F., Wamer, N. O., Niemi, G. J., & Boecklen, W. J. (1984). The Grinnellian niche of the wood thrush. *American Naturalist*, *124*(1), 17–47. doi:10.1086/284250

Kearney, M. (2006). Habitat, environment and niche: What are we modelling? *Oikos*, *115*(1), 186–191. doi:10.1111/j.2006.0030-1299.14908.x

Kearney, M., & Porter, W. (2009). Mechanistic niche modelling: Combining physiological and spatial data to predict species' ranges. *Ecology Letters*, *12*(4), 334–350. doi:10.1111/j.1461-0248.2008.01277.x PMID:19292794

Leathwick, J. R. (1998). Are New Zealand's Nothofagus species in equilibrium with their environment? *Journal of Vegetation Science*, *9*(5), 719–732. doi:10.2307/3237290

Lehmann, A., Overton, J. M., & Leathwick, J. R. (2002). GRASP: Generalized regression analysis and spatial prediction. *Ecological Modelling*, *157*(2-3), 189–207. doi:10.1016/S0304-3800(02)00195-3

Miller, J. (2010). Species distribution modeling. *Geography Compass*, *4*(6), 490–509. doi:10.1111/j.1749-8198.2010.00351.x

Miller, J., Franklin, J., & Aspinall, R. (2007). Incorporating spatial dependence in predictive vegetation models. *Ecological Modelling*, *202*(3-4), 225–242. doi:10.1016/j.ecolmodel.2006.12.012

Minor, E. S., & Urban, D. L. (2007). Graph theory as a proxy for spatially explicit population models in conservation planning. *Ecological Applications*, *17*(6), 1771–1782. doi:10.1890/06-1073.1 PMID:17913139

Moisen, G. G., & Frescino, T. S. (2002). Comparing five modelling techniques for predicting forest characteristics. *Ecological Modelling*, *157*(2-3), 209–225. doi:10.1016/S0304-3800(02)00197-7

Nally, R. M., & Fleishman, E. (2004). A successful predictive model of species richness based on indicator species. *Conservation Biology*, *18*(3), 646–654. doi:10.1111/j.1523-1739.2004.00328_18_3.x

Pearce, J., & Lindenmayer, D. (1998). Bioclimatic analysis to enhance reintroduction biology of the endangered helmeted honeyeater (Lichenostomus melanops cassidix) in southeastern Australia. *Restoration Ecology*, *6*(3), 238–243. doi:10.1046/j.1526-100X.1998.00636.x

Pearson, R., Dawson, T., Berry, P., & Harrison, P. (2002). SPECIES: A spatial evaluation of climate impact on the envelope of species. *Ecological Modelling*, *154*(3), 289–300. doi:10.1016/S0304-3800(02)00056-X

Pearson, R. G., & Dawson, T. P. (2003). Predicting the impacts of climate change on the distribution of species: Are bioclimate envelope models useful? *Global Ecology and Biogeography*, *12*(5), 361–371. doi:10.1046/j.1466-822X.2003.00042.x

Pearson, R. G., Dawson, T. P., & Liu, C. (2004). Modelling species distributions in Britain: A hierarchical integration of climate and land-cover data. *Ecography*, *27*(3), 285–298. doi:10.1111/j.0906-7590.2004.03740.x

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Peterson, A. T. (2003). Predicting the geography of species' invasions via ecological niche modeling. *The Quarterly Review of Biology*, *78*(4), 419–433. doi:10.1086/378926 PMID:14737826

Peterson, A. T. (2006). Uses and requirements of ecological niche models and related distributional models. *Biodiversity Informatics*, *3*(0), 59–72. doi:10.17161/bi.v3i0.29

Peterson, A. T., Martínez-Meyer, E., & González-Salazar, C. (2004). Reconstructing the Pleistocene geography of the Aphelocoma jays (Corvidae). *Diversity & Distributions*, *10*(4), 237–246. doi:10.1111/j.1366-9516.2004.00097.x

Phillips, S. J., Anderson, R. P., & Schapire, R. E. (2006). Maximum entropy modeling of species geographic distributions. *Ecological Modelling*, *190*(3-4), 231–259. doi:10.1016/j.ecolmodel.2005.03.026

Pulliam, H. R. (2000). On the relationship between niche and distribution. *Ecology Letters*, *3*(4), 349–361. doi:10.1046/j.1461-0248.2000.00143.x

Raxworthy, C. J., Martinez-Meyer, E., Horning, N., Nussbaum, R. A., Schneider, G. E., Ortega-Huerta, M. A., & Peterson, A. T. (2003). Predicting distributions of known and unknown reptile species in Madagascar. *Nature*, *426*(6968), 837–841. doi:10.1038/nature02205 PMID:14685238

Roloff, G. J., & Kernohan, B. J. (1999). Evaluating reliability of habitat suitability index models. *Wildlife Society Bulletin*, *27*, 973–985.

Scotts, D., & Drielsma, M. (2002). Developing landscape frameworks for regional conservation planning; an approach integrating fauna spatial distributions and ecological principles. *Pacific Conservation Biology*, *8*, 235.

Sinclair, S. J., White, M. D., & Newell, G. R. (2010). How useful are species distribution models for managing biodiversity under future climates. *Ecology and Society*, *15*, 8.

Soberón, J., & Peterson, A. T. (2005). Interpretation of models of fundamental ecological niches and species' distributional areas. *Biodiversity Informatics*, *2*(0), 1–10. doi:10.17161/bi.v2i0.4

Stockwell, D. (1999). The GARP modelling system: Problems and solutions to automated spatial prediction. *International Journal of Geographical Information Science*, *13*(2), 143–158. doi:10.1080/136588199241391

Stockwell, D. (2006). Improving ecological niche models by data mining large environmental datasets for surrogate models. *Ecological Modelling*, *192*(1-2), 188–196. doi:10.1016/j.ecolmodel.2005.05.029

Thomas, C. D., Cameron, A., Green, R. E., Bakkenes, M., Beaumont, L. J., Collingham, Y. C., ... Williams, S. E. (2004). Extinction risk from climate change. *Nature*, *427*(6970), 145–148. doi:10.1038/nature02121 PMID:14712274

Thuiller, W. (2004). Patterns and uncertainties of species' range shifts under climate change. *Global Change Biology*, *10*(12), 2020–2027. doi:10.1111/j.1365-2486.2004.00859.x PMID:25200514

Thuiller, W., Araújo, M. B., & Lavorel, S. (2003). Generalized models vs. classification tree analysis: Predicting spatial distributions of plant species at different scales. *Journal of Vegetation Science*, *14*(5), 669–680. doi:10.1111/j.1654-1103.2003.tb02199.x

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Thuiller, W., Lafourcade, B., Engler, R., & Araújo, M. B. (2009). BIOMOD–a platform for ensemble forecasting of species distributions. *Ecography*, *32*(3), 369–373. doi:10.1111/j.1600-0587.2008.05742.x

Thuiller, W., Lavorel, S., Araújo, M. B., Sykes, M. T., & Prentice, I. C. (2005). Climate change threats to plant diversity in Europe. *Proceedings of the National Academy of Sciences of the United States of America*, *102*(23), 8245–8250. doi:10.1073/pnas.0409902102 PMID:15919825

Vetaas, O. R. (2002). Realized and potential climate niches: A comparison of four Rhododendron tree species. *Journal of Biogeography*, *29*(4), 545–554. doi:10.1046/j.1365-2699.2002.00694.x

Wisz, M. S., Hijmans, R., Li, J., Peterson, A. T., Graham, C., & Guisan, A. (2008). Effects of sample size on the performance of species distribution models. *Diversity & Distributions*, *14*(5), 763–773. doi:10.1111/j.1472-4642.2008.00482.x

Woodin, S. A., Hilbish, T. J., Helmuth, B., Jones, S. J., & Wethey, D. S. (2013). Climate change, species distribution models, and physiological performance metrics: Predicting when biogeographic models are likely to fail. *Ecology and Evolution*, *3*, 3334–3346. PMID:24223272

Xu, T., & Hutchinson, M. (2011). *ANUCLIM Version 6.1. Fenner School of Environment and Society*. Canberra: Australian National University.

Yost, A. C. (2008). Probabilistic modeling and mapping of plant indicator species in a Northeast Oregon industrial forest, USA. *Ecological Indicators*, *8*(1), 46–56. doi:10.1016/j.ecolind.2006.12.003

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Section 4
Utilization and Applications

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Chapter 37
Information Societies to Interactive Societies:
ICT Adoptions in the Agriculture Sector in Sri Lanka

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ABSTRACT

Information is crucial for the development of any sector, including agriculture where information needs to be exchanged with farmers and other stakeholders quickly. Thus, efficient linkages for information sharing are essential. ICT innovations enable the shaping and reshaping of communication and interaction. Many of the technology driven information dissemination methods have been initiated by government, private, non-profit making bodies and independent research groups. This chapter explains the integration of ICT within Sri Lankan agriculture communities and how the focus is changing from information dissemination towards facilitating interactions among the stakeholders. The present status of agriculture information dissemination, including the ICT interventions is given. Prevailing issues and limitations in these ICT-based information dissemination approaches initiated by the different entities is explained, giving due recognition to various factors that have contributed to the adoption of ICT initiatives. The chapter ends outlining the possibilities for future focus on ICT activities in an agriculture information society.

AGRICULTURE INFORMATION SOCIETY

Agriculture plays an important role in the Sri Lankan economy. Agriculture provides a direct source of income for around 31% of the population (Central Bank of Sri Lanka, 2013b). The rural population in Sri Lanka is around 85% (World Bank, 2014), and agriculture is both a direct and indirect source of living for about 65% of the population who live in these rural areas. The contribution of agriculture to the country's gross domestic production is about 10.8% (Central Bank of Sri Lanka, 2013a).

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Right information delivered at the right time is vital for successful farming. Farmers need information regarding crop growth, pest and disease problems, and marketing. A study conducted by De Silva and Ratnadiwakara (2008) reports that information search cost accounts for 11% of the total cost, and nearly 70% of the transaction cost. Information search costs arises from the need to obtain information related to decisions such as the crops to plant, agronomic practices, pest and disease identification and management, harvesting, storage and post-harvest practices. Information systems which provide the required information are described in Table 1. Transaction costs are incurred in transactions related to the purchase of inputs such as seed, fertilizer, and pesticides, and also in the sale of produce. Additional transaction costs are seen when farmers deal with external agents indirectly through Farmer Organizations. In such instances transaction costs arise between farmers and the Farmer Organizations, and also between the Farmer Organizations and the external agencies such as input suppliers or buyers. Appropriate information systems can reduce the transaction costs incurred in such situations.

At present most of the information obtained, and transactions conducted are through traditional mechanisms. Generally in Sri Lanka farmers have been obtaining information through the farm visits of, or the office visits to, extension agents. Thus, if the time spent by the farmers for this activity is taken also into account appropriately the information cost is bound to increase. Furthermore, it is noted that this cost analysis is from the perspective of the farmer. When the time and other associated cost, such as the transport cost, of the extension agent is also taken into account the actual cost of such information would vastly increase. Hence mechanisms which obviate the need for such meetings could reduce the associated information costs. ICT mechanisms are very well positioned for this, thus being able to reduce this information costs. It is not argued that ICT mechanisms are appropriate for all situations. Rather, that it would be appropriate in many situations. The reasons for such an assertion are as follows. Unlike in mass communication, or even group communication methods adopted in agricultural extension, the information provided through ICT mechanisms could be tailored to the particular requirements of the specific farmer, as in the traditional individual extension methods. For example, the requirements for a particular crop, or variety, could be provided. The needed information could be obtained irrespective of the location of the farmer. Transport and time costs too would be almost eliminated. Interactivity, which is not generally used or possible through many other information providing channels, could also be used. For example, Smartphones could be used to take photographs of field problems such as pests or diseases which are sent for possible identification, after which requests for further information, or recommendations for the management of such problems, or the links to the appropriate information which is already available could be sent back to the farmer. The added advantage of this mechanism lies in the fact that if the first level of personnel handling such requests are unable to provide the information that they can channel it to increasingly higher levels of experts, according to the nature of the question, and then respond to the information seeker. Access to such higher levels of expertise would not normally be possible for most information seekers. Even in instances where such access may be possible, the time taken for access to personnel and awaiting their response could possibly lead to a situation where the response is of lesser value due to the associated delays. For example, measures against a pest or disease attack should be taken as quickly as possible. Even a delay of a few days could lead to substantial losses. A further advantage lies in the fact that the proficiency of the limited experts could be more widely utilized to service a larger group of people. Thus, the expertise of officers based in central stations could be utilized from almost any area of the country.

There are many traditional sources of agricultural information as seen in Table 1. Technical advice was traditionally provided by extension agents, including subject matter specialists, attached to various

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Table 1. Agriculture information sources which cater for farmers information needs

Sources of Information	Information Needs
Input suppliers (Agro chemical merchants)	• Seeds and planting materials • Agro chemicals: fertilizers, pesticides, herbicides • Agriculture equipment, machinery
Markets /buyers	• Market prices • Places
Extension agents	• Technical advice • Training opportunities, demonstrations, plant Clinic • Government subsidy schemes, loans
Subject matter experts and researchers	• Solutions for farm management practices • Latest innovations
Mass media	• Weather information • Market prices
Farmer organization	• Cultivation plans • Water availability
1920 Agri advisory service	• Technical information related to farming • Purchasing inputs • Marketing

Sources (Dissanayeke & Wanigasundera, 2014; Wijerathna, 2011; Dissanayake, Wijekoon, Madana, & Wickramasinghe, 2009)

government departments and institutions. For example, the Department of Agriculture had a vast network of field level extension agents who catered to the needs of farmers in the food crop sector. However, it is noted that this coverage has been greatly diminished due to the transfer of the field level extension agents to another department. Technical advice on crops such as tea, rubber and coconut, as well as information on subsidy schemes are provided by different agencies related to these crops. Whilst these agencies use mass media too, the 1920 Agri-Advisory Service is a telephone based service introduced by the Dept. of Agriculture. However, as seen in Table 1, apart from these sources there are numerous other information providers too. Though information suppliers like input suppliers are likely to be biased, farmers obtain information from them due to the relative convenience. Whilst physical markets also provide marketing information, its range and accuracy is certainly limited. Accordingly, most of the traditional information sources could be vastly improved as seen by the steps already taken, as given in this chapter, and also by initiatives that could be taken in the future.

Information Needs of the Farmers

As mentioned previously, farmers need information throughout the cultivation process until they harvest and sell the products. De Silva and Ratnadiwakara (2008) proposed a six stage value chain for agriculture information starting from the decision on which crop to cultivate until selling the harvest. During the first stage the farmers have to decide on several aspects such as which crop to cultivate, the extent of land to be allocated for a particular crop, when to start cultivation, and making arrangements for working capital. Selecting a suitable crop would be depending on many factors such as climatic conditions, season of the year, availability of seed and other raw materials including labour and, fertilizer.

The second stage is where they purchase or use their own seeds saved from previous cultivations. Land preparation and planting is regarded as the third stage in which plant beds are prepared and sub-

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sequently planting seeds. During this stage the farmers have to decide on labour; whether to hire or use family labour, and use of machinery in land preparation.

Growing is the fourth stage in the agriculture value chain, where farmers are faced with issues such as managing pest attacks, diseases, irrigation, fertilizer, weeding. During this stage, the farmers look for fertilizer and subsidy programmes. In the next stage farmers engage in harvesting, sorting and packing. During this period they have to find labour for harvesting, storing spaces. They would also look up to information on post-harvest management and value addition too. Selling represents the last stage of the value chain in which farmers have to make decisions on market prices, places to sell the produce and transport arrangements. Accordingly a farmer has to take numerous decisions regarding the cultivation of crops. Thus, a farmer is basically a manager who has to make numerous decisions from selection of crop to ultimate sale of produce. Thus, decisions support systems, which go beyond just the provision of generalized technical information, are needed for commercial farmers. A pilot product for such a decision support systems for the vegetable sector has been developed by one of the co-authors with the collaboration of many other technical personnel. It provides information to help decide what vegetable to grow, seed requirements, cultivation practices, input requirements including labour for specific growing areas, pest and disease control measures, harvesting and post-harvesting practices. The costs and returns of all these practices, as well as the cash flows and the overall income and expenditure are provided to facilitate farmers to take decisions.

In certain areas of the country farmers make collective decisions at the Farmer Organization level with respect to field and irrigation channel maintenance activities, as well as cultivation aspects such as cultivation dates and crops. Collective decisions are especially important when dealing with external agencies as in agreements related to Forward Sales Contracts, where Farmer Organizations could agree to provide a crop to a particular purchaser at agreed upon prices. In such instance access to market information to negotiate prices would help in reducing associated transaction costs. Furthermore, such systems should facilitate communication between the Farmer Organizations, or network/s of Farmer organizations, and the produce buyers. As Farmer Organizations make collective purchases of inputs, such as fertilizer, these information systems should enable the aforementioned communication abilities with potential suppliers of agricultural inputs too.

As indicated the need for information in agriculture is very wide. This need is further expanded as it includes a very large number of entities requiring widely differing types of information. In terms of sectors it needs to cater to the sectors such as crop, animal husbandry, and fisheries. Within a sector such as the crop sector it needs to cater to differing segments such as the food crop sector, the plantation sector, the protected agriculture sector, the floriculture sector, and the food processing sector. Within each segment it needs to provide information on crop and variety selection, cultivation practices, pest and disease management, harvesting and post-harvest practices as well as marketing information. Due to this diversity it is essential that an overall strategy to provide agricultural information take cognizance of this fact. Accordingly, multiple initiatives, rather than just a few, are needed by different players to provide the information requirements in agriculture. Institutions, which have developed strong ICT capabilities and initiatives, such as the Department of Agriculture, could be supported to provide advice and training to other agriculture organizations to develop their own information services. Such a mechanism should provide for new initiatives from the different organizations, to enable adaptation and innovation to develop and deliver products most suited for their clientele.

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Arising from the diversity of requirements noted above, another perspective is possible in terms of Agricultural Information Systems. Roling (1988) in his work on Agricultural Knowledge Systems identified many sub-systems such as the research, dissemination (or extension), user (or farmer), training, input supply/ marketing, policy, and NGO sub-systems. This view broadens the scope of agricultural information systems, indicating user needs beyond that of the farmer. An overall information strategy for the agricultural sector certainly needs to take account of all these needs. Clearly priority areas of importance, and possibility, need to be the initial initiatives. However, an overall strategy should not get bogged down only with the initial initiatives, and their maintenance, but also forge ahead to meet the other information requirements too.

Traditional Systems of Agriculture Extension

Traditionally, the scientific research and new knowledge related to agricultural practices were delivered to farmers through a process of farmer education, aiming to increase produce and productivity of agriculture. Provision of such information can lead to improved yields (Rosegrant & Cline, 2003). This process of disseminating agriculture information is known as *agricultural extension* whilst a village bound extension agents typically play the main role in bridging the gap between research and practice. A variety of teaching methods, such as individual methods e.g farm visits, group methods e.g. demonstrations, and mass methods e.g. television and radio programmes are used to educate the beneficiaries.

In a given agriculture education system, learning could take place along four paradigms; technology transfer, advisory work, human resource development, and facilitation and empowerment (National Agricultural and Forestry Extension Service [NAFES], 2005). Technology transfer involves a top-down approach to deliver specific recommendations related to cultivation practices the farmers need to adopt, while advisory services help farmers in clarifying problems, by responding to their queries with technical prescriptions. Facilitation for empowerment involves facilitating experiential learning and farmer to farmer exchanges. Farmers are encouraged to make their own choices, by interacting with each other.

However, it is seen that the traditional methods of information dissemination have become less successful and less cost effective due to various reasons. The average number of farm families to be served by a single extension officer has exceeded 4000, which is an extremely hard target to achieve. The withdrawing of grass root extension workers from extension activities and overburdening of extension workers with duties other than provision of extension services are two of the other constraints that affected the agriculture extension system in Sri Lanka. Decentralization of the extension services to provincial government has weakened the extension service seriously affecting the research –extension linkage, and the efficiency of the national agriculture extension system. Weak knowledge management systems especially in the areas of information sharing, dissemination of information, and agricultural extension is being regarded as one of the major challenges ahead of agriculture research and extension today.

Given the fact that many farmers are literate, and the growth of ICTs in the recent years, integration of ICT is seen as one of the promising solutions, which can be used to provide up-to date information to the agriculture sector. The efforts to harness ICTs in reaching agricultural communities were evident during last decade, when looking at the investments made by the agriculture organizations, including major projects such as the cyber extension project, which will be discussed later in this chapter. A number of agriculture based organizations have started websites and have started offering web based services.

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Access to ICTs

Compared to other low income countries Sri Lanka performs exceptionally well in its affordable ICT services, as it has remarkably lower mobile broad band prices (International Telecommunication Union [ITU], 2012). The ICT development index (IDI) ranks Sri Lanka in 105th position in year 2011, out of 155 countries. The same index places Sri Lanka at 50th position in terms of ICT prices. Table 2 shows the sub-indices used to calculate the IDI, and the rank of Sri Lanka based on the sub indices. Sri Lanka provides one of the lowest mobile –cellular prices thus being ranked in the 14th position in the mobile–cellular price category of the IDI. Mobile subscriptions per 100 people is as high as 99.2 at the end of year 2013 (TRCSL, 2013). It is noted that this value does not indicate the percentage of subscribers as it is fairly a common practice in Sri Lanka to have multiple subscriptions, probably due to the fairly low cost, and in some cases, free availability of such mobile subscriptions.

Internet

Sri Lanka has a well developed broadband infrastructure; however the penetration is relatively low. Fixed line penetration is 2.35%, while mobile broadband subscriptions are around 5.9% (Telecommunications Regulatory Commission of Sri Lanka [TRCSL], 2013). At present there is a well developed broadband market, with different fixed and mobile operators providing broadband services through different technologies. There is a potential to increase the broadband use in the future. Both the TRCSL and the Information and Communication Technology Agency of Sri Lanka (ICTA) have made broadband access a policy focus. Examples of recent ICT development projects include the setting up of over 500 rural tele-centers, a subsidy scheme to build and operate a fiber backbone in rural areas, and the development of e-government applications (ITU, 2014).

Literacy

The adult literacy rate in Sri Lanka is around 91% (Central Bank of Sri Lanka, 2013b) which indicates that the majority of the population, including the farmers, can read and write. High literacy levels give a definite advantage in using various ICT resources, and it is an important factor to be considered in planning for information and communication interactions.

Table 2. IDI sub indices and rank of Sri Lanka (Source ITU, 2012)

Index	Sub-Indices	Rank 2011	
ICT access/ readiness infrastructure	fixed-telephony mobile telephony international Internet bandwidth households with computers households with Internet	103rd	3.3
ICT intensity/ Usage	Internet users fixed (wired)-broadband mobile broadband	112th	0.67
ICT capability or skills	adult literacy gross secondary enrolment gross tertiary enrolment	98th	6.45

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ICT INTERVENTIONS

There are many ICT based interventions to serve the agriculture society in its various stages of the production process. Some projects stand out due to its coverage of population, publicity and investments: Among these are, the government initiated a cyber extension project, agri-advisory service, and other collaborated projects on SMS based market price dissemination systems. Websites are the most commonly adopted web technology by most of these organizations, which is similar to the observations reported by Rhoades and Aue (2010) who studied the use of social media in agriculture information dissemination. Use of social network sites like Facebook or micro blogging sites such as Twitter is not commonly seen at the organizational level. Interactive Voice Response (IVR) methods are still at research level and are successfully tried out with smaller communities. This section discusses some of the important ICT interventions that attempted to use ICTs in reaching various levels and categories of the farming community.

Cyber Extension Project

The DOA initiated a cyber extension project way back in 2004 as an "appropriate information exchange mechanism which seems affordable and convenient for rural farmers in satisfying their information needs" (Wijekoon, Emitiyagoda, Rizwan, Rathnayaka, & Rajapaksha, 2014). This was established in two phases; as a wireless extension strategy at first and as a real cyber extension mechanism with internet and telecommunication facilities as the second phase. It was felt necessary and important that farmers were provided with necessary information needed in the various stages of the farm decision making process and the extension system was facing criticisms that it was not being able to satisfy the information demands from the farmers. The Department of Agriculture was thus looking for alternative methods powered by the latest ICTs and their solutions is to introduce computer based learning to the farmer community.

Forty five agrarian service centers, out of the 550 centers, were selected to establish cyber extension units (CEU). A cyber unit was provided with a computer, digital camera, internet facility, telephone, printer and a scanner, similar to a rural information center with the aim of supporting the agriculture community in the area. Thus, a set of Interactive Multimedia CDs (IMMCDs) were designed as an offline cyber extension strategy to provide crop related information to the farmer community. Typically a CD contained information on various aspects of the growth of a particular crop including cultivation and management aspects of crops such as chili, big onion etc. There are also a few CDs which present information on more general topics such as 'integrated pest management', home gardening, and micro irrigation, which discuss important management practices that are common for a group of crops. The learning contents in the CDs were developed with the assistance of Research Officers who verified the technical information. These IMMCDs included video clips, audio narrations, graphics, images and text based illustrations.

The extension agent is to act as the officer in charge of the cyber unit while farmers can use the CDs when they visit the extension agents' office and learn the technical information provided in the CDs. The extension officer may also use the CDs in farmer training classes to design training aids. A list of IMMCDs that have been produced by the Department of Agriculture and is available in the sales outlets is presented in Table 3. These CDs are available mostly in Sinhala, some in Tamil, and a few in English.

Lack of awareness of the cyber mechanism was seen as one of the major problems according to (Wijekoon et al., 2014). Later the DOA had taken steps to popularize the CEUs among farmers. However

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Table 3. List of CDs available in the cyber extension units (Source Department of Agricutlure Sri Lanka [DOA], 2010)

Title of the CD	Languages [S] –Sinhalese, [T]- Tamil, [E] – English
Anthurium	[S], [E]
Banana cultivation	[S]
Bean cultivation	[S]
Betel	[S]
Big onion cultivation	[S] [T]
Brinjal cultivation	[S] [T]
Chili	[S]
Coconut (I, II)	[S]
Compost making	[S]
Cucurbitaceae plants	[S]
Forages	[S]
Gerbera cultivation	[S]
Home gardening	[S]
Integrated pest management	[S]
Jack	[S]
Leafy vegetables	[S]
Maize cultivation	[S]
Micro irrigation	[S]
Mushroom (I, II)	[S]
Orange /Citrus	[S]
Orchid	[S]
Paddy	[S] [T]
Papaya cultivation	[S] [T]
Potato cultivation	[S]
Protected agriculture	[S]
Pulses	[S]
Rambutan cultivation	[S]
Red onion cultivation	[S] [T]
Royal botanical garden	[E]
Soil conservation	[S]
Tibbatu	[S]
Tomato cultivation	[S] [T]
Underutilized fruit crops	[S]
Upcountry vegetables	[S]
Vegetable insect pests	[E] [S]

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there are other problems such as poor computer skills by the farmers to use CDs on their own (Dissanayeke, Wickramasuriya, & Wijekoon, 2009). Certain farmer groups are seen more confident in using CDs to obtain information. These are the well-educated and mostly part time farmers who have a main source of income other than agriculture. Some of them even had computer facilities in the home and they made copies of these CDs for later reference. However the majority of the famers had to mainly depend on the cyber extension unit to use these CDs, while they need the extension agent's assistance to select the relevant pieces of information. This interferes with the schedule of the extension agent because he is pre-occupied with other major responsibilities, rather than only managing the CEU. Considering this difficulty, the DOA is planning to appoint a separate officer to manage the CEU and help with farmers to find the necessary information.

The IMM CDs have an interactive user interface where the users have some control in selecting what information to be viewed and when. This can be considered as a positive development because farmers, being adult learners, need to have some control over what they want to view. However the best uses of these could not be harnessed by many farmers mainly due to the poor computer skills and less access to computer facilities.

A substantial amount of resources has been expended to develop good ICT material such as the IMM CDs for the food crop sector in Sri Lanka as mentioned above. However, as with any other information source, it is important to continuously update such material. While updating may not be as glamorous and rewarding as the initial development of a product, it is very important to ensure that the information seekers are provided with current information. Apart from the greater fulfillment of the information needs leading to greater customer satisfaction, it will also enhance the trust and credibility of these sources of information. This is especially so when such material becomes available online. To facilitate such updating and appropriate technical system, key responsible persons whose work will be appropriately recognized, adequate support staff and financial allocations are important.

Another important consideration of the cyber extension project is to link farmers with the other major agriculture stakeholders such as, wholesale traders, researchers and policy makers. It is considered necessary and important to regulate the information flow between stakeholders i.e. researchers and farmers, farmers and policy makers, farmers and traders. It is expected that this would enable farmers to make email queries to researchers seeking technical assistance to solve field problems. However this objective is achieved to a lesser extent so far due to limitations such as low computer literacy of farmers, Extension officers are overburdened with responsibilities other than managing the cyber unit and assisting farmers to send emails will add to their already heavy workload.

Marketing Information Systems

According to Dharmaratne (2013), Sri Lanka had commenced an Agriculture Market Information System (AMIS) as early as 1980s. Market data had been collected, analysed and finally disseminated to interested parties. The main purpose of the system was to measure food security and provide price signals to agriculture marketing stakeholders including the small farmers, traders and policy makers. AMIS had been initiated as two bulletins; a weekly publication that included information on wholesale and retail market prices of nine food items, including price comparisons with the previous week, producer price, statistical indicators such as range and average price. The bulletin was made available for policy makers, general public, and media agencies. The second publication was a monthly information system, which provided key indicators of prices, production, crop situation and food stocks.

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Some of the major problems with the initial years of implementing AMIS were poor understanding of the purpose of data and information collection, underutilization of data and information, ineffective communication and presentation, lack of internationally comparable and compatible methodologies for data and information handling and limited capacity of national programs. Farmers were also unable to use the system as the information provided by the system was limited to a few crop types. These were hardly enough to make right decisions. In addition the small farmers and traders were not skilled enough to interpret some of the data presented in the bulletin. It is also noted that these earlier systems did not meet the actual needs of farmers for real time information. Whilst this information is certainly useful for academic studies and policy decision makers, its utility to farmers is limited. However, present data collection, analysis, and dissemination possibilities have enabled the rapid collection and provision of user required specific information almost in real time. Thus, the use of present day Agricultural Marketing Systems by farmers too is bound to increase. However other stakeholders such as policy makers, scientists, and academics are also able to use the system in a useful way.

Agriculture Advisory Service

A call centre solution known as Agriculture Advisory Service is implemented by the DOA as a supplementary service to the present extension system in the country. This is foreseen as a quick mechanism of disseminating agriculture information to strengthen the linkages between research, extension, training, and farmers. This type of a system helps to facilitate a demand driven extension service, as the farmer initiates the communication process.

The extension officers, working in the call center, assist farmers in solving their various problems such as agriculture related technical matters, inputs and marketing problems. The service, which is available in the local languages, receives nearly 100 to 250 calls from the agriculture community every day and is regarded as one of the most wide spread ICT related agriculture activites in Sri Lanka (Dissanayake et al., 2009; DOA, 2010; Wijerathna, 2011). A study conducted by Dissanayake et al. (2009) reports that the farmer community is satisfied with the information provided, while the field extension staff regards the service as an effective solution which eases their work at the field level.

Mobile Based Information Services

Mobile based information dissemination methods recieved wide attention in the recent years mainly due to the availability of mobile phones among people in Sri Lanka, including the farmers. A recent study shows that about 73% of the rural farmers have access to a mobile phone while some extended farm families had access to more than one mobile phone at a time (Dissanayeke & Wanigasundera, 2014) making it a common household item. When compared with the use of computers with internet facilities, the mobile phone was found to be the most common ICT facility among the farmers. Wide usage and accessibility to mobile phones has given opportunities to see how to use mobile based information systems in reaching the farming community. Short message service (SMS) based systems to send market prices, toll free call line facilities to inquire about agriculture based queries, and interactive voice response systems have been experimented with, and later some used by government, private sector, non-government based organizations as well as by independent research groups. Some of the important mobile based initiations are discussed later in this chapter.

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Use of mobile SMSs to deliver important pieces of information has become popular worldwide due to the simplicity, effectiveness and low cost (Dhaliwal & Joshi, 2010; Fafchamps & Minten, 2012). Information related to commodity prices, market opportunities, crop advisory, and weather information are the main types of information that are sent to farmers using SMSs in the above studies. Many farmers preferred to have these informative SMSs as it is an inexpensive way to get access to important information. Given this fact that the present access and use of mobile devices is very high, and also that it could be expected to grow even further, this should be seriously considered as a tool that would have even more importance in the future. Initiatives should not be limited to basic cell phones but should cover applications for Smartphone too. While the majority of the present farming population may not own Smartphone yet, their prices will undoubtedly come down making them more affordable. Further, given the large number of migrant workers who have gone overseas from rural areas, the want for communicating with them will propel more people to purchase Smartphone even as prices come down as well. Thus ownership per se of Smartphone in the rural areas is bound to increase. Even if people may not have their own Smartphone, they are bound to have access to them through other rural people who own them. If the information is valuable enough farmers will probably be willing to pay enterprising people who could look up the information on behalf of the farmers for a small reasonable charge. Owners of communication centres that are spread all over the country could be one group that might show interest in such an enterprise.

Mobile SMS Based Price Information Dissemination Services

"Govi Gnana Seva"

The Govi Gnana Seva (GGS) project started as an independent price collection and dissemination service to help farmers get the best possible prices for their produce. This is one of the pioneer projects to initiate sending vegetable market prices to farmers in Sri Lanka (De Silva, 2008). The project operated from the Dambulla Dedicated Economic Center from where vegetable spot prices are collected and then sent by SMSs to the farmers who are registered with the system. Traditionally low farm-gate prices, especially for perishable crops such as vegetables, have been reported even when consumer prices for the same products are relatively much higher. Whilst the low bargaining power of individual small scale farmers is one factor, another factor is their lack of knowledge regarding the prevailing wholesale prices in major agricultural markets closer to the urban areas. Hence, the attempts to fill the information gap between farmers and markets became significantly important.

Later the GGS project started a partnership with a leading mobile company and continued to offer the service on a Tradenet platform (Dialog Axiata PLC, 2009). They have also expanded the service to collect price information from 2 other dedicated economic centers. The system can match the buyers with possible sellers and send alerts to both parties with their respective contact details (de Soyza, 2014). The buyer and seller can negotiate and proceed with the transactions. Buyers and sellers can upload posts to the Tradenet using web, WAP, call centre and IVR, SMS and USSD access technologies using English language or the two local languages.

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Interactive Voice Response (IVR) Systems

IVR System for Mushroom Farmers

The Ruhunu University together with a private mobile service provider developed an Interactive Voice Response (IVR) system to educate small-scale mushroom farmers. This is implemented as a technology dissemination programme under the Life Long Learning for Farmers (L3F) employing ICT for one of its components. The IVR system embedded pre-recorded messages of two minutes duration for six months to guide listeners on how to establish, and manage a mushroom shed. Business planning and financial management lessons are also included (Wijeratne & Silva, 2013). About 5000 farmers have taken part in the programme. Farmers are able to obtain needed information quickly and accurately using ICTs. The study reports that the majority have accessed the knowledge system, which can be considered as a positive development. They have listened to the voice mail during their free time. Poor feedback from farmers is seen as one of the limitations by the researchers. The L3F have recently started a similar programme in collaboration with the Open University of Sri Lanka (OUSL) and the same mobile service provider to offer financial management lessons to rural women using IVR systems.

Agricultural Price Information Index

In the recent years a government based agricultural research institutions have started offering daily whole sale vegetable price information, collected from eight markets Island wide with the assistance of a private mobile service provider, one of the leading mobile service providers in the country (Hector Kobbekaduwa Agrarian Research and Training Institute [HARTI], 2014; Mobitel Pvt Ltd, 2014). The service is made available in the two local languages using an Interactive Voice Response System (IVR) to the customers of the same mobile service provider. The callers have to bear the cost for using the IVR system.

Decision Support Systems

Social Life Network

Social Life Network (SLN) is an attempt in developing a holistic mobile based system to aid farmer information needs, throughout the farming life cycle (De Silva, Goonetillake, & Wikramanayake, 2012). The SLN will address issues such as 'how to strengthen the linkages among various agriculture stakeholders using mobile based systems', and 'how to capitalize on the latest mobile technologies such as inbuilt sensors and processing capabilities'. As implied in its name, this system intends to create a network of the users, who would generate real time information, through their participation in the SLN, which will eventually be accessible for the same user community in return. It is assumed that such systems would eventually help the stakeholders to make informed decisions by opening up opportunities for predictive models to strengthen the decision making process. Mobile interfaces of the SLN have been continuously tested with the stakeholders, using action research approaches, to assure user-friendly and usable designs

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Websites

The Internet and websites play a major role in today's information culture. A website can be used to post important information that could make the farming community instantaneously aware of relevant information (Reddy & Ankaiah, 2005). Websites can further act as an important medium to ensure the dissemination and sharing of essential agriculture information that fits the agriculture community's interests and needs. A content analysis study, which evaluated 27 agriculture related websites in Malaysia, concludes three important categories of information that should be there in agriculture websites namely technical information with regard to crops, fisheries, and livestock, training opportunities offered by the institutions, and the financial aspects related to capital, loan facilities and interest rates (Ramli, Hassan, Samah, Sham, & Ali, 2013).

A number of agriculture related organizations in Sri Lanka have marked their web presence (Table 4) providing useful information for the visitors. In fact reports do indicate a high impact on the agriculture sector, next to the telecommunications sector (Jayathilake, Jayaweera, & Waidyasekera, 2010). The types of information and services available through these websites include; technical information related to crop and livestock, marketing information, online services, training opportunities, organizational structure and administrative divisions, vision and mission, news briefs, and contact information.

Almost all the websites are available in English, while the majority has accommodated Sinhalese language as well. Only a few websites have the complete Tamil translations, while this facility is under construction on many sites. For systems where the target group is the farmers, in most instances the content material will have to be in both local languages which are Sinhala and Tamil. As the availability of the same content in both languages is not seen on all sites, this needs to be done. Hence efforts for automatic translation from one language to another needs to be enhanced. Such a facility, together with verification by experts, should be used to enhance the efficiency and reliability of having the content in both languages. To the extent possible, English versions are to be made available to meet requirements of multi-lingual companies and NGOs, as well as other users such as students.

The Department of Agriculture (DOA) website has been recognized both locally and internationally for its pioneer work in using ICTs for agriculture information dissemination in Sri Lanka. According to the website statistics, the number of hits exceeded 3 million as of 2014 whilst thousands of online users visit the website every day. This website has been recognized as the best website among the government websites over several years and provides an example for the other websites which followed. Thus we discuss some of the important features in the DOA website, which is of prime importance to understand the agriculture information culture in the country.

Technical Information Dissemination

Most of the websites presented in Table 4 have made efforts to share technical information related to cultivation aspects in their websites. Online learning resources, including pdf versions of printed publications, and video documentaries are most commonly used to achieve this objective.

The DOA website publishes technical information related to important crop varieties that are grown in the country under the crop recommendation section. These crops belong to the food crop sector including rice, vegetables, fruits, grains, tubers, oilseed crops and condiments. Specific information

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Table 4. Websites of some of the main (government) agricultural organizations

Organization	Some of the Important Features
Department of Agriculture (DOA) http://www.agridept.gov.lk	• Technical information dissemination – Video documentaries, online learning resources, publications • Market information • Training opportunities • Languages–Sinhalese, Tamil, English
Institute of Post Harvest Technology (IPHT) http://www.ipht.lk	• Technical information dissemination • Training opportunities • Languages: Sinhalese and English languages only
Department of Export Agriculture (DEA) http://www.exportagridept.gov.lk	• Subsidy schemes • Farm gate prices of export agriculture crops • Technical information dissemination related to crop management practices • Video documentary • Training opportunities • Languages
Tea Research Institute (TRI) http://tri.lk	• Technical information dissemination – list of publications and advisory circulars • Languages: Sinhalese and English languages only
Rubber Research Institute (RRI) http://www.rubberdev.gov.lk	• Technical information dissemination – online learning resources • Price information • Download applications for various services offered by the institution • News updates • Statistics • Languages – English, Sinhalese, Tamil
Rubber Development Department of Sri Lanka (RDD) http://www.rubberdev.gov.lk	• Services- subsidies, extension services • Download applications • Statistics • Price information
Coconut Research Institute (CRI) http://cri.gov.lk	• Technical information dissemination using, online learning resources, publications, and video documentaries • Online forms to make inquiries • News updates • Languages: English, Sinhalese, Tamil
Coconut Cultivation Board (CCB) http://www.coconut.gov.lk	• Technical information dissemination using online learning resources. • Subsidy programmes, credit facilities and loans facilities • Download loan applications • Crop input prices • News and event information • Languages: English, Sinhalese, Tamil
Coconut Development Authority (CDA) http://www.cda.lk	• Information on key products • Online directory to find exporters and traders • Publications • Statistics • Languages: English, Sinhalese, Tamil
Department of Animal Production and Health (DAPH)	• Online application portal to apply for import and export permits • Publications • Livestock statistics
Hector Kobbekaduwa Agrarian Research and Training Institute (HARTI) http://www.harti.gov.lk	• Display market information • Publications • Facilities available • News and events

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related to the nutritious value of the produce, recommended varieties, suitable climatic conditions, and crop management practices such as propagation, pest and diseases, fertilizer application, post-harvest handling, and value addition are presented in English and one other local language (Sinhalese). This technical information is presented in the format of online learning resources, using interactive menus to locate learning contents. Text based illustrations were the most commonly used medium, while graphics and photographs are also used appropriately to illustrate facts. Similar efforts have been made by several other organizations to disseminate technical information.

It is a positive trend to observe that many of these organizations have shared their printed publications on the website as a portable document format (pdf) files, giving an opportunity for online users to download them easily without any cost. These publications otherwise have to be purchased from selected sales outlets. Sales outlets sometimes face problems when certain publications are sold out, and when the farmers who are coming for the particular publication has to wait for the next print. Some other organizations have displayed the list of publications in the webpage with the respective prices, directing farmers to the sales centers where a copy can be obtained. Publications include books, leaflets, agriculture magazines, advisory circulars, and other agro-technology based reports that are originally designed to be in the printed format.

Video is a very powerful source to provide information, compared to other mediums as it can combine several media at the same time. It is seen that only a very few agricultural organizations other than the DOA is utilizing online videos to reach agriculture audiences. This situation is similar to the observations made elsewhere (Goodwin & Rhoades, 2009; Rhoades & Aue, 2010). The Department of Agriculture has a repository of video documentaries produced for national television that is made available for the online users. The DOA has its own video production unit at the Audio Visual Center where these documentaries have been produced. Thus a rich collection of more than 300 video documentaries are now available in the DOA website. The Department of Export Agriculture and the Coconut Research Institute are two other organizations that have made good use of online videos in agriculture related technical information dissemination. Both these organizations have shared these videos on YouTube, which is an important step in reaching non-agriculture audiences and especially young farmers. In fact it is important to get more agriculture related videos on such common platforms to reach a majority of the community.

Agriculture Information Management Systems

The Agriculture Information Management System (AgMIS) is developed by the DOA to share information related to food crops such as cultivation extents, production or yield forecast, and contact details of the farmers and officers involved. This is an interactive system which is developed to minimize marketing problems, while it is also expected that it would provide a comprehensive database for policy makers to help in planning and decision making (Food and Agriculture Organization of the United Nations [FAO], 2014). Latest news updates related to the food crop sector is displayed in the website for the frequent visitors in English and the two local languages. Only a few organizations are seen supporting online databases to manage information on buyers and sellers. The Coconut Development Authority maintains an online directory to provide information on manufacturers and importers for interested parties. Users can search a manufacturer based on the district, product and product type using an interactive menu in this website which help stakeholders to access important information easily.

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Agricultural Price Information

Use of websites to display market information is seen as one of the recent developments. As seen in Table 4, several organizations have started publishing market prices of the relevant crops as well as related products on their websites so that online users can glance through these prices before making important decisions. Some organizations are using multiple methods such as publishing on the website using interactive menus, mobile IVR based systems, and publishing as PDF documents. For instance the Hector Kobbekaduwa Agrarian Research Training Institute started publishing the daily and weekly food prices on their website for easy access. This is an interesting difference from the earlier system they had, which was available on printed format only. Wholesale, retail and farm gate prices of more than 100 commodities can be obtained through the web site in the two local languages and also in English. Interactive menu items help the users to locate and view a specific category of product easily, and this saves time as otherwise time has to be spent on browsing a long list of items. The same information available in the website is accessible using a mobile based IVR system too, as discussed under mobile based systems.

Farm gate prices for all the export agriculture crops, collected weekly by the Economic Research Unit of the Department of Export Agriculture, are displayed on their website. A mobile version of the website is also available, making it easier for the export agricultural crops stakeholders to view information using a Smartphone. Information for the past few years have been saved on the website that helps users to compare prices in different years and different seasons of the year, thus making it easier in taking important decisions such as selling the produce. The Rubber Development Department is yet another organization that uses their website to publish price information. The latest information is published on the home page itself, making it much easier for the users to have a quick glance over the prices. Detailed information related to a specific year or month or a date can be obtained easily using the interactive menus.

Agriculture Related Services

A comprehensive list of services offered by a particular organization is available on many of the web sites. These services include training opportunities, credit and loan facilities, subsidy programmes, provision of export /import permission, agriculture inputs, certifications and some analytical services such as soil testing. In most of these cases, the website is simply being used to create an awareness in the public of the types of services, posting a brief description of the services. A few organizations such as CCD and RRI have moved a step forward by enabling the download of a copy of an application form through the website. DAPH has an online application portal, which can be used to submit applications and track the progress of the application to obtain import and export permits, which is an interesting development.

Extension and training opportunities were displayed on most of the websites mainly to make the public aware about these programmes. Furthermore, information related to credit facilities and subsidy schemes are also seen, along with facilities to download application forms from the website, as in the case of the Coconut Cultivation Board.

Information and Communication Technology Agency (ICTA) of Sri Lanka

Most of the websites and the features discussed in the section above are funded by the ICTA, which is the single apex body, owned by the government, involved in ICT policy and direction in the country.

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Its work includes improving technological capacity of the country, such as building ICT infrastructure, and the ICT readiness of its people, through education and human resources development. ICTA has provided financial support to a number of agriculture based organizations to establish interactive information services that are directly related to agriculture information dissemination. A complete list of these organizations and types of services financially supported are presented in Table 5.

ICTA has also supported disseminating agricultural best practices through e-Learning by funding two important projects namely Wikigoviya by the Department of Agriculture, and Navagoviya by a private organization. Wikigovia consists of an e-learning system, agri-forum to discuss agricultural issues of importance, and an agriculture Wikipedia that can be edited by users ("Wikigoviya," 2014). The Navagoviya website is an initiation from a leading private sector company to develop and deploy e -earning and digital content to build awareness of new techniques and technologies in the agricultural sector. Most of these websites are published in English and two other local languages.

Rural resource centers, with internet facilities have been established to disseminate information at the village level. These centers are referred to as "*Nenasala* Centers" and currently there are 667 such centers. *Nenasala* centers provide a range of services including high speed internet access, e-mail, telephone, computer training classes and other ICT related services. The content essential to the rural community is available to all users in the Sinhala and Tamil languages. *Nenasalas* also caters to the diverse needs of the village community including agriculture, fisheries, and trade, which make it an important landmark in agriculture and related information culture in Sri Lanka.

ICTA has also funded a SMS enabled platform to exchange dairy product information among a small community of farmers. The system helped farmers to access a database to obtain necessary information, connect with the extension officer, the veterinarian, and other service providers. In addition a network of computers with touch screens were set up in public places for the easy access by farmers who does not have mobile phones (Mubarak, 2009).

Table 5. Interactive information services funded by ICTA (source Information and Communication Technology Agency [ICTA], 2013)

Organization	E-Service Offered by the Website
Rubber Development Department of Sri Lanka (RDD)	Provide Rubber Prices
Department of Animal Production and Health (DAPH)	• Online Application Submission portal • DAPH Application Manager
Department of Export Agriculture (DEA)	Market Information
Department of Agriculture (DOA)	• Farmer Database • Classifieds - Advertising platform for farmers to sell their products • Agriculturists – to get contact information of agriculture specialists and their publications
Hector Kobbekaduwa Agrarian Research and Training Institute (HARTI)	• Weekly food prices • Daily food prices
Tea Small Holdings Development Authority (TSHDA)	Subsidy Information
Sri Lanka Tea Board	• Tea Price • Tea Directory

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PROBLEMS AND LIMITATIONS

ICT adoption is seen to be moderate among the farmer community, and a large part of this success can be attributed to the growth of the telecommunication sector in the recent years. The latest ICT based inventions in the agriculture sector can be seen as more of an effort to harness the best uses of ICTs in the agriculture information dissemination process. In this context, it is more likely to expect the emergence of information dissemination systems that are more of a technology driven nature than that of user driven nature, which could be a major drawback. In the future it is more important to see how to develop systems that would cater to actual information needs of the farmer community, by getting their involvement in the design process.

On the other hand we can see reasons such as cost of technology, lack of ICT proficiency, and inability to cater for the actual user needs slowing down the adoption and use of ICTs in agriculture. According to Jayathilake et al. (2010) the cost of technology can be seen as the main drawback that limit ICT adoption among farmer. Farmers' reluctance to invest on ICT based services could be due to a low awareness of the benefits of such services, less trust on the return of the investment, and high initial cost. This especially affects small farmers who practice subsistence agriculture, who see spending on ICTs as a waste of money, and who do not see the benefits of investing on them. During the inception of ICT projects, we can see more farmers using the systems when the services are offered free of charge, and there is no financial cost to the farmer. Latterly the farmer has to bear at least a very small part of the cost such as the cost of the telephone call, which was toll free at the inception.

Lack of ICT proficiency is seen as another important reason that affects the use of ICT in agriculture. For instance the unfamiliarity with mobile based technologies may lead to poor adoption of mobile SMS based price information systems. The majority of the farmers would be more conversant with the voice based services, while only a few are comfortable with SMS due to various reasons such as lack of technical know-how, and language proficiency (Wijerathna, 2011). Poor language proficiency is mainly due to the inability in using the English alphabet in sending and receiving text messages, rather than their literacy levels. Sri Lanka enjoys fairly high literacy rates due to the free education system thus there is a high potential to impart technology based education. As most of the mobile phones used in the country have English language inbuilt, it is necessary to come up with solutions to have phones with local language facilities and information systems. Interestingly the young and progressive farmers are seen mostly using these ICT based systems, and generally, low income, elderly farmers lag behind being unable to use the SMS facility.

Little or no emphasis has been given on linking farmers with the other important stakeholders such as extension agents, researchers, subject matter experts, traders, and input suppliers. Even though the present ICTs can be successfully used in strengthening the existing networks, and can be used to facilitate interaction among stakeholders very little attention is paid in this regard. This does not encourage interaction between the various stakeholders and the farmer is generally unaware of who else will be there in the network. This might be one of the reasons for the poor adoption of such technologies. The other possible reasons may be lack of awareness, negative attitude of some individuals at senior management levels, and administration problems, as with the case of cyber extension project (DOA, 2010)

It is seen that most of the attention is presently devoted to developing websites however the power of other web technologies such as social media, video sharing, and micro blogging has not yet being

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recognized. Rhoades and Aue (2010) noted similar observations with a group of agriculture journalists from the United States. Accordingly, most participants have seen the benefits of such tools, but some are still doubtful to adopt them because of the fear of time and resources needed.

FUTURE FOCUS

The landscape of agriculture information systems is changing. Commercialization, intensification and a greater involvement of the private sector is seen. Furthermore an expansion of the food processing sector is also seen. Thus, the need for agriculture related information has changed and grown in terms of the end users as well as the need for specialized information as in the case of protected agriculture. With the drastic reduction of the field extension workers in the 1980's, the agricultural extension role of the Department of Agriculture too has changed. The private sector and the NGO sector have undertaken the provision of agricultural extension, or information, services. However, these are but limited initiatives. The varying ICT initiatives already undertaken have tried to address this gap between the need for enhanced information and the reduction in the traditional extension services provided. There certainly is the need for more initiatives, some, if not many, of which should be from the ICT sector.

An apex body, such as a joint one between the Council for Agricultural Research Policy (CARP) and the Information and Communication Technology Agency (ICTA) which are the main respective government bodes at the national level, together with representation from the private agricultural companies, the plantation companies, and representatives of the farming communities should be formed. Such a body should map out the overall policy and strategy for agricultural related ICT initiatives. Seed funding should be provided for initiatives. Funding could be under different categories serving different purposes. It could also be under different scopes to include small short term projects, as well as more complex and longer term projects. Joint proposals by a technical agricultural agency and ICT competent personnel should be encouraged. The technical agency should prove its commitment and capability to maintain such a system once developed. The rationale for the above are elaborated upon below.

Whilst efforts of individual agencies and personnel do contribute to the availability of agricultural information, those would be dependent on their priorities, capabilities, and interests. When uncoordinated, such efforts may be duplicated, not completed due to the lack of competence or funds, and not adequately maintained over time. Furthermore, important areas may not be addressed. Hence, the coordination of information systems in the agricultural sector is important. The strategy for such coordination should be done by a representative body. Thus for Sri Lanka, representatives keen and committed to this initiative, from the following organizations could be considered for such a body. The Sri Lanka Council for Agricultural Research Policy (CARP) is the main body for agricultural related activities, whilst the Information and Technology Agency (ICTA) is the main organization involved in public funded ICT initiatives and thus, is in a good position to play a key role. Representation from the Ministry of Agriculture would be required to align initiatives to related policy, and also to influence the formulation of such policy. The Department of Agriculture, whilst being the main organization for the food crop sector, is also the organization that has been innovative and done the largest amount of work in agricultural ICT sector, as indicated before, and thus should continue to play a leading role in this sector. It would also be important to obtain representation from other agriculture related Departments, and the plantation

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crop sector as well, as they generate the technology and information for such sectors as well as providing the agricultural extension services. Another sector to be included would be representation from the Universities, with Faculties of Agriculture, as they represent another important source of knowledge and research in agriculture. Whilst the organizations identified above are mainly the information providers, it would be important to include the actual users of such information too to make such initiatives more demand driven. Hence the importance of key farmer representatives who are in a position to understand the possibilities and requirements from anticipated information systems. These could be from different categories identified to be important. The consideration of the needs of larger entities such as the Regional Plantation Companies, which are responsible for the management of the private plantation estates, as well as the requirements of the small-holders in these sectors too need to be ensured through appropriate participation. Similarly the requirements of the private sector agricultural organizations that are playing an increasing role, especially in catering to the more commercialized agricultural ventures need to be ensured. The requirement of NGOs for reliable agricultural information is also high since many have agricultural components in their projects, and hence their needs also should be considered. A committee comprising all those identified might be too large. However, their representation and input would certainly add value to future efforts. Hence, one way to balance these competing requirements of wider representation and a leaner committee could be to have a committee with permanent representation from the relatively more important organizations, and rotating membership of the other segments. Wide representation of this nature would enable clearer identification of key ICT initiatives that need to be focused on, coverage of a wider area in terms of both technical areas and information requirements, and better maintenance and future enhancements to the products. This forum would also enable the determination of possible lead-roles, such as the Department of Agriculture providing leadership and support to other organizations in their areas of ICT development. It could also determine those with multiplier effects, such as a base ICT system that is developed for the technical content only to be included by the different agencies. Since many agricultural organizations could lack personnel competent to develop full information systems, systems such as these would enable those organizations, normally unable to do so, to provide information to their clients through these 'pre-written shells' of ICT systems.

The role of a committee, such as the one proposed above, should be mainly to determine overall policy, priorities, strategy, and funding mechanisms. Deliberations of such a committee should be infrequent, but well planned and prepared for, and of high intensity, whereby substantial objectives are accomplished. If implementation is to be handed over to such a committee, apart from the need for frequent meetings of the main personnel, it would also need additional support staff and other resources. Thus, a more feasible alternative for implementation of the coordination of initiatives would be the handling of such activities by an existing national level organization, such as the ICTA in Sri Lanka. Such an agency could call for proposals according to the guidelines determined by the main committee, and coordinate the selection of projects, fund disbursement, and the progress monitoring and evaluation of agricultural ICT projects, which would be then and addition to the nature of activities already undertaken by them. An agency such as this could be involved in ensuring the maintenance and thus the longer term sustainability and continued utility of these ICT initiatives.

Clearly, a mechanism to propel activities towards desired goals, as determined by a representative committee as outlined above, would be to provide funding for the determined areas. Given the fact that most ICT information system initiatives are of relatively lower cost in comparison to infrastructure projects or organizational expansion, and also the relative availability of funds as countries strive to become

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more knowledge based economies and allocate funds accordingly, the availability of funds for these purposes is probably not a constraint. Funds could be provided mainly for the development of products. This funding should cover the period beyond the testing and prototype stages to actual initial use by the end users. This funding would act as an incentive for innovative ideas and possibilities. It would also enable those agencies lacking the needed ICT personnel for product development to hire them for the period needed. Whilst the major portion of the available funding could be for new initiatives, it would also be prudent to allocate funds for enhancement of previous products. In any field, and especially in ICT products, continuous improvements are almost essential. Hence, whilst the agency undertaking the initiative should be able to fund and undertake normal maintenance of the product, periodic major revisions could be supported as in its initial development.

The allocation of available funds should be pre-determined based on the needs and priorities identified for ICT activities in agriculture. For example allocations could be done proportionate to both the relative importance and need of different sectors such as the crop, animal husbandry, fisheries, and food processing sectors. Even though important, the funding for an area could be curtailed if suitable ICT applications already exist for that area. Within a sector, such as the crop sector, a similar pre-determination of the allocation of funds could be done for the food crop and plantation sectors. This process could be continued to a reasonable level to ensure that adequate coverage is provided. Such pre-determination of allocations should allow for reasonable margins of cross over, whereby provisions for certain areas are increased above the pre-determined allocation, and another/others reduced correspondingly. This would minimize the acceptance of a weak proposal purely because of it falling within a given area of allocation, and also increase the acceptability of a good proposal which might not have been funded due to other better proposals being allocated the available funds for that particular area.

In the allocation of funding for different areas it would be beneficial to strategically allocate funds based on short term, and probably smaller and simpler systems, as well as more long term, and probably larger information systems. Whilst many ideas for the short term could be projects with a relatively limited scope the longer term projects could be more complex and of greater scope. A mix of both would be needed. Smaller applications could be completed quicker and show results fast, thus giving a quick return on investment, as well as being a motivating factor for further work by the basically non-ICT personnel who probably would be a major group desiring to develop such systems. The areas considered could either be technical areas of importance, or areas of information systems which are complex systems akin to Enterprise Resource Planning systems of other sectors. Thus, the need for more complex systems to cater for more integrated information requirements should not be overlooked. Especially in such instances the involvement of ICT professionals should be ensured.

In general the strength of a technical agency would be its personnel, knowledge base and research output in the crops or areas related to the agency. In terms of ICT initiatives a weakness in many of these agencies, especially the smaller ones, would be the lack of personnel competent enough to develop and continuously maintain information systems. Hence, it would be beneficial to promote collaboration between personnel in these organizations and ICT competent technical organizations or personnel. This could be accomplished through the specific indication of such a requirement for funding purposes. The evaluation of proposals could be based on the agricultural competence and accomplishments, as well as the ICT competence and accomplishments of the personnel involved.

In an era of knowledge explosion, updating data to minimize obsolete information is essential. Furthermore, maintenance of an information system by rectifying bugs, or errors in the system, and also

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minor modifications and upgrading of the system has to be done. Thus, to enhance the continued utility, and thus the use, of the information systems developed, the capacity and commitment of an organization desiring to develop a new system, to maintain such a system in the future should be determined. Possibilities for an external agency, or agencies, to provide such backup if needed should be determined. A network of practitioners could also be promoted to help both in the initial development, as well as this latter aspect of maintenance.

Facilitation of the Interaction among Agriculture Stakeholders

Use of ICT based information exchange systems is most commonly seen among young and progressive farmers. Thus, future ICT based agricultural information systems need to be able to cater to their information needs, by identifying these farmers as special target communities. While doing so it is vital to move toward more interactive systems and building communities of stakeholders those who would interact and learn from each other's. Facilitation of interactions is important for two reasons. Firstly, farmers are likely to learn more from their colleagues than the extension agent or other authorities, as the problems they experience in the field are similar to the other farmers. They are much more likely to follow the footsteps of a successful farmer from the same community as the results are proven readily. Farmers, in general, are knowledgeable on whom to go for advice, while they relate to their own community and colleagues first when they have a problem. Secondly, the farmers would like to discuss and share what they found as a useful piece of information with their colleagues. The farmers prefer to see the opinion of the others in the community before adopting agricultural practices even when the information is passed down by the extension agent or any other important source. Thus it is necessary to create ICT based systems that can be used to facilitate interaction and information sharing among the agricultural communities. Participation of agricultural extension officers and other subject matter experts in such systems is crucial for successful functioning of such systems. These officers can initiate interactions, aware farmers on latest technologies and practices, and various other opportunities available for their training and development. Using the traditional system of extension to give away such information would be more time consuming when compared to an ICT based system.

When implementing such ICT based mechanisms, we need to pay attention to three important aspects; use of existing technologies when and where applicable in order to minimize the cost, go for participatory methods in developing and implementing ICT based agriculture information systems, and providing training for target communities.

Ideally we can develop applications and software to facilitate farmer collaboration using ICTs. However this could take a long time, and may involve substantial costs for development and maintenance of such systems. One alternative is to choose from the existing web based technologies, namely social networking, blogging, sending and receiving SMSs and IVR services, that are freely available with minimum or no maintenance cost. Some of these technologies have been tested out with smaller communities and has given promising results. Being in the category of a middle income country, it would be useful for Sri Lanka to explore existing and emerging technologies and modify them based on the specific requirements of the target groups.

Adoption of such ICT based information systems by the agriculture community depends on a number of aspects. One important question is 'how a given farmer community choose a suitable web based

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technology for collaboration?' This could be made possible in a number of ways. Ideally the community could make use of web technology, including social media, which the members are already familiar with. There are farmers and other stakeholders, those who already use web based technologies for interactions. Especially, the young farmers today are well aware of social networks and they can be encouraged to use such networks to link with other farmers. Another option would be an outside facilitator, such as the extension agent or any other authoritative person, introducing farmers to networking using social media. With a little help from the government or another organization in training these officers, they can easily initiate these networks at village level.

Use of participatory and interactive project designs when implementing ICT interventions with agricultural communities would improve the chances of sustainable impacts on target communities (Donovan, 2011). Accordingly future projects can adopt design research approaches, while ensuring stakeholder participation throughout the design process. This would lead to higher participation, easy adoption and sustainability, as farmers would get a sense of ownership for the outcome.

In many instances the average farmers may not have the necessary skills and attitudes to use a given ICTs although they are willing to do so. Thus, it is important to provide necessary training for them. The farmers who are conversant in using such technology could be identified and they could be assigned to help the other farmers.

There are informal leaders and followers in the community. We need to identify these groups and help them identify suitable ICT based communication systems to facilitate collaboration. It is important to identify the existing means of communication (such as face-to-face gatherings) that can be enhanced, or replaced, with modern ICTs, to strengthen the networks that are already present in the community. This would give recognition to each stakeholder in the system and users would be more comfortable in interacting with people who are already known to them.

CONCLUSION

Information and communication technologies have revolutionized the traditional systems of information exchange mechanisms, while opening up number of gateways to integrate ICTs in the development process. The agricultural information society has been significantly affected by these latest ICTs. A number of interventions made to harness best use of ICTs in agriculture information dissemination. Computer based learning methods, mobile based information dissemination systems and websites are the most common.

The major challenges ahead of the agriculture information society are less emphasis on networking stakeholders, duplication of work due to poor coordination, cost for developing and maintenance of ICT based systems, lack of ICT proficiency among farmers, and inability to cater to the actual user needs by the existing systems The possibility of using existing web based technologies, which are freely available, have not been adequately explored.

Addressing the above limitations is going to be very challenging. However, some of them can be addressed by ensuring proper coordination among the organizations, developing suitable ICT based agriculture information systems by following participatory research approaches, choosing from the existing web based technologies such as social media and modify them to suit local situations, and provide support for target communities by providing necessary training.

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REFERENCES

Central Bank of Sri Lanka. (2013a). *Annual Report 2013*. Colombo: Si Lanka. Central Bank of Sri Lanka.

Central Bank of Sri Lanka. (2013b). *Sri Lanka Socio-Economic Data 2013* (Vol. XXXVI). Colombo, Sri Lanka: Central Bank of Sri Lanka.

De Silva, H. (2008). *Using ICTs to create efficient agricultural markets: A future vision for Sri Lanka* [PDF document]. Retrieved from http://www.lirneasia.net/wp-content/uploads/2008/03/de-silva_transaction-costs-in-sri-lanka-the-future.pdf

De Silva, H., & Ratnadiwakara, D. (2008). Using ICT to reduce transaction costs in agriculture through better communication: A case-study from Sri Lanka. Retrieved from http://www.lirneasia.net

De Silva, L. N. C., Goonetillake, J. S., & Wikramanayake, G. N. (2012). A holistic mobile based information system to enhance farming activities in Sri Lanka. In *Engineering and Applied Science (EAS 2012), IASTED Conferences, Vol 785* (pp. 91–99). ACTA Press. 10.2316/P.2012.785-092

de Soyza, M. (2014). Dialog Tradenet. *Digital Knowledge Center*. Retrieved from http://digitalknowledgecentre.in

ICT for Agriculture in Sri Lanka. (2010). Department of Agriculture Sri Lanka (DOA). Retrieved from http://www.afaci.org

Dhaliwal, R. K., & Joshi, V. (2010). Mobile Phones - Boon to Rural Social System. [LICEJ]. *Literacy Information and Computer Education Journal*, *1*(4), 261–265.

Dharmaratne, T. A. (2013). Agricultural market information system in Sri Lanka: Costs, transmission, reliability, volatility and adequacy to the policy needs. Proceedings of the *International Conference on Agricultural Statistics VI*. Rio de Janeiro, Brazil. Retrieved from http://www.fao.org

Dialog Axiata, P. L. C. (2009). Dialog Tradenet and GGS partnership set to revolutionise agri market access. Retrieved from http://www.dialog.lk

Dissanayake, D. M. L. B., Wijekoon, R. R. A., Madana, P., & Wickramasinghe, Y. W. (2009). Awareness and effectiveness of the toll free agricultural advisory service of the department of agriculture. *Abstract of Final Year Research Symposium 2009, Volume 03*. Faculty of Agriculture Rajarata University of Sri Lanka. Retrieved from http://repository.rjt.ac.lk/7013/1685

Dissanayeke, U., & Wanigasundera, W. A. D. P. (2014). Mobile based information communication interactions among major agriculture stakeholders: Sri Lankan Experience. *Electronic Journal of Information Systems in Developing Countries*, *60*, 1–12.

Dissanayeke, U. I., Wickramasuriya, H. V. A., & Wijekoon, R. (2009). Evaluation of Computer Based Learning Materials in Agricultural Information Dissemination in Sri Lanka. *Tropical Agricultural Research*, *21*(1), 73–79.

Donovan, K. (2011). Anywhere, anytime - mobile devices and their impact on agriculture and rural development. Proceedings of the *ICT in Agriculture: Connecting Smallholders to Knowledge, Networks, and Institutions* (pp. 49–70). Washington. Retrieved from http://www.ictinagriculture.org

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Fafchamps, M., & Minten, B. (2012). Impact of SMS-based agricultural information on Indian farmers. *The World Bank Economic Review*, *26*(3), 383–414. doi:10.1093/wber/lhr056

Food and Agriculture Organization of the United Nations (FAO). (2014). *Agriculture Management Information System. Department of Agriculture, Government of Sri Lanka (DOASL)*. Retrieved from http://www.agmis.lk/

Goodwin, J., & Rhoades, E. (2009). Agricultural Legislation: The Presence of California Proposition 2 [YouTube video]. Proceedings of the *Annual National Agricultural Education Research Conference*. Louisville, Ky.

Hector Kobbekaduwa Agrarian Research and Training Institute (HARTI). (2014). Mobitel agri price information index. Retrieved from http://www.harti.gov.lk

Information and Communication Technology Agency of Sri Lanka (ICTA). (2013). List of Interactive Information Services. Retrieved from http://www.icta.lk

International Telecommunication Union. (2012). Measuring the Information Society CH 1211. (p. 213). Geneva, Switzerland. Retrieved from http://www.itu.int

International Telecommunication Union (ITU). (2014). Statistical market overview: Sri Lanka. Retrieved from http://www.itu.int

Jayathilake, H. A. C. K., Jayaweera, B. P. A., & Waidyasekera, E. C. S. (2010). ICT adoption and its' implications for agriculture in Sri Lanka. *Journal of Food & Agriculture*, *1*(2), 54–63. doi:10.4038/jfa.v1i2.1799

Mobitel Pvt Ltd. (2014). *Agri Price Information Index.* Retrieved from http://www.mobitel.lk

Mubarak, C. (2009). e-Sri Lanka: What is in it for agriculture. Proceedings of *Joint National Conference on Information Technology in Agriculture* (pp. 7–10). Colombo, Si Lanka. University of Moratuwa, Sri Lanka and University of Ruhuna, Sri Lanka.

National Agricultural and Forestry Extension Service (NAFES). (2005). Consolidating Extension in the Lao PDR (p. 77). Retrieved from http://www.laolink.org

Ramli, N. S., Hassan, S., Samah, B. A., Sham, M., & Ali, S. (2013). Comparison of crop, fisheries and livestock information displayed on agriculture websites. *Journal of Basic and Applied Scientific Research*, *3*(6), 760–765.

Reddy, P., & Ankaiah, R. (2005). A framework of information technology-based agriculture information dissemination system to improve crop productivity. *Current Science*, *88*, 1905–1913.

Rhoades, E., & Aue, K. (2010). Social agriculture: Adoption of social media by agricultural editors and broadcasters. Proceedings of *107th Annu. Mtg. Of Southern Association of Agricultural Scientists* (pp. 1–20). Orlando, Florida.

Roling, N. (1988). *Extension Science: Information Systems in Agricultural Development* (p. 233). UK: Cambridge University Press.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Rosegrant, M. W., & Cline, S. A. (2003). Global food security: Challenges and policies. *Science*, *302*(5652), 1917–1919. doi:10.1126cience.1092958 PMID:14671289

Telecommunications Regulatory Commission of Sri Lanka (TRCSL). (2013). *Statistical Report -2013*. Retrieved from http://www.trc.gov.lk

Wijekoon, R., Emitiyagoda, S., Rizwan, M. F. M., Rathnayaka, R. M. M. S., & Rajapaksha, H. G. A. (2014). Cyber extension: An information and communication technology initiative for agriculture and rural development in Sri Lanka. *Food and Agriculture Organization. Document for Technical Consultant.* Retrieved from http://www.fao.org

Wijerathna, S. (2011). *Mobile telephony for agricultural development of Sri Lanka* (p. 45). Retrieved from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1976180

Wijeratne, M., & Silva, N. D. (2013). Mobile phone intervention for Sri Lankan mushroom producers. Proceedings of *27th Annual Conference of Asian Association of Open Universities*. Pakistan: Allama Iqbal Open University, Pakistan.

Wikigoviya. (2014). Retrieved from http://www.goviya.lk/index.php/en

World Bank. (2014). *Urban population Data*. Retrieved from http://data.worldbank.org

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Chapter 38
A Case Study of Innovation Platforms for Agricultural Research, Extension, and Development:
Implications for Non-Formal Leadership and Adult Learning

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ABSTRACT

Stakeholder organizations clearly need to have more than a symbolic role in IAR4D decision making. They are currently hindered by their lack of knowledge of leadership roles and capacity to implement the IAR4D. In this chapter, the authors have presented the use of the IAR4D in Sierra Leone with clear justification of how it fits into contemporary approaches and interventions at the national, regional and global levels. The chapter focuses on the "Dissemination of New Agricultural Technologies in Africa (DONATA)" project in Sierra Leone as a shining example of leadership development and adult learning in both formal and non-formal settings. The authors highlight current challenges of the use of innovation platforms through IARD and articulate implications of the case study for adult education, agricultural extension and non-formal training in agricultural research institutions. The chapter ends with recommendations for surmounting the current challenges of the case described.

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INTRODUCTION

This case is taken from the Sierra Leone Agricultural Research Institute (SLARI) using the success story of the Dissemination of New Agricultural Technologies in Africa (DONATA) project. The project was implemented by the Njala Agricultural Research Centre (NARC), which is one of the seven constituent centres of (SLARI). The case is developed from the reports covering the work of Sahr Fomba, Lansana Sesay, and Alhaji Massaquoi between 2008 and 2014. As Projects Development and Management Officer at one time and now Research Coordinator of SLARI, the lead author of this article participated in several of the activities of DONATA Project but he takes no responsibility for the reports from which the case is developed. Rather credit is fully given to the authors of those reports from which excerpts are taken.

The Authors' understanding of the aim of the publication for which this chapter is meant is the following:

1. Selection of a leadership case
2. Demonstration of why the selected case qualifies to be a shining example of leadership within the context of adult education (e.g. Agricultural extension, or other non-formal education projects)
3. Highlights of current challenges facing the case of leadership described.
4. Recommendations for surmounting the current challenges of the case described.

Within the above framework, we have structured the chapter into six sections as follows. The first section is the introduction which provides the reason for this chapter, what the chapter entails and the manner in which it is structured. The second section provides the historical perspectives of research in Sierra Leone including the various institutions conducting research, the approaches used and a clear differentiation of efforts before the IAR4D approach and what pertains presently. In the third section of the article, the authors specifically present the use of the IAR4D in Sierra Leone with clear justification of how it fits into contemporary approaches and interventions at the national, regional and global levels. The fourth section is about the case study on the "Dissemination of New Agricultural Technologies in Africa (DONATA)" as a shining example of leadership development and adult learning in both formal and non-formal settings. Following the case presentation, the authors focused discussion on the implications of the case for adult education, agricultural extension and non-formal training on innovation platforms. The sixth section of the article addresses the challenges facing the use of Innovation Platforms (IPs) which is presented in the case study as model example for the promotion, dissemination and adoption of agricultural technologies. Finally, the article ends with a discussion of the implications of the case study for leadership development in adult education settings.

HISTORY OF RESEARCH IN SIERRA LEONE

In this section, the authors looked at the institutional arrangements involved in conducting research from pre-colonial to the present time and also the approaches used for conducting research from independence (1961) to the present era of the Integrated Agricultural Research for Development (IAR4D).

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Institutional Setting

Sierra Leone has had a long history of agricultural research, spanning almost 100 years. Up to the early 1980s research efforts in Sierra Leone were fragmented and uncoordinated, with research programs controlled by separate institutions with the mandate confined to annual crops. In 1985, the National Agricultural Research Coordinating Council (NARCC) was established to coordinate research and harmonize research activities. The Mission of NARCC was to support the promotion of pro-poor sustainable growth for food security and job creation as part of Sierra Leone's Poverty Reduction Strategy Paper. The two constituent institutes of NARCC at the time were the Rice Research Institute dealing with rice, millet, sorghum, banana, plantain and vegetables, and the Institute of Agricultural Research dealing with cassava, sweet potato, yam, maize, cowpea, groundnut, soybean and sesame. In addition to the research institutes, Njala University and the University of Sierra Leone also carried out agricultural research. The devastation of research infrastructure during the ten year civil war (1992 – 2002) and the departure of well-trained scientists during this period brought agricultural research to a halt. Since 2001, many of the scientists have however returned and there is goodwill from the Government and partners to resuscitate the research establishment.

After a period of coordination of agricultural research under NARCC, the Government of Sierra Leone (GoSL) established the Sierra Leone Agricultural Research Institute (SLARI) through the SLARI Act of Parliament of 2007. SLARI is now the agricultural research and agricultural technology generating body for the benefit of the farming, fishing and forestry sectors and to provide for other related matters. As a major role player in addressing the many challenges facing the agriculture, fishery and forestry sub sectors in Sierra Leone, SLARI is expected to conduct research to obtain knowledge, information and technologies needed for sustainable development of the country's agricultural sector.

In order to position itself strategically as a key driver in the transformation of the agricultural sector from subsistence to a commercial and profitable business enterprise, SLARI has adopted the Agricultural Product Value Chain (APVC) approach to research for development within the framework of Integrated Agricultural Research for Development (IAR4D). The adoption of this approach to research requires SLARI to shift focus from production of commodities to differentiated agricultural products including increased value-addition to commodities within the rural areas and development and promotion of new products that fit the demands of the target market (SLARI, 2011a).

The adoption of the APVC approach to research for development has been necessitated by the renewed focus on agriculture and agribusiness as priority sectors for spurring economic growth in Africa with calls for development of APVCs that integrate producers and markets to make the agricultural sector more responsive to consumer demands. An important feature of the APVC approach according to Hawkins, Heemskerk, Booth, Daane, Maatman, and Adekunle, (2009) is that it permits analysis of the whole product system leading to the identification and prioritization of opportunities and problems throughout the system which facilitates the development of more realistic research and development intervention projects.

In addition to this, the APVC approach to research for development implies expansion of the research portfolio to components such as post-harvest processing, marketing and internalization of consumer needs. The approach involves working with all players along the different APVCs from resources, production, processing, marketing to consumption. The APVC approach is characterized by increased vertical coordination of many actors along the commodity chain including research, extension, farmers, policy, processors, input and output market, transporters, and agricultural financing agencies (FARA,2007), and

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would be expected to demand for more integration and coordination of all different service providers around priority APVCs.

Research Approaches

The history of research in Sierra Leone is tied to the use of a number of approaches which span from colonial to the present era. During the colonial era (1950 – 1960), the traditional approach to agricultural research was mainly supply-driven, in which researchers set the research agenda without consulting clients and other stakeholders. Up to the late 1960s, most research efforts tended to be largely commodity and factor oriented. The underlying paradigm is that understanding of the whole comes from understanding of the parts and their interactions. This paradigm works well especially where interactions among the parts are not important, that is, where the whole is essentially the sum of the parts. However, work done with farmers in many parts of the world has shown that they operate complex farming systems and they have to make difficult decisions about adoption of technologies (Bigs & Clay, 1981; Chanbers et al, 1989; Okali, Sumberg & Farrington, 1994). Because if this complexity of the farming systems, the traditional approach, often referred to as the top-down approach, to agricultural research and development was not having an impact on small-scale agriculture. Chambers et al. (1989) further observed that the way agricultural research and extension organized itself was a major reason why science was failing to improve the livelihood of the poor. Consequently, the linear research-extension-farmer linkage and technology transfer championed by the public extension service in 1960s and 1970s are no longer suited to agricultural research for development.

During the early 1970s and early 1980s following Independence of most African countries, there was a start in history with the formation and consolidation of the National Agricultural Research System (NARS) supported by International Agricultural Research Centres. During this era, we experienced disjointed disciplinary on-station research, and cultivar development. Towards the late 1980s, the need to strengthen the NARS was realized. This was also the advent of extension services as link to farmers. Linear technology transfer model was dominant. Emphasis was placed on improved management of NARS for program relevance to client. Analysis of complex farming systems under which farmers operate led to the conclusion that appropriate technology could only be developed if it was based on full knowledge of the existing farming system, and that technologies should be evaluated not only in terms of their technical performance in specific environments, but also in terms of their conformity with the objectives, capabilities and socioeconomic conditions of clients. As a result, research and development practitioners looked for alternative approaches to agricultural research and development.

Between the mid to late 1990s, the farming systems research approach became very popular with emphasis on adaptive on-farm research, sustainable agriculture, multi-disciplinary research approach, pluralistic participation, grassroots emphasis, information system and long term innovation development. From the definition, FSA is holistic and participatory, multi- and -interdisciplinary, demand-driven and problem-solving. It promotes partnerships and linkages, as well as synergies and cost-effectiveness in research and development. While FSA transformed the way research was conducted, its participatory nature was limited to incorporation of farmers and did not permeate research institutions that continued to operate singly. In the mid to late 1990s there was popularization of the farming systems research approach involving adaptive on-farm research. The FSA emphasis also remained at the farm level addressing production oriented issues with little attention directed at research on the other aspects such as processing and marketing.

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Realizing the weaknesses of the FSA at the end of the 1990s the concept of a "national system of innovation" emerged. The framework was developed after the realization that the objective of agricultural technology innovation must shift from increasing outputs and yields to transforming agriculture into a more responsive, dynamic and competitive sector. This shift was triggered by the emergence of major structural changes in the global food and agricultural systems including the integration of agriculture into global markets, the emergence of consumers as key drivers of technological change, the growth of private investment in new agricultural technologies, and the revolution in information and communication technologies combined with the growing recognition that agricultural innovation is far more complex and less linear than once believed.

In Agricultural Innovation Systems (AIS), heterogeneous actors interact in the generation, exchange and use of information and knowledge; individuals and organizations in the system learn and change; and social and economic institutions condition these interactions and processes. The concept embraces not only the science suppliers but the totality and interaction of actors involved in innovation. It includes the farmer as part of a complex network of heterogeneous actors engaged in innovation processes, along with the formal and informal institutions and policy environments that influence these processes.

In effect, this framework represents a move away from a more linear interpretation of innovation as a sequence of research, development and dissemination, to an interpretation that recognizes innovation as a complex web of related individuals and organizations, notably private industry and collective action organizations, all of whom contribute something to the application of new or existing information and knowledge. The concept of agricultural innovation systems can be summarized by at least ten basic principles that include Focus on innovation rather than production; Interaction and learning; Linkages for accessing knowledge and learning; Broad spectrum of actors with new actors and new roles in the innovations process; Attitudes, practices and interaction of behavioral patterns that determine the propensity to innovate; The importance of policies in innovations; The inclusion of stakeholders and the demand side in the innovations process; Experiential learning and capacity building; Changing to cope with change; and Coping with "sticky" information that is local and specific to owners and not easily available to others. In the recent era of 2000 till now, the need to refocus research for development is emphasized. It involves the development of technology transfer approaches, multi-disciplinary and multi institutional approaches, and development of the IAR4D.

THE USE OF IAR4D IN THE SIERRA LEONE AGRICULTURAL RESEARCH INSTITUTE

A growing awareness amongst rural development practitioners of a need for "new and alternative ways of doing business" has created an increased demand for capacity development in how teams and partnerships are formed, planned, operated and managed. This search for an alternative integrated innovation process has led to the development of Integrated Agricultural Research for Development (IAR4D) approach. The IAR4D approach emerged after it was realized that the advances in research through the integrated pest management (IPM), integrated soil fertility management (ISFM) and integrated natural resource management (INRM) approaches offered an alternative approach for integrated research, although they fell short of integrating policies and markets, among others, into the research process. The IAR4D approach sets out a process and progressive procedures and accompanying tools for planning the resolution of complex problems and implementing rural development activities that respond to the

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needs of beneficiaries and involved stakeholders, contribute to broad development objectives and that use multi-dimensional participatory and systems approaches.

The IAR4D is a process-oriented approach that recognizes the need for collective action by involving a broad range of stakeholders and multiple knowledge sources including indigenous knowledge and technology that can be used to address complex development challenges. The IAR4D approach also recognizes both spatial and temporal scales and interdependencies; multiple effects and trade-offs of different options; and the need to involve a wide range of stakeholders often with conflicting interests in collective action. Equally important is the inclusion of the social component including negotiation between differing perspectives, policy formulation, institutional change and development, land use and planning, and conflict and information management.

The need to break away from single disciplinary and conventional research approaches and instead focus more holistically on the context (social, ecological, economical and institutional) which determines success and failure in achieving impact required a range of actions, the most important of which include (i) Facilitating more engagement of farmers and other participants in production to consumption chain; (ii) Enabling farmers to access efficiently functioning agricultural output and input markets; and (iii) Providing support to smallholders and pastoralists to engage in knowledge intensive integrated management of their natural resources and achieve sustainable improved livelihood. In order to achieve the desired results, these services are to be achieved in an integrated manner with closer interactions and wider ranging partnerships between and within research institutions, public, private and civil society organizations.

An Innovation Platform (IP) forms the core of the IAR4D structure. The IP is an informal coalition, collaboration, partnership and alliance of agricultural research for development actors, that is, public and private scientists, extension workers, representatives of farmers, farmers' associations, private firms and NGOs, and government policy makers who communicate, cooperate and interact to set priorities, develop concepts and plans to promote agricultural productivity and profitability. The core competencies brought to bear by IP are greater than the sum of IP's constituents acting independently.

The implementation of IAR4D hinges on four interactive process oriented support pillars namely (i) bringing about organizational and institutional change, capacity building for project teams and institutions; (ii) knowledge management and information sharing; (iii) monitoring, evaluation, impact assessment and lesson learning; and (iv) change and integration of markets, policies, NRM and productivity into innovation processes. The impact pathway for IAR4D begins with the establishment of IP where priorities that would determine the objectives of the research are agreed upon, a concept and plan of action developed and roles of each actor or groups of actors on the platform are clearly defined. The research process would then involve the use of inputs which is further broken into three phases as follows:

1. Identification of a common challenge through the IP and using inputs through an action research process to generate outputs in accordance with the project's priorities and objectives.
2. Innovation stage which involves development of processes to deliver the outputs to beneficiaries (putting research into use, sometimes referred to as the innovation process). This involves putting into use the outputs generated by the research process. This process is facilitated by the IP and leads to incremental changes in relationships and behavior of stakeholders, in particular the users of the research outputs.

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3. Out-scaling by using agricultural development processes leading to improved food security, income, livelihood assets, the natural resource base and resilience to shocks; that is, impact. The mandate of IP actors ordinarily stretches beyond the IAR4D site. Accordingly, these actors serve as agents for out-scaling the research approach and its outputs beyond the initial site.

CASE STUDY: DISSEMINATION OF NEW AGRICULTURAL TECHNOLOGIES IN AFRICA (DONATA) PROJECT

Background

Promotion of Science and Technology for Agricultural Development in Africa (PSTAD) is an African Development Bank (AfDB) project with DONATA as subproject aims to improve on the agricultural productivity of resource-poor farmers. In 2008 SLARI/NARC with the sponsorship of AfDB, FARA, and ACORAF/WECARD established five demonstration/multiplication plots in five rural communities in the Bombali Shebora chiefdom in the Bombali District of Northern Sierra Leone and the Njaluahun Chiefdom in the Kailahun District of Eastern Sierra Leone. In 2011 another chiefdom, Gbendembu Ngowahun, Bombali District, and two others, Konike Barrina and Kolila Rowala in Tonkolili District, Northern Sierra Leone were added with total of ten platforms. In the same year, the Kayamba and Kori chiefdoms in the Moyamba district were added with a total of eight platforms, while in the Eastern Sierra Leone, Small Bo and Gaura chiefdoms in Kenema district and Luawa chiefdom in the Kailahun district were added with a total of 12 platforms. Overall, a total of thirty five innovation platforms were established between 2008 and 2011.

Farmer-Based Organizations (FBOs) under the Dissemination of New Agricultural Technologies in Africa (DONATA) project in Sierra Leone has been much referred to as an example of successful Innovation Platforms (IPs) in rural markets. The activities of FBOs have developed since 2008, supported by various NGOs and the Njala Agricultural Research Centre (NARC), a constituent centre of the Sierra Leone Agricultural Research Institute (SLARI). During this period, the group collaborated with private sector individual partners in Bo and Makeni townships and effective intermediaries to set up an effective supply system of the desired quantity of quality gari product suitable for the urban markets of Freetown, Conakry and Monrovia. This has resulted in in increased yields and income for the participating farmers, as well as a dependable supply of quality cassava and gari products for the urban consumers of Sierra Leone, Guinea, and Liberia.

DONATA's aim was the wide-scale dissemination and adoption of new and proven agricultural technologies in stakeholders' communities of Sierra Leone, to enhance food security and reduce rural poverty. While the focus of DONATA in Sierra Leone was on cassava based technologies in CORAF/WECARD,

DONATA had three main elements:

- Establishment of Innovation Platforms for Technology Adoption (IPTA) to strengthen the innovation capacity of stakeholders in agricultural research and development on the African continent.
- Dissemination of new proven technologies, and
- Upgrading knowledge and skills.

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The Innovation Platform for Technology Adoption (IPTA) actors in Sierra Leone include farmers, processors, traders, researchers, extension workers, policymakers, drivers and micro finance organizations. The farmers form the foundation of the Innovation Platform for Technology Adoption (IPTA). They are the producers of the cassava tubers, the basis for processing and transformation. The traders most often buy either cassava tubers and sell to the cassava processors or buy processed products of cassava and sell to consumers. The processors transform cassava into products such as gari, fufu and starch. The researchers develop higher yielding cassava varieties and associated agronomic practices to replace low yielding local strains while the extension workers organize these stakeholders into platforms and facilitate meetings of the actors. The micro finance organizations target these platforms to offer micro credits. Loans are often given to only farmers and traders of the platforms who have the capacity to pay back. The ward councilors facilitate access to land and settle dispute among members of the platform.

The expected outputs from the DONATA project were improved cassava varieties of SLICASS 1, 4, 6 and TME419 promoted and disseminated, and timely planting in Northern Sierra Leone were promoted and adopted. Farmers were actively involved in multiplying cassava cuttings for sale, while selling the tubers to processors, who produce gari and fufu for the markets. Technologies were demonstrated, disseminated and adopted through innovation platforms for technology adoption (IPTAs). To build capacity in development and promotion of selected technologies, training was given to researchers and extension agents. Some researchers received formal (M.Sc. level) training and short-term training, while extension agents receive training from the National Agricultural Research System (NARS).

The development of innovation platforms under the DONATA project was neither a single approach, nor the efforts of a single organization that assisted the FBOs. Rather, it was the FBOs that attracted the attention of the organizations that assisted them in pursuing their objectives, improving their skills and desire to be innovative. There was constant collaboration between the FBOs that constituted the innovation platforms and the Njala Agricultural Research Centre in identifying and selecting other IP stakeholders including processors, transporters, marketers, and input suppliers. This is to say that the IP which initially started with a farmer based organization had only farmers as the pioneers on an innovation platform. The International Institute for Tropical Agriculture (IITA) with a sub-regional office in Sierra Leone also gave important support, directly or through the Sierra Leone Agricultural Research Institute. Research organizations played a service-provision role and, over a longer period, engaged in capacity building of stakeholders within the cassava value chain.

Before the establishment of the IPTAs, improved cassava planting materials were not wide spread. They were only available to contact farmers who were in close touch with the research institute. The IPTA has facilitated a wider spread of improved technologies from research. Farmers' output in cassava production and processing has greatly improved. Cassava was initially processed into two major forms; gari and fufu. Now cassava is both cash and an industrial crop in Sierra Leone. Most of the IPTAs feed the cassava processing factories with raw tubers. Before the IPTAs, most farmers depended on local planting materials that were lower in yields and susceptible to pests and diseases. Cassava products such High Quality Cassava Flour (HQCF), odorless fufu flour and some others are the initiative of the IPTAs in Sierra Leone. Also, through IPTA there has been an effective grasshopper control on most cassava farms through date of planting. The cassava value chain initiative has also been promoted by the IPTAs. Now even cassava leaves are not thrown away but dried in solar driers milled into powder for sale on the market. Much more income is now realized by farmers from cassava production and processing than before the IPTAs.

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Knowledge and skills on the cassava value chain were enhanced in most part of the country by the establishment of the IPTAs. In Bombali district, the IPTAs increased cassava production by 50%. That necessitated the cassava value chain initiative at all platforms. Skills on how to process cassava leaves into powder for cassava leaf source were learnt. Processing cassava into HQCF was also learnt by most people through the IPTA. Odorless Fufu flour was until recently completely absent in Sierra Leone. Now most IPTAs with cassava processing facilities process cassava into HQCF and they do so with safer measures by containing them in plastic sachets and label. These skills have enhanced variety of cassava products on the markets and contributed to diversification of food consumption in Sierra Leone. In the past most Sierra Leoneans only accept having eaten when their meal is rice. That is gradually changing as more appealing products are now formed from cassava.

With the IPTAs, income levels of most cassava producers is improving as the land size cultivated to cassava is increased and more processing centers established. In Bombali district most DONATA platforms have graduated into Farmer Based Organization (FBO) and started bank accounts for savings. Some platforms have raised quite some amount of money and initiated a loan revolving scheme for the group members. This to a large extent has improved on the welfare of most IPTA members. The table below gives highlights of the income generated from IPTA farms in Bombali district.

IMPLICATIONS OF THE CASE

The case described above qualifies as a shining example of leadership within the context of adult education (E.g. Agricultural Extension, or Other non-formal education projects). Below is a narrative of how the case has illustrated the principles of adult learning in three areas of adult education and lifelong learning.

Adult Learning Principles Illustrated

Knowles' in the 1970s identified six adult learning principles as listed.

1. Adults are internally motivated and self-directed in setting goals and planning learning activities.
2. Adults bring life experiences and knowledge to learning experiences. Subject matter and learning experiences must be provided that begins where the learner is.
3. Adults are goal oriented. Learning activities should be provided that take into account the wants, needs, interests, and aspirations.
4. Adults are relevancy oriented
5. Adults are practical and they learn what they practice.
6. Adult learners like to be respected.

The question is how can the adult learning principles be illustrated to facilitate stakeholders' learning on an innovation platform within the IAR4D?

Principle 1: Adults are internally motivated and self-directed in setting goals and planning learning activities.

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Adult learners according to Fidishun (2000) resist learning when they feel others are imposing information, ideas or action on them. The role of the facilitator on an innovation platform is to move the actors towards more self-directed and responsible learning as well as to foster the actor's internal motivation to learn. As an experienced facilitator, you can:

- Set up a training program that is less structured but gives more responsibility to the actors on the IP with less supervision and at the appropriate place that is challenging but not overloaded for the IP actors/learners.
- Develop dialogue with the actors to optimize your approachability and encourage asking of questions and exploration of concepts. As the actors provide solutions to the facilitator's questions, they feel more confident and more equal with the facilitator in knowledge sharing.
- Show interest in the IP actor's thoughts and opinions by actively and carefully listening to the questions they pose.
- Lead the actors toward inquiry before supplying them with the facts.
- Provide regular constructive and specific feedback, which could be either positive or negative.
- Set projects or tasks for the IP actors which reflect their interests and which they must complete within a specified timeframe.
- Encourage the use of their resources first before considering other options in the pursuit of their goals.
- Acknowledge the actors' preferred way of learning or doing and to discuss this with the group.

Principle 2: Adults bring life experiences and knowledge to learning experiences.

Adults like to be given opportunity to use their existing foundation of knowledge and experiences gained from life, and apply it to their new learning experiences. As an experienced facilitator on the IP, you can:

- Find out about the actors on the platform in terms of their interests and past experiences in the family and at work.
- Assist the actors to draw on past experiences when problem-solving, reflecting and applying critical reasoning processes.
- Facilitate reflective learning opportunities which Fidishun (2000) suggests can also assist the learners to examine existing biases or habits based on life experiences and "move them toward a new understanding of information presented".

Principle 3: Adults are goal oriented.

Adult learners become ready to learn when 'they experience a need to learn it in order to cope more satisfyingly with real-life tasks or problems (Knowles, 1980 p.44) as cited in Fidishun (2000). Your role as an IP facilitator is to facilitate learners' readiness for problem-based learning and increase the actors' awareness of the need for the knowledge or skill presented. As an experienced facilitator, you can:

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- Provide meaningful learning experiences that are clearly linked to personal, client and fieldwork goals as well as assessment and future life goals.
- Provide real case studies as a basis from which to learn about theory, methods, functional issues and implications of relevance.
- Ask questions that motivate reflection, inquiry and further research.

Principle 4: Adults are relevancy oriented.

Adult learners want to know the relevance of what they are learning to what they want to achieve. Some ways to help learners on an IP is to see the value of their observations and practical experiences throughout their involvement on the platform are to:

- Ask the actors to do some reflection on for example, what they expect to learn prior to the experience, on what they learnt after the experience, and how they might apply what they learnt in the future, or how it will help them to meet their learning goals.
- Provide some choice of fieldwork project by providing two or more options, so that learning is more likely to reflect the actors' interests.

Principle 5: Adults are practical.

Through practical field experiences, interacting with real clients and their real life situations, learners move from classroom and textbook mode to hands-on-problem solving where they can recognize first hand, how what they are learning applies to life and the work context. As an experienced facilitator, you can:

- Clearly explain your critical reasoning when making choices about assessments, interventions and when prioritizing client's needs.
- Be explicit about how what the learner is learning is useful and applicable to the job and client group you are working with.
- Promote active participation by allowing learners to try things rather than observe. Provide plenty of practice opportunity in assessment, interviewing, and intervention processes with ample repetition in order to promote development of skills, confidence and competence.

Principle 6: Adult learners like to be respected. Respect can be demonstrated to your learners by:

- Taking interest
- Acknowledging the wealth of experiences that the learner brings to the platform.
- Regarding them as colleagues who are equal in life experience.
- Encouraging expression of ideas, reasoning and feedback at every opportunity.

It is important to keep in mind that the learner is still developing occupational therapy clinical practice skills. However, with the theory and principles of adult learning in mind, you can facilitate the learning approach of the students to move from novice to more sophisticated learning methods. This facilitates greater integration of knowledge, information and experience. The learner learns to distinguish what is important when assessing and working with clients, how to prioritise client needs, goals and caseload.

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When rules can be put aside and how/when the approach to occupational therapy practice and professional communication emerges from strict modelling of behaviour into a unique therapeutic and professional expression of self (Fidishun, 2000; Lieb, 1991).

Agricultural Extension Principles Illustrated

The case of DONATA project in Sierra Leone has also demonstrated the principles of agricultural extension in the promotion and dissemination of agricultural technology for the benefits of cassava value chain actors. The Njala Agricultural Research Centre has done this with the following guiding principles for growth in agricultural production illustrated:

Principle 1: Empowerment of end-users to ensure their meaningful participation in setting priorities and work program for research, extension and training to ensure their relevance.

Principle 2: Planned subsidiarity to give responsibility and control over resources for agricultural research, extension and training activities at the lowest appropriate level of aggregation (local, national and regional).

Principle 3: Pluralism in the delivery of agricultural research, extension and training services so that the diverse skills and strengths of a broad range of service providers such as universities, non-governmental organizations (NGOs), public and the private sector can contribute to publicly supported agricultural productivity operations.

Principle 4: Evidence-based approaches with emphasis on data analysis, including economic factors and market orientation in policy development, priority setting and strategic planning for agricultural research, extension and training.

Principle 5: Integration of agricultural research with extension services, the private sector, training, capacity building, and education programs to respond in a holistic manner to the needs and opportunities for innovation in the sector.

Principle 6: Explicit incorporation of sustainability criteria in evaluation of public investments in agricultural productivity and innovation programs (fiscal, economic, social and environmental).

Principle 7: Systematic utilization of improved management information systems, in particular for planning, financial management, reporting, and monitoring and evaluation.

Principle 8: Introduction of cost-sharing with end-users, according to their capacity to pay, to increase their stake in the efficiency of service provision and to improve financial sustainability.

Principle 9: Integration of gender considerations at all levels, including farmers and farmers' organizations, the private sector, public institutions, researchers and extension staff.

Principle 10: Farmer operations based on demand driven technologies generated by research.

IAR4D Principles Illustrated

Principle 1: Integration of perspectives, knowledge and actions of different stakeholders around a common theme

The various members of each Farmer Based Organization initially received training in Farmer Field Schools (FFS) on basic farming skills, records keeping, farm management, business skills, group dynamics and governance of social organizations. Graduation of farmers from FFS with these basic farm

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skills qualified them to form an FBO which further received training on cassava production techniques, cassava disease management and cassava seed multiplication, which has led to an increase in production and productivity. The increase in production presented a marketing problem, and through the assistance from SLARI with financial support from Common Funds for Commodity (CFC) and DONATA Project, contact with potential buyers was established, credit was obtained and farmers were given training in developing business plans. The demand of quality processed cassava led to technical support from IITA with training on various processing equipment for gari and high quality flour products. Training, exposure and interaction of members has made it possible to separate entry points within the same IP with some acting as producers, and others as processors, transporters, and marketers.

Principle 2: Integration of learning that stakeholders achieve through working together

Beyond a simple concerted process, IAR4D according to Hawkins, Keemskert, Daane, Maatman and Adekunle (2009) is a social learning process, with stakeholders learning from the experience of working together. The different collaborative activities between SLARI, IITA, NARC, and local NGOs have provided improved insight into rural innovation process facilitated by DONATA staff but experimented and managed successfully by the various IP all actors. The focus in this kind of learning as noted by Hawkins et al. (2009) is primarily on the processes of stakeholder interaction themselves, rather than on the specific solutions to the research and development challenge, and learning occurs at the individual, innovation platform and institutional levels.

Principle 3: Integration of analysis, action and change across the different dimensions of development

The various IP groups have managed to substantially increase incomes from the cassava sales. As presented in the NARC Annual Technical Report for 2014, a total of ten (10) innovation platforms (IPS) have been established between 2008 to 2011 and are now fully functioning with a total membership of 5650 (3065 males and 2600 females) in the cassava value chain.

In 2013, a total of 45.7t of gari was produced by all the IPs, valued at US$44,244.15 and marketed. This was followed by high quality cassava flower (HQCF) at 6t, fetching US$6976.70 and wet foo-foo and foo-foo flour at 42.25 t which fetched US$22,266.20. The total sale of all processed products was 162.25t and valued at USD121,919.14, and together with the sale of 29,600 bundles of cassava sticks (a bundle = 100 x 1m cassava sticks) valued at US$ 41,400 giving a gross income of US$ 163,359.14 for all the ten IPs. A total area of 452 ha was under cassava cultivation in all the IPs with average yields of 29-30t/ha for SLICASS 4, and 30-35t/ha for SLICASS 6 (Sesay, Massaquoi, & Fomba, 2014).

There is no evidence however if men and women were paid the same prices and whether both gender gained equal benefits. Similarly, the work on DONATA does not show whether gains from the project were invested in natural resource management, which signals the need to address these issues.

Principle 4: Integration of analysis, action and change at different levels of spatial and social organization

To be effective in promoting innovation, IAR4D needs to promote change and enhance learning at all levels of the organization, including field, farm and watershed, product, firm, value chain, business cluster, individual, group, community, organization, and innovation levels (Hawkins et al. (2009). Elements in the success of the Innovation Platforms were the building of group cohesion as a result of the

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FFS training, working together as a FBO and also learning the processes of starting and operating an innovation platform.

Implications of the Case Study for Leadership Development

Leadership as observed by Oduaran (n.d) is one of the most studied, observed and least understood phenomena people have grappled with over the years. The difficulty in understanding the concept according to Oduaran arises from the fact that there are no commonly agreed criteria by which we can describe the essence and process of leadership. The authors of this paper briefly explore the meaning of leadership in this section, and move on to identify the functions of a leader in the IAR4D approach.

A synthesis provided on the definition of leadership by Northouse (2013) is that whether viewed as a personal quality or an organizational function, leadership can only be defined more correctly from at least six perspectives, which include:

- The focus of group processes in which the leader is the individual who is at the middle of group change and activity and entails the ability to get the will of the group on his/her side.
- Perspective of personality elements in which leadership is perceived as "a combination of special traits or characteristics" that an individual has. It is those special traits or characteristics that enable the leader to motivate others to accomplish or complete given tasks.
- Perceived as an act or behavior in which interest is in the kind of things that leaders do in order to bring about change in a given group.
- From the point of view of power relationship when leadership is perceived as the exercise of power in order to bring about a change in the followers.
- Perceived as an instrument of goal achievement, which portrays leadership to be something that could be used in helping members of the group to achieve their goals while at the same time meeting their needs.
- From the skills perspective, when leadership places emphasis on capabilities including knowledge and skills that bring about effective leadership.

In every definition of leadership, the leader and the followers are equally important. However, it is often the leader who is expected to initiate the relationship, create the communication linkages and strive to maintain the relationship that s/he has established. Thus, leadership is a relationship activity in which the leader and followers must be understood thoroughly. From the synthesis provided by Northouse (2014),

Leadership can be defined as a process of influencing others, in which the leader demonstrates ability to develop a vision that is well communicated, builds trust among colleagues, and takes effective action to maximize the efforts of others towards the achievement of a common goal.

Technically speaking a leader could use social influence to just *organize* the efforts of others, without necessarily *maximizing* their effort. However, leadership is not about getting people started for developing cassava and rice technologies to improve productivity and food security." It is rather, "the leader sees the present food insecurity and poverty", and influence the followers to get started and see how fast they can achieve the goal of improving productivity and food security. We can achieve the goal of

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improving productivity and achieving food security in twenty five years. However, if the same goal can be attained in three years, we are both effective and efficient.

Functions of Leaders:

Common activities for leaders are planning, organizing, directing, and controlling. In a typical research setting, leaders are expected to execute these common activities as shown in Table 1 below:

- Firstly, leaders focus the attention of a group on purpose. For example, a leader will focus attention of colleagues by asking "Why do we constitute the rice research task force?" "What is our mission?"
- Leaders are result oriented. That is leaders organize work around results that will make the vision a reality. This means moving from a written document to action within a specified time frame.
- Leaders help the group internalize the vision through communication and information sharing.
- Leaders define a clear set of values and guiding principles that support the vision and promote individual accountability. This accountability is the glue that holds the vision intact.
- Leaders inspire trust by motivating, challenging, encouraging, empowering and moving their people.
- Leaders take a risk by stepping outside their comfort zone and think outside their mandate.
- Leaders innovate and develop rather than maintaining the status quo.
- Rather than doing things right, leaders do the right things.

CURRENT CHALLENGES FACING THE USE OF INNOVATION PLATFORMS

The use of innovation platforms is a major tool in the implementation of the IAR4D processes. The DONATA projects in Sierra Leone have made significant contributions towards improving productivity in the past seven years through the promotion and dissemination of improved crop varieties particularly cassava coupled with key management practices. The impact indicators of the long-term investments in agricultural research using the case of DONATA are beginning to show but are yet to be evaluated

Table 1. Common activities executed by leaders

	Leader
Planning	• Devises strategy • Sets direction • Creates a vision
Organizing	• Gets people on board for strategy. • Communicates strategy • Networks with those led.
Directing	• Empowers people
Controlling	• Motivates • Inspires • Gives sense of accomplishment

The characteristics of leaders emerging from the functions listed above are critical to reiterate.

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in terms of: (i) the productivity impact that focuses on the efficient use of resources; (ii) the livelihood impact which determines whether gains of increased productivity benefit the mass of society; and (iii) the environmental impact which determines whether the gains achieved by the first two impact indicators can be sustained. Despite the gains realized in DONATA, there are numerous challenges that need to be addressed to achieve a sustainable broad based agricultural growth. These are:

General Challenges

The major challenges facing the agricultural sector include but not limited to the following:

1. Sierra Leone's population stands at 5.93 or 6% but 70.2% of the population leaves below the poverty line of $1.25. Poverty and unemployment is rampant.
2. 26% of the population is undernourished and are food insecure with impaired physical and cognitive values.
3. Poor physical infrastructure e.g. roads, marine transport, markets, communications (ICT) and energy. Without the prerequisite infrastructure it will be difficult to achieve agricultural products value chain activities.
4. Poor knowledge infrastructure and therefore need to advance the harnessing of Science, Technology and Innovations to improve competitiveness That is, there is need to promote science policy and its implementation.
5. Inherently poor soils. Most soils in Sierra Leone are ferralitic in origin and low in mineral nutrients reserves and therefore inherently low in fertility. Soil management including integrated soil fertility management practices should be given priority in our research agenda.
6. Low agricultural production growth rate (5.31%): low adoption of technology and area expansion for yield versus low intensification practices.
7. Planning approach is usually of short horizon and lack of foresight thinking. Our population is projected to double by 2050 and it means doubling or tripling current production levels. Planning approach is also based on limited scenarios and problem solving with little or no focus on exploiting opportunities.
8. Programs are usually fragmentary (between research, extension, training and education, NGO, farmers and policy makes) and are implemented in isolation resulting to duplication. There is weak human and institutional capacity.
9. Need to change mind-set of dependency and waiting for problems to be solved rather than exploiting opportunities.

Challenges in Developing Research Leaders for IAR4D

The major challenges in developing leadership of IAR4D are:

1. Resources for training at various levels of academic certification. The least cost for training research leaders based on our present experience with the World Bank project is as follows:
   a. MSc/Phil degree: $34,000 - $56,000
   b. PhD degree: $74,000 - $126,000

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To reduce the cost of leadership development, the Sierra Leone Agricultural Research Institute (SLARI) recruits people with a first degree as Research Assistant. Better still SLARI preferably recruit research scientists with a Master of Science degree over first degree holders.

2. Retentions of leaders in research institutions. Very few research institutions in Sub-Saharan Africa have adequate capacity to retain the very leaders they have trained. Incentives such as competitive salaries, standard accommodation, recreational facilities, educational facilities for the children of research leaders, and transportation are lacking. In real cases also there is the lack of laboratories, equipment and financial resources for research scientists to prove their leadership potentials in working with their colleagues.
3. The right gender balance between male and female scientists is hardly achieved because of the lack of female scientists to fill similar leadership positions like their male counterpart. In Sierra Leone, we have traced the gender gap right from the primary and secondary stages of our educational system where the girls are not encouraged to do sciences like physics, chemistry, biology, and mathematics. When this foundation is missed, getting the females into university programs like food sciences, agricultural sciences, engineering sciences, and environmental sciences becomes impossible. The ultimate consequence is that few females are available to take positions of soil scientist, agronomist, breeder, food technologist, entomologist, plant pathologist, hydrologist, irrigation specialist, biotechnologist, and biometrician.
4. Getting the right diversity of scientists to fill the leadership gaps as dictated by our research programs has not been achieved, and will continue to be a major challenge in the near future. Not until recently with the advent of the IAR4D which encourages the use of the Agricultural Product Value Chain (APVC) approach, our research focus has been mainly biological and/or production oriented with little or no attention to non-biological or non-production oriented activities such as processing, fortification, transporting, packaging, marketing, and consumption. Now that research diversity could be enhanced under the IAR4D using the APVC approach, trained leadership is required to achieve the strategic goals of the research institution.

REFERENCES

Biggs, S. D., & Clay, E. J. (1981). Sources of innovation in agricultural technology. *World Development*, *9*(4), 321–336. doi:10.1016/0305-750X(81)90080-2

Chambers, R. (1989). Farmers First: Farmer Innovation and Agricultural Research. London: IT Publications.

Chema, S., Gilbert, E., & Roseboom, J. (2003). *A Review of Key Issues and Recent Experiences in Reforming Agricultural Research in Africa*. ISNAR. Available at ftp://ftp.cgiar.org/isnar/publicat/PDF/rr-24.pdf)

FARA (2007). *Sub-Saharan Challenge Program, Medium Term Plan 2008-2010*. FARA.

Hawkins, R., Heemskerk, W., Booth, R., Daane, J., Maatman, A., & Adekunle, A. A. (2009). *Integrated Agricultural Research for Development (IAR4D).* Paper prepared for the Forum for Agricultural Research in Africa (FARA) Sub-Saharan Africa Challenge Program (SSA CP).

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Jones, M. (2009). *Integrated Agricultural Research for Development (IAR4D).* Paper prepared for Forum for Agricultural Research in Africa (FARA) Sub-Saharan Africa Challenge Program (SSA CP).

Lieb, S. (1991). *Principles of adult learning*. Phoenix, AZ: Vision – South Mountain Community College. Retrieved from http://honolulu.hawaii.edu/intranet/committees/FacDevCom/guidebk/teachtip/adults-2.htm

Mukiibi, J., & Youdeowe, A. (2005). *Agricultural Research Delivery in Africa: An assessment of the requirements for efficient and effective and productive African NARS*.

Northouse, P. G. (2013). *Leadership: Theory and Practice*. Los Angeles: Sage Publications.

Okali, C., Sumberg, J., & Farrington, J. (1994). *Farmer Participtory Research: Rhetoric and Reality*. London: Intermediate Technology publications. doi:10.3362/9781780444932

ADDITIONAL READING

Brookfield, S. D. (1986). *Understanding and Facilitating Adult Learning. A comprehensive analysis of principles and effective practices*. Milton Keynes: Open University Press.

Collins, M. (1991). *Adult Education as Vocation. A critical role for the adult educator*. London: Routledge.

Courtney, S. (1989). Defining adult and continuing education. In S. B. Merriam & P. M. Cunningham (Eds.), *Handbook of Adult and Continuing Education*. San Francisco: Jossey-Bass.

Darkenwald, G. G., & Merriam, S. B. (1982). *Adult Education. Foundations of practice*. New York: Harper and Row.

Fomba, S. N. (2011). *Promotion of Science and Technology for Agricultural Development in Africa (PSTAD)*. Quarterly Progress Report to FARA on RAILS and DONATA.

Fomba, S. N. (2014). *Dissemination of New Agricultural Technologies in Africa (DONATA). Semi-yearly progress Report*. January – June.

Jarvis, P. (1987). *Adult Learning in the Social Context*. Beckenham: Croom Helm.

Sahr N. Fomba (2012). Report on the Tour of the Parliamentary Oversight Committee on Agriculture of the NARC Research sites, infrastructure and facilities.

SLARI. (2011a). Sierra Leone Agricultural Research Institute. Strategic Plan, 2012-2021

SLARI. (2011b). Sierra Leone Agricultural Research Institute. Operational Plan, 2012- 2016

SLARI. (2011c). Sierra Leone Agricultural Research Institute. Investment Plan, 2012-2021 http://www.fara-africa.org/networking-support-projects/ssa-cp

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KEY TERMS AND DEFINITIONS

Adult Education: A practice in which adults engage in organized and sustained learning activities intentionally designed for the purpose of bringing about gains in new forms of knowledge, skills, attitudes, or value among those whose age, social roles, or self-perception define them as adults.

Adult Learning: 'The entire range of formal, non-formal and informal learning activities which are undertaken by adults after a break since leaving initial education and training, and which results in the acquisition of new knowledge and skills'.

Agricultural Extension: Is a general term involving the provision of assistance to farmers to help them identify and analyze their production problems and become aware of the opportunities to make improvement through farmer education and the application of scientific research and new knowledge to agricultural practices.

Agricultural Product Value Chain (APVC): Although there is no universally accepted definition of the term, it normally refers to the full range of value adding activities required for an agricultural product or service to move through the different phases of production, including procurement of raw materials and other inputs, assembly, physical transportation, acquisition of required services such as transport or cooling, and ultimately response to the end customer's demand (Kaplinsky and Morris, 2000).

'Demand': What people ask for, need and value so much that they are willing to invest their own resources, such as time and money, in order to receive the services.

Demand Driven Technology Transfer: The demand drive technology transfer maintains the assumption that new technology drives innovation, that generation of this technology is most by publicly funded research institutions (Rogers, 1070), and that this technology is generated and transferred to the end users in a demand/market driven and more outward looking process (Chema, Gilbers & Roseboom, 2003) by involving the end users in assessing their needs and social realities which informs the technology generation and transfer processes.

Farming Systems Approach (FSA): "A multi- (inter- and intra-) disciplinary approach to generation and diffusion of knowledge and technologies for specific target groups of clients with their participation focusing on identified priority problems, constraints and opportunities of the production system under consideration in different biophysical and socioeconomic conditions, with emphasis on improving the productivity of the existing system".

Integrated Agricultural Research for Development (IAR4D): An action research approach for investigating and facilitating the organization of groups of stakeholders, including researchers, to innovate more effectively in response to changing complex agricultural and natural resources management contexts for improved developmental outcomes (FARA, 2007).

Innovation Platform (IP): "A physical and/or virtual network of stakeholders which has been set up around a commodity or system of mutual interest to foster collaboration, partnership and mutual focus to generate innovation on the commodity or system" (Adekunle and Fatundi 2012).

Multidisciplinary Approach: An approach which involves drawing appropriately from multiple disciplines to redefine problems outside of normal boundaries and reach solutions based on a new understanding of complex situations.

Multi-Institutional: Institutional system consisting of more than one service facility which has cooperative administrative arrangements through merger, affiliation, shared services, or other collective ventures.

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Multi-Stakeholders: These are persons with common interests and have agreed rules about cooperation. They are involved in learning and are action oriented and system thinking. They are concerned about knowledge and information sharing. Participation and empowerment is their goal.

National Agricultural Research System (NARS): In any given country, all institutions and organizations actually or potentially involved in agricultural research and technology development together constitute the NARS of that country. Strong linkages are necessary between National Agricultural Research Institutes (NARIs) and specialized commodity research institutes, universities, industrial research laboratories, development organizations and the extension services, which are all involved in agriculture-related development activities.

Stakeholders: Stakeholders refer to individuals, groups or organizations that can affect or are affected by a particular issue, system or innovation, Related terms are "interest groups", which indicate that people can be grouped according to a common interest, and "actors" which emphasizes that some or all stakeholders are active and interact with each other (Hawkins et. al, 2009).

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Chapter 39
Economic Transformation of Austrian Agriculture Since EU Accession

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ABSTRACT

After joining the European Union (EU) in 1995 Austria adopted the Common Agricultural Policy (CAP). This chapter reviews the changes in agricultural production and the economic situation of agriculture since the accession to the EU. The analysis is primarily based on macro-economic data from the Economic Accounts for Agriculture (EAA) over the period between 1995 and 2014. Select examples identify the developments applicable for Austria – also in comparison to other EU countries and groups of countries as well as to Switzerland. Expectations and forecasts regarding the consequences of integration, e.g. changes in the price levels, have been more or less fulfilled but there is a need for further research on the development of regions and on special issues such as the resilience of Austrian agriculture.

INTRODUCTION

With its accession to the EU Austria adopted all rights and obligations pursuant to the Common Agricultural Policy (CAP) (Art. 137 of the Act of Accession). Market organisations, price policies and payments to agriculture and forestry (in short: "farm payments") had to be adjusted to the EU regime (Schneider, 1997). In general, competition was endorsed by the CAP, interventions in agricultural and food markets were reduced and measures to support prices were cut drastically and replaced by direct payments. With respect to structural policies, more emphasis was devoted to efficiency and performance.

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Environmental aspects got increased attention; regional policy including programs for rural areas was upgraded (Schneider, 1997, p. 156). In order to mitigate losses of income due to inherent competitive weaknesses, structural disadvantages and accession-related price cuts, temporary transitional assistance in the form of degressive compensatory payments and aid for the write-down on agricultural products were granted (Ortner, 1996; Sinabell, 2004; Hofreither, 2006, p. 23).

Since then the CAP was subject to four reforms, the last of them in 2009 and 2013. These reforms were gradual adaptations of the mechanisms that were put in place to achieve the objectives spelled out in the Treaty of Rome (Hambrusch, Heinschink, & Tribl, 2015). In the context of these reforms new objectives have been added (Regulation Establishing Rules, 2013; Regulation on Support, 2013). These encompass economic objectives (ensuring food security through sustainable agricultural production, improving competitiveness and increasing Value Added in the food chain), environmental objectives (sustainable use of natural resources and combating climate change), and territorial objectives (ensuring economic and social dynamics of rural areas) (Massot, 2013).

The current chapter addresses the question of how, in this context, the economic situation of Austrian agriculture has developed since accession to the EU. The chapter is organised in several sections, starting with the history of agricultural developments and events in Austria. A brief introduction into the methodology applied is followed by an outline of the importance of agriculture by its Value Added and its contribution to the overall economy; a description of the components of agricultural output and the development of their shares; a portrayal of the composition and significance of farm payments for the development of the economic situation in agriculture; and an illustration of the development of agricultural income. Based on these results authors highlight strategies of how to mitigate or adapt Austrian agriculture to current challenges, followed by a section on possible fields of further research.

The chapter is based on statistical data from Economic Accounts for Agriculture (EAA). Key developments in Austria and other EU countries as well as Switzerland are addressed. Furthermore, payments for Austrian agriculture are compared to the overall budget and the net contribution to the EU budget using data of National Accounts (NA), reports of the Ministry of Finance (Bundesministerium für Finanzen, 2013, 2015), reports of the Ministry of Agriculture (Bundesministerium für Land- und Forstwirtschaft, Umwelt & Wasserwirtschaft, 2015) and the Financial Report of the European Commission (2015b).

BACKGROUND

Austrian agriculture was perceived as a sensitive area with regard to EU integration. The main problems of the sector were:

- Inadequate preparation for the Single Market;
- The country's idiosyncratic natural and structural features;
- Differences in agricultural policies (Schneider, 1989, 1993, 1994).

The adoption of the CAP was associated with a fundamental transformation of economic conditions including profound changes in market organizations, price policy, agricultural support, and competitiveness.

Traditionally, the role of government in agriculture has been strong in Austria, in particular in the dairy and cereals sectors where marketing boards administered prices, managed production and exports. In addition, equity considerations and environmental concerns remained very important. Politicians com-

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mitted themselves not to let per capita farm income fall behind the level of income growth in the overall economy. This was done in order to maintain the small-scale structure of farming (family farms) and to give farmers in disadvantaged (mountainous) regions the opportunity to stay viable through supplementary income payments. However, these direct payments were counterbalanced by production and fertilizer levies and accounted only for a part of support given to the agricultural sector (as measured by the Producer Subsidy Equivalent) (Organisation for Economic Co-operation and Development, 1995). The major policy instrument was market price support through border protection and export subsidies. The result was that farmers increased production until the government introduced quantitative restrictions on milk deliveries and support to oilseeds and protein crops in order to clear cereals markets.

Joining the EU provided an opportunity for market liberalisation and access to the huge EU market for agricultural products, which was almost closed until then except for certain tariff quotas, a situation that forced the government to spend substantial amounts for export subsidies to allow excess production to be sold in world markets. However, the prospect of low agricultural producer prices in the EU was a major concern for farmers and processors who had hitherto been protected from competition in the domestic market. In the EU agricultural producer prices had been lowered following the CAP reform in 1992. In Austria, price adjustments had been postponed but were unavoidable after the conclusion of the Uruguay Round of negotiations of the General Agreement on Tariffs and Trade (GATT), which obliged Member States' agriculture and food sectors to reduce export subsidies, internal support and border protection (Ortner, 1994).

Thus, the challenge was to adjust Austrian agriculture to international markets while meeting policy objectives and securing support for EU accession. Agricultural prices dropped in the wake of EU accession by 22% on average while farmers could expect to pay only slightly less for inputs (Schneider, 1997). In the short run, the challenge was met surprisingly well due primarily to a momentous upgrade of support payments. Degressive compensatory payments were granted upon accession until 1999 to facilitate adjustment. Income support to farmers in mountainous and disadvantaged regions almost doubled, and the scope and volume of payments under the Austrian Program for Environmentally Sound Agriculture increased substantially (Ortner, 1996, 1997a).

While the immediate changes upon accession are well documented in the literature, it is less obvious how Austrian agriculture developed in the longer run. Was there a major drop in agricultural income? Did production go down? How did the structure of agricultural output change? These developments are considerably steered by the evolution of agricultural policies and markets. Rather than outlining these changes here, the authors will comment on them as data which shed light on these issues is presented and discussed.

MAIN FOCUS OF THE CHAPTER

Methodology

The economic situation of Austrian agriculture is the subject of agricultural statistics both from a microeconomic and a macroeconomic perspective. The microeconomic situation is surveyed in terms of standardised accounting results at the level of agricultural holdings in the EU – the Farm Accountancy Data Network (Gahleitner, Kirner, & Resl, 2015). The macroeconomic approach accounts for agriculture

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overall, using the framework of EAA (Regulation on the Economic Accounts, 2003; European Union, 2013).

Aggregate economic accounts for agriculture have been published within the EU since 1964 and from 1969 onwards based on common definitions and procedures. The EU's EAA has been continuously adapted (Berkeley, 1996, p. 91). Several documents about the methodology on the EAA – with a standard set of concepts, definitions and roles for accounting – are available on the Internet (European Commission, 2000; Regulation, 2003; European Union, 2013).

The EAA is a complementary (satellite) system to National Accounts which provides more detailed and comprehensive branch-specific information on agriculture than would be possible within the framework of NA (European Commission, 2000). The EAA is based on the collection and aggregation of numerous statistical information presented within a consistent framework. It draws upon agricultural production statistics (such as the harvest survey and slaughtering statistics), supply balance sheets, price statistics and farm accounting data as well as administrative data of the paying agency (Agrarmarkt Austria) and the Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW), information from the Chambers of Agriculture, producer associations and non-agricultural statistics (External Trade Statistics). In the course of preparing and systematically compiling the EAA the data is checked for consistency, plausibility and comprehensiveness (Kniepert, Mayer, & Ortner, 2009, p. 84).

The EAA is made up of a sequence of linked accounts which enable the assessment of the economic performance of the agricultural industry, from production to primary income generated. Financial flows to and from the government (taxes on production, subsidies), wages paid as well as rents and interest are constituent parts in this framework (European Commission, 2000). Furthermore, the EAA records basic data on wealth creation and labour input into agriculture (Bundesamt für Statistik, 2006, p. 40). The EAA provides comparable monetary values which inform about the general structure of agricultural production and changes in the economic values of agricultural production and income. The calculation scheme is presented in Figure 1.

Figure 1. Agricultural economic accounts – scheme
Source: European Commission, 2000; Regulation, 2003

	Output at Producer Prices
-	Taxes on Products
+	Subsidies on Products
=	**Output at Basic Prices**
-	Intermediate Consumption
=	**Gross Value Added at Basic Prices**
-	Consumption of Fixed Capital
=	**Net Value Added at Basic Prices**
-	Other Taxes on Production
+	Other Subsidies on Production
=	**Net Value Added at Factor Costs (Factor Income)**
-	Compensation of Employees
=	**Net Operating Surplus / Net Mixed Income**
-	Rent Paid
-	Interest Paid
+	Interest Received
=	**Net Entrepreneurial Income**

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The indicators and figures calculated within the EAA provide the basis for a wide range of possible analyses, e.g. production patterns, input mix, terms of trade and productivity. Changes in the monetary values of output, intermediate consumption and Value Added can be broken down into price and volume components. However, in order to investigate the causes of the trends observed, it is often necessary to consult further information sources not included in the EAA, such as data on world markets, exchange rates, consumer preferences, legislation, economic conditions, policies, etc. (Kniepert et al., 2009, p. 84).

These economic data play a prominent role in CAP policy formation as well as in monitoring past behaviour of the agricultural industry. Even in the absence of an agricultural policy with specific income goals, the economic activities of the agricultural industry would have to be accounted for as there is a general need to monitor the state of the agricultural system (Berkeley, 1996, p. 90). Furthermore, the EAA form the basis for depicting the agricultural industry in National Accounts. Since there are certain conceptual differences between these two systems of economic accounts, the EAA data has to be adapted for inclusion into NA.

In order to maintain consistency, data of NA is used for comparisons of developments of the agricultural industry with that of the overall economy in the following section. The comparisons are based on NA data compiled according to the former European System of Accounts 1995 (ESA 1995) as this data is available since 1976.

Position of Agriculture in the Economy

ESA 1995 data show that from EU accession in 1995 to 2012 the Gross Value Added (GVA) of the overall economy increased nominally from €157.4 billion to €277.6 billion, representing an increase of 76%. During the same period GVA of the primary sector (agriculture, forestry and fishing) increased by only 14%, from €3.9 billion to €4.4 billion (Statistics Austria, 2013). Within the primary sector, GVA of forestry increased significantly more strongly (44%) than that of agriculture (5%). In this regard, however, it is necessary to note that the development of GVA in agriculture – in contrast to that of forestry – was significantly influenced by changes in the types of support to agriculture, i.e., the introduction of degressive compensatory payments from 1995 to 1998 and decoupling of subsidies since 2005.

The direct contribution of agriculture to the economic performance of Austria as a share of agricultural GVA in Total Value Added of the economy dropped from 4.5% in 1976 to 1.9% in 1995. From 1995 to 2005, the share of agriculture decreased further to 1.1%. In the period 2006 to 2012 the share of agriculture in Gross Value Added fluctuated between 1.0% and 1.2% (Figure 2).

In comparison to other EU countries, the share of agriculture in Austria was at 1.2% in 2011, lower than the average of EU-28 (1.5%) and slightly lower than that of EU-15 (1.3%). The relative economic weight of agriculture is significantly lower in Western and Northern Europe than in Eastern and Southern Europe. The contribution to Total Value Added is highest in Romania (2011: 6.8%) and Bulgaria (5.1%), followed by Hungary (4.4%), Poland (3.6%), and Lithuania (3.2%). The lowest levels can be found in Luxembourg (0.3%), Sweden (0.4%), Belgium and the United Kingdom (0.6% each), and Germany (0.7%) (Figure 3). Furthermore, Figure 3 illustrates that countries with a high share of agriculture, forestry and fishing in Total Gross Value Added have been experiencing a strong slowdown since 1995.

The Value Added share of agriculture in the overall economy, however, is an insufficient indicator of the relevance of this industry as agriculture contributes significantly to the economic performance of its upstream and downstream sectors (Ortner, Neuwirth, & Wagner, 2010). Furthermore positive and negative externalities which go along with agricultural production, e.g. the contribution to security

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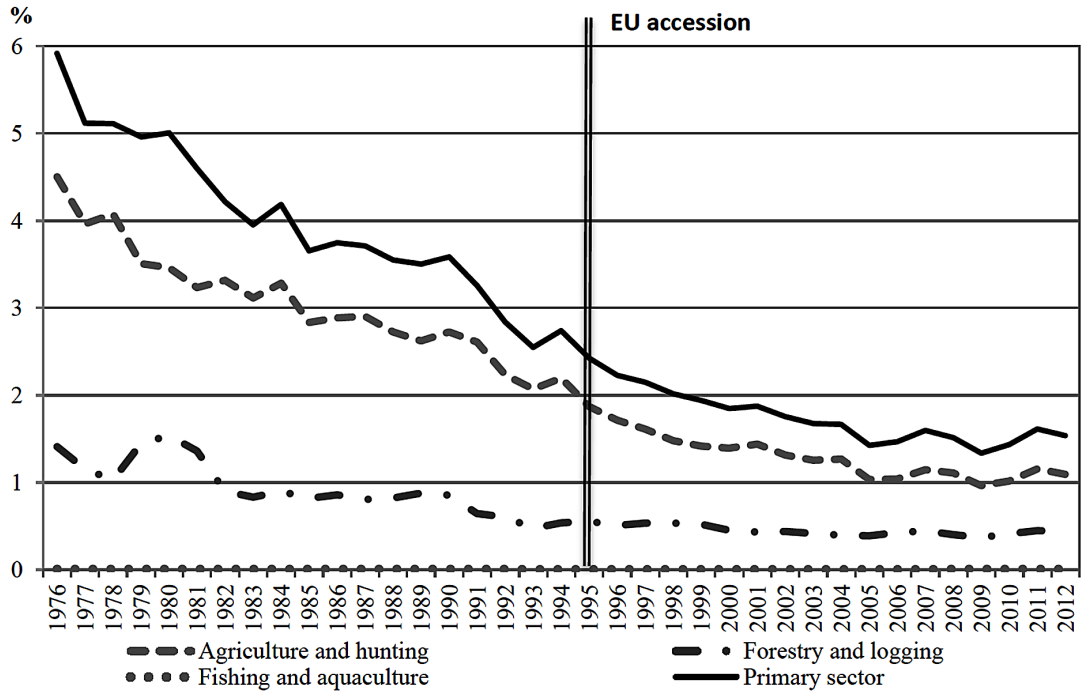
Figure 2. Share of the primary sector in the Gross Value Added of the Austrian economy, in %, 1976-2012
Source: Statistics Austria, 2013



of food supply, the environmental impact of farming practices, the amenity of certain landscapes and wildlife, etc., remain unconsidered.

Agricultural Production

Output Value: Composition and Development

In 1995 Austrian agriculture produced goods and services at a total value of €5.83 billion (Statistics Austria, 2015). This value includes subsidies on products amounting to €0.95 billion minus taxes on products in the amount of €0.02 billion. Until 1999, the output value of the agricultural industry at basic prices, which is referred to below as total output value of agriculture, declined to €5.4 billion. This decrease was primarily due to the schedule of degressive compensatory payments that were granted to facilitate EU accession. Between 2000 and 2004, the trends in the total output value were primarily dictated by the development of producer prices and output volumes. The annual rates of change of the output value of the agricultural industry fluctuated during this period within a range of (-3.2%) (2002) to (+6.2%) (2001). After a slight increase in 2000 and a hefty price-induced increase in 2001 there were declines in 2002 and 2003 and another increase in 2004. In 2005, decoupling of a large share of acreage premiums and certain livestock premiums led to a strong decrease of the total output value. Year 2006 marked the start of a very dynamic development characterized by a strong upward trend in agricultural output value, which was interrupted by a slump in 2009 in the wake of the financial and economic crisis. Particularly high growth rates occurred in 2007 and 2011. In the years 2012 and 2014, weather-related crop failures

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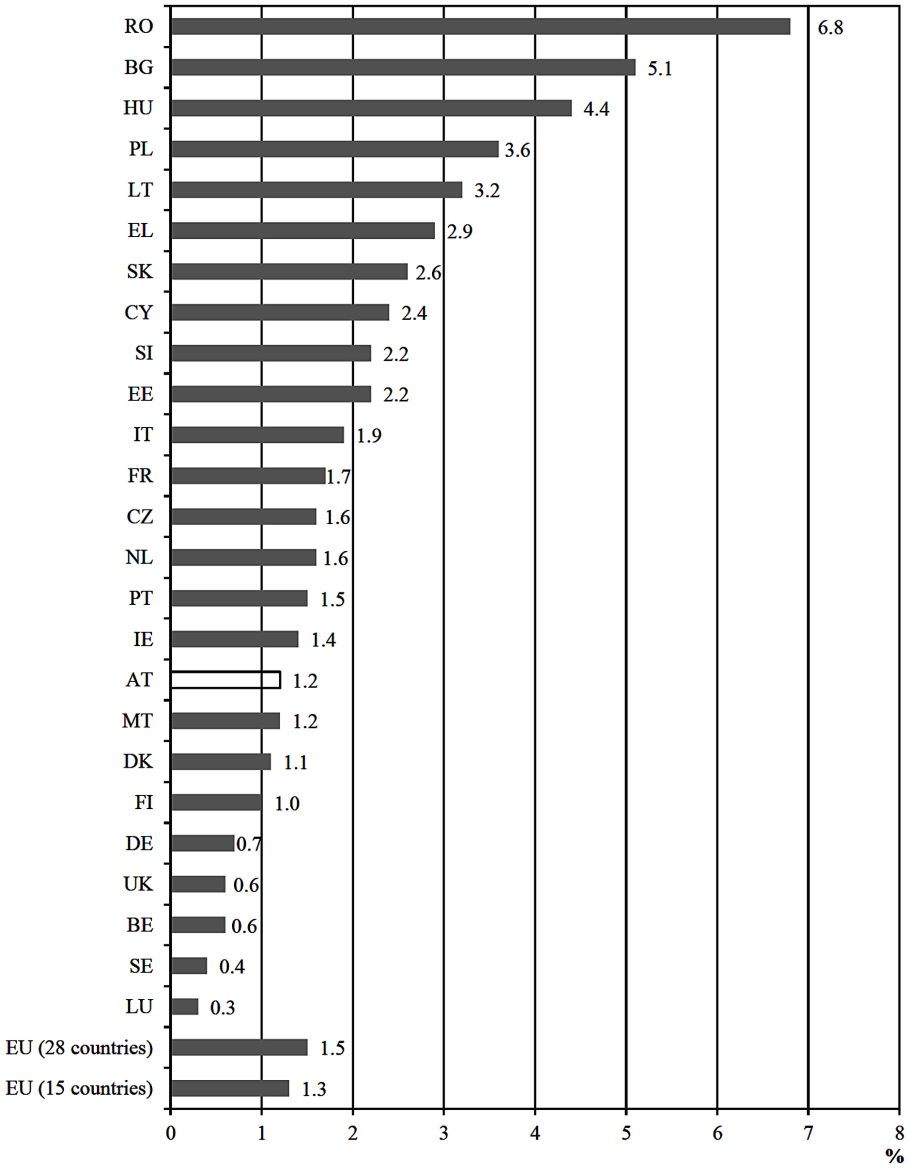
Figure 3. Share of agriculture, forestry and fishing in the Total Gross Value Added by Member States of the EU, 2011
Source: Eurostat, 2015a



No data available for Croatia, Spain and Latvia.

and low yields weakened the result. In 2012, despite generally favourable price developments in agricultural markets, the output value of the agricultural industry increased only slightly, and it dropped according to preliminary calculations by 2.3% to some €7.1 billion in 2014. Only €0.09 billion of this amount were subsidies on products while taxes on products amounted to approximately €0.05 billion in 2013 (Statistics Austria, 2015). Austrian agriculture contributed about 1.7% to the total output value of the agricultural industry of EU-28 in 2013; its share of EU-15 was 2.1% (1995: 2.3%) (Eurostat, 2015b).

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The output of the agricultural industry includes agricultural goods (crops and livestock), agricultural services and inseparable non-agricultural secondary activities. On average over the years 1995 to 2013 the share of animal output was 47% (with a minimum of 44% in 1999 and the maximum of 51% in the years 2005 and 2006) and that of crop output 43% (minimum: 39% in 2005; maximum: 46% in 1999 and 2011). Inseparable non-agricultural secondary activities accounted for 5% to 7%. The importance of agricultural services increased slightly although their share was still comparatively low at some 4.5% in 2014 (Statistics Austria, 2015).

In the period 1995 to 2014 there was no systematic shift in the relative contribution of crop and animal output to the total output value of the agricultural industry. Their shares fluctuated from year to year at times rather strongly. However, the importance of individual branches within the crop and animal production changed. Within crop production, the share of special crops (wine, fruit and horticulture) increased from 30% in 1995 to 46% in 2005 while the share of arable crops declined during the same period from 51% to 32%. These shifts were due, inter alia, to the scaling down of degressive compensatory payments granted upon EU accession and decoupling of most acreage premiums in 2005. From 2006 to 2012, the shares of arable crops in crop output fluctuated rather strongly, from slightly less than 30% in 2009 to between 40% and 42% in the years 2007 and 2010 to 2012. A major contributor to these fluctuations was the cereals sector whose output value dropped in 2005 as a result of the replacement of acreage premiums by the single farm premium but increased significantly afterwards, although subject to very large annual fluctuations. Within the cereals sector, the share of maize increased markedly at the expense of barley, oats, and rye. Protein crops lost out and within oilseeds, soy cultivation increased significantly in recent years. In animal production, which is dominated by milk, cattle, and pigs, the share of poultry and eggs increased at the expense of other animals and animal products (Statistics Austria, 2015).

Development of Volumes and Prices

Figure 4 shows the developments of volume and price indices of the agricultural industry's output in the years 1995 to 2014 in comparison to the corresponding indices of intermediate consumption. It reveals a significant increase in the prices from 2006 to 2012 of output as well as intermediate consumption; obviously, the cost of inputs increased more heavily. 2013 and 2014 prices declined, with a stronger decline of output prices. The output volume of the agricultural industry exhibits stronger dynamics after 2006.

The volume of crop output is, due to weather conditions, subject to rather large annual fluctuations while the volume of animal output developed rather evenly. In both crop and animal production, the output volume increased relative to the level in 1995. In crop production, output volumes of arable and special crops increased, whereas fodder production declined. With respect to prices, there was a relatively steady upward trend for special crops while the prices of arable crops were significantly more volatile (Figure 5).

In animal production, the increase in output volume was, inter alia, due to an increase in milk production. Prices followed an upward trend in recent years, which, however, was less pronounced than that of crops (Figure 6).

Agricultural Payments

This section presents the development of agricultural payments overall as well as in the context of the EAA, followed by an analysis of subsidies on products and other subsidies on production and their shares

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Figure 4. Volume and price indices[1)] for output and intermediate consumption of Austrian agriculture, 1995-2014, 1995 = 100
Note: 1) based on previous year's prices
Source: Statistics Austria, 2015

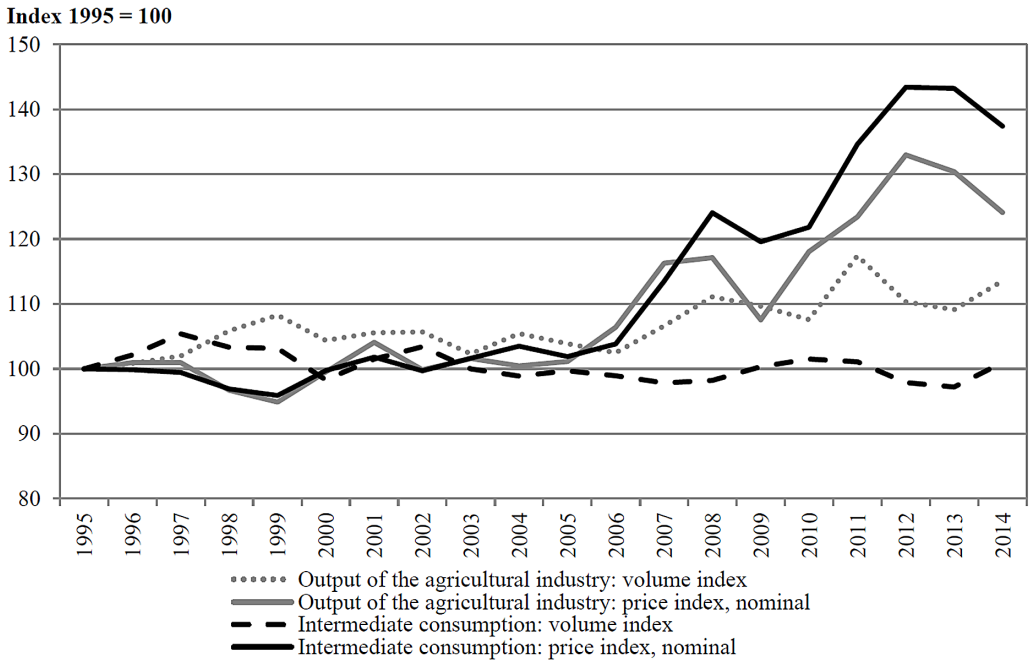

Figure 5. Crop output in Austria, volume and price indices[1)], 1995-2014, 1995 = 100
Note: 1) based on the previous year's prices. Fodder: prices based on production cost.
Source: Statistics Austria, 2015

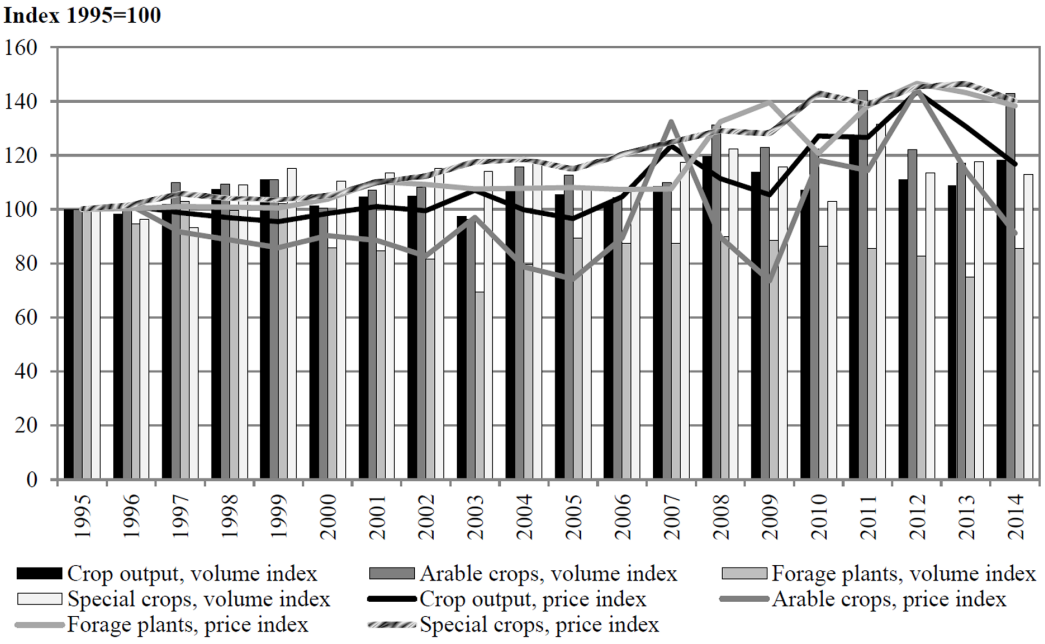

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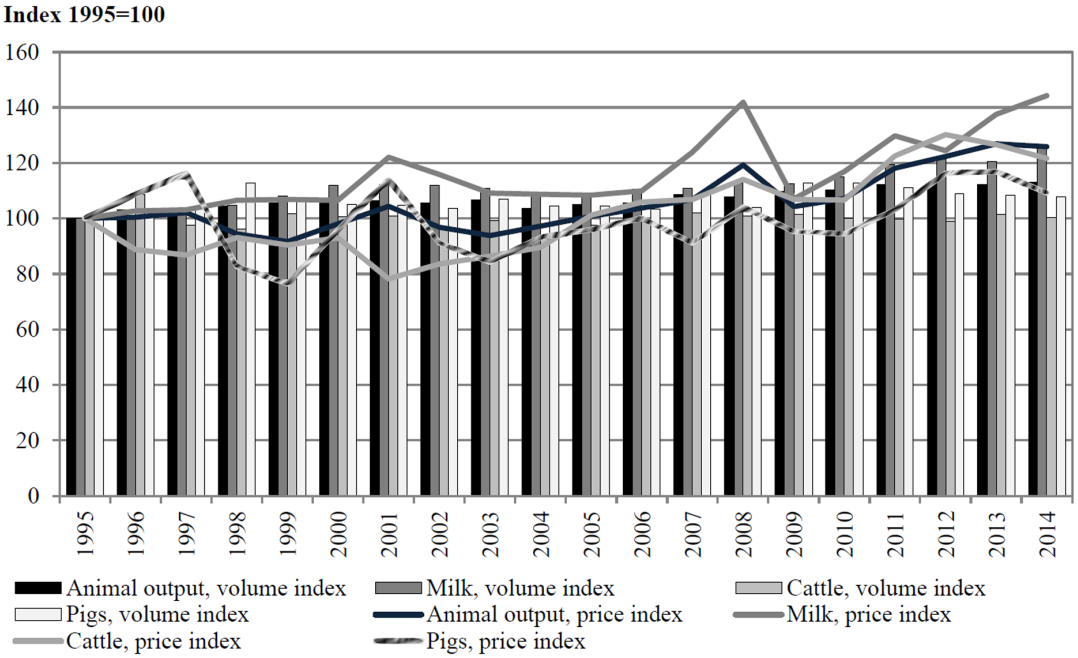
Figure 6. Animal output in Austria, volume and price indices[1)], 1995-2014, 1995 = 100
Note: 1) based on the previous year's prices.
Source: Statistics Austria, 2015



in factor income. A comparison with select EU countries and groups of countries is made in order to allow for an assessment of these developments.

The European Commission (Regulation Establishing Rules, 2013; Regulation on Support, 2013) uses the term "payments" for monetary transfers from the public sector to the agriculture and forestry sector. Most of these payments are relevant for the EAA, in particular payments under pillar 1 (e.g. direct payments to farmers linked to market organizations) and pillar 2 (e.g. payments in the form of compensation for environmental activities, payments for the modernization of agricultural holdings).

In paragraph 2 the Austrian Agriculture Law of 1992 provides for direct payments, interest subsidies and other grants and subsidies to agriculture: production-neutral direct income support and performance-related direct payments, improvement of quality, support for environmentally sound activities and production-limiting measures in the crop and livestock sectors, measures to improve the competitiveness in agricultural production and marketing, measures to sustain farming and infrastructure, research and development and their adoption in agriculture, forestry and water management, and measures to promote investment into agriculture and forestry (Bundeskanzleramt, 2015).

Overall

In the period of 1959-1994, payments for agriculture and forestry in Austria were granted through the so-called "Green Plan" established by the Agriculture Law and by payments in connection with market

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organizations (Ortner, 1997b). EU accession and thus the adoption of the CAP called for significant changes in the grant regime, and additional measures of the CAP had to be implemented (Bundesministerium für Land- & Forstwirtschaft, 1996, p. 145; Hambrusch et al., 2015).

Since its creation, the CAP has always been adapted to respond to challenges of the time. Major reforms have been implemented in the wake of the following milestones (European Commission, 2015b):

- The Agenda 2000 reform improving competitiveness in world markets by lowering producer prices and introducing policies to enhance rural areas, the environment and food safety, in particular "cross-compliance" (payments are conditional on environmental, animal welfare and health standards) and the modulation of premium payments (thresholds);
- The 2003 reform or "mid-term review" decoupling of direct payments from production and introducing the single farm payment in connection with cross compliance requirements;
- The 2008 CAP "Health Check" expanding rural development policy, discarding the acreage set-aside obligation and limiting the EU's agricultural expenditure;
- The CAP reform 2014-2020 maintaining the two pillars but increasing the links between them, thus offering a more holistic and integrated approach to policy support. Specifically it introduced a new architecture of direct payments to be better targeted, more equitable and "greener", an enhanced safety net against income loss, and strengthened rural development.

The described policy evolution over roughly a decade and a half can be characterised as a slow transformation process from a set of universal, obligatory, 100% EU-financed, agricultural commodity support measures towards a more market-oriented, decoupled, decentralised and co-financed rural development approach. This seems to recognise that compensatory payments should be transitional and ultimately phased out, leaving the regionalised and co-financed rural development measures as the core of the policy. If this comes about to the extent established by the goals of a common EU policy, common financing will be justified (Buckwell, 2015, p. 515).

Figure 7 shows changes in the development of the payments for Austrian agriculture and forestry in the years between 1990 and 1994 and the following financial periods as an EU member state. Since accession, payments for agriculture and forestry in Austria have been funded by the EU, the Federal State and the Federal Provinces. They were allocated for the EU financial periods 1995-1999, 2000-2006 and 2007-2013 to facilitate planning and evaluation. Since the year 2000, these funds have been split into budgets for direct payments and market-related measures (1st pillar of the CAP), rural development (2nd pillar of the CAP) and other expenditures (Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, 2015, p. 102). The figure clearly shows the effects of accession and the reforms of the CAP during that time.

The EAA only includes payments paid to farmers directly. Payments that are related to agriculture but granted to other industries – such as exports subsidies – are not considered (Kniepert et al., 2009, p. 83). Furthermore payments are divided into three categories: "subsidies on products", "other subsidies on production" and "capital transfers". Income is defined as including payments classified as "subsidies" but not capital transfers which remain unconsidered in the calculation of agricultural income (Regulation on the Economic Accounts, 2003, Annex I, para. 3.051, 3.088).

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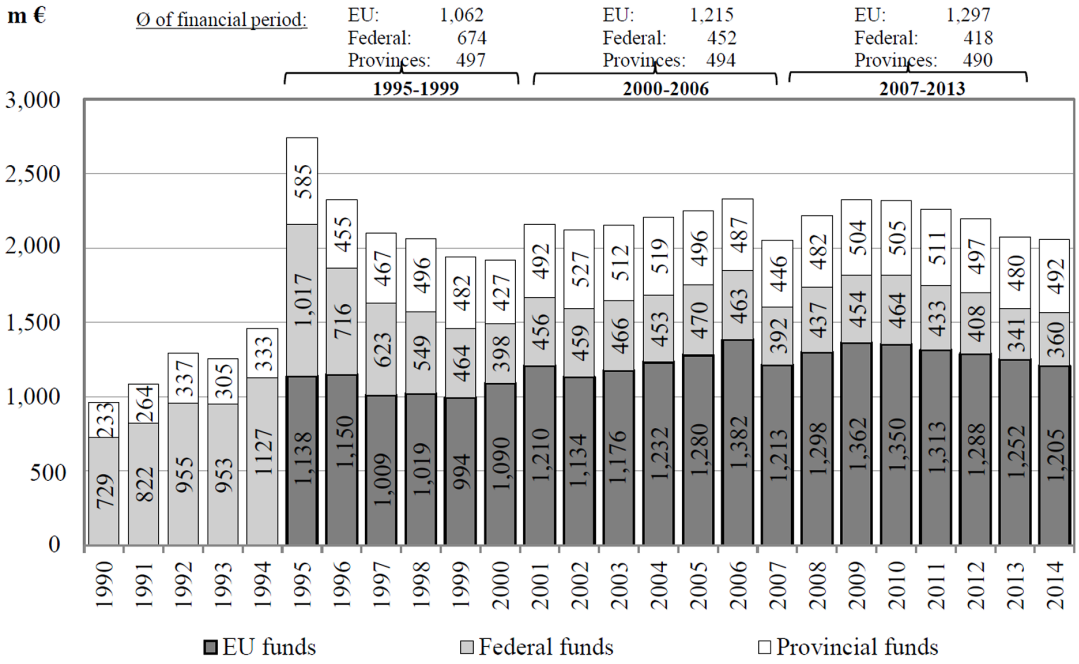
Figure 7. Development of the payments for Austrian Agriculture and Forestry (EU, federal and provinces funds) in € million, 1990-2014
Source: Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, 2015; Bundesministerium für Finanzen, 2013



Development According to EAA

The change in the orientation of the CAP is demonstrated by the evolution of expenditures, echoing the policy shift since 1990. Figure 8 shows that payments which are to be recorded in the EAA (subsidies and capital transfers paid to farmers) increased during the observation period while the share of payments related to agriculture but excluded from the EAA decreased. The share of capital transfers remained almost constant.

Subsidies on products (direct payments for crop and animal production) increased significantly upon EU accession. In 2005, most of them were transformed to constitute the single farm payment. The jump in 1995 followed by the slump until 1999 is due to the implementation of degressive compensatory payments. Since EU accession, payments for environmental activities have constituted a significant share of total payments. The corresponding amounts stayed at about the same level over the years, as did those for compensatory allowances (support to unfavourable areas). While capital transfers exhibited a slight upward trend, the trend of other items in the category "other subsidies on production" (those except agri-environmental measures, compensatory allowance and single farm payment) declined slightly (Figure 9).

Share of Subsidies in Factor Income: Comparative Analysis for Selected EU Countries and Country Groups

The relative contribution of subsidies to farm income is quite different in the various EU countries. Among the countries surveyed here Austria (AT), after Finland (FI), followed by Sweden (SE) is one

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Figure 8. Share of payments included in the EAA in total agricultural payments in AT, in %, 1990-2014
Source: Statistics Austria, 2015

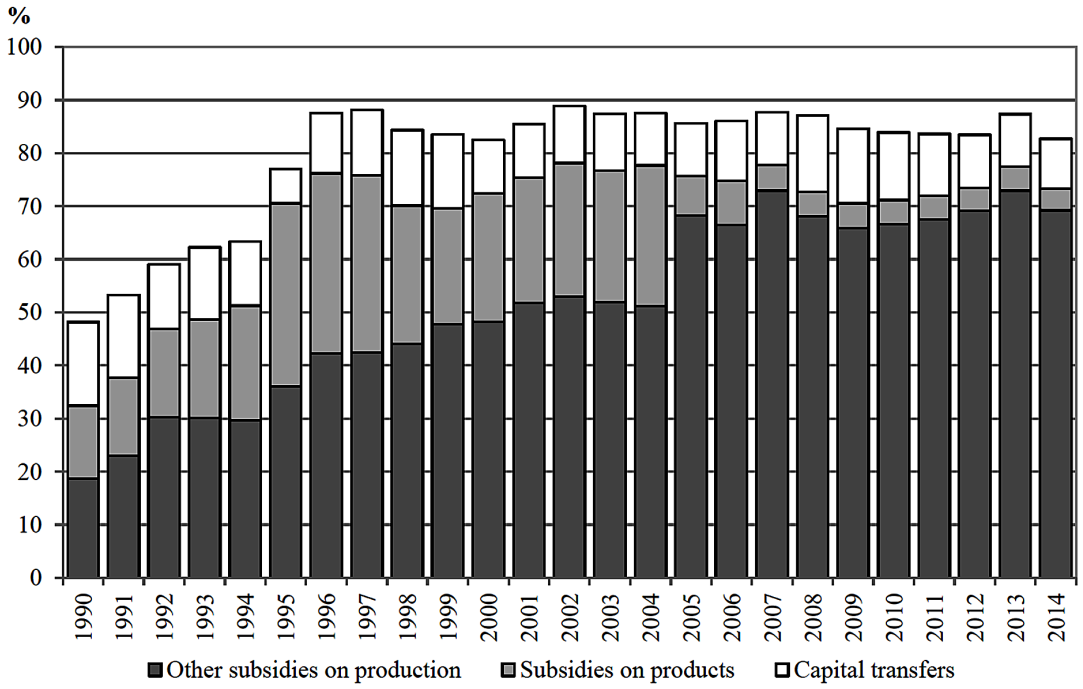
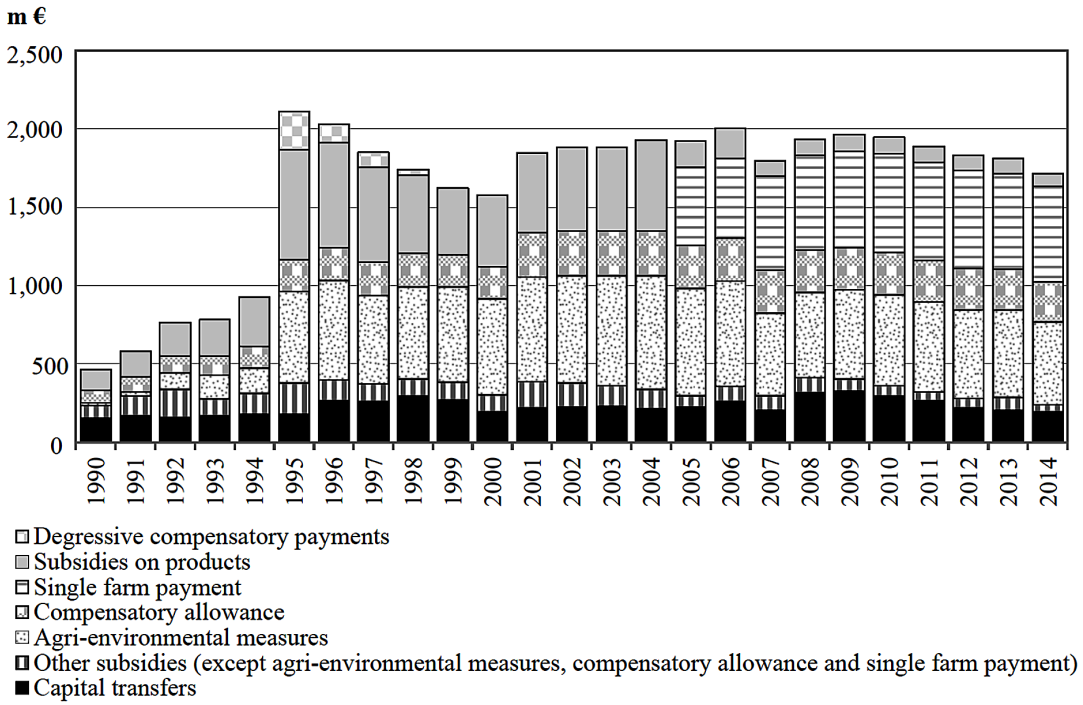


Figure 9. Austrian agricultural payments included in the EAA, in € million, 1990-2014
Source: Statistics Austria, 2015



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of the countries with the highest share of subsidies in factor income. Italy (IT) has the lowest share, and France (FR), the United Kingdom (UK), Germany (GE), and Switzerland (CH) occupy the middle ground between Italy and Austria. While the shares in Switzerland and the United Kingdom have changed rather evenly over the years, other countries showed stronger fluctuations (Figure 10 and Figure 11).

The share of product-related subsidies and other subsidies in factor income in the EU East has been aligning itself to that of the EU West over the years. The countries of the EU South clearly exhibit the smallest share. There is an obvious gap between northern and southern EU countries. The shares in the EU North fluctuate more widely. Austria's share is within the range of the EU North (Figure 12 and Figure 13).

A comparison with the EU average shows that the share in the EU South is smaller and the EU East is about average. In the EU West, the EU North and Austria the contribution of subsidies to factor income is significantly higher (Figure 13).

Since these shares are not available differentiated by structural features, it is difficult to analyse the impact of these features. The European data, which are available, support only a macro view, which means that the existence of different average farm sizes in individual countries distorts the comparison between them. In countries with a significant number of small and micro enterprises, subsistence farms and farms with negative profit, the inclusion of these businesses in a survey produces lower average incomes which are difficult to compare. Moreover, these statistics do not convey information about whether agricultural payments are targeted and efficient in achieving their targets at minimum cost.

A Note on the Federal Budget and Net Contribution

Table 1 shows the development of the federal budget and the agricultural budget and its composition during the period from 1995 to 2014. From there it is obvious that the agricultural payments share does

Figure 10. Share of subsidies in factor income, in % – AT, GE, FR, UK, IT, FI, SE, and CH, 1995-2014
Source: Eurostat, 2015b

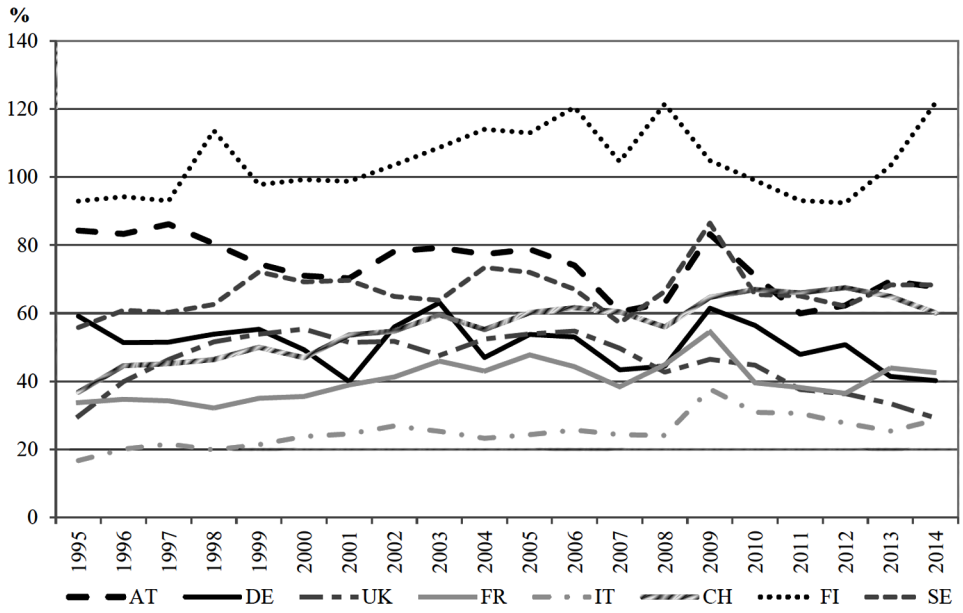

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Figure 11. Share of subsidies in factor income, in % – AT, GE, FR, UK, IT, FI, SE, and CH as well as in the euro area and the EU-27 and EU-28, average for the period 1995-1999, 2000-2006, and 2007-2014
Source: Eurostat, 2015b

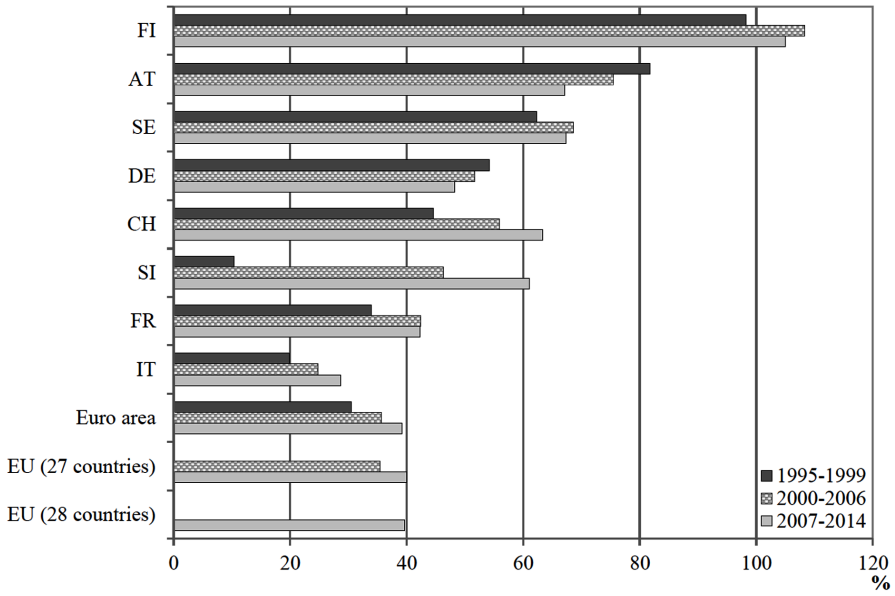

Figure 12. Share of subsidies in factor income, in % – AT and the EU sub-regions (EU North, EU South, EU West, and EU East), 1995-2014
Note: EU North: Denmark, Finland, Sweden, Estonia, Lithuania, and Latvia; EU South: Italy, Portugal, Spain, Greece, and Cyprus; EU West: Belgium, Germany, France, Luxembourg, the Netherlands, the United Kingdom, Ireland, and Austria; EU East: Bulgaria, Czech Republic, Croatia, Hungary, Poland, Romania, Slovenia, and Slovakia (after Eurovoc).
Source: Eurostat, 2015b

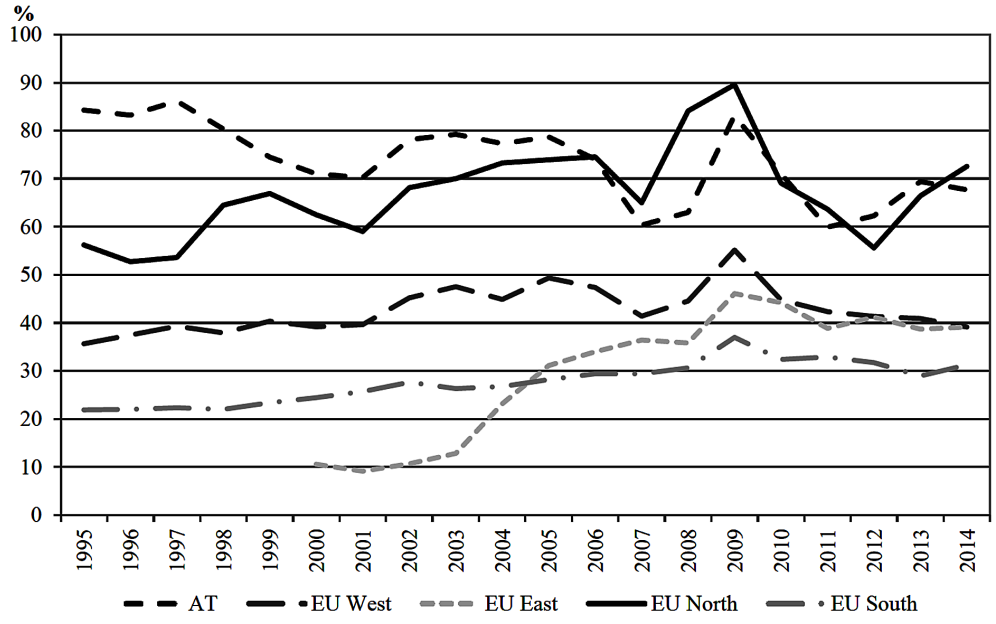

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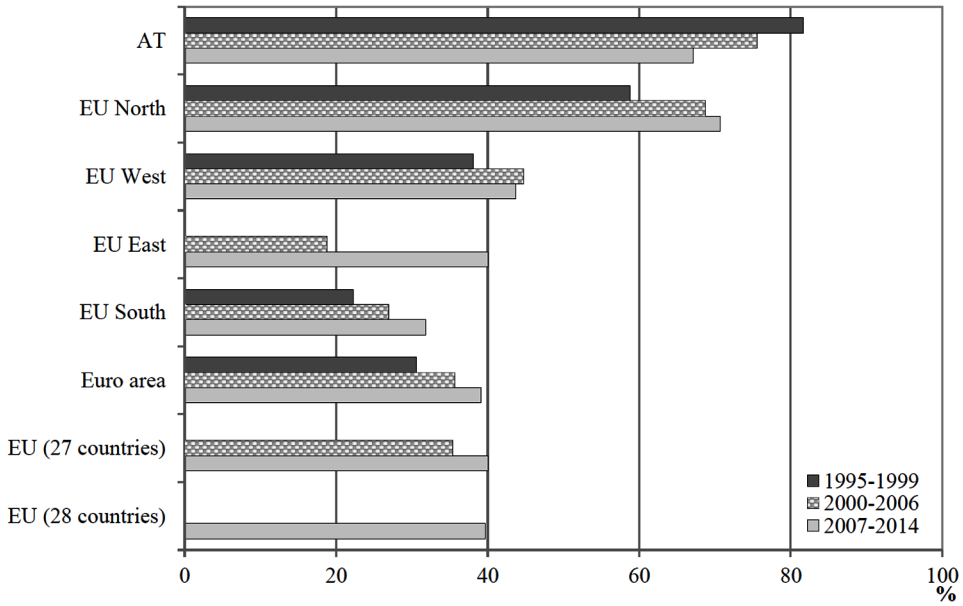
Figure 13. Share of subsidies in factor income, in % – AT, the EU sub-regions (EU North, EU South, EU West, and EU East), the euro area, the EU-27 and EU-28, average for the periods 1995-1999, 2000-2006, and 2007-2014
Source: Eurostat, 2015b



not exceed single digits. The highest share was 4.3% of the federal budget in 1995; before it was around 2%, and it hovered around 3% after 2005.

Table 1 also shows that a significant share of agricultural payments is financed by the EU. Nowadays the EU general budget originates mainly from so-called own resources (Art. 311 TFEU, formerly Art. 269 TEC). These funds are collected by Member States and forwarded to the EU budget. A comparison of the contributions of a Member State with its remittances from the EU budget delivers the net financial position (Figure 14 and Figure 15). This parameter gives information about the immediate financial consequences arising from the inclusion of the Member State in the EU budget. However, the net financial position is not sufficient to capture the total economic impact of EU membership. Such general assessments must be based on a far more comprehensive economic theory and statistical studies.

The balance of a country shows whether it is a net contributor (negative sign) or a recipient (positive sign). Although the balance solely compares contributions to and receipts from the EU budget, it is an instrument of budgetary discipline and plays a significant role in negotiations and decisions on the allocation of the EU funds ("net contributor discussion"). The sum of all negative balances (2000: €15.2 billion; 2005: €17.5 billion; 2010: €31.0 billion; 2014: €43.5 billion) measures the extent of redistribution between Member States which is generated by the EU budget (Bundesministerium für Finanzen, 2013, 2015; European Commission, 2015a).

The financial contribution of the Member States to the EU budget evolved very dynamically. As Figure 14 and Figure 15 show, net recipients and contributors change over time. Some Member States, like Germany, Austria, Belgium, and Luxembourg, are net contributors (Figure 14). The main net recipients are less developed regions (Figure 15).

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Table 1. The federal budget and the agricultural budget of AT, in € billion, million, and in %, 1990-2014

Year	Overall federal budget	Expenses for agriculture and forestry (agricultural budget)	Share of agriculture and forestry in % of the total budget	of which				Share of subsidies for agriculture and forestry in % of the federal budget	Share of subsidies in % of agricultural budget
				Subsidies for agriculture and forestry (1)	of which share of EU-funds	Personnel and material expenses (2)	Protective hydraulic engineering and avalanche control		
	€ billion	€ million							
1990	45.4	1,035	2.3	729				1.6	70.4
1991	49.3	1,148	2.3	823				1.7	71.7
1992	53.7	1,286	2.4	955		213	118	1.8	74.3
1993	62.2	1,294	2.1	953		220	121	1.5	73.6
1994	62.0	1,487	2.4	1,021		228	128	1.6	68.0
1995	55.6	2,408	4.3	2,022	960	264	122	3.6	84.0
1996	54.9	2,119	3.9	1,743	1,010	264	112	3.2	82.3
1997	60.5	1,933	3.2	1,536	911	272	125	2.5	79.5
1998	56.5	1,828	3.2	1,461	927	242	126	2.6	79.9
1999	57.2	1,749	3.1	1,332	876	279	138	2.3	76.2
2000	58.2	1,953	3.4	1,513	1,041	302	138	2.6	77.5
2001	60.4	1,924	3.2	1,467	1,052	327	130	2.4	76.3
2002	61.8	1,994	3.2	1,502	1,062	337	155	2.4	75.3
2003	61,4	2,024	3.3	1,557	1,098	322	145	2.5	76.9
2004	65.0	2,075	3.2	1,623	1,187	327	124	2.5	78.2
2005	66.0	2,294	3.5	1,818	1,388	331	145	2.8	79.2
2006	70.5	2,319	3.3	1,792	1,360	338	188	2.5	77.3
2007	72.3	2,037	2.8	1,521	1,193	347	170	2.1	74.7
2008	80.3	2,181	2.7	1,641	1,249	364	176	2.0	75.2
2009	69.5	2,252	3.2	1,814	1,353	253	185	2.6	80.6
2010	67.3	2,176	3.2	1,755	1,297	244	176	2.6	80.7
2011	67.8	2,034	3.0	1,610	1,236	247	177	2.4	79.2
2012	72.9	2,109	2.9	1,673	1,263	253	184	2.3	79.3
2013	75.6	2,494	3.3	1,979	1,269	306	209	2.6	79.4
2014	75.8	2,226	2.9	2,074	1,287	308	141	2.7	93.2

Note: 1) expenditure on agriculture, forestry and water management, federal budget, 2) personnel and operating expenses of the central government and subordinate agencies, administrative expenses of the AMA.

Source: Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, 2015, p. 228

Austria's net contribution to the EU amounted to €435.5 million in 2000; it grew until 2014 to €1,240.6 million (European Commission, 2015a). In the year 2000 Austria received about €0.9 billion and in 2014 approximately €1.3 billion of the EU funds. They were spent primarily for the benefit of Austrian agriculture which received approximately 70% of the total EU budget remittances (Bundesministerium für Finanzen, 2013, p. 36; European Commission, 2015a).

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Figure 14. Financial net positions – net contributors to the EU budget (operational budget balances in % of Gross National Income, GNI), 2000-2014
Source: Bundesministerium für Finanzen, 2013, 2015; European Commission, 2015a

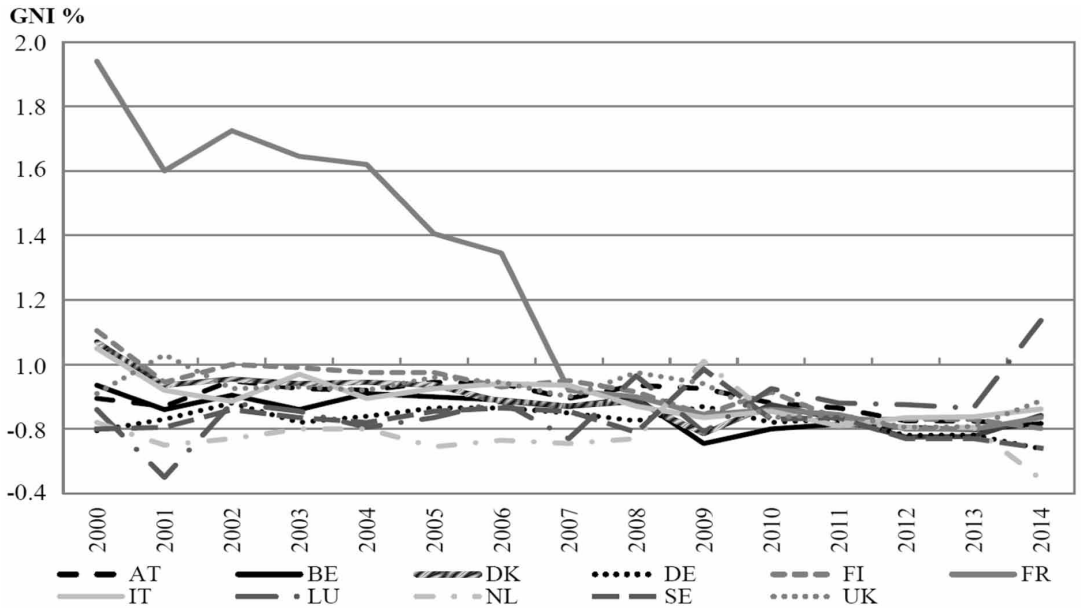
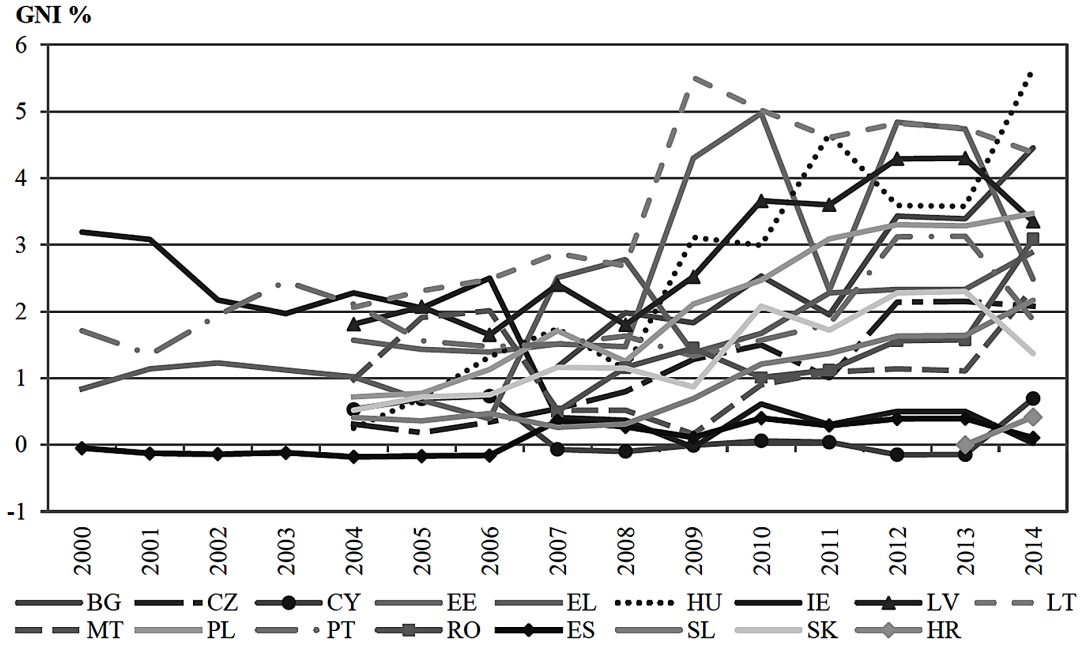


Figure 15. Financial net positions – net recipients of the EU budget (operational budget balances in % of GNI), 2000-2014
Source: Bundesministerium für Finanzen, 2013, 2015; European Commission, 2015a



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Income From Agricultural Activity

One of the main objectives of the CAP is to ensure a fair standard of living for the agricultural population, in particular by increasing the individual earnings of persons engaged in agriculture (see. Art. 39 of the Treaty on the Functioning of the European Union, TFEU). For an assessment of whether this objective is being achieved data on the composition and evolution of agricultural income is provided, inter alia, by the EAA. Income aggregates and indicators provided by EAA solely relate to income generated by agricultural activities and exclude income from other sources such as income from other gainful activities, wages and salaries or social benefits.

The EAA provides several income figures for the agricultural industry, among them Net Value Added at factor cost ("factor income") which measures the remuneration of the factors of production: land, labour and capital.

In 1995, the total of the output value of the agricultural industry at producer prices plus agricultural payments in the form of subsidies on products and other subsidies on production amounted to €6.8 billion. About a third of this, €2.3 billion, remained as factor income. In subsequent years, this share varied between 27% and 35%; in 2014, the share was 25% of the output value (approximately €8.4 billion). The development of the total of the agricultural output value and subsidies, what it was used for and how much remained as factor income, are presented in Figure 16 and Figure 17.

Net entrepreneurial income is agricultural factor income minus compensation of employees, rents and interest paid, plus interest received. It measures the remuneration of non-paid labour (i.e., labour by family members spent in their agricultural units), owned land and capital.

Figure 16. Value of Austrian agricultural output at producer prices, subsidies on products and other subsidies on production, in € billion at current prices, 1995-2014
Source: Statistics Austria, 2015

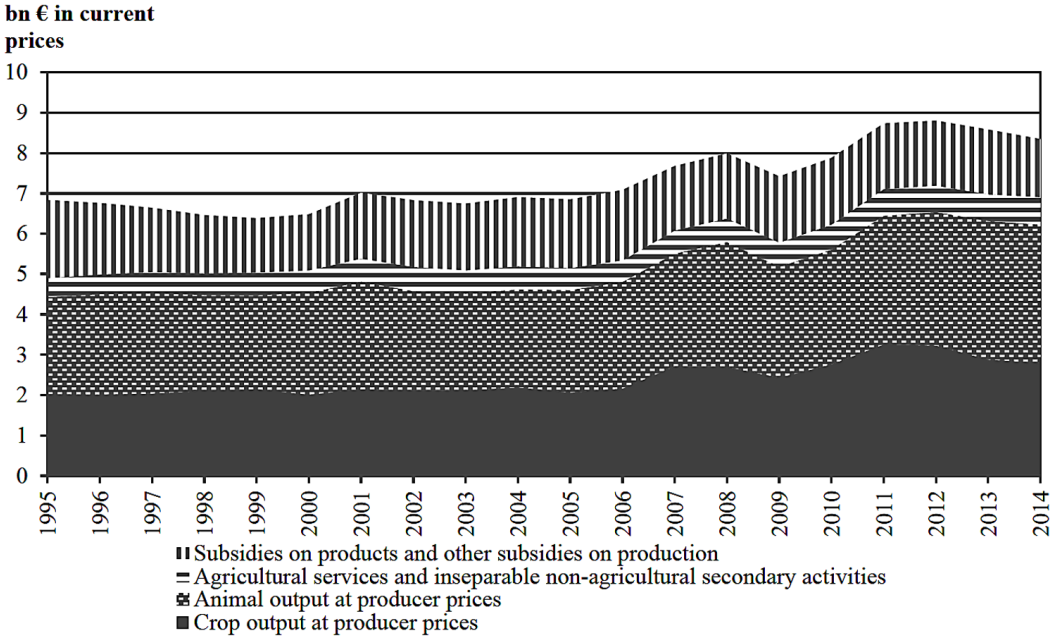

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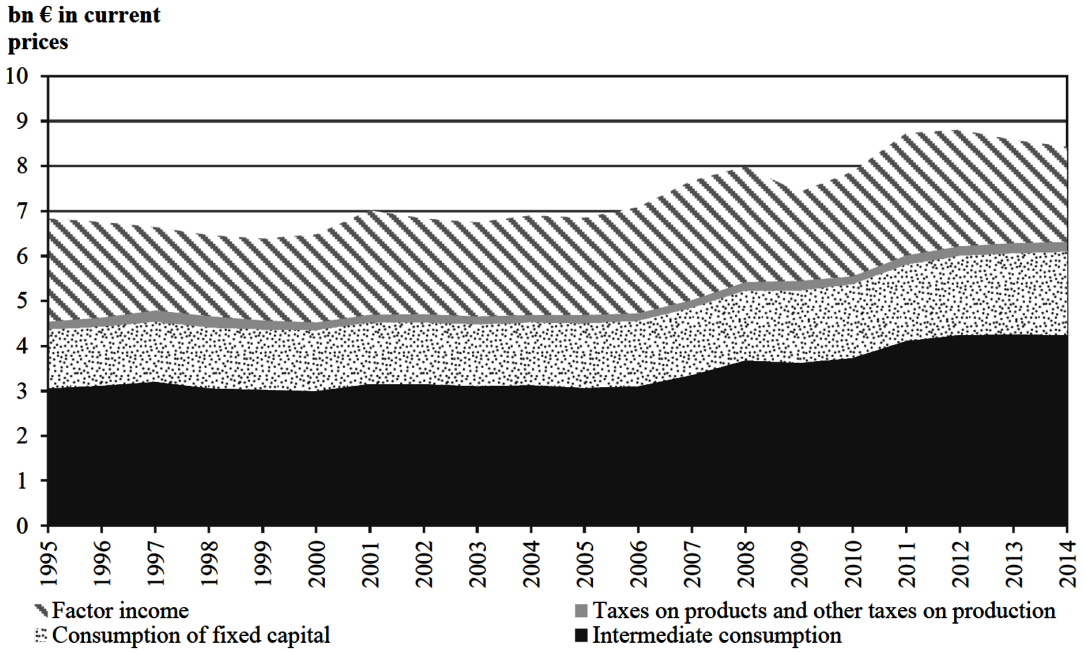
Figure 17. Production costs and factor income of Austrian agriculture, in € billion at current prices, 1995-2014
Source: Statistics Austria, 2015



In 1995, net entrepreneurial income of the agricultural industry amounted to approximately €2 billion, which corresponded to 90% of factor income (Figure 18). Its share in factor income followed a declining trend in the observation period except for annual fluctuations. In 2014, it accounted only for 73% of factor income.

Farm incomes are very volatile over time. The development of factor income is determined by changes in output levels and prices; subsidies and taxes on products; intermediate consumption levels and prices; consumption of fixed capital; other subsidies and taxes on production (Chatellier, Guyomard, Latruffe, & Levert, 2007, p. 3). The development of net entrepreneurial income also depends on changes in compensation of employees, rents paid and interests paid and received.

In Austria, the scheduled reduction of degressive compensatory payments was one of the main causes for the drop in income in the years immediately after EU accession. However, in 2001 factor income returned to the level of 1995 in nominal terms. Significant increases in income were observed in 2006 and 2007 as well as 2010 and 2011. The decline in 2009 was due to a sharp drop in agricultural prices in the wake of the economic and financial crisis. In the years 2012 to 2014, farm incomes decreased again. In real terms, i.e., deflated by the implicit price index of Gross Domestic Product at market prices (GDP), both factor income and net entrepreneurial income declined during the observation period.

Despite the declining amounts of real income generated by agricultural activity in total, income per work unit has exhibited an upward trend since 2001 – although with significant annual fluctuations (Figure 19). This development was due to structural changes in agriculture and the associated decrease in agricultural labour input. According to the EAA, agricultural labour input decreased from 188,400 annual work units (AWU) in 1995 by almost a third to 127,600 AWU in 2010. A decrease of non-salaried

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Figure 18. Income generated by agricultural activity in Austria, in € billion, 1995-2014
Source: Statistics Austria, 2015

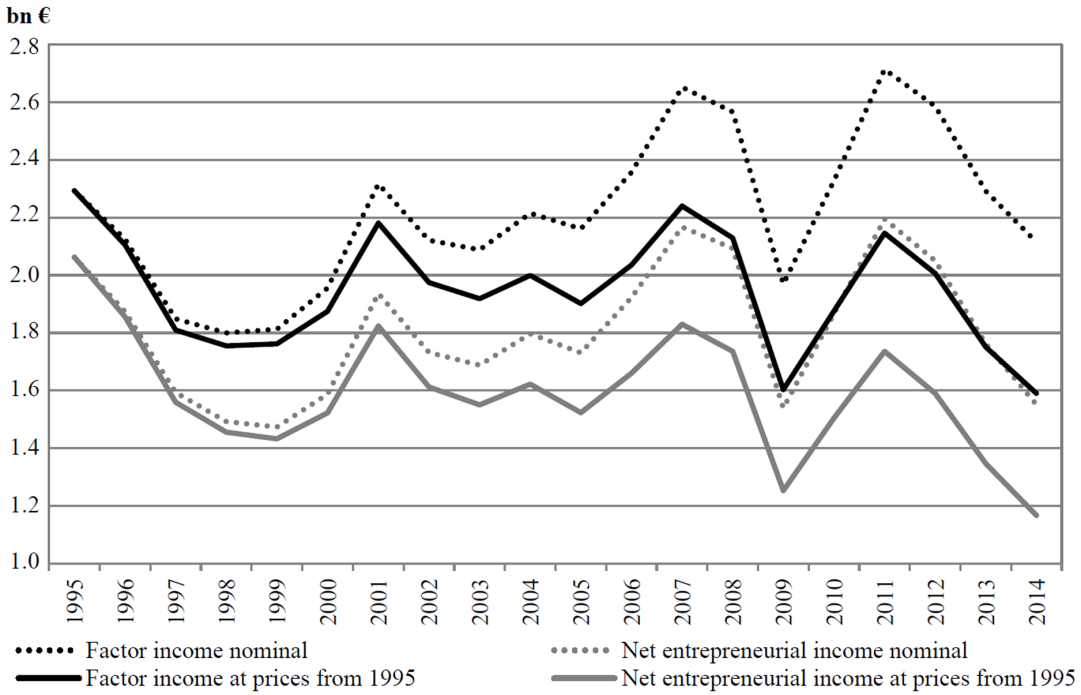

Figure 19. Index of nominal and real agricultural income per AWU in Austria, 1995 = 100, 1995-2014
Source: Statistics Austria, 2015

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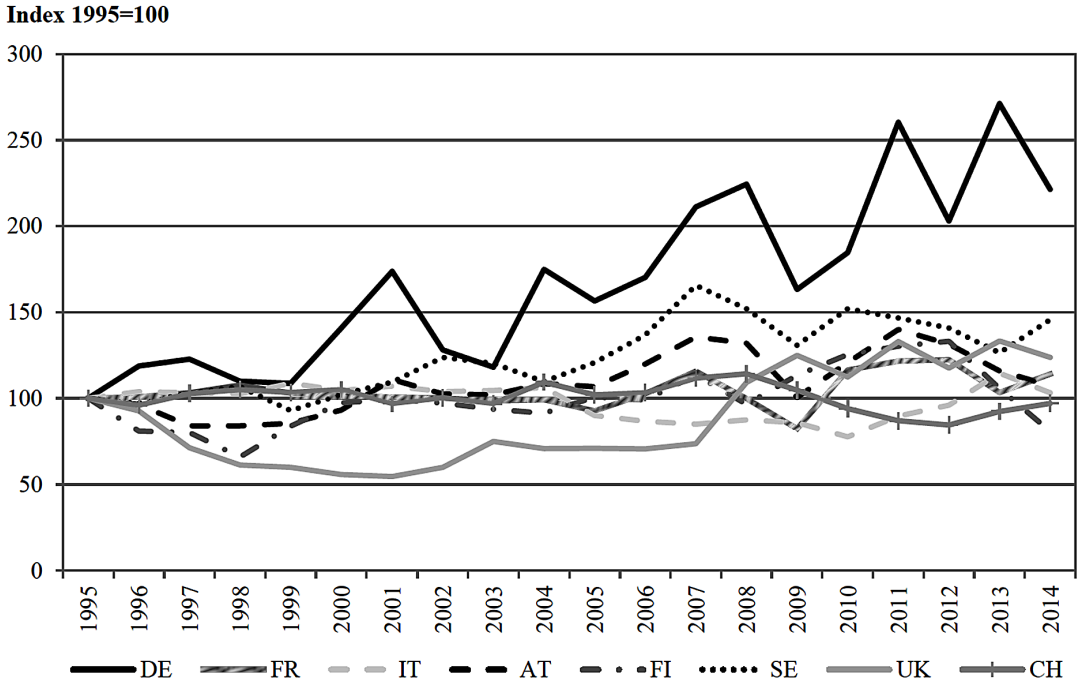
labour was partially offset by an increase of salaried employees whose share in agricultural labour input increased from 6% in 1995 to 11% in 2010.

At the European level, the index of real factor income per annual work unit (which is also referred to as indicator A) is primarily used to monitor agricultural income development and for income comparisons between Member States. As Figure 20 shows, indicator A developed quite differently in Austria, Germany, France, the United Kingdom, Italy, Switzerland, Finland, and Sweden. Germany and Sweden exhibit a trend similar to that of Austria from 2000, with factor income per AWU growing more variedly and steeper in Germany than in Sweden and Austria. In Switzerland, the development was quite stable, with a little slope and slight fluctuations. France, however, had a similar development to that of Austria from 2005, but from 1995 to 2000 factor income per AWU declined slightly, followed by a stable increase. Finland showed an extreme decrease until 1998, followed by a stable increase. In Italy, factor income per work unit remained at the level of 1995 until 2004, decreased until 2010 and recovered until 2013.

Main Developments in a Nutshell

Accession to the EU made Austria part of a single market, thereby intensifying competition through the elimination of trade barriers to other Member States. The preceding analysis showed that Austrian agriculture, which was considered a critical industry regarding EU accession (Schneider, 1997), has managed to weather the last twenty years since joining the EU without incurring massive losses of production and income (Gahleitner et al., 2015; Hambrusch et al., 2015). For Austrian agriculture the consequences of integration have more or less manifested themselves as follows:

Figure 20. Index of real agricultural factor income per AWU, 1995 = 100 – AT, GE, FR, UK, IT, FI, SE, and CH, 1995-2014
Source: Eurostat, 2015b



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- The relative economic weight of the primary sector is below the EU-28 average. The economic importance of agriculture, measured as Value Added share in the overall economy, has been declining. The overall economy benefitted from accession as other sectors grew, due to integration effects (research and development, foreign direct investment) which are difficult to determine exactly (Breuss, 2003, p. 551).
- Even though output volume expanded over the observation period and output prices showed a significantly upward trend from 2006 onwards, real factor income as well as real Entrepreneurial Income generated by agricultural activity fell below the levels of 1995. Real income per AWU has however risen due to structural changes in agriculture leading to a significant decrease in the agricultural labour force.
- Agriculture in Austria and other EU countries depends heavily on direct payments. There has been a gradual reduction in subsidies, as a result of continuing pressure from the World Trade Organization (WTO), although subsidies in emerging economies have been increasing in recent years. Furthermore, the 2007-2008 world food price crisis has renewed calls for farm subsidies to be removed in light of evidence that farm subsidies may influence the level of food prices, which has a particularly detrimental impact on farmers in developing countries (EurActor Network, 2008).
- Changes in agricultural subsidies are necessary and occur continuously. The reduction of production-related subsidies andtransfers and the targeting of subsidies are seen as important for the liberalisation of markets and the sustainable development of developing and emerging countries. Current economic developments such as the financial crisis, intensive lobbies in various Member States, elections and political power struggles but also the need to deliver public goods suggest that the transformation of funding and the diminution of EU agricultural subsidies are likely to continue from financial period to financial period (Kraut, 2009, p. 61).

Other critical developments are less predictable. There are significant "wild cards": global warming, biotechnology and the changing role of Africa, China, Russia and the Middle East.

SOLUTIONS AND RECOMMENDATIONS

The fact that Austrian agriculture has managed to weather the last twenty years since joining the EU without incurring massive losses of production and income (Gahleitner et al., 2015; Hambrusch et al., 2015) was mainly due to substantive public measures and structural adjustment. In order to cope with current and futures challenges like global warming, volatile prices and tightening of public budgets, Austrian agriculture can adopt the following strategies:

- New customer segments: The growth in emerging markets of both population and the economy increases the level and quality of demand for agricultural and food products. According to forecasts of the Food and Agriculture Organization (2011) overall food demand will increase by 1.1% a year between 2006 and 2050, or by 70% over the whole period (KPMG International, 2013, p. 13).
- Diversification of output: Whereas the primary goal of agriculture is to produce food, feed and fibre, the sector is also being asked to provide a range of non-commodity outputs which are associated with agriculture such as access, recreation, conservation, amenity, heritage, tourism and

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ecosystem services. Farmers and policymakers face the challenge to meet these demands by exploiting opportunities and offering targeted support to specific priorities as exemplified by the 2nd Pillar of the CAP.

- Customer awareness: The population is aware that Austrian agriculture provides important ecological and social services (open landscape, road access, accommodation, skills, education, etc.), especially in the less-favoured areas. In order to match demand for and supply of these services, their level depends on the willingness to pay (WTP) for positive and the avoidance of negative externalities. Agriculture will benefit from 'green subsidies' and adapt to them depending on how they are implemented in different agricultural policy measures, i.e., the rural development programme.

FUTURE RESEARCH DIRECTIONS

Areas of potential interest for future research include the following:

- The ongoing shifts in policy objectives and the volatile income in agriculture increase the necessity for policy-makers and scientists to take into account all sources of income of agricultural households, not just those derived from agricultural activity. Generally, in the EU, data on agricultural household incomes is scarce and calculation methods are not harmonised. Nevertheless, the European Commission (2010, p. 3) concludes "that farm households in many Member States derive a significant share of income from off-farm sources, i.e., mainly other gainful activities, but also social transfers and property income. Importantly, the share of off-farm income has increased in many of the countries for which data is available" (Statistic Canada, 2009; Schnepf, 2015, p. 24).
- In a free market, people ignore the positive externalities of consumption, e.g. when cycling to work, you take the cultivated landscape for granted. This raises the question about the value of these externalities, which are subject to agricultural policy and EU subsidies and can be estimated by WTP. WTP is the amount of money a person would be willing to pay for a higher level of environmental or commodity quality (Golan & Kuchler, 1999; Spencer, 1996). According to James (2002), tools for measuring WTP (which include the contingent valuation, travel cost and hedonic pricing) can be used to answer questions such as how much consumers are willing to pay for a quality upgrade or what impact a particular government intervention might have.
- Agriculture is confronted with the following challenges – as described in the following familiar mix of broad European rural development objectives – of maintaining resilience and improving agricultural productivity to help ensure food security for citizens at a lower resource cost; improving environmental performance of agriculture; contributing to reasonable living standards for primary producers; assisting the development of rural areas, especially remote and marginal areas (Buckwell, 2015, p. 512). In upcoming evaluation activities as well as for further reforms it has to be examined whether these objectives are met.
- Conventional agricultural accounts – such as EAA – allow a macro level follow-up of economic functions but offer no insights into the multifunctional contribution of the agricultural industry to society, nor do they reflect the true costs of agricultural production for society. There is a need to

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analyse the relationship between the economic activities of agriculture and the environment, with agriculture having both positive and negative impacts on the local and surrounding environment. For this purpose, the System of Environmental-Economic Accounting for Agriculture, Forestry and Fisheries (SEEA AFF) is currently being developed within the framework of the SEEA Central Framework. A further step would be to consider social aspects as well as cultural ones.

- And finally, Austrian and European agriculture are becoming more frequently influenced by volatile producer prices, volatile energy markets, localised natural hazards such as flooding, and the effects of regulations on technology use and labour supply. Some agricultural areas continue to lose their competitive edge to other regions with, say, more favourable climate or adequate labour supply. Unfortunately, many agricultural programmes tend to favour stability-enhancing management strategies with little attention to adjustment capacity in agriculture itself. There is a need to examine the adjustment capacity of agriculture and to analyse the role that institutional factors and in particular product market regulations play in this adjustment process.

CONCLUSION

This chapter provides key insights into the evolution of Austrian agriculture within the EU. The authors' results are in line with the literature on Austrian's accession to the EU (Breuss, 2003; Schneider, 1997) and studies at European level (European Commission, 2010). Analyses have demonstrated that Austrian agriculture in general has so far found ways to adapt to the change in the agricultural regime attendant to EU membership and its wide-reaching effects on agricultural markets and production conditions. As the evolution of the CAP gets underway, the future development of Austrian agriculture remains to be seen. It will depend primarily on the development of markets under globalization and climate change as well as technological advancement along with the consumers' demand. Future agricultural reforms are likely to be made in relation to the goals of developing intelligent, sustainable and inclusive growth as outlined in the Europe 2020 strategy, while taking into account the productivity and diversity of agriculture.

NOTE

This chapter is a revised version of a contribution by Christina Mayer and Erika Quendler entitled '*Die österreichische Landwirtschaft seit dem EU-Beitritt aus Sicht der Landwirtschaftlichen Gesamtrechnung'* published in E. Egartner, T. Resl (Hrsg.). Einblicke in Österreichs Landwirtschaft seit dem EU-Beitritt (p. 155-195). Schriftenreihe 108. Wien: Bundesanstalt für Agrarwirtschaft.

REFERENCES

Berkeley, H. (1996). *Farm Incomes, Wealth and Agricultural Policy* (2nd ed.). Aldershot, Hong Kong, Singapore, Sydney: Avebury.

Breuss, F. (2003). Österreich, Finnland und Schweden in der EU – wirtschaftliche Auswirkungen. *Monatsberichte – WIFO, 76*(7), 529–556.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Buckwell, A. (2015). Where Should the CAP Go Post-2020? In J. Swinnen (Ed.), *The Political Economy of the 2014-2020 Common Agricultural Policy. An Imperfect Storm* (pp. 509–529). London: Rowman & Littlefield International Ltd.

Bundesamt für Statistik. (2006). *Der Primärsektor Ergebnisse der Gesamtrechnungen 1990-2005 und Schätzung der Landwirtschaft 2006*. Neuchâtel: BFS.

Bundeskanzleramt. (2015). *Landwirtschaftsgesetz No. 375/1992 in der Fassung vom 02.12.2015.* Retrieved June 10, 2015, from https://www.ris.bka.gv.at/GeltendeFassung.wxe?Abfrage=Bundesnormen&Gesetzesnummer=10010681&ShowPrintPreview=True

Bundesministerium für Finanzen. (2013). *Bericht zum EU-Haushalt und zu seinen Auswirkungen auf den österreichischen Bundeshaushalt*. Wien: BMF.

Bundesministerium für Finanzen. (2015). *Bericht zum EU-Haushalt und zu seinen Auswirkungen auf den österreichischen Bundeshaushalt*. Wien: BMF.

Bundesministerium für Land- und Forstwirtschaft. (1996). *Grüner Bericht 1995*. Wien: BMLF.

Bundesministerium für Land- und Forstwirtschaft. Umwelt und Wasserwirtschaft. (2015). Grüner Bericht 2015. Wien: BMLFUW.

Chatellier, V., Guyomard, H., Latruffe, L., & Levert, F. (2007). *Agricultural Incomes in the EU and Public Policies.* Paper presented at the DG Joint Research Centre and DG Agriculture Expert Workshop "Income and Factor Markets under the 2003 CAP Reform", Seville.

EurActor Network. (2008). *Food Crisis Set to Weigh on CAP Reform.* Retrieved June 04, 2015, from http://www.euractiv.com/sustainability/food-crisis-set-weigh-cap-reform/article-172484

European Commission. (2000). *Manual on the Economic Accounts of Agriculture and Forestry EAA/EAF 97 (Rev.1.1).* Retrieved October 24, 2015, from http://bookshop.europa.eu/en/manual-on-the-economic-accounts-for-agriculture-and-forestry-eaa-eaf-97-rev.1.1--pbKS2700782/

European Commission. (2010). *Developments in the Income Situation of the EU Agricultural Sector.* Retrieved May 24, 2015, from http://ec.europa.eu/agriculture/rica/pdf/hc0301_income.pdf

European Commission. (2015a). *EU Budget 2014. Finanical Report 2014*. Brussels: EC. Retrieved October 24, 2015, from http://ec.europa.eu/budget/financialreport/2014/foreword/index_en.html

European Commission. (2015b). *The CAP*. Retrieved October 28, 2015, from http://ec.europa.eu/agriculture/cap-history/agenda-2000/index_en.htm

European Union. (2013). *European System of Economic Accounts. ESA 2010.* Retrieved September 15, 2014, from http://ec.europa.eu/eurostat/documents/3859598/5925693/KS-02-13-269-EN.PDF/44cd9d01-bc64-40e5-bd40-d17df0c69334

Eurostat. (2015a). *Database Economic Accounts*. Luxemburg: Eurostat. Retrieved October 23, 2015, from http://ec.europa.eu/eurostat/web/national-accounts/data/database

Eurostat. (2015b). *Database Economic Accounts for Agriculture*. Luxemburg: Eurostat. Retrieved October 24, 2015, http://ec.europa.eu/eurostat/web/agriculture/data/database

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Food and Agriculture Organization. (2011). *Towards a System of Environmental Economic Accounting for Agriculture (SEEA-AGRI).* Retrieved May 15, 2014, from http://unstats.un.org/unsd/envaccounting/ceea/meetings/UNCEEA-6-27.pdf

Gahleitner, G., Kirner, L., & Resl, T. (2015). Entwicklung der Einkünfte aus Land- und Forstwirtschaft seit dem EU-Beitritt. In S. Egartner & Th. Resl (Eds.), *Einblicke in Österreichs Landwirtschaft seit dem EU-Beitritt* (pp. 121–154). Wien: Bundesanstalt für Agrarwirtschaft.

Golan, E., & Kuchler, F. (1999). Willingness to Pay for Food Safety: Cost and Benefit of Accurate Measures. *American Journal of Agricultural Economics*, *81*(5), 1185–1194. doi:10.2307/1244105

Hambrusch, J., Heinschink, K., & Tribl, Ch. (2015). Risiken der Landwirtschaft und die Rolle der öffentlichen Hand beim Risikomanagement unter Berücksichtigung der GAP. In S. Egartner & T. Resl (Eds.), *Einblicke in Österreichs Landwirtschaft seit dem EU-Beitritt* (pp. 229–276). Wien: Bundesanstalt für Agrarwirtschaft.

Hofreither, M. F. (2006). Anpassungsprozesse der österreichischen Landwirtschaft als Folge des EU-Beitritts. *Die Volkswirtschaft. Das Magazin für Wirtschaftspolitik*, *9*, 23–26.

James, J. S. (2002). *Research Project Outline on Consumer Valuation of Food Quality Attributes*. Philadelphia, PA: The Pennsylvania University, College of Agricultural Sciences.

Kniepert, M., Mayer, Ch., & Ortner, K. M. (2009). Agrarwirtschaftliche und agrarpolitische Entwicklungen im Spiegel der Landwirtschaftlichen Gesamtrechnung Österreichs von 1964 bis 2007. *Jahrbuch der Österreichischen Gesellschaft für Agrarökonomie. Band, 18*(1), 81–90. Retrieved August 28, 2014, from http://www.awi.bmlfuw.gv.at/fileadmin/download/Kniepert_Mayer_Ortner.pdf

KPMG International. (2013). *The Agricultural and Food Value Chain: Entering a New Era of Cooperation*. Retrieved October 20, 2015, from https://www.kpmg.com/US/en/IssuesAndInsights/ArticlesPublications/Documents/agricultural-food-value-chain-report.pdf

Kraut, S. (2009). *Die Zukunft von Agrarsubventionen in der EU: Herausforderungen durch aktuelle Marktentwicklungen bei Nahrungsmitteln und nachwachsenden Rohstoffen*. Norderstedt: GRIN Verlag.

Massot, A. (2013). *Die Instrumente der GAP und ihre Reformen.* Retrieved September 29, 2014, from http://www.europarl.europa.eu/aboutparliament/de/displayFtu.html?ftuId=FTU_5.2.3.html

Organisation for Economic Co-operation and Development. (1995). *Agricultural Policies, Markets and Trade in OECD Countries. Monitoring and Outlook*. Paris: OECD.

Ortner, K. M. (1994). GATT-Verpflichtungen für die Landwirtschaft. *Der Förderungsdienst, 42*, 75–80, 113–117, 145–152.

Ortner, K. M. (1996). *The Austrian Farm Sector's Adjustment to the CAP in 1995. Agriculture after Joining the EU – Sectoral Analyses for Austria*. Wien: AWI.

Ortner, K. M. (1997a). *Auswirkungen des EU-Beitritts auf die Landwirtschaft. Die österreichische Landwirtschaft im EU-Agrarsystem*. Klosterneuburg: Agrarverlag.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Ortner, K. M. (1997b). *Die österreichische Agrarpolitik bis zum EU-Beitritt. Die österreichische Landwirtschaft im EU-Agrarsystem*. Klosterneuburg: Agrarverlag.

Ortner, K. M., Neuwirth, J., & Wagner, K. (2010). Economic Effects of the Common Agricultural Policy on Employment in Austria. *Rural Areas and Development*, *7*, 213–223.

Regulation Establishing Rules for Direct Payments to Farmers under Support Schemes within the Framework of the Common Agricultural Policy. (2013). Publication No. 1307/2013. Brussels: The Official Journal of the European Union. Retrieved May 13, 2015, from http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1431545697703&uri=CELEX:32013R1307

Regulation on Support for Rural Development by the European Agricultural Fund for Rural Development (EAFRD). (2013). Publication No. 1305/2013. Brussels: The Official Journal of the European Union. Retrieved May 13, 2015, from http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1431545955727&uri=CELEX:32013R1305

Regulation on the Economic Accounts for Agriculture in the Community. (2003). Publication No. 138/2004. Brussels: The Official Journal of the European Union. Retrieved October 20, 2015, from http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32004R0138&qid=1447943645565&from=EN

Schneider, M. (1989). *Österreichs Land- und Forstwirtschaft und der EG-Binnenmarkt*. Vienna: WIFO.

Schneider, M. (1993). *EG-Binnenmarkt als Herausforderung für Österreichs Landwirtschaft und Nahrungsmittelindustrie*. Vienna: WIFO.

Schneider, M. (1994). Chancen und Risiken der Landwirtschaft im EU-Binnenmarkt. *Österreich in der Europäischen Union. Anforderungen und Chancen für die Wirtschaft*, *67*, 46–61.

Schneider, M. (1997). Österreichs Landwirtschaft unter EU-Bedingungen. *WIFO-Monatsberichte*, *3*, 155–170.

Schnepf, R. (2015). U.S. Farm Income. *Outlook for*, *2015*. Retrieved from http://fas.org/sgp/crs/misc/R40152.pdf

Sinabell, F. (2004). *Entwicklungstendenzen der österreichischen Landwirtschaft seit dem EU-Beitritt.* Retrieved August 28, 2014, from http://www.bmlfuw.gv.at/land/laendl_entwicklung/Online-Fachzeitschrift-Laendlicher-Raum/archiv/2004/Sinabell.html

Spencer, H. (1996). Consumer Willingness to Pay for Reduction in The Risk of Food Poisoning in UK. *Journal of Agricultural Economics*, *47*(3), 403–420.

Statistic Canada. (2009). *Statistics on Income of Farm Operators.* Retrieved June 1, 2015, from http://www.statcan.gc.ca/pub/21-206-x/2012000/t078-eng.htm

Statistics Austria. (2013). *Volkswirtschaftliche Gesamtrechnungen. Hauptergebnisse 1980-2012*. Wien: Statistik Austria. Retrieved September 15, 2014, from http://www.statistik.at/dynamic/wcmsprod/idcplg?IdcService=GET_NATIVE_FILE&dID=146425&dDocName=071993

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Statistics Austria. (2015). *Landwirtschaftliche Gesamtrechnung. Datenbankabfrage vom 19.11.2015. Eigene Berechnungen*. Wien: Statistik Austria.

ADDITIONAL READING

Aiginger, K. (2009). Strengthening the Resilience of an Economy. Enlarging the Menu of Stabilisation Policy to Prevent Another Crisis. *Inter Economics*, *44*(September/October), 309–316. doi:10.100710272-009-0308-9

Chatterton, J., Audsley, E., Graves, A., Morris, J., & Williams, A. (2012). *Using Systems-based LCA to Investigate the Environmental and Economic Impacts and Benefits of the Livestock Sector in the UK*. Cranfield: Cranfield University.

Cunha, A., & Swinbank, A. (2011). *An Inside of the CAP Reform Process. Exploring the Mac-Sharry, Agenda 2000 and Fischler Reforms*. Oxford: Oxford University Press. doi:10.1093/acprof:oso/9780199591572.001.0001

Egartner, E., & Resl, Th. (Eds.), *Einblicke in Österreichs Landwirtschaft seit dem EU-Beitritt*. Wien: Bundesanstalt für Agrarwirtschaft.

European Commission. (2002). *The European Framework for Integrated Environmental and Economic Accounting*. Retrieved May 24, 2015, from http://ec.europa.eu/eurostat/documents/39314/44178/Handbook-IEEAF-2002.pdf/c7b2aeaa-c4dd-49ce-bf25-05740d90e043

Hovorka, G. (2009). *Eckpunkte einer zukunftsfähigen (Berg) Landwirtschaft*. Retrieved May 17, 2011, from http://momentum-kongress.org/hovorka-gerhard-eckpunkte-einer-zukunftsfahigen-berglandwirtschaft

Kay, A. (2003). Path Dependency and the CAP. *Journal of European Public Policy*, *10*(3), 405–420. doi:10.1080/1350176032000085379

Matthew, A. (2015). Reflections on the CAP post 2014. In J. Swinnen (Ed.), *The Political Economy of the 2014-2020 Common Agricultural Policy. An Imperfect Storm* (pp. 493–508). London: Rowman & Littlefield International Ltd.

Philippidis, G., & Hubbard, L. J. (2001). The Economic Cost of the CAP Revisited. *Agricultural Economics*, *25*(2-3), 375–385. doi:10.1111/j.1574-0862.2001.tb00216.x

Pieters, H., & Swinnen, J. (2014). *Trading-off Volatility and Distortions? Food Policy during Price Spikes*. Retrieved November 25, 2015, from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2533975

Swinnen, J. (2015). The Political. *De Economía*, 2014–2020.

Treasury, H. M. (2008). *Global Europe: Vision for a 21st Century Budget*. London: HM Treasury.

Verhaegen, E., Wustenberghs, H., Lauwers, L., & Mathijs, E. (n.d.). *Integrated Economic and Environmental Accounting for Agriculture*. Retrieved June 1, 2015, from http://www.nass.usda.gov/mexsai/Papers/multifunc.pdf

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KEY TERMS AND DEFINITIONS

Agricultural Industry: A collection of local kind-of-activity units that carry out agricultural activities including both farms and specialist agricultural contractors. The output of agriculture also includes inseparable non-agricultural secondary activities that these units carry out. It excludes services relating to design, planting and maintenance of gardens, parks, and green areas for sports facilities. It also excludes units producing solely for their own consumption.

Agricultural Labour Input: All employed and self-employed persons that provide paid and unpaid labour input to residential units, which perform characteristic activities (agricultural and inseparable non-agricultural secondary activities) of the agricultural industry. Due to the consideration of part-time and seasonal work, labour force and its changes are measured in annual work units (AWU). One AWU equals one person in full-time employment in agriculture in one year. Employment has an important influence on the calculation of the income indicators.

Agricultural Production at Basic Prices: Equals value of crop and animal output, agricultural services output and the value of inseparable non-agricultural secondary activities, valued at basic prices. Valuation at basic prices means the taxes on products and services are excluded and subsidies on products and services are included. The output of the agricultural industry results from the market production of goods and services as well as non-market production for individual final use (own consumption by agricultural households, own-account produced fixed capital goods of crops and livestock). Furthermore, parts of the output consumed by the agricultural units themselves are included in the output value (crop products that are used as fodder within the unit).

Agricultural Production at Producer Prices: Equals the value of crop output, animal output, agricultural services and the value of inseparable non-agricultural secondary activities, valued at the (farm-gate) producer prices without VAT.

Basic Prices: Amounts received by the producer for a unit of goods or services, minus any tax payable on that unit as a consequence of production or sale (i.e., taxes on products), plus any subsidy receivable on that unit as a consequence of production or sale (i.e., subsidies on products).

Capital Transfers: Require the acquisition or disposal of an asset, or assets, by at least one of the parties to the transaction. Whether made in cash or in kind, they result in a commensurate change in the financial, or non-financial, assets shown in the balance sheets of one or both parties to the transaction.

Economic Accounts for Agriculture (EAA): The purpose is to analyze the production process of the agricultural industry and the primary income generated by this production. It contains provides detailed data on value of output (at producer prices and basic prices), intermediate consumption, subsidies and taxes, consumption of fixed capital, rents and interests, capital formation, etc. The values are in current as well as in constant prices. Furthermore, Agricultural Labour Input (ALI) and Unit Values (UV) are an integrated part of the overall concept of EAA.

Entrepreneurial Income: Equals net operating surplus/net mixed income less rents paid and interest plus received interest that refers exclusively to agricultural production.

Factor Income: An amount for the remuneration of the production factors: labour, capital and land. Factor income incorporates subsidies on agricultural products and other subsidies on agricultural production. Due to the importance of the subsidies in agriculture and redirection of the common agricultural policy in indirect support in the form of other subsidies on production, factor income is more appropri-

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ate for reflecting the economic state of agriculture than Value Added. Factor income equals Net Value Added at basic prices less other taxes on production plus other subsidies on production. Factor income also equals the sum of net operating surplus/mixed income and compensation of employees.

Gross Domestic Product (GDP): Aggregate measure of production equal to the sum of the Gross Value Added of all resident institutional units engaged in production (plus any taxes, and minus any subsidies, on products not included in the value of their outputs).

Subsidies: Current unrequited payments which general government or the institutions of the European Union make to resident producers with the objective of influencing their levels of production, their prices or the remuneration of the factors of production. Subsidies on agricultural products are subsidies payable per unit of a good or service produced. Other subsidies on production include all subsidies, other than subsidies on products, from which resident producer units can benefit as a result of engaging in production (for example agri-environmental measures, subsidies for agricultural production in less favoured or mountain areas and compensation for current loses).

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Chapter 40
Economic Growth and Climate Change:
An Exploratory Country-Level Analytics Study

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ABSTRACT

In this article, the authors use analytics to explore the association between economic growth and climate change at a country-level. They examine different indicators to better understand the macro issues and guide policy decision-making. The authors analyze global economic growth and climate change using the World Bank data of 131 countries and 16 indicators for the period 2005 to 2010. The analysis shows overall economic growth is positively associated with climate change. This implies country leaders should design and implement structured development plans if they are to promote economic growth to alleviate poverty while simultaneously mitigating climate change.

INTRODUCTION

According to scientists and policymakers, the earth's climate is changing. Temperatures are rising, snow and rainfall patterns are shifting, and extreme weather events—intense rainstorms, record-high temperatures, alternating cyclone/hurricane occurrences and long dry spells—are wreaking havoc in different parts of the world (International Monetary Fund, 2008; U.S. Environmental Protection Agency, 2016). Researchers are generally confident that many of these changes and trends are associated with increased levels of carbon dioxide and other greenhouse gases (GHG) in the earth's atmosphere, and that these increases have been brought about by human activities (International Monetary Fund, 2008; U.S. Environmental Protection Agency, 2016)). Climate change refers to "any substantial change in

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measures of climate (such as temperature or precipitation), lasting for an extended period (decades or longer). Natural factors have caused the climate to change during previous periods of the Earth's history, but human activities are the primary cause of the changes that are being observed now (International Monetary Fund, 2008; Stern, 2006; The National Academies Press, 2010a, 2010b; U.S. Environmental Protection Agency, 2016)." Human activities are generally understood to include economic development and growth activities (The National Academies Press, 2010a, 2010b; Ward and Shively, 2012).

The primary sources of greenhouse gases, in order of importance, are: electricity generation, land-use changes (e.g., deforestation), agriculture, and transportation (International Monetary Fund, 2008; Stern, 2006; The National Academy of Sciences, 2014). While the literature strongly suggests rich (developed) countries have historically dominated emissions, and poor (developing) countries will contribute to the rise in emissions rapidly, the current debate and global talks on climate change center around how to mitigate climate change while keeping equity and poverty reduction (Soubbotina, 2004; Tol, 2009) in mind (International Monetary Fund, 2008; Markandya, 2011). For example, increases in energy-related emissions of carbon dioxide, the largest and fastest growing source of GHG emissions, are primarily driven by growth in GDP capita and population increases, and these increases are only partially offset by more efficient use of energy (Markandya, 2011; Ward and Shively, 2012). While China, India, and other developing countries contribute to most of the growth in emissions, developed countries account for most energy-related emissions in the past and, thus, for most of the current stock of these emissions (Markandya, 2011). When changes in land-use and deforestation are considered, however, advanced countries are responsible for less than half of the current stock of total emissions (Markandya, 2011). In other words, the amount of carbon dioxide a country emits into the atmosphere depends mainly on the size of that country's economy, the level of its industrialization, and the efficiency of its energy use (Mattoo and Subramanian, 2012; Raghupathi and Raghupathi, 2016; The National Academies Press, 2010b). Until now, though developing countries contain most of the world's population, their industrial production and energy consumption per capita have been relatively low. There can be little doubt that the primary responsibility for global warming lies with developed countries. But the link between economic growth and increased energy consumption, in conjunction with increased carbon dioxide emission, is direct and positive for all countries (Mattoo and Subramanian, 2012). That said, at high-income levels, there are indications of lower per capita energy consumption and pollution despite economic growth (Raghupathi and Raghupathi, 2016; The National Academies Press, 2010b) explained by increased efficiency in energy use thanks to environmentally cleaner technologies. Also, a higher-income country will typically demand a proportionally larger service sector, and service is a far less energy intensive sector compared to, say, manufacturing (Mattoo and Subramanian, 2012).

In summary, we know that developed countries have to reduce emissions, and they need to identify innovative strategies and technologies to develop and use. Furthermore, developed countries need to transfer and make these technologies available to developing countries. Progressive development assistance and aid have to be provided to developing countries, engaging them in rapid economic development and poverty reduction, and at the same time, keeping greenhouse gas emissions in check (The National Academies Press, 2010a). However, considering most developing countries do not commit to reduce greenhouse gas emissions, arguing that these commitments would undermine their economic development and impede poverty alleviation, finding the right balance between economic growth and climate change is a key challenge (Mattoo and Subramanian, 2012; The National Academies Press,2010a; United Nations Development Program, 2013). Naturally, all countries contemplating mitigation will want to

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understand the economic impact and whether climate change mitigation will allow them to enhance or maintain growth (International Monetary Fund, 2008).

Key to this research, therefore, is the question of whether there is an association between economic growth (development) and climate change: Is climate change directly associated with economic growth? If so which indicators are significant? In this exploratory study, we address these questions. The findings have numerous implications. First, if an association exists, developed countries should make reparations for past and current emissions. Second, they should help developing countries engage in structured development by promoting equity to balance poverty alleviation with climate change mitigation and prevention. Third, countries with innovative strategies and technologies should facilitate the transference of such technologies to developing countries to mitigate climate change. Fourth, countries with experience and expertise in climate-change-mitigation strategies, studies, and research should share those experiences with countries that do not have similar experience or resources.

The rest of this paper is organized as follows: First, we describe the methodology of our study; we then discuss results and offer analysis; thirdly, we outline the scope and limitations of the study; fourthly, we offer contributions; finally, we offer conclusions and policy implications.

MATERIALS AND METHODS

We study the association between climate change and economic growth at a global level, using analytics. Analytics is the "application of models, methods, and tools to analyze large data sets to gain insight to make informed decisions (Raghupathi & Raghupathi, 2016). Analytics, a collection of decision support technologies, enables scientists and policymakers to understand and make better/faster decisions related to a domain. As more data is generated digitally and otherwise, decision-makers strive to leverage abundance of rich data using sophisticated analytic techniques - including artificial intelligence, machine learning, statistics, and visualization - so as to be data-driven in their decision-making.

The domain of climate change is complex and multidimensional including facets of climate impacts, adaptation, mitigation and policy (Becken, 2013). Public knowledge of the domain is limited and its effects are perceived as abstract and unclear. In addition, the perception about climate change varies between countries (Capstick et al., 2015). In order to be effective, global concern about climate change should be preceded, at the very least, by knowledge about its nature and effects (Shi et al., 2014). There is therefore a basic need for research to communicate all relevant information related to the domain in a simple and effective manner. With this premise in mind, we deploy the analytic technique of visualization in the current research. Visualization has been used in domains such as environmental and climate science to effectively communicate the meaning in complex and large data sets to a wide audience (Bohman et al., 2015). Additionally, in the realm of climate change, since the impact varies geographically, there is an inherent spatial dimension to its adaptation and mitigation which lends itself very well to visualization. Visual representation of scientific data helps communicate and increase the knowledge and recognition of the effects of climate change and of planning and decision making in the domain (Salter et al., 2009; Sheppard 2012; Sheppard et al. 2011; White et al. 2010). Being an exploratory research, our objective is to be data-driven and identify patterns and meaning in the data by directly interacting with the data, gaining insight, drawing conclusions and making fact-based recommendations. We call this evidence-based climate change analysis.

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The research methodology is comprised of the following phases: data collection, indicator selection, data preparation, analytics platform and tool selection, and analytics implementation (Table 1). The phases are general enough to be applied to any domain in which analytics is deployed (Raghupathi & Raghupathi, 2016).

The data for climate change and economic growth indicators for the years 2005 to 2010 were downloaded from the World Bank website (http://data.worldbank.org/data-catalog/world-development-indicators). This was the only available data. There are a few reasons why data was not available for some indicators, countries and years, in the data source. Some indicators are derived from sporadic surveys and are only available every few years. Additionally, some countries do not report data on a regular basis due to several reasons such as conflict, lack of statistical means, and others. Also, in some countries data simply does not exist for some years. Despite these challenges, the indicators from World Bank are generally accepted as authentic indicators of economic growth and climate change (http://data.worldbank.org/indicator). As the World Bank says, "the primary World Bank collection of development indicators, compiled from officially-recognized international sources…presents the most current and accurate global development data available, and includes national, regional and global estimates."

The economic indicators include GDP (current US$), GDP per capita, GDP growth (annual %), Gross savings (% of GDP), Trade (% of GDP), Industry (% of GDP), and Exports of goods and services (% of GDP). The climate change indicators include CO2 emissions (kt), CO2 emissions per capita, Forest area (% of land), Improved water source (% of population with access to improved water), Energy use (kt of oil equipment), Energy use per capita (kg of use per capita), and Electric power consumption per capita (kw per capita). Table 2 shows a description of the variables with measures.

We collected the data for 131 countries and used the income group classifications from the World Bank (http://go.worldbank.org/CWTURYIPS0): low income, lower middle income, upper middle income, and high income. The high-income classification is bifurcated into member and non-member countries of the Organisation for Economic Co-operation and Development (OECD). The OECD strives to promote and maintain the economic and social well-being of its member countries. Most country-level research uses World Bank's income group classification as the benchmark for comparative trend analyses. In our data, 47 countries fall under the high-income classification, 40 under upper middle income, 32 under lower middle income, and 12 under lower income classification. We included the geographic regions where the countries belong, such as East Asia and Pacific, Middle East and North Africa, Europe and Central Asia, Latin America and Caribbean, North America, South Asia, and Sub-Saharan Africa.

Table 1. Research methodology summary

Data Collection	World Bank
Indicator Selection	Economic and Climate Change indicators Control: Income group, Region
Data Preparation	Data extracted from World Bank website in csv format and prepared for loading into analytic tools
Platform /Tool Selection	Multiple tools
Implementation	Analysis and reports implementation using analytic tools

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Table 2. Description of indicator variables

Climate Change Indicators	
CO2 emissions (kt)	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. Excludes carbon dioxide produced during consumption of solid, liquid, and gas fuels, and of gas flaring.
CO2 emissions per capita	CO2 emissions divided by population
Forest area (% of land area)	Land under natural or planted stands of trees of at least 5 meters in situ, whether productive or not, and excludes tree stands in agricultural production systems (e.g., in fruit plantations or agroforestry systems) and trees in urban parks and gardens
Improved water source (% of population with access)	% of population using an improved drinking water source, including piped water on premises and other improved drinking water sources (public taps, standpipes, tube wells, boreholes, protected dug wells and springs, rainwater)
Energy use (kg of oil)	Use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, less exports and fuels supplied to ships and aircraft engaged in international transport
Energy use per capita (kg of oil per capita)	Energy use divided by population
Electric power consumption (kw per capita)	Measures the production of power plants and combined heat and power plants, less transmission, distribution, and transformation losses and own use by heat and power plants
Economic Growth Indicators	
GDP (US$)	Gross Domestic Product
GDP per capita (US$)	GDP divided by population
GDP growth (annual %)	Annual Percentage Growth of GDP at market price based on constant local currency
Gross savings (% of GDP)	Gross national income less total consumption, plus net transfers measured as a share of Gross Domestic Product
Trade (% of GDP)	Sum of exports and imports of goods and services measured as a % of GDP
Industry value added (% of GDP)	Net output of a sector after totaling all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources. Comprises value added in mining, manufacturing, construction, electricity, water, and gas.
Exports of goods and services (% of GDP)	Value of all goods and market services provided to the rest of the world. Includes the value of merchandise, freight, insurance, transport, travel, royalties, license fees, and other services, including communication, construction, financial, information, business, personal, and government services; excluding compensation of employees, investment income, and transfer payments.
Control Variables	
Income Group	High OECD/non-OECD, upper middle, lower middle, low
Region	East Asia/Pacific, Europe/Central Asia, Latin America/Caribbean, Middle East/North Africa, North America, South Asia, Sub-Saharan Africa

The raw data were extracted in CSV format from the sources, and the extracted data were integrated, cleansed, and standardized for loading into the analytics tool. To perform the analytics, several tools, which utilize visualization and other techniques, were chosen for identifying trends and patterns in the data and for facilitating various analyses. To reiterate, based on the literature, our overall data-driven research proposition is that economic growth is positively associated with climate change. In the data-driven approach, we let the data tell the story (U.S. Environmental Protection Agency, 2016).

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RESULTS AND ANALYSIS

The distribution of the sample by region and by income are shown in Figure 1.

Figure 1 shows that the region of Europe and Central Asia has the majority of high-income OECD countries followed by North America. North America is comprised of all high-income OECD countries. The region of Sub-Saharan has the highest number of low-income countries. We analyzed the different income groups to discern possible trends and variations in economic growth and economic growth.

CO_2 Emissions

Since CO2 emission is an important indicator of climate change, we analyzed it for the sample countries for the period 2005 to 2010 (Figure 2).

Figure 2 reveals a drop in CO_2 emissions in 2008-09 for all income groups. There is a likely explanation for the drop: the 2007-08 global financial crisis saw the failure of large financial institutions, drop of stock markets worldwide, and an overall decline in industrial and economic activity. It's reasonable to presume that the drop in CO_2 emissions is associated with the decline in the global economy that followed the crisis.

We compared the median and average CO_2 emissions across different income groups to gain a better understanding of the pattern of CO_2 emissions over the years (Figure 3).

The top panel in Figure 3 shows average emissions, and the bottom panel shows the median emissions, for the four income groups. In terms of average emissions, upper middle-income countries have surpassed high income countries since 2009, while in median emissions terms, high-income countries take the lead. The low-income group shows the lowest emissions and no variation over the years in terms of average or median emissions. CO_2 emissions seem to be positively associated with the income of

Figure 1. Distribution of the sample of countries by region and by income group

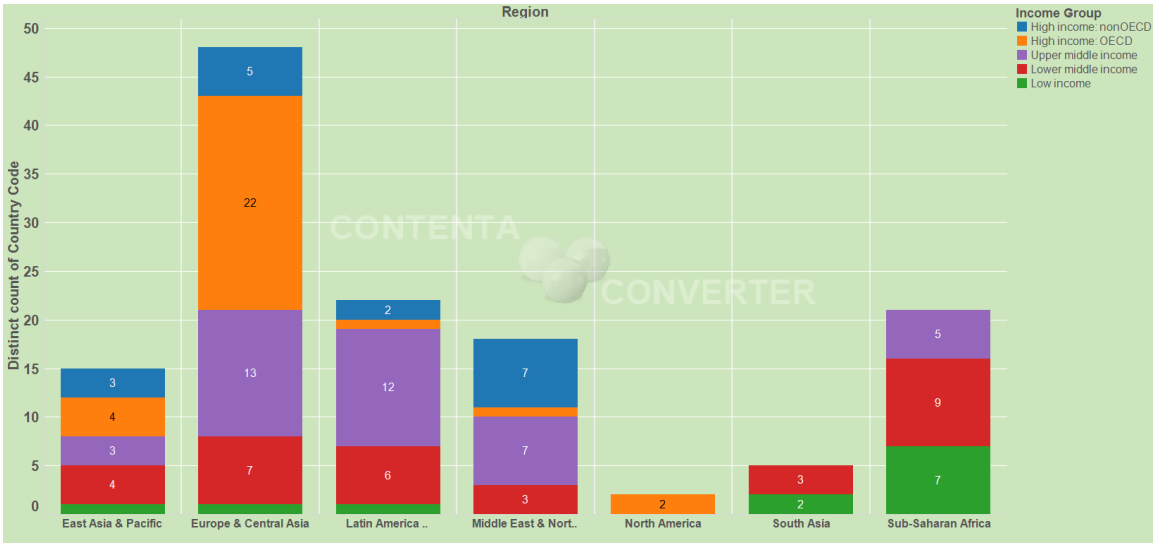

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Figure 2. Trend of CO_2 emissions

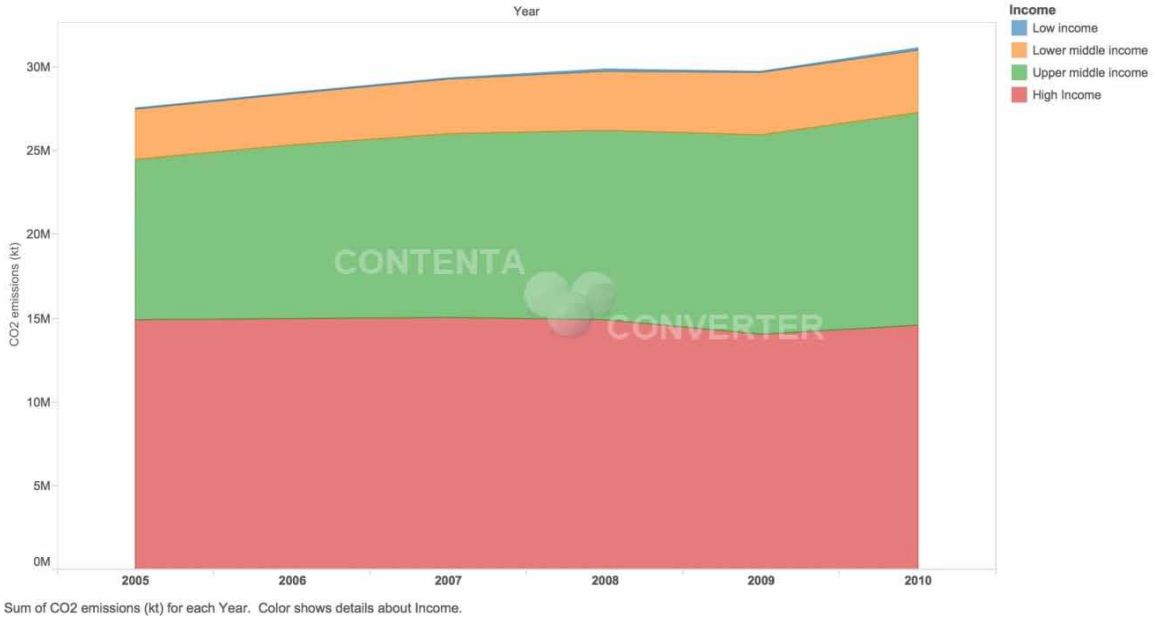

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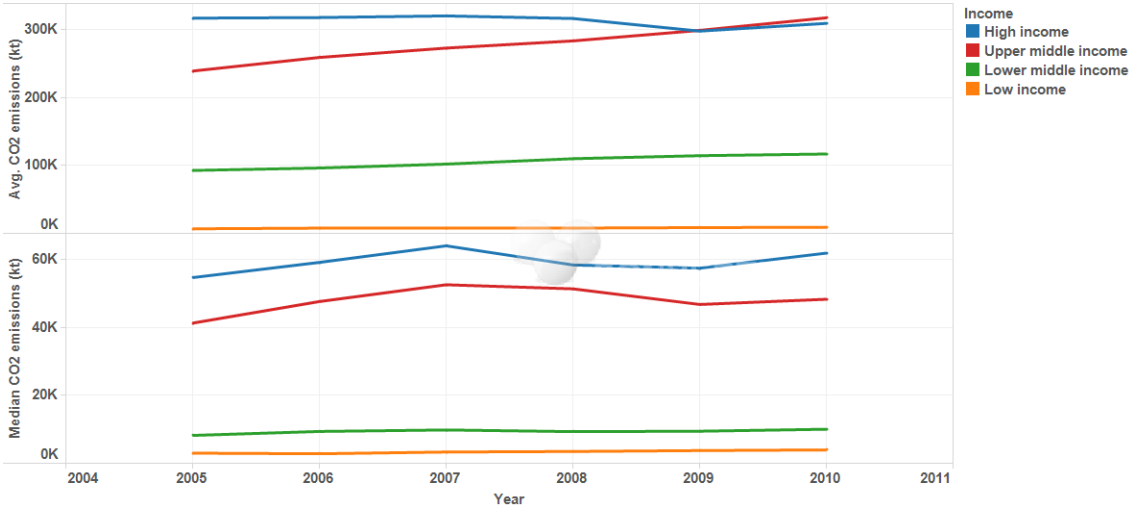
Figure 3. Trend of median and average CO_2 emissions



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countries. For a clearer picture, we considered CO_2 per capita emissions instead of total CO2 emissions, because per capita takes population into account. It is a fact that low-income countries have a much higher population than high-income countries, and therefore including per capita emission in our study offers a more balanced approach for analysis.

The box chart in Figure 4 clearly shows that the per capita CO_2 emissions is much higher in high-income countries than in others. Elevated levels of industrialization in high-income countries accounts

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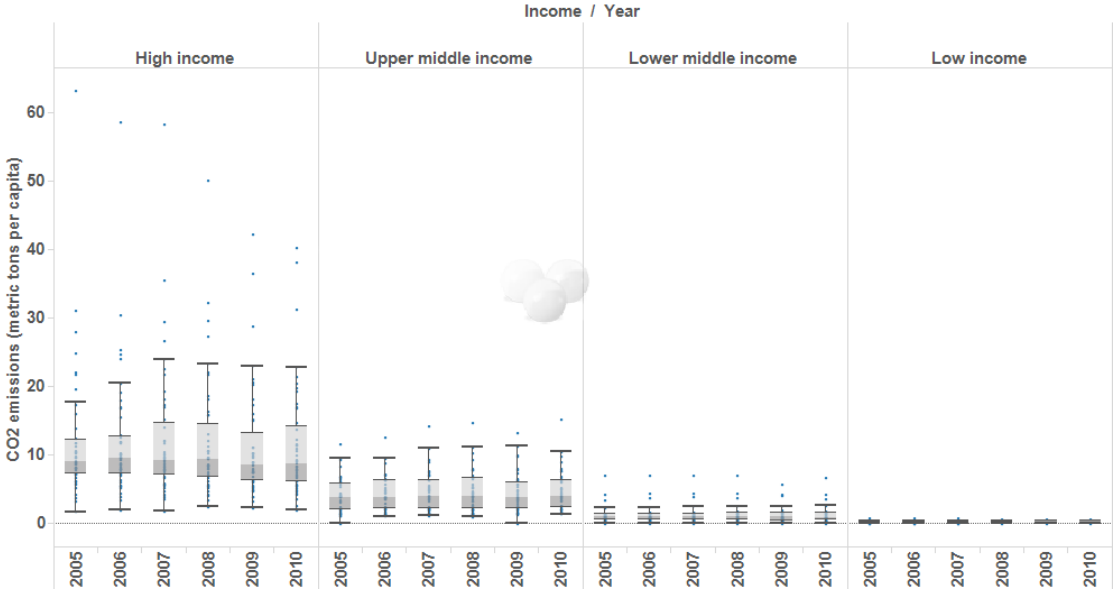
Figure 4. CO_2 emissions per capita



for the high emission levels. Not surprisingly, low-income countries show the lowest emissions per capita. Clearly, there is a positive association between a country's per capita CO_2 emissions and income. Economic growth is associated with higher income and therefore with higher emissions (Ravallion et al., 2000). Countries need to consider a possible trade-off between economic growth and social equity in ensuring prevention of climate change and global warming. The Kyoto Protocol (KP) is an international treaty that extends the 1992 United Nations Framework Convention on Climate Change (UNFCCC) that commits its parties to reduce greenhouse gas emissions, including CO_2 emissions (Iwata and Okada, 2014). The KP was initially adopted in Japan in 1997 and entered into force in 2005 with an objective to reduce GHGs by about 5% from 1990 levels. In the second commitment period, parties committed to reduce GHG emissions by at least 18% below 1990 levels during the years 2013-2020. Countries that have binding emission targets under the KP have consistently lower CO_2 emissions (about 7-105 lower) than they would, in the absence of benchmarks (Almer and Winkler, 2017; Grunewald and Martınez-Zarzoso, 2009). In spite of controversy on the effectiveness of the KP (Bohringer and Vogt, 2003), enforcing such treaty is generally viewed as an integral step to addressing global climate change (Rollings-Magnusson and Magnusson, 2000).

Energy Use and Electricity Consumption

Figure 5 shows the distribution of energy usage and electricity consumption for the four income groups over the six years we are focused on here. The top portion of the graph shows the distribution for energy usage and the lower portion depicts the distribution for electricity consumption.

As seen in Figure 5, high-income OECD countries have the highest electricity consumption, and the consumption has increased steadily over time. The consumption in the low- and middle-income countries has been limited and did not change significantly in the period 2005 to 2010. With respect to energy

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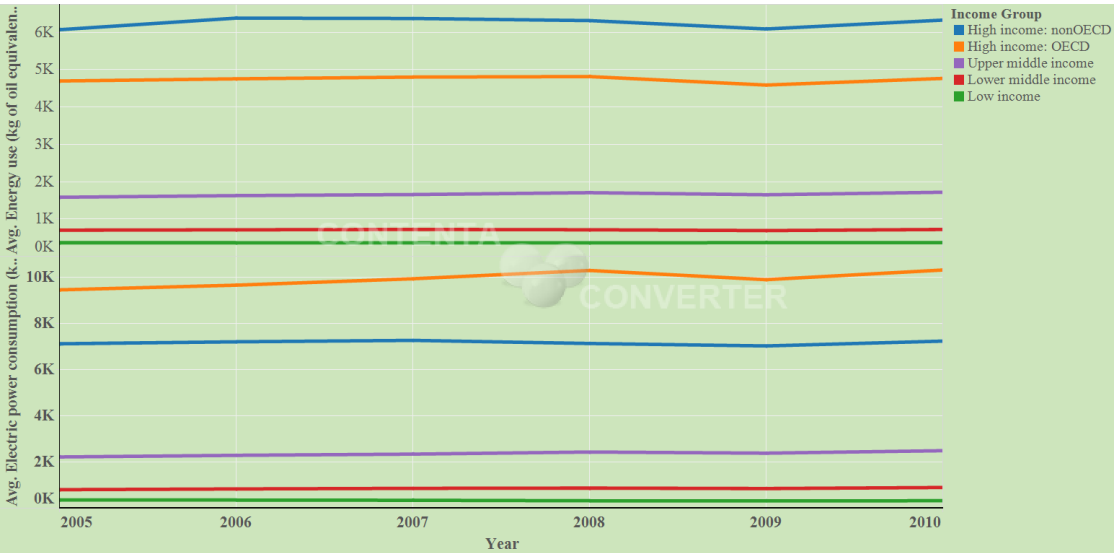
Figure 5. Distribution of energy use and electric power consumption



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usage, high-income non-OECD countries exhibit the greatest energy usage, followed by high-income OECD. Lowest usage is by low-income countries.

Our results reflect two important issues that need to be addressed. One is the disparity between high and low-income countries in terms of energy and electricity usage or consumption. The United Nations Framework Convention on Climate Change (UNFCCC) under the Kyoto Protocol set up international funding programs such as the Adaptation Fund to finance projects aimed at helping low income countries adapt to the harmful effects of climate change. This enables transfer of funds and technology from developed/high income to developing/low income countries.

The second issue is to ensure that the high usage and consumption of energy and electricity by high income countries does not adversely impact climate change. It is therefore imperative that these countries reinforce the importance of sustainable energy sources and consumption (Winston et al., 2017). Reducing emissions from the energy sector is a major challenge for climate change since electricity generation is one of the major contributors to anthropogenic emissions (Hansen et al., 2007; Voorspools et al., 2000; Vougioukli et al., 2017). There is a need for countries to explore alternative means of electricity production using renewable rather than non-renewable sources. An example is the hydropower which is a way of producing electricity using moving water (Vougioukli et al., 2017). Hydropower can be used on a small scale to generate electricity in remote or mountainous areas.

Forest Area

We looked at the distribution of forest area, which represents the percentage of natural or planted trees that are preserved, excluding trees in urban parks and gardens. Figure 6 shows the distribution by region.

Figure 6 depicts a heat map and shows regions with high forest area in green and low forest area in red. Regions such as East Asia and Pacific (Brunei, Japan, Korea, Malaysia, Cambodia, and Indonesia), Europe and Central Asia (Finland, Sweden, Slovenia, Latvia, and Estonia), parts of Sub-Saharan Africa

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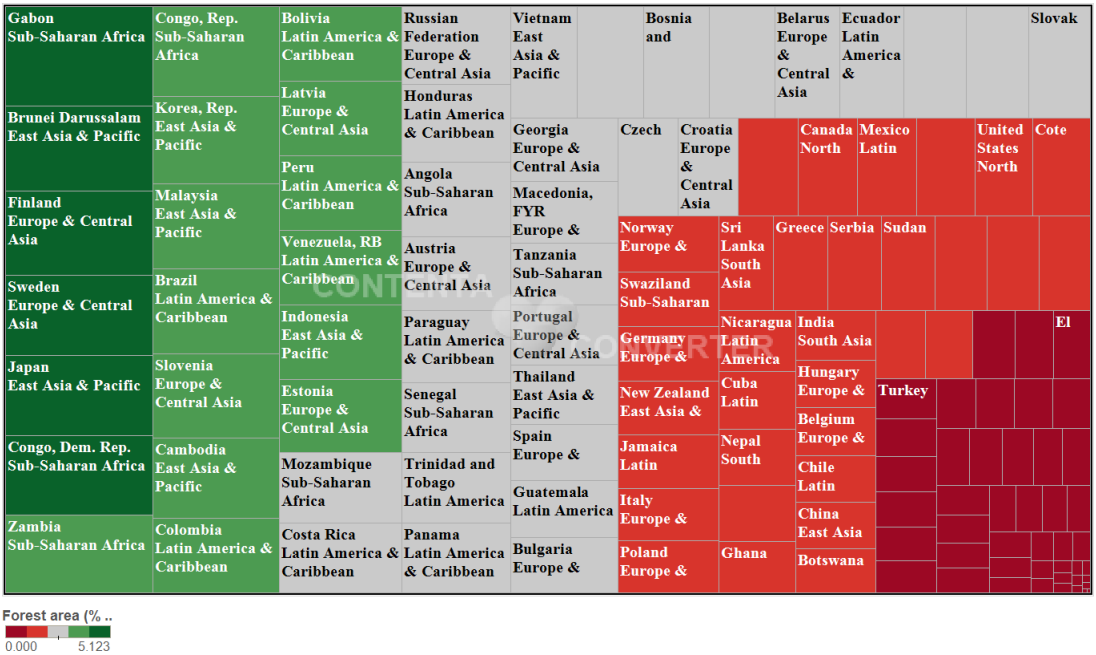
Figure 6. Distribution of forest area by region



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(Gabon, Congo Democratic Republic), Latin America and Caribbean (Brazil, Columbia, Bolivia, Peru, and Venezuela) show high levels of forest area. The Sub-Saharan region belongs to the low-income country classification, but it also shows a high level of forest area.

We looked next at the distribution of forest area by income to see whether there is any association (Figure 7). We expected to find that high-income countries emphasize industrialization over agriculture and would show greater deforestation compared to medium- and low-income countries.

Figure 7 shows that high-income OECD countries have the largest percentage of forest area, followed by upper middle- and low-income countries. While the level of forest area is fairly consistent for the high and upper middle-income countries, it decreases over time for low-income and lower-middle-income countries. Efforts to increase industrialization may account for this decrease in forest area in low- and lower-middle-income countries. It's noteworthy that, contrary to our expectation, economic development did not adversely affect forest area; high-income countries still show the greatest percentage of forest area. This finding offers promise.

GDP per Capita and Energy Usage per Capita

We looked at the economic indicator of GDP per capita for an association with energy usage per capita to learn whether developed countries with high GDP per capita use more energy than other income groups (Figure 8).

Figure 8 shows the relationship between GDP per capita and energy use per capita to be significant ($p<0.0001$) for all groups except the low-income group. For high-and middle-income groups, the association between GDP per capita and energy usage is positive, indicating that as the GDP per capita increases, energy usage also increases.

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Figure 7. Distribution of forest area by income

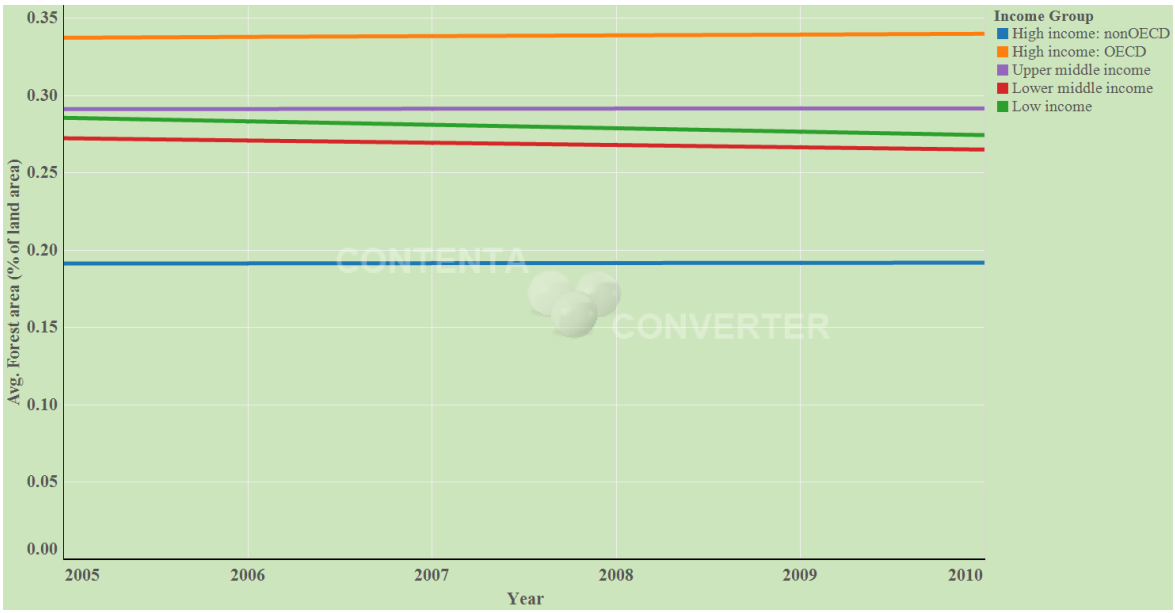

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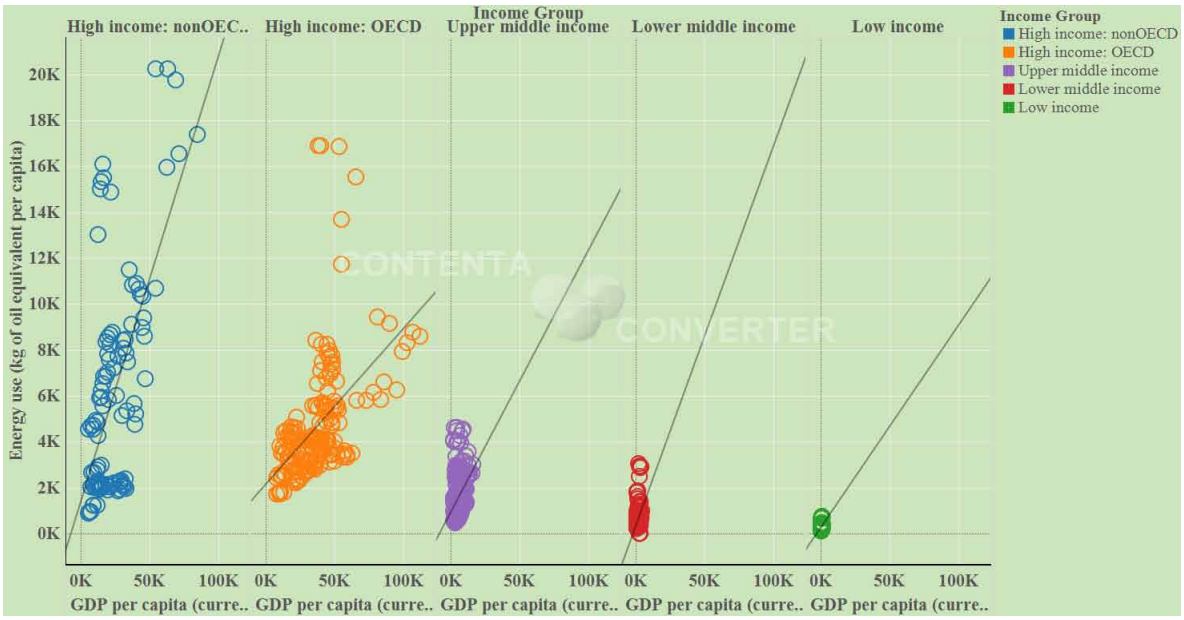
Figure 8. GDP per capita and energy use per capita



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GDP per Capita and Forest Area

For each income group in the sample, we looked at GDP per capita and forest area for the different income groups (Figure 9).

In Figure 9, the color of the bubble denotes the % of forest area and the size denotes the GDP per capita. As seen in the figure, countries with high GDP per capita also have a large % of forest area, while countries with low GDP per capita have a low % of forest area. An explanation for this pattern can be drawn from the environmental Kuznets curve which suggests that economic development by a country initially leads to deterioration in the relationship with its environment, but once a certain level of development is achieved, the economy begins to improve its awareness of the environment and the extent of environmental degradation reduces (Cuaresma et al., 2017). Countries with low GDP per capita work towards improving their economic development by de-emphasizing agriculture and emphasizing industrialization. This causes a decrease in forest area at a rapid pace in the initial stages of economic growth. Once these countries achieve a certain level of growth and development, the tendency of deforestation stabilizes and reduces. High income countries, on the other hand, have already reached a level of development which does not require them to pursue more industrialization. Our findings are consistent with research on GDP and regional forestation (Cuaresma et al., 2017).

GDP per Capita and Improved Water Use

We look for an association between GDP per capita and improved water use for each of the income groups in the sample (Figure 10).

Figure 10 shows that for high-income non-OECD and lower middle-income countries, there is no significant relationship between GDP per capita and percentage with access to improved water source.

Figure 9. GDP per capita and forest area

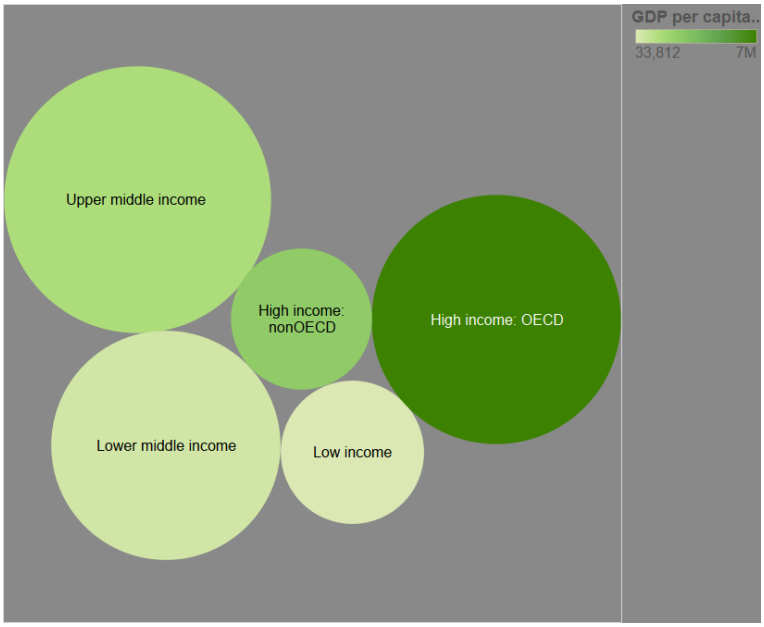

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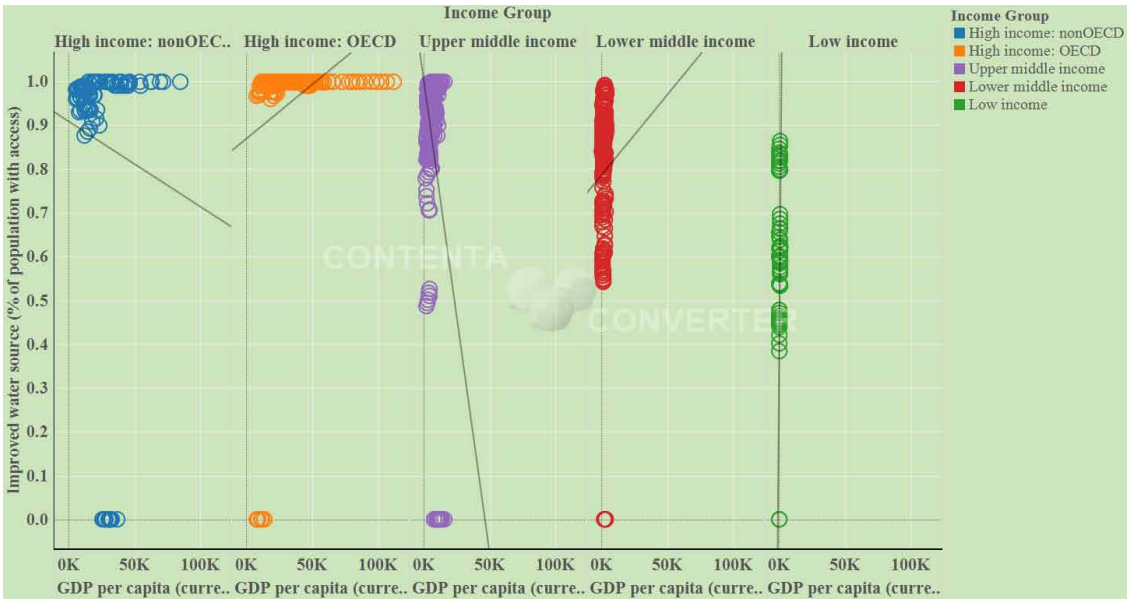
Figure 10. GDP per capita and Improved water source



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For high-income OECD countries, there is a significantly positive relationship ($p < 0.001$), which indicates that when the GDP increases the percentage of population with access to improved water sources also increases. On the other hand, for upper middle-income countries, there is a significant negative relationship ($p < 0.0001$) between the two. This demonstrates that for the upper middle-income countries in our study, as the GDP per capita increases there is a related decrease in the percentage of population with access to improved water sources. This implies that upper middle-income countries may not give priority to providing access to improved water sources. There may be other public policies that take precedence. Meanwhile, for low-income countries, there is a significant positive relationship ($p < 0.001$) to show that as the GDP per capita increases, the percentage of the population with access to improved water sources also increases.

CO2 Emissions and Industry Value Added

Industry value added, also known as the gross domestic product (GDP)-by-industry, represents the contribution of a private industry or government sector to overall GDP. It includes components such as compensation of employees, taxes on production and imports less subsidies, and gross operating surplus. We looked for any significant association between the industry value added and CO2 emissions across all income groups in the sample (Figure 11).

Figure 11 shows a significant relationship between CO2 emissions and industry value added, but only for high-income OECD and low-income countries. The relationship is negative for high-income OECD countries: as the value-added increases, CO2 emissions decrease. This is favorable for climate change mitigation. For low-income countries, however, the relationship is positive; as the industry value added increases, CO2 emissions also increase. This is a noteworthy result which will be discussed in the following paragraph summarizing the results.

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Figure 11. CO2 emissions and industry value added

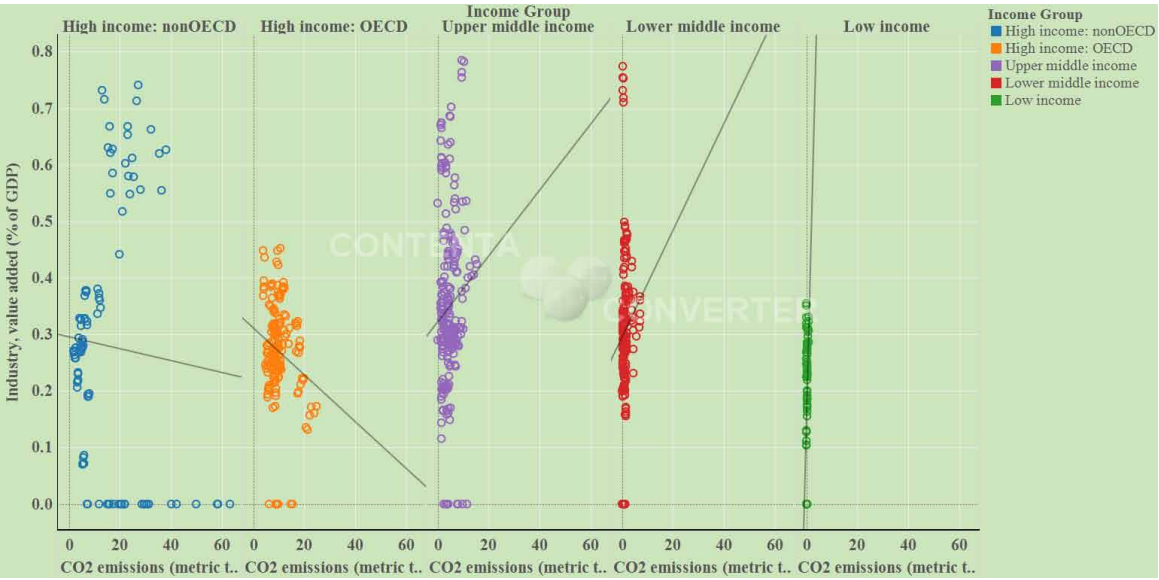

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Table 3 presents a summary of results from the analyses.

In summary, our results show that economic growth is associated with climate change. There is a positive association of income and GDP per capita with CO2 emissions, electricity consumption, and energy usage. These associations are adverse for climate change. However, in terms of forestation, the results are interesting. Upper middle-income countries have the highest forest area, followed by high income countries. Economic growth does not seem to adversely affect forestation, if the income level is already high. However, low income countries, in their efforts at industrialization, need to focus on maintaining forest areas if they intend to be sustainable and mitigate climate change. Industry value added shows a negative association with CO2 emissions for high income countries. This means that the higher a country's industry value added, the lower the carbon emissions. A large proportion of CO2 production comes from industrial activities (Zekos, 2016). We suggest that low income countries should emphasize sustainable industrial sectors such as biotechnology. Industrial biotechnology is a sector based on renewable resources that can save energy and significantly reduce CO2 emissions. Additionally, for this sector to significantly influence climate change, countries need to increase their R&D investment in it so as to promote new products/services that can be brought to market. In fact, the OECD expects industrial biotechnology to contribute up to 39% of biotechnology's gross value added in 2030. This clearly signals the importance and the global need to focus on industries that increase the industry value added percentage without adversely impacting climate change (Zekos, 2016).

While on the one hand our results reflect the need for developed (high income) countries to redress their past and current emissions, on the other, it reinforces the need for developing (low income) countries to have a strategic trade-off between economic development and environmental sustainability by exploring alternative industries that use renewable sources of energy and power. Additionally, there should be transference of knowledge and solutions from the developed to the developing countries to promote universal environmental stability and mitigate global climate change.

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Table 3. Summary of results

Figure#	Analysis	Results
1	Distribution of countries by region and income	Shows the number of countries in each region by income group of high non-OECD, high OECD, upper middle, lower middle, and low.
2	Distribution of average CO2 emissions by income	Drop in CO2 emissions for all income groups from 2008-2009.
3	Trend of median and average CO2 emissions by income	In terms of average emissions, upper middle-income countries have surpassed high income countries since 2009, while in median emissions terms, high-income countries take the lead.
4	CO2 emissions per capita and income	High income countries show the highest emissions per capita. Low-income countries show the lowest emissions per capita. There is a positive association between a country's CO2 emissions per capita and income.
5	Distribution of energy use and electricity consumption	High-income OECD countries have the highest electricity consumption. The consumption in the low- and middle-income countries has been limited. With respect to energy usage, high-income non-OECD countries exhibit the greatest energy usage, followed by high-income OECD. Lowest usage is by low-income countries. Positive association of income with electricity consumption and energy usage.
6	Distribution of forest area by region	Regions of East Asia & Pacific; Europe & Central Asia; Sub-Saharan Africa; Latin America & Caribbean show a high distribution of forest area.
7	Distribution of forest area by income	High income countries have the highest forest area followed by upper middle-income countries, and there is not much change in forest area over time. For low income countries, the % of forest area decreases over time.
8	Association between GDP per capita and Energy usage per capita	High-and middle-income countries show a positive association of GDP per capita and energy usage per capita. For low income countries, the association was not significant.
9	GDP per capita and forest area	High and middle-income countries with higher GDP per capita also have a larger forest area than low income countries.
10	GDP per capita and improved water use	For high income countries there was a positive association between GDP per capita and improved water usage. For upper middle countries, this was negative. For low income countries, the association was positive.
11	CO2 emissions & Industry value added	For high income countries the association between CO2 emissions and industry value added was negative. For low income countries, it is positive.

SCOPE AND LIMITATIONS

There are some limitations to our work here. First, our study looks at data for the 2005 to 2010-time period. Future studies can include wider time spans in their investigations and conduct detailed panel analyses that shed light on longer-term patterns and trends. Second, we did not investigate causality in the relationship between economic growth and climate change; we only analyzed the association between economic growth indicators and climate change indicators. Future studies can include explorations of causality. Third, we considered a cross-section of indicators only. Clearly, there is the potential for other intervening indicators at the country level, which may offer additional insight; and identifying these indicators may change the perspective. Also, the data we extracted from the World Bank data set is secondary in nature. The economic growth and climate change indicators are aggregated from multiple models and sources. Moreover, many of the country indicators are interrelated, so it is likely that the omission of correlated indicators has influenced our results.

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CONTRIBUTIONS

Despite limitations, our study contributes in several ways to the literature on both economic growth and climate change. We also demonstrate the potential of data-driven analytics to help make informed decisions regarding climate change. Using analytics, we offer a panoramic view of the global economic growth and climate change data, and our analysis offers insight for policy-making in climate change. The overall association between economic growth indicators and climate change indicators suggests that developed (rich) countries must make reparations for past emissions. Second, because rapid economic growth could lead to increased emissions, developed countries and aid institutions must help design and implement structured development plans to alleviate poverty while simultaneously mitigating climate change in developing countries. Third, countries with advanced and innovative technologies, such as clean air technologies (e.g., carbon capture), must facilitate the sharing and transfer of these technologies to countries that need them. Without equity, developing countries may resist prioritizing climate change.

CONCLUSION

In summary, economic growth has an adverse impact on climate change. The more developed a country in terms of high GDP or income, the higher the levels of energy usage, consumption of electricity, and CO2 emissions, and the lower the availability of natural forest area. These factors are attributed to the focus on industrialization that accompanies economic growth. We also see that level of CO2 emission has risen steadily over time and will continue to rise with economic growth if efforts at climate change mitigation are not introduced. In terms of sanitation facilities, such as access to improved water, our study shows that for high-income OECD countries there is a positive association between GDP and access to clean water. Emphasis given to green growth and the enforcement of policies encouraging economic growth and sustainable development explain this positive association. However, for upper middle-income countries, we show a negative association between GDP per capita and percentage with access to improved water. At face value, this appears to contradict the general notion that economic growth (as evidenced by high GDP) should ensure increased access to sanitation facilities, but there is a rationale for this result among middle-income countries. Due to the rapid growth in national income, especially during the 2000s, many countries have been reclassified from the category of 'lower income' to that of 'middle income' (United Nations Development Program, 2013). But in these reclassified countries, a majority of the population continues to live in below-average economic conditions, earning $1.25 to $2.00 per day (United Nations Development Program, 2013) and living without access to improved sanitation facilities. Additionally, in these countries, the sudden growth in national income widens the gap between the rich and the poor and the discrepancy in access to facilities.

Industry value added is another important indicator of economic growth that impacts climate change. Our results show an interesting trend in this regard. For developed economies, the relationship between industry value added and CO2 emissions per capita is negative, which means the greater the industry value added, the lesser the CO2 emissions. This trend is encouraging vis-a-vis climate change. However, for low-income economies, the results show that as the industry value added increases, the level of CO2 emissions per capita also increases. One explanation for this trend is the fact that high-income countries 'outsource' most of the production efforts that create CO2 emissions to low-income countries (Goldenberg, 2014). Developing, or low-income, countries, in an effort to build the economy and national

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income, undertake the manufacture of materials that often produce toxic emissions. The governments of these low-income countries need to focus efforts on promoting 'green growth' in addition to economic growth. Green growth places attention on sustainable development policies as well as economic policies. These green growth efforts have two goals: the continued economic growth needed to reduce poverty and improve wellbeing and the improved environmental management necessary to manage resource scarcity and climate change. There is a pressing global need for the promotion of green growth as a new source of progress, one that helps to advance sustainable development along with economic growth through the practicable use of natural resources, efficient use of energy and electricity, and preservation of the ecosystem. Governmental efforts in this area include carbon taxes, green energy funds, renewable energy initiatives, and natural resource management initiatives.

REFERENCES

Almer, C., & Winkler, R. (2017). Analyzing the effectiveness of international environmental policies: The case of the Kyoto Protocol. *Journal of Environmental Economics and Management*, *82*, 125–151. doi:10.1016/j.jeem.2016.11.003

Becken, S. (2013, April). A review of tourism and climate change as an evolving knowledge domain. *Tourism Management Perspectives*, *6*, 53–62. doi:10.1016/j.tmp.2012.11.006

Bohman, A., Neset, T., Opache, T., Rod, J.K. (2015). Decision support for adaptive action. assessing the potential of geographic visualization. *Journal of Environmental Planning and Management*, 58(12), 2193_2211.

Bohringer, C., & Vogt, C. (2003). Economic and environmental impacts of the Kyoto Protocol. *The Canadian Journal of Economics. Revue Canadienne d'Economique*, *36*(2), 475–494. doi:10.1111/1540-5982.t01-1-00010

Capstick, S., Whitmarsh, L., Poortinga, W., Pidgeon, N., & Upham, P. (2015). International trends in public perceptions of climate change over the past quarter century. *WIREs Climate Change*, *6*(1), 35–61. doi:10.1002/wcc.321

Cuaresma, J. C., Danylo, O., & Fritz, S., McCallum, I., Obersteiner, M., See, L., & Walsh, B. (2017). Economic Development and Forest Cover: Evidence from Satellite Data. *Scientific Reports*, *7*. doi:10.1038rep40678 PMID:28091593

Goldenberg, S. (2014, January 19). CO_2 emissions are being 'outsourced' by rich countries to rising economies. *The Guardian*. Retrieved Feb 21, 2016 from http://www.theguardian.com/environment/2014/jan/19/co2-emissions-outsourced-rich-nations-rising-economies

Granados, J. A. T., Ionides, E. L., & Carpintero, O. (2012). Climate change and the world economy: Short-run determinants of atmospheric CO_2. *Environmental Science & Policy*, *21*, 50–62. doi:10.1016/j.envsci.2012.03.008

Hallegatte, S., Fay, M., Bangalore, M., Kane, T., & Bonzanigo, L. (2015). *Shock waves: managing the impacts of climate change on poverty*. World Bank Publications. doi:10.1596/978-1-4648-0673-5

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Hansen, J., Sato, M., Ruedy, R., Kharecha, P., Lacis, A., Miller, R., ... Zhang, S. (2007). Dangerous human-made interference with climate: A GISS model E study. *Atmospheric Chemistry and Physics*, *7*(9), 2287–2312. doi:10.5194/acp-7-2287-2007

International Monetary Fund. (2008). *Climate change and the global economy*.

Iwata, H., & Okada, K. (2014). Greenhouse gas emissions and the role of the Kyoto Protocol. *Environmental Economics and Policy Studies*, *16*(4), 325–342. doi:10.100710018-012-0047-1

Markandya, A. (2011). Equity and distributional implications of climate change'. *World Development*, *39*(6), 1051–1060. doi:10.1016/j.worlddev.2010.01.005

Mattoo, A., & Subramanian, A. (2012). Equity in climate change: An analytical review. *World Development*, *40*(6), 1083–1097. doi:10.1016/j.worlddev.2011.11.007

Raghupathi, W., & Raghupathi, V. (2016). Business analytics: an overview (working paper).

Ravallion, M., Heil, M., & Jalan, J. (2000). Carbon emissions and income inequality. *Oxford Economic Papers*, *52*(4), 651–669. doi:10.1093/oep/52.4.651

Rollings-Magnusson, S., & Magnusson, R. C. (2000). The Kyoto Protocol: Implications of a flawed but important environmental policy. *Canadian Public Policy*, *26*(3), 347–359. doi:10.2307/3552405

Salter, J. D., Campbell, C., Journeay, M., & Sheppard, S. R. (2009). The digital workshop: Exploring the use of interactive and immersive visualisation tools in participatory planning. *Journal of Environmental Management*, *90*(6), 2090–2101. doi:10.1016/j.jenvman.2007.08.023 PMID:18558460

Sheppard, S. R. J. (2001). Guidance for crystal ball gazers: Developing a code of ethics for landscape visualisation. *Landscape and Urban Planning*, *54*(1-4), 183–199. doi:10.1016/S0169-2046(01)00135-9

Sheppard, S. R. J. (2012). *Visualizing Climate Change: A Guide to Visual Communication of Climate Change and Developing Local Solutions*. New York: Earthscan.

Sheppard, S. R. J., Shaw, A., Flanders, D., Burch, S., Wiek, A., Carmichael, J., ... Cohen, S. (2011). Future Visioning of Local Climate Change: A Framework for Community Engagement and Planning with Scenarios and Visualisation. *Futures*, *43*(4), 400–412. doi:10.1016/j.futures.2011.01.009

Shi, J., Visschers, V. H. M., Siegrist, M., & Arvai, J. (2016). Knowledge as a driver of public perceptions about climate change reassessed. *Nature Climate Change*, *6*(8), 759–762. doi:10.1038/nclimate2997

Soubbotina, T. (2004). The risk of global climate change. In *Beyond Economic Growth*. The World Bank.

Stern, D. I., Common, M. S., & Barbier, E. B. (1996). Economic growth and environmental degradation: The environmental Kuznets Curve and sustainable development. *World Development*, *24*(7), 1151–1160. doi:10.1016/0305-750X(96)00032-0

Stern, N. (2006). What is the economics of climate change. *World Economy*, *7*(2).

The National Academies Press (2010a). America's Climate Choices: Panel on Advancing the Science of Climate Change; Board on Atmospheric Sciences and Climate; Division on Earth and Life Studies; National Research Council. Advancing the science of climate change.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

The National Academies Press. (2010b). *America's Climate Choices: Panel on Informing Effective Decisions and Actions Related to Climate Change; Board on Atmospheric Sciences and Climate; Division on Earth and Life Studies*. National Research Council.

The National Academy of Sciences, the Royal Society. (2014). Climate change: evidence and causes.

Tol, R. S. J. (2009). The economic effects of climate change. *The Journal of Economic Perspectives*, *23*(2), 29–51. doi:10.1257/jep.23.2.29

United Nations Development Program. (2013). Challenges of the Middle-Income Countries Seoul Debates 2013. Retrieved Feb 21, 2016 from http://www.undp.org/content/dam/uspc/docs/MIC-Seoul-Report-2013.pdf

U.S. Environmental Protection Agency. (2016). Climate change indicators in the United States, fourth edition. EPA 430-R-16-004. Retrieved Feb 21, 016 from www.epa.gov/climate-indicators

Voorspools, K. R., Brouwers, E. A., & D'haeseleer, W. D. (2000). Energy content and indirect greenhouse gas emissions embedded in 'emission-free' power plants: Results for the Low Countries. *Applied Energy*, *67*(3), 307–330. doi:10.1016/S0306-2619(00)00016-7

Vougioukli, A. Z., Didaskalou, E., & Georgakellos, D. (2017). Financial Appraisal of Small Hydro-Power Considering the Cradle-to-Grave Environmental Cost: A Case from Greece. *Energies*, *10*(4), 430. doi:10.3390/en10040430

Ward, P., & Shively, G. (2012). Vulnerability, income growth and climate change. *World Development*, *40*(5), 916–927. doi:10.1016/j.worlddev.2011.11.015

White, D. D., Wutich, A., Larson, K. L., Gober, P., Lant, T., & Senneville, C. (2010). Credibility, salience, and legitimacy of boundary objects: Water managers' assessment of a simulation model in an immersive decision theater. *Science & Public Policy*, *37*(3), 219–232. doi:10.3152/030234210X497726

Winston, A., Favaloro, G., & Healy, T. (2017, January-February). Energy strategy for the C-suite. *Harvard Business Review*, *95*(1), 138–146.

Zekos, G. I. (2016). The role of competition, IPRs and labor in FDI inflows/outflows, GDP growth and industry value-added. *The IUP Journal of Knowledge Management*, *14*(2), 28–47.

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Chapter 41
The Role of Irrigation in the Development of Agriculture: Srem District (Serbia)

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ABSTRACT

The Srem district is home to producers of corn, oilseeds, sugar beet and tobacco, a leading region in the production of pome fruits (apples, pears) and drupes (plums, peaches, cherries) in the country and a perspective area for the development of organic plant and livestock production in protected areas. The current irrigation policy in the Republic of Serbia was not directed at systematic water use with the goal of forming an optimal structure of a market propulsive and a highly profitable agricultural production. The authors in the paper analyse the structure of agricultural production in the Srem district in Serbia and its market potentials as well as the economic effects of irrigation in light of the planned integral irrigation system construction in the Srem district in order to reflect economic benefits of irrigation and its role in the development of agriculture.

1. INTRODUCTION

Irrigation will remain a critical factor in ensuring the production of high quality food in sufficient quantities for a growing world population. The share of irrigated in total world food production will rise from 40% today to more than 45% by 2030 (Faurès et al., 2007). According to International Commission on Irrigation and Drainage [ICID] data for the years 2013-14, the area equipped for irrigation at the world level is about 318 million ha, while the actual irrigated area is about 300 million ha. Most of the irrigated area lies in Asia (72%) followed by America (15%), Europe (8%) and Africa (5%) (ICID, 2014).

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According to the 2010 EU Survey on agricultural production methods [SAPM] data, the irrigated area in EU-27 (excluding figures for Belgium, France, Luxembourg, Austria and Slovenia) accounts for 8.4 million ha (5% of the UAA). Almost the full amount of water used for irrigation was used in Spain (45%), Italy (31%), Greece (10.5%) and Portugal (9%), which together account for 96% of the water used for irrigation (European Commission [EC], 2012a).

In the climatic conditions, prevailing in the northwest of the Republic of Serbia irrigation is applied as a supplement to precipitation and is a favourable influence on yields stabilisation. The effect of irrigation is different by years, depending on the amount of precipitation and their distribution in the vegetation period. In favourable years this effect is lacking or is very modest, while in years with serious draught, irrigation increases the yields of agricultural plants by two or more times (Maksimović & Dragović, 2004; Pejić, Maksimović, Milić, & Rajić, 2010).

The agricultural sector is highlighted in national planning and development documents as one of the pillars of the Serbian economy. In 2014, the value of exports in the agriculture and food industries accounted for one-fifth (20.7%) of the total exports of the Serbian economy (Statistical Office of the Republic of Serbia [SORS], 2015a).

There are real opportunities for further growth in exports, especially to the Russian market, as well as to return to the markets of the Middle East, the Maghreb and the United States. Cereals and cereal preparations, vegetables and fruit, then beverages and tobacco, and sugar and sugar preparations hold the biggest share in export value.

The Srem district is a traditional producer of cereals, oilseeds, sugar beet and tobacco, the leading region of intensive fruit production in the country and promising area for the development of organic plant and livestock production in protected areas.

The irrigation policy in the previous period did not aim at systematic use of water in order to form an optimal structure of a market propulsive and highly profitable agricultural production. The entire agricultural and food value chain must be transformed and developed in accordance with the new structure of costs and yields provided by irrigated agriculture.

Agricultural policy must accompany this transformation by focusing support to intensive and stable irrigated agricultural production, adapted to market demands.

Irrigation systems in the Republic of Serbia have mainly been built on the most productive land classified into classes I and II according to suitability for irrigation, which cover over 1.36 million ha and are located mainly in the province of Vojvodina (in Srem only, it comprises nearly 50% of the soil suitable for irrigation) (Official Gazette of the Republic of Serbia [OG RS], no 11/2002).

The hydrosystem Srem is designed to irrigate 185 thousand ha with water, supplied to the main channels from the Danube, Sava and the Bosut rivers, and 15 thousand ha with water from its own catchment (31 accumulations on the Fruška gora mountain) (Official Gazette of the Autonomous Province of Vojvodina [OG APV], no 22/2011). The currently built parts of hydrosystem Srem cover only 3,254 ha of which it is in working order on 1,134 ha (Ministry of Agriculture, Trade, Forestry and Water Management of the Republic of Serbia [MATFWM], 2011).

The Ministry of Agriculture has begun activities on the project of rehabilitation and construction of new irrigation systems in 2012. Strategy of development of water infrastructure is directed towards integrated systems, which allow resolving interdependent issues of use and protection of water, including irrigation, regulation of water regime and flood protection, with respect to environmental and social demands of the surroundings. The new project of integrated irrigation system of the Srem district provides

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reconstruction of existing and construction of new irrigation systems on an area of more than 225,000ha (Belgrade Banking Academy [BBA] Consortium, 2014).

This paper presents the main results of cost-benefit analysis of irrigation on the projected area in Srem district in light of production and market opportunities of irrigated agriculture. The analysis is aimed at verifying the hypothesis that high and stable yields achieved in irrigated agriculture justify investment in optimizing the structure of production and modernization of the agricultural sector and thus contribute to the valorisation of comparative advantages of Srem county agriculture in domestic and international markets.

2. BACKGROUND

Whereas the importance of R&D investment in agriculture is widely recognised, better allocation of limited funding is essential to improve food production. In this context, the common and often large gap between actual and attainable yield is a critical target (Connor & Mínguez 2012; Sumberg 2012).

In yield gap analysis the relative importance of growth factors and inputs (including water as one of *growth-limiting* factors) is investigated to explain actual yield levels and resource-use efficiencies and to analyse differences between potential and actual yield levels to open ways for improvement (Van Ittersum & Rabbinge 1997).

The gap between potential and water limited yield is an indication of yield gap that can be removed by irrigation (Sadras et al., 2015). Irrigating rainfed areas is expected to lead to higher average yields and to higher quality of crops, essentially changing the production technology in a manner that allows more intense production (Ignaciuk, & Mason-D'Croz, 2014).

Yield responses to irrigation for major annual and perennial crops have been recently reviewed by FAO, with the aim to provide the necessary knowledge and skills for assessing the effect of water shortages on crop production; comparing the results of several water allocations plans; optimizing irrigation scheduling; enhancing management strategies to increase water productivity and water savings; and investigating the impact of climate change on crop yield (Steduto, 2012).

Climate change is altering the role of irrigation in agricultural production, particularly in the region of Southeast Europe. Projections of climate change contained in the Fifth IPCC report (2014) point to a further rise in air temperature and decrease for rainfall in these areas (Kovats et al., 2014). Deteriorative conditions for rainfed agriculture will increase water demand for irrigation (Daccache & Lamaddalena, 2010; Trnka et al., 2011; Savé et al., 2012).

Farmers are oriented towards irrigation as a self-insurance tool against drought and resulting income instability (Amigues et al., 2006; Foudi & Erdlenburch, 2011), but the availability of water for irrigation will be jeopardized by increasing demand and climate change induced decline in groundwater level (Majone, Bovolo, Bellin, Blenkinsop, & Fowler, 2012). To match water demand, irrigation system costs could increase and since the economic benefits are expected to be small, irrigation would require changes in institutional and market conditions (Finger, Hediger, & Schmid, 2011).

A strong call to recognise the importance of improving the efficiency of water and soil use in a sustainable manner by the agricultural sector was made by the G20 leaders in mid-2012. Since then, the OECD and several other international organisations have identified a set of policy recommendations to make water use in agriculture more efficient and to improve water supply infrastructure, including by increasing investments in these areas (Ignaciuk & Mason-D'Croz, 2014).

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Water use efficiency programmes in conjunction with incentive pricing policies should provide sustainable use of water in agriculture. More efficient use of water should be achieved through water metering, improving irrigation efficiency and irrigation scheduling (Poláková et al., 2013). The ability of increases of water prices to provide the right incentive for efficient use of water in irrigation is closely linked to price elasticity of water demand, which depends on: a) the initial level of efficiency in water use, b) the availability and relative cost of alternative water sources, c) the availability of alternative crops with the lowest water requirements and more efficient irrigation technology, d) the share of water charges in overall production cost for farmers, and e) the value of cultivated crops (Dworak et al., 2007).

A shift in crop production to higher value crops ensures that margins remain the same, but it is more dependent on the geographic and socio-economic situation than on water prices themselves (EC, 2012b). In general, countries will need to tailor irrigation investment more closely to the availability of land and water resources, stage of national development, share of agriculture in the national economy and comparative advantage in local, regional, and world markets. Irrigation investment needs to be more site-specific and much more closely linked with policies and plans in agriculture and other sectors (Faurès et al., 2007).

3. AGRICULTURAL PRODUCTION AND MARKETS

3.1. Land Use and Agricultural Production Structure

The Srem district is located in the north-western part of the country, in the western part of Vojvodina Province, in the Pannonian Plain, between the Fruška Gora mountain, the Danube and the Sava rivers (including the far north of the Mačva region) and includes the municipalities of Inđija, Irig, Pećinci, Ruma, Sremska Mitrovica, Stara Pazova and Šid (Figures 1 and 2).

The Srem district is inhabited by around 308.5 thousand residents (SORS, 2014), with around 58 thousand living and working on agricultural family holdings, and another 2 thousand people being employed on the agricultural holdings of legal persons and entrepreneurs (SORS, 2013a).

Agricultural land takes about 72.9% of the territory of the Srem district – from 59.9% in the wooded area of the Šid municipality to 85.2% of the Stara Pazova municipality (SORS, 2014).

According to data from the Agricultural Census from 2012 (SORS, 2013a), 28,533 out of 29,313 agricultural holdings have 229,195 ha of utilized agricultural area (UAA) at their disposal. Smaller holdings with up to 5ha are prevalent (70.6%), but they have only 12.8% of the UAA. The greatest part of the UAA (43.8%) is run by 27.1% of holding ranging from 5ha to 50ha of UAA, and almost the same amount (43.4%) is run by the 2.3% of large holdings, larger than 50ha in UAA. These agricultural holdings include a significant number of producers who are market oriented and capable of investing in agricultural production intensification and purchase of modern equipment and mechanisation, including irrigation equipment.

More than 90% of UAA is arable land, except in Irig municipality, where this percentage does not go over 80%. The arable land is mostly used for the cultivation of cereals – maize (40.6%) and wheat (25.7%), and industrial plants – soya (13.5%) and sunflower (4.1%). The municipalities of Sremska Mitrovica and Ruma are home to more than 40% of the land used to cultivate cereals in the Srem district. Soya production is concentrated in the municipalities of Šid and Sremska Mitrovica, while sunflower is most widespread in Pećinci and Inđija. More than half of the total area used for the cultivation of tobacco in

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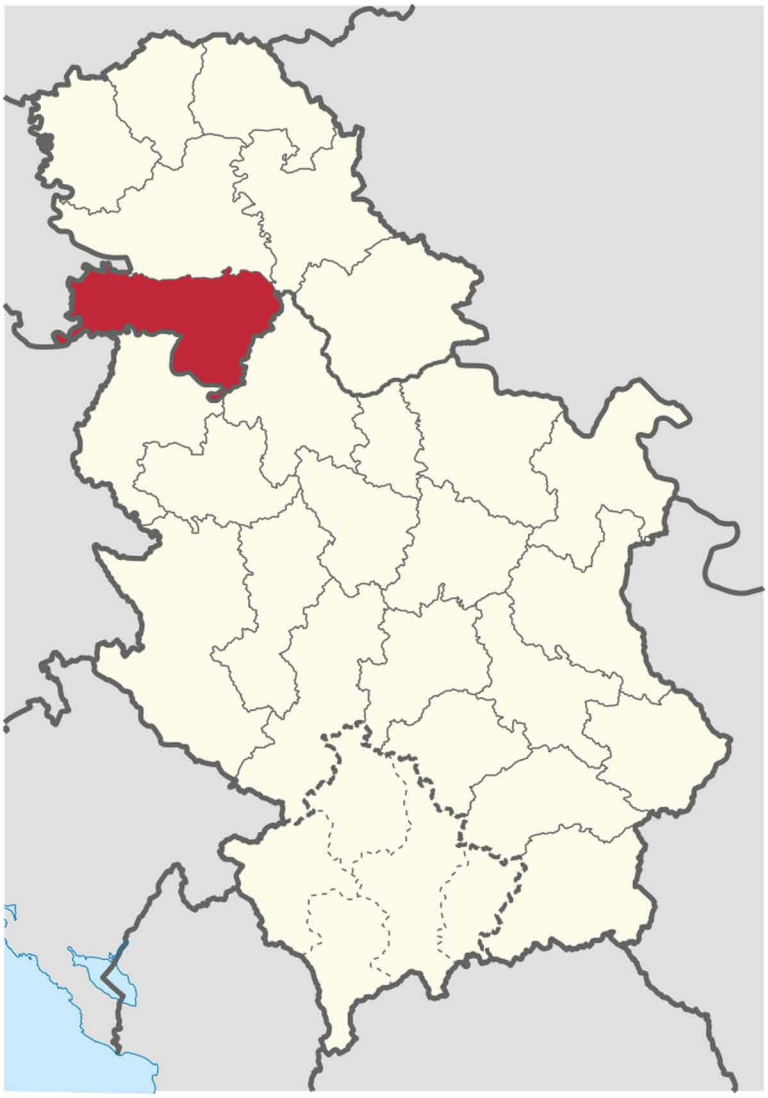
Figure 1. Srem district in the Republic of Serbia
Source: http://upload.wikimedia.org/wikipedia/



the country is situated in the Srem district, on 1.3% of the arable land, of which more than 90% is on the territories of the municipalities of Stara Pazova, Inđija, Šid and Ruma. Sugar beet is cultivated on about 5.7%, fodder crops (alfalfa, clover, silage maize) on 3%, and vegetables (mostly sweet peppers, tomato and onion), watermelons and strawberries on 1.1% of the arable land. Half of the land under sugar beet is in the municipalities of Stara Pazova and Sremska Mitrovica. The largest amounts of land under fodder crops are situated in Sremska Mitrovica and Pećinci, while vegetable production and watermelon and strawberry production are concentrated in Ruma, Pećinci and Sremska Mitrovica.

Srem district is known for modern fruit and grape plantations. Fruit plantations occupy 5,153 ha (2.2% of UAA), and most of them are those with apples, plums, peaches, cherries and pears. Inđija, Irig and Šid are the leading producers of apples, and Sremska Mitrovica and Irig are the dominant producers

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Figure 2. The municipalities of Srem district
Source: http://upload.wikimedia.org/wikipedia/

of plums. Peaches and sour cherries are mostly cultivated in Inđija and Irig, while pear cultivation is mostly located in Šid and Irig. Vineyards cover 1,172 ha (0.5% UAA). Varieties for wine with protected designation of origin take up 12% of the land under grape vines, while other grape vines use 70.5% and table grape varieties take up 17.5%. Irig, Šid and Inđija are the municipalities that host the most vineyards. Micro-spatial distribution of fruit production and introducing new technologies into the production of fruit, grapes and wines, including irrigation and the use of an integral and organic production method, following quality standards, associating and constant education of the producers, as well as strengthening family owned wineries and developing wine tourism are basic tasks for improving fruit and wine production.

The number of livestock units in relation to the used agricultural area of agricultural holdings (54 LSU/100ha UAA) is close to the national level of 59 LSU/100ha UAA. The Srem district farms 9.6% of the total number of pigs in the Republic of Serbia. Most pig farmers are situated in the Sremska Mitrovica municipality, while pig farming is also present in Ruma, Stara Pazova and Šid. Sremska Mitrovica is also where the largest number of cattle and sheep are farmed. The Šid municipality is in the second place in number of sheep, but holds the first place in poultry and beehives. Goats are mostly farmed in the municipalities of Inđija and Sremska Mitrovica. Having in mind the fodder base (fodder crops on 2.8% UAA and meadows and pastures on 3.2% of UAA) and the potential for growth in the irrigated production of corn, oilseeds and fodder crops, as well as tradition and market possibilities, livestock farming remains an underused production and export potential of Srem agriculture.

3.2. Land Use Planning and Agriculture

The existing structure of agricultural production and its spatial distribution are synchronised with the heterogeneous natural, resource and agro-ecological capacities of the area and with the infrastructural, technological and socio-economic characteristics of agriculture and local community and economy using appropriate regional development and spatial planning.

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The *Spatial Plan for the Republic of Serbia 2010-2020* (OG RS 88/2010) defines the priority directions for spatial distribution of agricultural production. Crop production is defined as the primary sector of market oriented production in the *plain area* of the Srem district, while pig and poultry farming are complementary, with fruit and vegetable farming as distinct specialisations of certain localities. The *hill area* emphasises mixed livestock production and complementary production of organic food, while smaller localities also include growing vine.

The operative goals of agriculture development, included in the *Regional Spatial Plan for the AP Vojvodina* (OG APV, 22/2011) state the following as particularly significant goals for agriculture in the Srem district: 1) increasing agricultural production that will satisfy domestic needs and create export surpluses, 2) intensifying crop production by increasing the yields and changing the sowing structure toward more market valuable crops (vegetables, industrial and fodder plants, orchards, vineyards), 3) intensifying livestock production with regard to the ecological optimum, 4) better use of natural resources, especially through irrigation, and 5) using a part of agricultural resources for multifunctional agriculture (agro-ecotourism, eco-production and production of renewable energy), with the goal of increasing economic efficiency and profitability of agriculture.

The construction and revitalisation of regional systems (Bačka, Banat and Srem) for supplying irrigation water, the technological needs of industry and other needs are among the operative goals for the development of water infrastructure in the *Regional Spatial Plan of the AP Vojvodina*.

Sustainable development of fruit, vine and vegetable farming as well as farming medicinal and honey plants with growing use of the integral and organic production method, and building eco-farms with organic plant and animal production are the basic directions for agriculture development on the special purpose area of the Fruška Gora mountain (parts of the municipalities of Irig, Inđija, Šid, Sremska Mitrovica and Ruma), according to the decisions stated in the *Master Plan for Sustainable Development on Fruška Gora mountain 2012-2022* (The Assembly of AP Vojvodina, 2011).

The Mačva part of the municipality of Sremska Mitrovica is home to the largest part of the Special Nature Reserve "Zasavica". The Special Nature Reserve "Obedska Bara" and its protected zone are part of the municipalities of Pećinci and Ruma. These areas are also equipped with favourable agro-ecological conditions for the development of low-intensity production of vegetables and medicinal and aromatic herbs and flowers, especially in greenhouses with the use of thermal waters.

In the surroundings of the city centres, there is developed intensive, periurban agriculture. According to the *Spatial Plan for the Republic of Serbia (2010-2020)*, the functional urban area (FUP) Belgrade (the category Metropolitan Growth Area – MEGA) includes the following municipalities of the Srem district: Stara Pazova, Pećinci, Ruma, and Inđija, while the FUP Novi Sad includes the municipalities of Irig and Inđija. The location of the mentioned municipalities within the belt of the highest-intensity development in the country has numerous advantages for agricultural production and sale of agricultural products, related to traffic accessibility, the absorptive capability of the market in big cities, availability of input and services from scientific research organisations and advisory services, as well as the proximity of processing capacities and exporters.

3.3. Exports of Agricultural Products

In 2014, agriculture and food industry (divisions 00-09, 11, 12, 21, 22, 29, 41-43 SITC, Rev. 4) have realised an export in the value of 3.068 bln USD (20.7% of total export), while import was 1.729 bln USD (8.4% of total import). The biggest export value was made in the divisions: 04 Cereals and cereal

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preparations, 05 Vegetables and fruit, 11 Beverages, 12 Tobacco and tobacco manufactures, 06 Sugars, sugar preparations, and honey (SORS, 2015a).

More than 95% (95.9%) of export of agriculture and food industry was realised on the markets of the EU-28, CEFTA, the Russian Federation, Belarus and Kazakhstan – members of the Eurasian Customs Union, EFTA, Turkey and USA, with which the Republic of Serbia has signed free trade agreements, i.e. use the general system of preferences approved by the USA (SORS, 2015b).

The market of the EU-28 receives almost half of all exported agricultural and food products (49.1% in 2014), most cereals (maize, mercantile), fruit (raspberries and sour cherries, frozen), sugars and vegetable fats and oils. Export to the CEFTA countries in 2014 made 33.4% of agriculture and food industry export. The CEFTA countries usually import cereals and cereal preparations and beverages from Serbia. Most of the exported beverages, live animals, dairy products, fish and preparations, and tees and spices go to the markets of these countries. The export to the Russian Federation in 2014 was 10.2% of the total export of agricultural and food products from Serbia. Russia mostly imports fruit and vegetables, meat and preparations and dairy products from Serbia (Table 1).

In 2014 Russia was the biggest importer of Serbian apples, plums, peaches and nectarines, cherries and sour cherries, strawberries, pears and quinces (fresh), fresh grapes and wine, then early season potatoes and cabbage and similar edible vegetables, fresh, and beans and string beans and other vegetables and mixtures of vegetables, frozen. In 2014, Russia imported 96% of the Serbian export of meat of swine, frozen and 93% of export of fresh cheese (SORS, 2015b).

Rising world food prices, trade liberalisation with the EU, CEFTA and the Russian Federation and the efforts to reform the sector and improve competitiveness have led to a growth in export of the Serbian agriculture during the past decade. There is still room for further development (particularly on the Russian market, which is especially important for the agriculture of the Srem district) as well as for the return to the markets of the Middle East, Maghreb and USA.

4. EFFECTS OF IRRIGATION ON YIELDS AND FARM INCOME

4.1. Yields and Irrigation

The central part of the Srem loess plateau which covers the southern slopes of Fruška Gora and stretches to the loess terrace in southern Srem (dominantly covered with chernozem typical, carbonate) and the lower, Srem loess terrace (covered in dry and marsh loess, with predominant chernozem of lesser productivity and a higher level of groundwater), represent the area of intensive crop and livestock production. The production of fodder plants and livestock fall behind the resource and market potentials and the agro-ecological demands of preserving the soil fertility.

The farms of the Srem district achieve above-average yields of cereals, fodder crops and fruits and grapes, compared to the national level, but the yields and quality of field crops, vegetables, fruits and grapes in rainfed production have strong yearly oscillations, both at the level of the Srem district, and on the national level, mostly due to more frequent and longer draught periods. Unstable yields in the production of fodder crops discourage farmers to engage in livestock production (Table 2).

The climate of this region is a temperate continental with warm summers and harsh winters. The average annual precipitation is around 680mm (in the western part of the district and on Fruška Gora up to 780mm, and in the eastern and plain areas 580-650mm). Irrigation in these climate conditions has

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Table 1. Exports and imports of agricultural and food products in 2014, by divisions of SITC, Rev. 4

	Total	EU-28			CEFTA			Russian Federation		
	USD '000	USD '000	Share in total imports (%)	Share in imports of divis. (%)	USD '000	Share in total imports (%)	Share in imports of divis. (%)	USD '000	Share in total imports (%)	Share in imports of divis. (%)
00Live animals other than animals of div. 03	39198.5	308.5	0.0	0.8	38195.8	3.7	97.4	3.3	0.0	0.0
01Meat and meat prep.	147341.9	4829.2	0.3	3.3	65903.0	6.4	44.7	67938.2	21.8	46.1
02Dairy products and birds' eggs	107503.5	16158.2	1.1	15.0	58840.1	5.7	54.7	30700.5	9.8	28.6
03Fish(not marine mammals),crustaceans, molluscs and aquatic invertebrates; preparations thereof	7147.3	2164.0	0.1	30.3	4803.2	0.5	67.2	19.5	0.0	0.3
04Cereals and cereal preparations	787023.2	490643.6	32.6	62.3	271373.5	26.5	34.5	10787.7	3.5	1.4
05Vegetables and fruit	747676.6	457523.5	30.4	61.2	57378.2	5.6	7.7	173658.4	55.6	23.2
06-Sugar, sugar preparations and honey	161202.0	100380.4	6.7	62.3	57890.4	5.6	35.9	377.7	0.1	0.2
07Coffee, tea, cocoa, spices, and manufactures thereof	87080.4	19983.0	1.3	22.9	62773.8	6.1	72.1	532.0	0.2	0.6
08 Feeding stuff for animals (not including unmilled cereals)	135953.9	70988.7	4.7	52.2	56435.1	5.5	41.5	3587.9	1.1	2.6
09 Miscellaneous edible products and preparations	146602.7	52597.0	3.5	35.9	69798.4	6.8	47.6	7334.1	2.4	5.0
11 Beverages	222596.3	50312.9	3.3	22.6	157101.4	15.3	70.6	7978.2	2.6	3.6
12 Tobacco and tobacco manufactures	175704.2	58268.5	3.9	33.2	25457.8	2.5	14.5	18.0	0.0	0.0
21 Hides, skins and furskins, raw	44050.5	30652.1	2.0	69.6	10399.2	1.0	23.6	0.0	0.0	0.0
22 Oil-seeds and oleaginous fruits	66411.4	37736.4	2.5	56.8	20978.2	2.0	31.6	3284.0	1.1	4.9
29 Crude animal and vegetable materials, n.e.s.	41579.2	20761.6	1.4	49.9	10233.1	1.0	24.6	4439.5	1.4	10.7
41 Animal oils and fats	5687.3	3092.3	0.2	54.4	1058.8	0.1	18.6	1424.3	0.5	25.0
42 Fixed vegetable fats and oils, crude, refined or fractionated	139182.8	84833.4	5.6	61.0	54151.5	5.3	38.9	0.0	0.0	0.0
43 Animal or vegetable fats and oils, processed; waxes, n.e.s.	6083.4	4118.5	0.3	67.7	1964.2	0.2	32.3	0.0	0.0	0.0
TOTAL	**3068025.1**	**1505351.8**	**100.0**	**49.1**	**1024735.7**	**100.0**	**33.4**	**312083.3**	**100.0**	**10.2**

Source: SORS, 2015b. External Trade of Serbia. Database.

a supplementary character, i.e. it is an addition to natural precipitation and it positively influences the increase and stabilization of yield of the grown plants, especially in draught years.

Climatic changes could significantly change the role of irrigation in this area. The yearly temperature trend of 1951-2012 indicates a rise in temperature on the whole territory of the Republic of Serbia (Serbian

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Table 2. Yields in crop production, 2009-2013

	Srem district					Republic of Serbia				
	2009	**2010**	**2011**	**2012**	**2013**	**2009**	**2010**	**2011**	**2012**	**2013**
Wheat, *kg/ha* *Family holdings* *Legal entities and coop.*	3,858 5,298	3,465 4,333	4,189 6,117	4,163 6,013	5,313 6,542	3,423 4,565	3,184 4,202	3,943 5,652	3,719 5,303	4,552 6,028
Maize, *kg/ha* *Family holdings* *Legal entities and coop.*	5,683 7,476	6,001 7,729	5,394 7,943	2,341 3,097	5,374 6,210	5,148 6,879	5,723 7,494	4,948 7,399	2,697 3,735	4,832 6,182
Sunflower, *kg/ha*	2,495	2,236	2,536	1,912	2,704	2,400	2,234	2,479	2,193	2,725
Sugar beet, *kg/ha*	46,552	50,729	51,032	31,224	48,559	45,564	50,038	50,729	35,949	47,800
Clover, *kg/ha*	7,990	6,767	6,093	4,465	6,934	4,507	4,536	4,020	3,163	3,758
Alfalfa, *kg/ha*	6,504	6,874	6,049	4,168	5,870	5,862	5,837	5,320	4,032	4,963
Apples, *kg/tree,*	19.3	17.9	19.3	10.8	18.6	18.1	15.1	16.6	10.6	18.2
Plums, *kg/tree,*	17.1	11.0	14.1	8.3	23.2	15.9	10.4	14.3	9.7	18.7
Grapes, *kg/tree*	1.9	1.3	1.7	1.3	1.8	1.5	1.1	1.2	1.0	1.3

Source: SORS (2010). Municipalities of Serbia; SORS. (2011-2014). Municipalities and regions of the RS.

Environmental Protection Agency [SEPA], 2013). Uneven and insufficient precipitation threatens the achievement of high and stable agricultural yields. Precipitation deficit accompanied by high temperatures and heat waves have resulted in an increase in the frequency and intensity of droughts (Popović & Ugrenović, 2015). Investing in new irrigation systems is one of the climate change adaptation measures, which must take an important place in the national and regional adaptation action plans and/or sectoral adaptation plans for agriculture (Popović & Mijajlović, 2013).

In the Srem district in the season of 2011/2012, 3,655ha of land was irrigated, i.e. 1.6% of UAA, which is less than the Republic level (2.9%) and the autonomous province level (3.6%). The structure of the irrigated areas consists mostly of arable land – 2,484ha (vegetables, watermelons and strawberries in the open, cereals and silage corn, sugar beet), but the participation of irrigated land in the total area of this UAA category is rather small and has the percentage of 1.2% (3.6% at the AP Vojvodina level, and 3.4% at the Republic level). Attention is directed at orchards, which cover 1,152ha, although the participation of irrigated land in the total orchard areas is smaller than on the province level and is 22.4%, compared to 29.9% in the APV (on the national level, this percentage is far lower at 8.2%). The application of irrigation in vineyards, meadows and other permanent crops is not widespread (Table 3).

Thanks to a high level of fruit plantations in the irrigated areas, the Srem district has a favourable structure for irrigation in the sense of used irrigation methods. The most effective irrigation method from the aspect of water saving, drip irrigation, mostly used in fruit plantations, increasingly in vegetable farming and showing good results in tobacco production, is used on 44.3% of the irrigated area, sprinkler systems on 18.3%, and least effective, surface method is used on 37.4% of the irrigated area. In regard to source of irrigation water, the situation is less favourable. Groundwater (wells) on the holding are used to a high degree (49.0%), followed by surface waters from outside the holding (33.8%) (SORS, 2013a).

The Republic of Serbia, according to the value of the Water Exploitation Index lies in the zone without of water stress, with the value of this index being in the interval between 11% and 20%, which gives it certain comparative advantages in world trade in virtual water compared to the countries with severe

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Table 3. Irrigated land by categories of use in agricultural year 2011/2012

	Utilized agricultural area, ha	Of which irrigated area											
		Utilised agricultural area		Arable land		Fruit plantations Orchards		Vineyards		Permanent grassland		Other permanent crops	
		ha	% of UAA	ha	% of arable land	ha	% of fruit plantations	ha	% of vine yards	ha	% of permanent grass land	ha	% of other perm. crops
Srem district	*229,195*	*3,655*	*1.6*	*2,484*	*1.2*	*1,152*	*22.4*	*11*	*0.9*	*3*	*0.0*	*5*	*11.4*
Inđija	30,343	138	0.5	76	0.3	55	4.4	5	2.1	-	-	3	42.9
Irig	11,242	352	3.1	33	0.4	316	25.6	3	1.3	-	-	-	-
Pećinci	24,938	378	1.5	242	1.0	135	55.3	1	16.7	-	-	-	-
Ruma	41,336	1,108	2.7	968	2.4	136	27.2	0	0.0	2	0.4	1	3.7
Sremska Mitrovica	54,443	941	1.7	892	1.8	48	6.5	2	3.6	0	0.0	-	-
Stara Pazova	30,287	231	0.8	190	0.6	40	27.0	1	1.3	-	-	-	-
Šid	36,608	507	1.4	83	0.2	422	40.7	0	0.0	-	-	2	33.3
AP Vojvodina	*1,608,896*	*58,251*	*3.6*	*52,907*	*3.6*	*5,050*	*29.9*	*89*	*1.8*	*22*	*0.0*	*183*	*39.1*
Republic of Serbia	*3,437,423*	*99,773*	*2.9*	*84,858*	*3.4*	*13,344*	*8.2*	*215*	*1.0*	*602*	*0.1*	*754*	*41.0*

Source: SORS. (2013a). Census of Agriculture 2012 Database.

water stress (SEPA, 2013; Petković, 2003). This does not mean that the situation will not change with the development of irrigation. According to research from the Institute for Soil, Belgrade, for the needs of irrigation, including the limited use of water from Danube, it is possible to provide around 400m^3/s of water, which would cover around 450 thousand ha. In order to irrigate areas up to 800 thousand ha, it is necessary to acquire compliance from other countries in the basins of Danube, Sava and Tisa (Božić, 2012).

Ensuring sufficient amounts of water of satisfying quality is turning into a limiting factor for the development of agriculture in the conditions of climate change (Popović, Nikolić & Katić, 2011). That is why it is already now necessary to consider the matters of economic efficiency of irrigation and water productivity, including the water price policy, when rehabilitating and constructing irrigation systems.

4.2. Economic Effects of Irrigation

Average actual yields of rainfed crops in the Srem district are at a satisfying level, if compared to the national average. However, these yields are far below the yield potential of the observed plant species. As already indicated above, the gap between potential and water limited yield is an indication of a yield gap that can be removed with irrigation.

Yield growth in irrigated production is especially visible in sugar beet, potato, clover, carrot, beans, alfalfa and cauliflower. Irrigation is an indispensable agro-technical measure on modern fruit and vine plantations, which are one of the pillars of export of agriculture in the Srem district.

The expected yield growth and the economic effects of irrigation in plant production in the Srem district are presented in Table 4, which shows the calculated average yield, revenue, costs and the net effect (the difference between the income realised in rainfed and irrigation production,) per hectare, for certain plant products.

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Table 4. Economic effects of irrigation in crop production

	Rainfed production			Irrigated production			Net result (000 RSD[3] /ha)
	Yield[1], t/ha	Revenue[2] (000 RSD[3]/ha	Costs[4] (000 RSD[3]/ha	Yield[1], t/ha	Revenue[2] (000 RSD[3]/ha)	Costs [4] (000 RSD[3]/ha)	
	1	2	3	4	5	6	7=[(5-6)-(2-3)]
Cereals							
Wheat	4.8	105.6	68.6	5.5	121.2	63.0	21.2
Grain maize	5.8	104.4	67.9	10.0	180.0	86.4	57.1
Seed production							
Seed maize	-	-	-	3.6	835.0	267.2	567.8
Seed sugar beet	-	-	-	2.7	791.1	134.5	656.6
Seed sunflower	-	-	-	1.8	307.8	95.4	212.4
Pulses							
Peas for dry grain	5.0	135.0	78.3	8.1	218.7	83.1	78.9
Beans	1.2	120.0	69.6	3.2	315.0	119.7	144.9
Potatoes	9.9	147.9	99.1	27.0	405.0	182.3	173.9
Sugar beet	45.6	223.4	167.6	67.5	3,300.8	2,178.5	1,066.4
Industrial crops							
Tobacco	2.5	1,500.0	975.0	3.6	2,160.0	1,252.8	382.2
Oilseed rape	2.0	58.0	18.6	3.2	91.4	14.6	37.3
Sunflower	2.3	80.5	28.2	3.2	110.3	27.6	30.4
Soya	2.8	109.2	41.5	4.3	168.5	42.1	58.7
Vegetables							
Tomato	30.0	450.0	216.0	67.5	1,012.5	374.6	403.9
Cabbage and kale	25.0	362.5	239.3	54.0	783.0	391.5	268.3
Peppers	15.0	300.0	198.0	27.0	540.0	270.0	168.0
Cauliflower	10.0	170.0	112.2	22.5	382.5	191.3	133.5
Carrots	15.0	450.0	247.5	40.5	1,215.0	425.3	587.3
Peas, green	6.4	224.0	129.9	9.0	315.0	119.7	101.2
Fodder crops							
Maize for silage	28.0	126.0	71.8	40.5	182.3	69.3	58.8
Clover	6.2	74.2	53.4	15.8	189.0	96.4	71.8
Alfalfa	6.0	90.6	58.0	15.3	229.5	103.3	93.6
Successive crops							
Sweetcorn	-	-	-	13.5	189.0	54.8	134.2
String beans	-	-	-	10.8	432.0	129.6	302.4
Fruit and grapes							
Apples	38.4	960.0	504.0	63.4	2,029.0	1,103.8	469.2
Pears	30.0	1,050.0	636.3	54.1	2,272.4	1,424.8	433.9
Peaches	22.0	1,100.0	700.7	40.5	2,308.7	1,521.4	388.0
Sour cherries	15.0	900.0	500.4	25.5	1,619.4	931.2	288.6
Grapes	9.1	318.5	207.0	20.0	1,000.0	670.0	218.5

Notes: 1) The average five-year yields in crop production (rainfed and irrigated) of Srem district in 2008-2012; 2) Average producer price of selected (rainfed and irrigated) crops for the 2008-2012 period; 3) The exchange rate 1 EUR = 115.00 RSD; 4) Variable costs of production, including variable irrigation costs (cost of fuel, and water charges according to Regulation on Fees for water in 2014 (OG RS, no 15/2014).

Source: Authors' calculations based on data from SORS (2013a), Agricultural marketing information system of Serbia [STIPS] database (http://www.stips.minpolj.gov.rs/), and field survey data.

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The best net effect from irrigation can be expected in the production of the following crops: sugar beet (income growth of about 20.1 times), potato and clover (about 4.5 times), carrot, beans and alfalfa (about 3.9 times), cabbage and kale and cauliflower (3.2 and 3.3 times, respectively), grape (3.0 times), tomato and peppers and peas for dry grain (2.7 and 2.4 times, respectively). The producers of silage maize (income growth of 2.9 times), peas (2.8 times) as well as apples, pears and peaches (2.0 times increase) would also benefit significantly from applying irrigation in their production process.

Investment decisions must be based on strict quantitative and qualitative performance measurement, which will ensure investing in the best (most efficient) project variants (Subić, 2010). A high level of investing in irrigated agriculture, especially in fruit production, must be justified with higher yields, revenues and net effects, with reducing and controlling all production risks, considering that the expectations of the producers are aimed at a reasonable payback period and an acceptable rate of return on investment.

Using modern irrigation systems in fruit production refer to a modern date plantation based on fruit-growing technology which includes closer planting, market attractive assortment of fruit varieties and the use of integral production method. Intensive production ensures a better yield with a fruit of better qualitative characteristics, and thus enables contracting production and successful sales on the growingly demanding national and international markets. This fruit production technology, however, requires significantly higher investment, considering that it entails the use of multipurpose irrigation system, with functions of fertirrigation, classic irrigation, anti-frost protection etc., as well as anti-hail protection, the use of special mechanisation and equipment and the construction of cold storages and outbuildings.

According to calculations contained in *The Feasibility Study for Regional Irrigation System of the Srem Region* (BBA Consortium, 2014), it is expected that the use of irrigation system in the Srem district will generate annual net-effects of, on average, 751 EUR/ha in arable crop production (the income would almost triple in comparison to rainfed production), 1,113 EUR/ha in vegetables (the income would increase 1.8 times) and 3,323 EUR/ha in production of fruit and grapes (the income would double) (Table 5).

The total net-effect of the Project is expected to reach 194.1 million EUR at the annual level, which would enable generation of additional profit to farmers of 113.1 million EUR. The expected rate of profit is 9.3%. The projected price of water, based on full-cost recovery principle (operating and capital costs of irrigation) amounts to 0.1297€/m^3 on the user's level, but, regarding the growth of income in irrigated agriculture, it should create high interest among farmers to use the irrigation system services (Table 6).

In terms of sources of the project finance, it is assumed that donations (primarily from EU funds) will account 58.6% of total investment (70% of primary irrigation infrastructure costs and 10% of watering equipment costs), 20% will be provided from loans (20% of primary irrigation infrastructure costs and 20% of watering equipment costs), and 21.4% from own resources (10% of primary irrigation infrastructure costs by investors – irrigation service provider, and 70% of watering equipment costs by users of the irrigation service) (BBA Consortium, 2014).

Table 5. Total effects of the new irrigation system by crop group, in EUR/ha

	Rain-fed agriculture			Irrigation agriculture			Net-effects		
	Revenues	**Expenses**	**Income**	**Revenues**	**Expenses**	**Income**	**Revenues**	**Expenses**	**Income**
Arable crops	1,054	653	400	2,233	1,081	1,152	1,179	428	751
Vegetable	2,410	943	1,467	3,724	1,145	2,579	1,314	202	1,113
Fruit and grapes	7,066	4,066	3,000	15,706	9,383	6,322	8,640	5,317	3,323

Source: BBA Consortium, 2014.

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Table 6. Net effects of project investments and expected rate of profit on service users' level

	Unit of Measure	Amount	EUR/Unit of Measure	EUR
Net-effects of irrigated agriculture	Land (ha)	225,129	862	194,097,148
Irrigation costs	Water (m^3)	624	0.1297	80,950,427
Profit				113,146,721
Total investment				1,222,019,500
Profit/Investment				9.3%
Net-effects/Irrigation costs				239.8%

Source: BBA Consortium, (2014).

The current structure of water charges in the irrigation sector in Serbia, defined by the Law on Waters (OG RS, 30/2010; 93/2012) is complex due to the presence of various irrigation systems of different complexity, but also the intention to ensure the highest possible level of cost recovery. Unfortunately, the existing water tariff levels do not even provide coverage of operation and maintenance costs (Popović & Ugrenović, 2015).

According to calculations of variable costs in irrigated agriculture on selected production lines on the territory of Vojvodina in production of *vegetables* average irrigation costs (fuel and water charges) make for 4.97% of variable costs, where water charges make for 11.15% of irrigation costs; in production of *field crops* 7.37%, with participation of water charges in irrigation costs of 21.85%; and in fruit production 1.00%, with participation of water charges in irrigation costs of 8.54% (Cvijanović, Subić, Popović, Ugrenović, & Jeločnik, 2014).

At their current level, water charges cannot represent the right incentive for efficient use of water in irrigation. The application of the EU Water Framework Directive full-cost recovery principle (Directive 2000/60/EC, Art. 9), which includes a resource and an ecological component besides the financial one, requires significant and well-timed production, market and institutional changes, in order to ensure a level of profitability that enable farmers to use the irrigation system service.

The harmonization with WFD requirements in the policy of water prices will contribute to improving the service quality in the water sector, increasing efficiency in water use and protecting water resources and ecosystems, but this will happen gradually, over a longer transitional period. Until then, the role of the state in financing the rehabilitation and construction of new irrigation systems and subsidizing the cost of irrigation in Serbia remain significant (Cvijanović et al., 2014).

SOLUTIONS AND RECOMMENDATIONS

Bearing in mind underdeveloped irrigation infrastructure and related institutional capacities in the country, there is a clear need for significant investment into irrigation modernisation, which would contribute to the agricultural growth and competitiveness on the international market.

The existing water tariff levels do not even provide coverage of operation and maintenance costs. Capital investments in the revitalization and development of the irrigation infrastructure, including hydrosystem water facilities are financed from budget revenues and foreign credits. Along with the

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construction and upgrading of irrigation systems, it is necessary to make the appropriate legal and institutional changes that will ensure the existing and newly-built irrigation systems an adequate funding, management and advisory services.

The stated results of cost-benefit analysis of the planned irrigation system in the Srem district are based on modified production structure. The optimization of production structure in irrigated agriculture is necessary and should be directed towards increasing area under industrial plants and seeds at the expense of area under cereals, intensifying the production of vegetables and fodder crops, especially in the form of intercropping and further increasing area under fruit plantations, in parallel with the land protection against degradation.

The agricultural advisory and expert service as well as the associations of farmers and water users should play an important role in diffusion and implementation of advanced knowledge and skills in irrigated agriculture.

FUTURE RESEARCH DIRECTIONS

Innovation is one of the key motors for economic and social development of society, and therefore of agriculture as its integral part. Innovation in irrigation systems, which raises resource use efficiency and profitability of agricultural production, promotes organic food production and use of renewable energy, is attracting increasing attention of scientists and society. That refers particularly to research connected to the use of solar panels in irrigation systems in the cultivation of vegetables, cereals, industrial and fodder plants, fruit and forests. Solar water pumping has been found to be economically viable in comparison to electricity or diesel based systems for irrigation and water supplies in rural, urban and remote regions. The investment payback for some photovoltaic water pumping systems has been found to be 4–6 years (Chandel, Naik, & Chandel, 2015).

Another potential solution for efficient use of irrigation in agriculture is the innovative method of subsurface capillary irrigation, where the basic principle is to deliver the water to the root system of the plant through specially designed water transmitters, built in beneath the soil tillage depth. There are three main characteristics that separate this system from all other existing irrigation systems: 1) functionality at extremely low pressure (in terms of energy efficiency, it stands out as the most efficient, as no other irrigation system will work at the low pressure of only 0.2 baryes), 2) the possibility of long-term exploitation of the system (it is characterised by the impossibility of water transmitter clogging, which is a prerequisite for system longevity) and 3) self-regulation in plant watering (no other irrigation system has this option). According to preliminary research, this system is suitable for use in vegetable crops production, in a greenhouse and in open field, and in the continuing research; it is expected to become further developed for use in fruit, and later in field crop production (Zloh, 2013; Zloh et al, 2013).

More efficient use of water should be achieved through *improving irrigation efficiency and irrigation scheduling*. The automated determination of irrigation norms and irrigation time based on high precision satellite data such as the ENORASIS system integrates a range of advanced technologies, methodologies and models in the fields of: 1) weather prediction systems that exploit satellite observations; 2) irrigation optimization techniques; 3) smart card irrigation or other systems in order to arrive at a solution that will be easy to use for farmers and that will be flexible and robust enough for use by irrigation water providers; 4) wireless sensor networks (functioning with solar energy) as key enabling

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technology for field measurements and monitoring conditions, all with the aim of motivating farmers towards optimizing the use of irrigation water (ENORASIS Consortium, 2012).

As it is mentioned earlier, the role of the state in financing the rehabilitation and construction of new irrigation in Serbia is of key significance for irrigatated agriculture development. In addition to budget resources, the government relies on foreign loans and EU funds to finance irrigation development.

According to the *Loan Agreement between the Government of the Republic of Serbia and Abu Dhabi Fund for Development to finance Development of Irrigated Agriculture – Phase I* (Official Gazette of the Republic of Serbia - International Agreements [OG RS - IA], no. 5/2014), line ministry may withdraw funds in the amount of 356,281,000 dirhams (97 million dollars) by the end of 2017 to finance the construction and revitalization of irrigation systems in 13 locations, mainly in Vojvodina Province (Banat and Bačka regions), with total area of 24,000 ha. The project comprises civil construction works (pumping stations buildings, canal excavation and canal lining), hydro-mechanical and electrical equipments and installation and irrigation equipments.

During 2015, it is expected calls for proposals in the framework of continuing EU Instrument for Pre-Accession Assistance [IPA] cross-border programmes [CBC] - IPA 2, for which there are prepared proposals aimed at addressing the acute problems in the field of water management. In cooperation with partners from Hungary, two strategic projects are prepared and submitted for co-financing with EU grants (*Reconstruction Planning of Baja Bezdan Canal* project and *Water supply and infrastructure development in the catchment area of the Tisza and the border severed watercourses – WASIDCA project*, that include irrigation network development) (PWMC "Vode Vojvodine", 2015).

CONCLUSION

The Srem district is a traditional producer of cereals, oilseeds, sugar beet and tobacco, the leading region of intensive fruit production in the country and promising area for the development of organic plant and livestock production in protected areas.

The central part of the Srem loess plateau, dominantly covered with chernozem typical, carbonate, and the lower, Srem loess terrace, covered in dry and marsh loess, with predominant chernozem of lesser productivity and a higher level of groundwater, represent the area of intensive crop and livestock production. The greatest part of 229,195 ha of utilized agricultural area (43.8%) is run by 27.1% of holding ranging from 5ha to 50ha of UAA, and almost the same amount (43.4%) is run by the 2.3% of large holdings, larger than 50ha in UAA. These agricultural holdings include a significant number of producers who are market oriented and capable of investing in agricultural production intensification and purchase of modern equipment and mechanisation, including irrigation equipment.

Rising world food prices, trade liberalisation with the EU, CEFTA and the Russian Federation and the efforts to reform the agricultural sector and improve competitiveness have led to a growth in export of the Serbian agriculture during the past decade. There is still room for further development, particularly on the Russian market, which is especially important for the agriculture of the Srem district (export of fresh pome fruits, drupes and strawberries, fresh grapes and wine, vegetables fresh and frozen, frozen swine meat and fresh cheese). The proximity of large metropolitan markets of Belgrade and Novi Sad is another advantage for Srem agriculture.

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The availability and quality of agricultural resources and the market potentials are good reasons for investments in improving the agricultural production of the Srem district. The farms here achieve above-average yields of cereals, fodder crops and fruits and grapes, compared to the national level, but the yields and quality of field crops, vegetables, fruits and grapes in rainfed production have strong yearly oscillations, both in the Srem district and on the national level, mostly due to more frequent and longer draught periods.

Irrigation is a precondition for ensuring high and stable yields in crop production, which would justify investment in high-quality inputs and modern storage and processing capacities. However, in the season of 2011/2012, only 3,655ha of land was irrigated, i.e. 1.6% of UAA. The new project of integrated irrigation system of the Srem district should provide irrigation on an area of more than 225,000 hectares.

A high level of investing in irrigated agriculture, especially in fruit production, must be justified with higher yields, revenues and net effects, with reducing and controlling all production risks, considering that the expectations of the producers are aimed at a reasonable payback period and an acceptable rate of return on investment. According to calculations, the total net-effect of the Project as well as the projected price of water should create high interest among farmers to use the irrigation system services.

The basic premise of the above results is optimized production structure, adjusted to irrigation agriculture (increased area under industrial plants and seeds at the expense of area under cereals, intensifying the production of vegetables and fodder crops, especially in the form of intercropping, further growth in area under fruit plantations), along with the application of new technologies and production practices in the production of fruit, grapes and wine. The potential for growth in the irrigated production of maize, oilseeds and fodder crops, tradition and market possibilities underline the necessity of livestock production improvement.

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REFERENCES

Amigues, J. P., Debaeke, P., Itier, B., Lemaire, G., Seguin, B., Tardieu, F., & Thomas, A. (Eds.). (2006). Sécheresse et agriculture. Réduire la vulnérabilité de l'agriculture à un risque accru de manque d'eau. Expertise scientifique collective. Rapport: INRA (France).

Belgrade Banking Academy Consortium. (2014). *Feasibility study for regional irrigation system of Srem region*. Belgrade: Belgrade Banking Academy Consortium.

Božić, M. (2012, September 25). *The expansion of irrigation passed over Serbia. Politika online*. Retrieved January 16, 2014 from http://www.politika.rs/rubrike/Sta-da-se-radi/Ekspanzija-navodnjavanja-mimoisla-Srbiju.sr.html

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Chandel, S. S., Naik, N. M., & Chandel, R. (2015). Review of solar photovoltaic water pumping system technology for irrigation and community drinking water supplies. *Renewable & Sustainable Energy Reviews*, *49*(September), 1084–1099. doi:10.1016/j.rser.2015.04.083

Connor, D. J., & Mínguez, M. I. (2012). Evolution not revolution of farming systems will best feed and green the world. *Global Food Security*, *1*(2), 106–113. doi:10.1016/j.gfs.2012.10.004

Cvijanović, D., Subić, J., Popović, V., Ugrenović, V., & Jeločnik, M. (2014). *Analysis of the state of irrigation and possibilities of application of ENORASIS irrigation project's results and platform in the territory of Vojvodina and the Republic of Serbia. FP7-ENV Collaborative Project: ENORASIS WP 6: Implementation of the pilot and further improvements. Belgrade: PWMC "Vojvodina Waters"*. Belgrade: Novi Sad and Institute of Agricultural Economics.

Daccache, A., & Lamaddalena, N. (2010). Climate change impacts on pressurised irrigation systems. *Proceedings of the Institution of Civil Engineers-Engineering Sustainability*, *163*(2), 97–105. doi:10.1680/ensu.2010.163.2.97

Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for Community action in the field of water policy, OJ L327, 22.12.2000 (2000)

Dworak, T., Berlund, M., Laaswer, C., Strosser, P., Roussard, J., Grandmougin, B., . . . Montesinos, P. (2007). EU water saving potential. European Commission.

ENORASIS Consortium. (2012). *D2.2: ENORASIS business models*. FP7-ENV Collaborative Project: International Environment and Quality Services North Greece Ltd. Retrieved 14 August, 2015 from http://www.enorasis.eu/uploads/files/ENORASIS_Deliverable_2.2_v1.pdf

European Commission. (2012a). *Rural Development in the European Union*. Statistical and Economic Information Report 2012.

European Commission. (2012b). *The role of water pricing and water allocation in agriculture in delivering sustainable water use in Europe*. ARCADIS. Final Report. Project number 11589.

Faurès, J. M., Svendsen, M., Turral, H., Berkhoff, J., Bhattarai, M., Caliz, A. M., . . . Zhanyi, G. (2007). Reinventing irrigation. In D. Molden (Ed.), Water for food, water for life: A Comprehensive Assessment of Water Management in Agriculture (pp. 353-394). London, UK: Earthscan.

Finger, R., Hediger, W., & Schmid, S. (2011). Irrigation as adaptation strategy to climate change – a biophysical and economic appraisal for Swiss maize production. *Climatic Change*, *105*(3-4), 509–528. doi:10.100710584-010-9931-5

Foudi, S., & Erdlenbruch, K. (2011). The role of irrigation in farmers' risk management strategies in France. *European Review of Agriculture Economics*, *39*(3), 439–457. doi:10.1093/erae/jbr024

Ignaciuk, A., & Mason-D'Croz, D. (2014). *Modelling Adaptation to Climate Change in Agriculture. OECD Food, Agriculture and Fisheries Papers, No. 70*. OECD Publishing.

International Commission on Irrigation and Drainage (ICID). (2014). *International Cooperation in Agriculture Water Management*. Annual Report 2013-14. New Delhi: ICID.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Kovats, R. S., Valentini, R., Bouwer, L. M., Georgopoulou, E., Jacob, D., Martin, E., & Soussana, J. F. (2014). Europe. In V. R. Barros, C. B. Field, D. J. Dokken, M. D. Mastrandrea, K. J. Mach, T. E. Bilir, & L. L. White (Eds.), *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 1267–1326). Cambridge, UK: Cambridge University Press.

Majone, B., Bovolo, C. I., Bellin, A., Blenkinsop, S., & Fowler, H. J. (2012). Modeling the impacts of future climate change on water resources for the Gállego river basin (Spain). *Water Resources Research*, *48*(1), W01512. doi:10.1029/2011WR010985

Maksimović, L., & Dragović, S. (2004). Water requirements of field crops and effects of irrigation. *Acta biologica Iugoslavica – Series A: Land and a plant, 53*(2), 85-92.

Ministry of Agriculture, Trade, Forestry and Water Management of the Republic of Serbia. (2011). *Water Management Plan for the Danube River Basin. Part 1: Analysis of the characteristics of the basin of the Danube in Serbia*. Belgrade, Serbia: Institute for Water Resources “Jaroslav Cherni”.

Official Gazette of the Autonomous Province of Vojvodina, no. 22. (2011). *Decision on adoption of Regional Spatial Plan of the Autonomous Province of Vojvodina*. Author.

Official Gazette of the Republic of Serbia. (2010). *No. 88*. Law on Spatial Plan of the Republic of Serbia.

Official Gazette of the Republic of Serbia. (2012). *No. 30/2010, 93*. Law on Waters.

Official Gazette of the Republic of Serbia, no. 15 (2014). *Regulation on Fees for water in 2014*. Author.

Official Gazette of the Republic of Serbia - International Agreements, no. 5. (2014). *Loan Agreement between the Government of the Republic of Serbia and Abu Dhabi Fund for Development to finance Development of Irrigated Agriculture – Phase I.* Author.

Official Gazette of the Republic of Serbia, no 11. (2002). *Regulation on Establishing Water Master Plan of the Republic of Serbia*. Author.

Pejić, B., Maksimović, L., Milić, S., & Rajić, M. (2010). Effect of irrigation and nitrogen rates on yield and water productivity of sugar beet. *Contemporary Agriculture*, *59*(1-2), 1–7.

Petković, S. (2003). Irrigation Development Strategy in Serbia. *Vodoprivreda*, *35*(1-2), 3–9.

Poláková, J., Berman, S., Naumann, S., Frelih-Larsen, A., Von Toggenburg, J., & Farmer, A. (2013). *Sustainable management of natural resources with a focus on water and agriculture. Study - Final Report*. Institute for European Environmental Policy, BIO Intelligence Service and Ecologic Institute.

Popović, V., & Mijajlović, N. (2013). Climate Change and Sustainable Development in Agriculture and Forestry. In A. J. Vasile, A. Turek Rahoveanu, J. Subić, & D. Dusmanescu (Eds.), *Sustainable Technologies, Policies, and Constraints in the Green Economy* (pp. 140–171). Hershey, PA: IGI Global. doi:10.4018/978-1-4666-4098-6.ch008

Popović, V., Nikolić, M., & Katić, B. (2011). Agricultural land use and protection in Serbia. Belgrade, Serbia: Institute of Agricultural Economics.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Popović, V., & Ugrenović, V. (2015). Improved Irrigation Management for Sustainable Agriculture. In G. Popescu & A. Jean-Vasile (Eds.), *Agricultural Management Strategies in a Changing Economy* (pp. 357–378). Hershey, PA: IGI Global.

PWMC. (2015). *Vode Vojvodine*. Annual Business Programme for.

Sadras, V. O., Cassman, K. G. G., Grassini, P., Hall, A. J., Bastiaanssen, W. G. M., Laborte, A. G., . . . Steduto, P. (2015). Yield gap analysis of field crops – Methods and case studies. FAO Water Reports No. 41.

Savé, R., de Herralde, F., Aranda, X., Pla, E., Pascual, D., Funes, I., & Biel, C. (2012). Potential changes in irrigation requirements and phenology of maize, apple trees and alfalfa under global change conditions in Fluvià watershed during XXIst century: Results from a modeling approximation to watershed-level water balance. *Agricultural Water Management*, *114*, 78–87. doi:10.1016/j.agwat.2012.07.006

Serbian Environmental Protection Agency. (2013). *The Report on the State of Environment in the Republic of Serbia for 2012*. Author.

Statistical Office of the Republic of Serbia. (2010). *Municipalities of Serbia 2010.* Author.

Statistical Office of the Republic of Serbia. (2011). *Municipalities and Regions of the Republic of Serbia 2011*. Author.

Statistical Office of the Republic of Serbia. (2012). *Municipalities and Regions of the Republic of Serbia 2012*. Author.

Statistical Office of the Republic of Serbia. (2013a). *Census of Agriculture in the Republic of Serbia 2012*. Database. Retrieved April 12, 2014 from http://popispoljoprivrede.stat.rs/popis/wp-content/themes/popis 2012/sadrzaj cir.htm

Statistical Office of the Republic of Serbia. (2013b). *Municipalities and Regions of the Republic of Serbia 2013*. Author.

Statistical Office of the Republic of Serbia. (2014). *Municipalities and Regions of the Republic of Serbia 2014*. Author.

Statistical Office of the Republic of Serbia. (2015a). *External Trade of Serbia, Final Data 2014.* Statistical Release, No. 189, Year LXV, 15.07. 2015. Statistics of external trade. Author.

Statistical Office of the Republic of Serbia. (2015b). *External Trade of Serbia. Database*. Retrieved August 16, 2014 from http://webrzs.stat.gov.rs/WebSite/public/ReportView.aspx

Steduto, P., Hsiao, C. T., Fereres, E., & Raes, D. (2012). Crop yield response to water. FAO Irrigation and Drainage Paper No. 66.

Subić, J. (2010). Specifics of the investment process in agriculture. Belgrade, Serbia: Institute of Agricultural Economics.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Sumberg, J. (2012). Mind the (yield) gap(s). *Food Security*, *4*(4), 509–518. doi:10.100712571-012-0213-0

The Assembly of the Autonomous Province of Vojvodina. (2011). *Master Plan for Sustainable Development of Fruška Gora mountain 2012-2022*. Author.

Trnka, M., Olesen, J. E., Kersebaum, K. C., Skjelvag, A. O., Eitzinger, J., Seguin, B., ... Žalud, Z. (2011). Agroclimatic conditions in Europe under climate change. *Global Change Biology*, *17*(7), 2298–2318. doi:10.1111/j.1365-2486.2011.02396.x

Van Ittersum, M. K., & Rabbinge, R. (1997). Concepts in production ecology for analysis and quantification of agricultural input-output combinations. *Field Crops Research*, *52*(3), 197–208. doi:10.1016/S0378-4290(97)00037-3

Zloh, Z. (2013). "Agro kapilaris" – a revolution in irrigation. In *Proceedings of the 1 st International Congress on Soil Science: SOIL-WATER-PLANT*. Belgrade: Soil Science Society of Serbia and Soil Science Institute, Belgrade, Serbia.

Zloh, Z., Miladinović, M., Ugrinović, M., Rudić, D., Savić, N., & Kokotović, N. (2013). Successful application of "Agro kapilaris" concept in agricultural production. In *Proceedings of the 1 st International Congress on Soil Science: SOIL-WATER-PLANT*. Belgrade: Soil Science Society of Serbia and Soil Science Institute, Belgrade, Serbia.

ADDITIONAL READING

Dragović, S. (2001). Irrigation requirements and effects on yield increase and stabilization in agricultural regions in Serbia. *Zbornik radova Instituta za ratarstvo i povrtarstvo*, (35), 445-456.

European Environment Agency. (2012). *Towards efficient use of water resources in Europe*. EEA Report No 1/2012.

FAO. (2004). Economic Valuation of Water Resources in Agriculture – From a sectoral to a functional perspective in Natural Resource Management. FAO Water Report 27. Rome.

FAO. (2012). *Coping with water scarcity. An action framework for agriculture and food security*. FAO Water Reports, no. 38.

Institute of Water Resources. (2001). *Jaroslav Cherni*. Master Plan for Development of Water Resources in Republic of Serbia.

Interwies, E., Dworak, T., Görlach, B., & Best, A. (2006). *WFD and Agriculture Linkages at the EU level, Incentive water pricing and cost recovery in the WFD - Elements for linking EU Agricultural and Water Policies. Report*. Final Paper for the EC – DG Research.

Interwies, E., Kampa, E., & Görlach, B. (2005). Economic Instruments and Water Rights. *Background Paper for the International Workshop Integrated Water Resources Management*: *Course for North Africa*. Rabat, Morocco.

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IPCC. 2014. Summary for policymakers. In C.B. Field, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, … L.L. White (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability.Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 1-32). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

Karamanos, A., Aggelides, S., & Londra, P. (2005). Water use efficiency and water productivity in Greece. In N. Lamaddalena, M. Shatanawi, M. Todorovic, C. Bogliotti, R. Albrizio (Eds), Water use efficiency and water productivity: WASAMED project (pp. 91-99). Bari: CIHEAM, 2007 (Options Méditerranéennes: Série B. Etudes et Recherches; n. 57).

Kijne, J. W., Barker, R., & Molden, D. (Eds.). (2003). *Water Productivity in Agriculture: Limits and Opportunities for Improvement.Comprehensive Assessment of Water Management in Agriculture Series, No. 1*. Wallingford, UK: CABI Publishing. doi:10.1079/9780851996691.0000

Obradović D., Teofanović Ž., Petrović P., Petrović M., & Ružičić L. (2012). Significance and impact of irrigation on the natural and economic effects of agricultural yield. *Traktori i pogonske mašine,17*(5),46-53.

Svendsen, M., & Turral, H. (2007). Reinventing irrigation. In Molden, David (Ed.). Water for food, water for life: A Comprehensive Assessment of Water Management in Agriculture (pp. 353-394). London, UK: Earthscan; Colombo, Sri Lanka: IWMI.

Wriedt, G., Van der Velde, M., Aloe, A., & Bouraoui, F. (2008). *Water Requirements for Irrigation in the European Union. A model based assessment of irrigation water requirements and regional water demands in Europe. JRC Scientific and Technical Reports. WWF– EIC. (2012)*. Climate Vulnerability Assessment - Serbia.

KEY TERMS AND DEFINITIONS

Agricultural Holding: A technically and economically independent production unit with a single management on which an enterprise, farm cooperative, institution or another legal entity, entrepreneur or family household undertakes agricultural production, either as primary or secondary activity.

Average Actual Yield: An average of many recent years of actual yields achieved by crop producers in a given region under dominant management practices and soil properties.

Irrigation Efficiency: The share of water that is effectively used by crops relative to water withdrawal for irrigation. It consists of conveyance efficiency (the efficiency of irrigation system in delivering abstracted water to the field) and field application efficiency (the efficiency of irrigation system in transporting water to the plants).

Irrigation System: A hydraulically distinct network of structures – pumps, channels and pipes used to abstract, distribute and apply irrigation water to a defined land area, including accompanying land, infrastructure and equipment necessary to operate, maintain and repair the system.

Utilised Agricultural Area: Agricultural area used for kitchen garden, arable land (including fallow land), permanent crops (fruit plantations, vineyards, nurseries, and other permanent crops), permanent grassland and pastures.

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Water Limitation Index: The gap between the water-limited yield potential (Yw) and the water non-limiting yield potential (Yp) as a percentage of yield potential, so (1 – Yw / Yp) * 100%. For a given location, the water limitation index is calculated for a single crop within the current cropping system and farm management practice.

Water-Limited Yield Potential: Defined for rainfed a crop, the yield of a crop cultivated is limited by water supply, and hence determined by solar radiation, temperature, CO2 concentration, and genetic characteristics and influenced by soil type and field topography.

Yield Potential: Defined for irrigated crops, the yield of a crop cultivated with non-limiting water and nutrients in the conditions of effectively controlled biotic stress. Therefore, it is determined by solar radiation, temperature, CO2 concentration and genetic characteristics.

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Chapter 42
Characteristics Development of Agriculture and Agricultural Policy Southeast European Countries

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ABSTRACT

In general the agricultural policy South East European countries are characterized by high volatility, which is expressed in terms of applied instruments and measures as well as in regard to the products to which it relates. In the first phase of price and trade liberalization, most countries have abolished or significantly reduced non-tariff barriers to the import and export of a wide range of products. Also, most countries have reduced or abolished production subsidies and left import tariffs as the main instrument to protect producers. This chapter emphasizes that the further development of CAP in many ways depended on negotiations with the countries of Southeast Europe. Some of these countries are already in the EU and some candidate countries which are at different levels of negotiation with the EU. Southeast European countries are basically agricultural country with low productivity and low prices of agricultural products to be completely restructured. These countries can be reintegrated into CAP only respect the rules and with the help of EU member states.

INTRODUCTION

Region Southeast Europe (SEE) has achieved significant progress of stability, implementation of economic reforms and in European integration, which also represent one of the most important political and economic challenges the whole region. At the Zagreb Summit in November 2000, leaders from the European Union (EU) and the countries of Southeast Europe have confirmed their full commitment to the

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Stabilization and Association Process (SAP), which is led by the EU and at the end of its implementation, would lead to full membership in EU. Countries are currently divided into three groups; Croatia, which became an EU member of 1 July 2013; Macedonia, Montenegro, Serbia and Albania, which have been a candidate for EU membership;[1] Bosnia and Herzegovina, which is a potential candidate country for EU membership. In this context, fulfilling the criteria laid down by the EU for membership is extremely important. (Volk, Erjavec, Mortensen, 2014, p 3)

The SEE countries have clearly identified the European integration as a political priority, which is defined, among other things, reforms of agricultural policy and the need for modernization of agriculture. The accession process involves not only increasing competitiveness over the entire chain of agricultural and food products, but also in a broader sense, adopting a completely different model of agricultural policy which is mainly complicated in its conceptual, administrative and financial aspects. In the countries of South Eastern Europe agriculture and agricultural policy are very different from the agrarian policy applied in the EU. Therefore, it is necessary to reform and harmonize the legal institutions of the EU and to create conditions for integration of the agricultural sector in the countries of Southeastern Europe with the EU single market in the most efficient way possible. (Volk, Erjavec, Mortensen, 2014, p 3-4)

Agrarian policy of the SEE countries is characterized by high volatility which is expressed in terms of applied instruments and measures and in terms of products, referred to in (EC, 1998). In the first phase of price and trade liberalization, most countries have abolished or significantly reduced non-tariff import and export barriers for a wide range of products. Also, most countries have decreased or abolished subsidies in production and retained import tariffs as a basic instrument to protect producers. Input prices have risen considerably for producers, and this has caused a decreased in agricultural income. (Volk, 2004, p. 20-21)

The negative effects of the transition and the real decrease of income, have led to the fact that in many countries they introduced an ad-hoc price and foreign intervention in the function of stabilizing agriculture and the protection of consumers and producers. SEE countries had delayed transition caused by political reasons that have caused primarily disintegration of Yugoslavia. For this reason, countries in the region have led to a strictly controlled agricultural policy.

In principle, the strategic objectives of the country are more or less aligned with the principles of the EU, and can be summarized in ensuring stable production of high-quality food with reasonable prices and safety and food; sustainable resource management; increasing efficiency and ensuring adequate living standards (income) for the farmers and the rural population. However, in terms of operational programs and agricultural policy implementation, as well as customizing ZAP, major differences exist between countries. Croatia has already become part of the European Union. Enough elements to comply with legislation and program documents of the EU, especially in the field of rural development SAPARD5 (2005-2006) and IPARD6 (2007-2013) programs can be found in Macedonia, where it is prepared and implemented IPARD program, in Montenegro, where at the level of programming, all documents (strategies, a national program, legislation) have been prepared in accordance with EU principles. Rural Development Programmed documents which were made on the basis of the regulations of EU rural development were adopted in Albania and Serbia. Bosnia and Herzegovina has a specific situation because there is no single ministry of agriculture at state level. There are two separate strategies for agriculture and rural development at the entity level, while agricultural policies have been partly implemented even at the lower levels (cantons). Although the program documents and the activities planned in these

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countries closely linked to EU integration, agricultural policy is still carried out mainly on the basis of the annual program budget allocations, which are not stable in terms of resources, support measures and criteria. (Volk, 2010, p. 25-26).

BACKGROUND: CAP AND THE COUNTRIES OF SOUTHEAST EUROPE

Negotiations with the countries of South Eastern Europe represent the next major step in the development of CAP. Countries in this part of Europe are basically agricultural country with low productivity and low prices of agricultural products to be completely restructured. These countries can be reintegrated into CAP only respect the rules and with the help of EU member states. In practice this would mean that the level of productivity and prices of agricultural products will be competitive CAP and EU countries.

For this reason, the countries of Southeast Europe have started with the implementation of various aspects of the reform and modernization, which is contained in the following points:

1. Legal harmonization, which contains four main regulations of the Common Agricultural Policy (CAP) (direct payments, a common market organizations, rural development and financial rules). The country must be able to implement these regulations on the first day of accession. Aligning with this policy prior to accession, it is not mandatory.
2. Improving the capacity to implement. Institutions responsible for legal harmonization and implementation of the rules CAP European Union should be strengthened or, in some cases, to establish them. Implementation of the IPARD pre- accessions support for agriculture and rural development serves as a test of the capacity for the implementation of the country.
3. Policy reform and economic adjustment. The ability of the rural economy in food production in agriculture must modernize and prepare for the "soft landing" in the framework of CAP after accession. Increasing competitiveness and providing alternative income for rural residents must be considered as a major goal. In addition, substantial reform of agricultural policies is necessary before accession in order to prepare future beneficiaries of measures CAP and for the administration to work in the institutional and economic framework of EU agricultural policy.
4. The accession negotiations. Include a summary of the above questions, as well as negotiations on transition periods, or in some rare cases, negotiations on permanent derogations from the legal framework of the EU. Agriculture is also an important part of the financial package and each candidate country requires intense work and preparation. (Volk, Erjavec, Mortensen, 2014, p 4).

Directorate-General for Agriculture and Commission calculated that the transitional period and after the approach is important for harmonization with the new system of CAP. Total financial support for this country amounted from 12 billion to 15 billion ECUS including all important investments in infrastructure, economy and development. Also from the Common Structural Fund is planned to allocate 15 billion ECUS a year. (European Commission, 1997, p. 7)

We would like to point out that after 2004, when the European Union joined the eight countries of Eastern and Central Europe, increased assistance to farmers. There was a regime of agrarian policy of integrating these eight countries with the common agricultural policy of the EU. (Anderson, Swinnen, 2008, p. 54) In this extension, the most successful countries was those that were duly endorsed by the

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application of the above points that proved to be necessary for the implementation of the CAP, while producers are prepared for the procedure and the level of support to be applied after accession. Rational (taking into account the possibilities and needs) and the gradual introduction to CAP represent the best approach. Elements that no longer exist or are significantly different from those applied in the EU should not be adopted. This is particularly important to the candidate countries.

AGRICULTURAL POLICY IN THE COUNTRIES OF SOUTHEAST EUROPE

Development problems of Southeast European countries, especially the countries of the Western Balkans, have been more pronounced than it was in the countries of central and Eastern Europe that joined the EU in 2004. The development process, with limited domestic resources, with dosing financial support on a bilateral and multilateral level with per capita foreign direct investment, which is considerably smaller than it was in the countries of eastern and central Europe, in most of these countries did not lead to overcoming the transition shock or substantial approaching the level of the EU countries 15th. (Gajić, Tošin, 2008, p.84).

Although the share of agricultural sectors in the economy has declined from 2000, still has a relatively important role in Southeast Europe in terms of value added and employment. As subsistence agriculture still dominates in most parts of the region, we can point out that agriculture provides a minimum level of food safety and socio-economic stability in rural areas. Thus, this sector plays an important role as a social and economic buffer for the rural economy. On the other hand, policy-makers are faced with many challenges, such as low competitiveness of the agricultural sector, inadequate use of the potential of agricultural production and the depopulation of rural areas. (Volk, Erjavec, Mortensen, 2014, p.4).

Notwithstanding market-oriented economy of many countries, the role of the state through the development and implementation of agrarian policy represent a significant element. You may say that, if the economy is more market-oriented, the role of the state is larger, or implementing measures in agricultural policy is more comprehensive. (Simonović, Cvijanović, & Hamović, 2010, p.73-82)

Intervention in the domestic and international market characterized agricultural policies in almost all countries where governments have used a large number of often very complex measures in order to support the agricultural sector. These measures include price support, quantitative restrictions on production or input use, budget payments, trade barriers, subsidizing inputs and the like. All these measures affect the allocation of production resources to the productive sectors and regions, and therefore to the use of inputs, farm structure, personal income and rural economy. In general agricultural policy initiated by the increase in the use of inputs and the use of resources in agricultural production. (Lovre, Zekić, 2008, p. 93)

If you look at the level of liberalization of agricultural markets in all these countries it is quite different from country to country. Border protection is the subject of agricultural policy on these countries. In recent years the level of border protection is reduced. For reasons on negotiations in the WTO and quotas (accept preferential) were eliminated (or not introduced at all). Tariffs are set at a relatively low level in Albania, Bosnia and Herzegovina, and Macedonia (0% to 15%), while in Serbia, Croatia and Montenegro, customs duties for some products are higher (up to 40%). All countries these countries signed several free trade agreements (most important of all is CEFTA7), which significantly reduce the current level of efficient foreign trade protection. Generally speaking, one can say that the level of trade protection in for countries is relatively low (Table 1).

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Table 1. The forms of support measures for the market

	Albania	Bosnia	Croatia	Macedonia	Montenegro	Serbia
Border protection	Yes	Yes	Relevant	Yes	Relevant	Relevant
Export support	No	No	No	No	No	Relevant
On the market intervention	No	No	Relevant	No	No	Yes
Other support measures	-	Yes	-	-	-	-

Source: Research authors.

Export subsidies (refunds) are only important measure of market support in Serbia.In other countries, this measure has not been implemented. The intervention in the market system formally exists only on Croatia and Serbia, but in recent years intervention buying-in was rarely enforced. Among other measures support the market, administered prices is implemented in Bosnia and Herzegovina (wheat and rye).

Measures of direct subsidies to producers are certainly the most important instrument of agricultural policy on all countries. This instrument contains all the basic shapes, except separate payments. However, the composition of support varies by country (Table 2).

Most of the observed means of support, paid on the basis of output (cost), which is still very important to all the countries, but particularly in Bosnia and Herzegovina. Direct payments based on area and number of animals is the most abundant form of grants shall be implemented in all countries. The significance of these payments is particularly important to Macedonia, and also in Croatia. In all these countries, the use of inputs (seeds, fertilizers ...) is also subsidized. In Serbia, input subsidies are the most important form of direct support for producers. The process of splitting these payments in these countries is delayed no matter what you was planned.

Support for public services in agriculture is present in all countries of Southeast Europe. More attention of veterinary and phytosanitary services is provided in the candidate countries (Table 3).

Table 2. The forms of direct subsidies to producers

	Albania	Bosnia	Croatia	Macedonia	Montenegro	Serbia
Direct payments for production	Included	Relevant	Included	Relevant	Relevant	Relevant
Direct payments - animals	Included	Relevant	Relevant	Relevant	Relevant	Included
Variable input subsidies	Included	No	Included	Included	Relevant	Relevant
Separate payments	No	No	No	No	No	No

Source: Research authors.

Table 3. Support to agricultural extension service

	Albania	Bosnia	Croatia	Macedonia	Montenegro	Serbia
Restoration services	Yes	Yes	Relevant	Relevant	Relevant	Relevant
Veterinary and phutosanitary protec.	Yes	Yes	Relevant	Relevant	Relevant	Yes
Other	Yes	Yes	Relevant	Yes	Yes	Yes

Source: Research authors.

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This part of agricultural policy modestly commented the statements of all these countries. Therefore gets pretty murky picture of the true state of affairs. If we look at the program in terms of volume of agricultural budgetary funds allocated for this purpose, then it could be said that the importance of public services in all these small countries. Some experts believe that these services are financed from other sources (donors, other ministries), but without long-term financing is difficult to expect the development of public institutions necessary to rapidly develop agriculture.

In addition to displaying the total amount earmarked for the support, and is an important structure and support, which is an indicator of agricultural policy. When comparing the evolution of total assets and the evolution of their structure, observed four different models. In Bosnia and Herzegovina, and after 2003, also in Montenegro, with growth in total support, its composition is also changing. Indeed, the share of assets related to rural development measures increases at the expense of reductions in direct funding support to producers. This is not the case of Croatia and Macedonia, which is a structure of recent years quite rigid and the share of direct support to producers has remained very high. Serbia is a special case. In addition to the significant decline in total support since 2005, dramatic changes in the structure of direct support for producers can be seen in recent years - a shift from direct payments to input subsidies. The case of Serbia (Macedonia until 2004) clearly points to the problem of stability of agricultural policy.

As for the budget support we are given in the table show the percentage of how much each country stands out from its budget to agriculture (Table 4). In millions of euro's this can be seen in the following table (Table 5).

If we look at the agricultural policy each of these countries individually we can observe the following situation:

In Albania, support for agricultural policy on the period 2010-2012 was weak, variable in absolute values and in programming. The support scheme is not sufficiently focused attention on the market and direct support to producers due to weak financial resources and an unclear reference to issues such as sustainable use of natural resources, sustainability of rural life and the balance of territorial development. (Thomaj, 2015, p.314-316) Low budgetary support, together with unfavorable infrastructure, high cost of inputs, poor access to services such as credit and market advisory services and highly fragmented production increased vulnerability Albanian farmers by their counterparts from the EU, primarily in the areas of investment and improved productivity. (Zhllima, Gjeci, Imami, 2014, p.68) A comprehensive strategy that will be relevant of agriculture and rural development is absent.

Table 4. The share of expenditure on subsidies in agriculture percentage of the total budget expenditures SEE countries

Country	2010	2011	2012
Albania	3,0	3,0	3,0
Montenegro	1,4	1,4	1,4
Bosnia and Herzegovina	6,2	3,1	3,7
Croatia	4,6	4,8	4,4
Macedonia	4,8	5,4	5,6
Serbia	2,3	2,4	3,9

Source: Statistical Yearbooks for each of the countries in the table, the websites of the Ministries of Agriculture in each of those countries, a publication of the World Bank.

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Table 5. Agrarian Budget SEE countries 1 000 Euros

Country	2010.	2011.	2012.
Albania	19.0	26.8	23.7
Montenegro	18.6	21.1	14.5
Bosnia and Herzegovina	82.2	71.2	82.7
Croatia	577.5	581.5	498.5
Macedonia	85.8	98.7	101.6
Serbia	171.9	171.2	225.3

Source: Statistical Yearbooks for each of the countries in the table, the websites of the Ministries of Agriculture in each of those countries, a publication of the World Bank.

Agricultural policy of Bosnia and Herzegovina and its entities (Federation, BH, Serbian Republic and the Brcko District) in the period from 2010 to 2012 clearly indicate that formal and substantive implementation process and the adjustment of agrarian policy of Bosnia and Herzegovina with CAP is still unsatisfactory. Agricultural policy of both entities is significantly different from the EU. In both entities, shall be made direct payments per unit of output account for much of the direct support to producers. Such forms of payment basically do not exist on EU countries. Modest transfers of rural development measure almost entirely related to investment in agricultural holdings, while the measures to preserve the environment, as a mandatory part of the CAP, and practically do not exist on Bosnia and Herzegovina. (Bajramović, & Nikolić, 2014. p. 9) Legal harmonization was introduced gradually, but the institutions are still in the development stage. Deficits in institutional structures and in human resources management give a result that produce poor motivation and lack of political will in the past few years, which will inevitably produce consequences of the development of Bosnia and Herzegovina as a state. It can freely be said that the agricultural policy on Bosnia and Herzegovina does not exist. It is quite expensive, contains a lot of elements of the policy, which is conditioned by the entities and cantons, with little coordination among them. (Bajramović, Nikolić, Butković, 2014, p. 92)

Croatian agriculture and agricultural policy is at a crossroads. With the accession to the EU, creates opportunities that Croatia used to increase the funds that are specifically focused on the agricultural sector and the rural economy as a whole. Moreover, the long period of preparation and learning from the experiences of Member States that had joined the EU in 2004 and 2007 should help Croatia to face the challenges of membership. However, Croatia has entered the EU in a moment of global and national economic crisis, with the decline in overall national economic growth has subsided and agricultural production. This has led to a situation where the agricultural sector is not sufficiently prepared for a stronger competition in the EU and has produced more fear of farmers that fear for their future. It is also produced harsh criticism of the authorities on failing to provide proper preparation and implementation of IPT and that could mitigate the unfavorable situation of farmers. (Kumrić, Franić, 2005, p. 34-36) Data onto Croatia's agriculture shows that Croatian agricultural and food products are not competitive in the international market, although there are some products of lower prices and the positive agro-food trade's balance. The reasons for the low competitiveness of the EU and international markets are mainly associated with high production costs, unfavorable agricultural structure of its small farms with low economic power, the lack of cooperation between farmers, poor risk management with high influence of climatic conditions in production, poor physical infrastructure market (storage facilities, cold storage installation). (Mikuš, 2014, p. 95)

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The main shortcomings of the Macedonian agricultural policy are frequent deviations from budget transfers to be paid to the long-term as well as the annual program. (Report No: ACS5258, 2013, p 19) The problem lies in the lack of a strategic approach and behavior of stakeholders (farmers' associations and other interested parties) involved in the process. In this way, demonstrate the political resistance which leads to the fact that it does not perceive the real problems. Another serious problem of the Macedonian agricultural policy a number of measures with complicated procedures on the one hand, while on the other hand, 58% of farms cultivate less than one hectare of agricultural land, and many of them have low education levels A large number of measures, in the form of direct support to producers complicate administrative procedures, which increase the cost of implementation and hence lead to user confusion.

Developer's agricultural policy on Macedonia should adapt the same measures and procedures to meet the needs of all types of farmers and at the same time to meet the national objectives in agriculture. In this regard, the recommendations are in line with the latest reform of the CAP, which suggests a simplified support scheme. (Dimitrevski, Kotevska, Janeska Stamenovska, Tuna, Nacka, 2014, p. 95)

The main documents in the design and implementation of agricultural policy and rural development in Montenegro are: Strategy; National program; Law on Agriculture and Rural Development and Strategy agro-budget. Since 2006, Montenegro has focused its reform in three main areas: agricultural policy (CAP gradual introduction); legislation (harmonization of legislation with the EU); and institutions (the modernization and strengthening of institutional capacity to enable effective implementation of policies).

The key problems of Montenegrin agriculture are small farms, the outflow of labor to cities, low level of use of machinery and agro-technical measures, and low income that arise as a consequence of the above reasons. Improving Montenegrin agriculture can be achieved by increasing the credit support to agriculture, increasing amount of subsidies, providing tax relief, raising the level of technical equipment and new agricultural practices, as well as improving general living conditions in the countryside. (Fabris, Pejović, 2012 p. 670)

Agrarian-budgets are adopted each year, on the basis of the Law on Agricultural and Rural Development and the Law on Budget of Montenegro. Regarding the implementation of the designed policy on an annual basis, some measures should be particularly emphasized: better stakeholder participation in the preparation of measures; full respect for the legal and policy framework; Reporting on the execution of each measure. For better implementation, preparation and adoption of the agricultural budget need financial preparations before the start of each fiscal year, which was not the case until now. (Marković, 2014, p. 95)

Key issues in the implementation of agricultural policy of Serbia are the appearance of discontent growing number of agricultural stakeholders, institutions and many other entities. Not yet reached the concept of sustainable agriculture. This gives to rise to the reform of agricultural policy has not yet yielded some results. One gets the impression that the main feature of the reform of agricultural policy of the period from 2000 to 2007 was its unpredictability and inconsistency.

Measures and instruments that Serbia must in the future to undertake and guide through budgetary support in many ways depend on the reform solutions in the Common agricultural policy of the EU. Significant changes in this area in the EU are expected, considering that the last analysis, despite evident positive results in growth of competitiveness and environmental and social sustainability, and pointed to the shortcomings of the existing support schemes against agriculture and rural development. We must point out that the essential difference in compliance Serbia's agricultural policy of CAP is reflected in the fact that the measures of agricultural support on our country still determined sectored rather than spatial, and there is no comprehensive regional policy and rural development. However we must admit

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that a few years ago adopted a strategy of regional development of the Republic of Serbia and that should soon bring rural development strategy. This means that the agricultural policy of Serbia on its way to be any time soon adapts CAP. (Simonović, 2014, p. 301)

EXPENDITURES FOR ZAP IN 2013 IN THE EU MEMBER STATES BORDERING THE COUNTRIES OF SOUTHEAST EUROPE

Compared to the EU 28, transfers from the budget of agriculture in these countries are relatively low by relative indicators. However, the actual level of support in most of these countries is comparable to levels in some Eastern European countries at the beginning of the accession process. Croatia's pre-accession period during 2007 recorded a much higher level of support to agriculture per capita and per area of some of the countries that are EU member states (Romania and Bulgaria). In addition to the total amount of support, the support structure is also an important indicator of the agricultural policy.

The complexity of the proceedings, which put the countries of Southeast Europe, is enough to say that agriculture was the greatest chapter in the negotiations countries of Eastern Europe before their accession to the EU. With Bulgaria and Romania Negotiations on the agricultural section lasted until the end of 2004, while ten country candidates in 2004 completed in December 2002. Even with direct income support rather than support prices would lead to a drastic increase in the cost of CAP due to enlargement. One of the main topics at the stage of accession of new EU members was whether or not to extend the system to direct payments to the new members. Implementation of the obligations of direct payments has required a substantial increase in the budget of CAP. (Cvijanović, Simonović, & Mihailović, 2011, p. 368-369) Results stemming from negotiations and relate to the fact that the new EU member states gradually fit into the system of direct payments of 2004 and 2013. Direct payments will start from the level of 25% in 2004 compared to the level of the EU 15, 2005 increased to 30% and 35% in 2006. In the coming years will increase by 10%, to 2013 reached a level of 100%. Also new member states will these funds be able to add and national subsidies.

Table 6 whether we show how countries that are members of the European Union and are located in the immediate environment of the countries of Southeast Europe allocate financial resources to its agricultural budget.

If we observe how much has been allocated funds, the level of the whole European Union, we can notice that the subsidies ZAP influenced, in the given circumstances that agriculture in these countries

Table 6. Expenditures for ZAP in 2013 in the EU member states bordering the countries of Southeast Europe 1 000 Euros

EU Country	Direct Payments	Market Measures	Rural Development	Total
Bulgaria	494 436	43 095	395 700	933 231
Greece	2 282 265	63 078	671 478	3 017 092
Romania	1 086 815	122 405	1 356 173	2 565 393
Slovenia	130 184	8 660	113 031	251 875

Sources: European Commission, Directorate General for Agriculture and Rural Development (2013 EAGF Financial Report) and Commission Decision 2010/236/EU Updated: October 2014.

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to be competitive with other countries (Table 7). This only proves that almost the entire agricultural sector artificially maintained. The reasons for this attitude should be sought in the fact that neither of the countries has a competitive advantage in relation to other countries in Europe or in the world. Just such a situation has led policy of large subsidies that allowed agricultural firms to stay on the market no matter the low efficiency.

Changes CAP adopted before the entry to Eastern European countries into the Union indicate that there will be a weakening of central policies of agriculture and there will be a kind of rationalization of the agrarian policy. In such a changing situation sets up question of what they can from such ZAP to seek the Southeast European countries?

MARKET-PRICE POLICY

Agrarian market in Southeast European countries is still under construction, i.e. It is not built sufficiently. Just arranging agrarian market includes more complex actions. Some of these actions are: the choice of production, technical and technological equipment, financial credit support. Each of these issues is, we have to admit, is very complex. Thus, the choice of production means to find comparative agricultural products that would be competitive. For example, the quality of Serbian raspberries is a real brand even though it is not formally branded. Therefore, landscaped land markets means branding or the introduction to quality standards. All this is a complex task for countries in transition that are just entering their agrarian products wholesale market of the EU.

Market price policy is not just about financial support and production support but also support prices in order to achieve competitiveness. It is itself a market-price policy consists of the following measures:

- Support measures for the market,
- Measures of direct budget support products and
- Other direct payments.

In a large area of Europe are encountered with many countries in transition are different problems. The regulated market would be differentiated and specialized agricultural production of Europe.

The process of price liberalization had different effects in countries in Southeast Europe in relation to the countries of Central and Eastern Europe where he was a greater intensity. Some of the CEE countries such as Hungary and the Czech Republic supported the export of agricultural products by providing export credits. In the early nineties of the twentieth century, Croatia and Albania have liberalized the prices of their agricultural products. In 1997, Romania has liberalized the agricultural policy of abolishing the system of direct control of administered prices relating to agricultural products. In early 1999, Romania

Table 7. Expenditures for CAP in 2013 for all EU member states 1 000 Euros

	Direct Payments	Market Measures	Rural Development	Total
EU	41 658 276, 9	3 193 228.9	14 788 920.8	59 640 426.3

Sources: European Commission, Directorate General for Agriculture and Rural Development (2013 EAGF Financial Report) and Commission Decision 2010/236/EU Updated: October 2014

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began to implement the second phase of liberalization which relates to the reduction of import tariffs by 45% for imports of sensitive products such as meat and dairy products and introduced a higher rate for other agricultural products. Poland has risen to import tariffs on imports of wheat, corn and sugar products from other CEFTA countries. (OECD. 1999, p. 149-150) At the beginning of the transition period in Bulgaria the prices of agricultural and food products have not been fully liberalized. In this country through the system of price controls and profit margins tried to achieve double protection for consumers and producers. This system was abandoned in 1998 when the liberalization.

The abolition of control of the market price in the countries in transition, prices of domestic products began to jump and to come closer to prices valid on the world market.

In the countries of Southeast Europe, the conditions for macro-economic development of agriculture, this is one of the important characteristics that are important to the development of a market economy. Open rates and a regulatory framework are applied to these countries is more or less in a position to influence the situation on the world market. Support that is allocated to agriculture, but also the protection for the internal market became stronger after 1995 than it was in the first half of 1990. However, the level of indirect and direct support for agriculture continues to be below average, which is valid across the EU. (Csaki, 2000, p.50-51) Frequent changes in the legislation constituted a kind of problem. The introduction to a common agricultural policy of the EU is a positive trend that directly affects the direct application of efficiency and competitiveness, which is increasingly coming to the fore in the system of agricultural support.

Price liberalization in South Eastern Europe has led to the growth of price levels and the fall in domestic aggregate demand of no easy access to foreign markets. For reasons for constant representation of the economic crisis in the former Soviet Union lead to the loss of traditional markets, on the other hand the EU market was largely closed to the largest number of agricultural products, the countries in transition. Measure that states have undertaken in the first half of the nineties were ad hoc and were related to the import tariffs, export subsidies, minimum guaranteed prices, determination of maximal dimensions and import restrictions. In the period that follows in the second half of the nineties and later, the complete liberalization of prices and trade flows of agricultural products, as well as the formulation of comprehensive agricultural policy

PROBLEMS OF INTEGRAL AGRARIAN DEVELOPMENT

Problems of integral agrarian development of the European Union as well as its impact on the agricultural policy of countries in South East Europe must be viewed through a segment of CAP. The common agricultural policy as we have already stated is based on three basic principles. These are the common market, financial solidarity and orientation towards the formation of community.The period of the last few decades of the last century was marked by the search for alternative solutions to economic development, as the antipodes classical model of industrialization and urbanization. These attempts on finding new solutions led to the theoretical and practical valorization of ecology, natural resources and sustainable development. That is how the policy of integral agrarian development, which studies specific concepts, measures and procedures for solving development problems, both in developed EU countries and countries in transition countries and new EU member states and candidate countries.

Integrated Agricultural Development is complete and comprehensive. In it is:

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- Development of private property,
- The development of agriculture in line with the natural conditions
- Development of irrigation systems and irrigation
- Development of Agricultural Organizations (individual farmers, cooperatives, agricultural enterprises, etc.).
- Development of vertical and horizontal integration and development of agricultural system
- Development of multifunctional agriculture
- Development of rural systems in the agricultural environment
- Development of sustainable development
- Development and conservation of natural resources
- Land legal regulation
- Building of market institutions
    1. Agrarian brands
    2. Agrarian Standards
    3. Agrarian Exchange and fairs
    4. Various agricultural services
- System branding, development and construction, decoration studies for export ISO and others.All these points are present in the initial form. They need to develop further and to raise their level. This process requires a versatile work and extensive preparation if you would like to achieve some results.

During the adjustment of agricultural policy of the countries in transition integral agrarian development, the attention to national governments should be directed, along with primary orientation in the direction of ending the liberalization of prices and markets, land reform, privatization, institutional reforms, primarily on the part of the agricultural infrastructure that is related to public goods, public services. It also should establish regulations that are related to land issues, antitrust regulations, and regulations concerning insurance. Sam adjustment program should include

- The balance of macroeconomic and sectored measures and compliance of the exchange rate and trade policies.
- Completing the process of liberalization of markets and prices, land reform, privatization and institutional reforms.
- The policy of public investment in social and economic infrastructure.
- Prevention of large farms and agro-industrial sector in acquiring a privileged position
- The introduction of measures aimed at developing the agricultural sector where should dominate technologically developed farms that rely on their workforce. (Lovre, Trkulja. 2003, p. 12-14)

CONCLUSION

We believe that the objective of the economies of Southeast Europe coincides with the interests of the EU and that the increase in population welfare of all its members. In order for a country to become a full member of the EU, it must carry out a number of changes which are primarily related to the creation of stable legal, economic and social systems, as well as a fundamental change in the role of government in

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these countries. Stable institutions need to create the basis for the elimination of transitional deformity, crime, and corruption, which are burdened countries that until recently housed in transition. (Bogdanov, 2007, p.11)

Developed countries underdeveloped only provide a picture of a better future. It is natural that you learn from better to suffer the impact successfully. But in the case of European agrarian model is not about an imaginary model of what was the Soviet model in agriculture, for example, but it is a real model of the experience of developed countries what they want to become and countries that have until recently been in transition.

In development of agriculture and agricultural policy of, observed generally prevailing two elements.

The first is that the European model is successful in all aspects: productivity, quality and quantity of production, the production of healthy food, in terms of sustainable development, the use of waste and others. The second is that the model is based on market principles, as one of the best in the world and which exerts a strong influence on agriculture and agricultural policy in transition countries, primarily European.

On the other hand, the countries of the European Union wished to facilitate access to new countries. In this sense, the changes made to the CAP adopted before the entry of Eastern European countries into the Union. The changes that have been made indicate a weakening of central policies towards agriculture and a kind of rationalization of the agrarian policy. The best examples for this statement represent the premium for exchange rate differences. These premiums are paid out of the national state and since the introduction of the euro exchange rate differences disappeared, premiums in 2000 redefined as a national envelope. They should serve to determine the special premium for beef and milk. (Prokopijević, 2009, p. 223).

The current state of things in the process of adaptation and harmonization of agricultural policies, the countries of South East Europe can be divided into four groups: (1) countries with planned activities and partial implementations with CAP (Serbia); (2) countries with elements of harmonization, mainly at the level of adjustment (Macedonia and Montenegro); (3) countries at the initial stage of partial harmonization with the EU at the level of adjustment (Albania); and (4) with the "pragmatic" approach with no real direction in the development of CAP in their policy instruments (Bosnia and Herzegovina).

Finally, we wish to emphasize that our recommendation to pay more attention to the analysis, monitoring, and evaluation of agricultural policy. In recent years, these countries have started to harmonize methods of data collection and processing with EU practice. However, data sets, especially with regard to agricultural policy measures, still do not meet the analytical needs. In the future, it should improve upon, updates and use them to analyze agricultural policy on a regular basis. Part of these activities could be given to independent researchers and state authorities. Finally, ideas for future joint projects should be developed. In addition, should prepare impact assessment of the effects of EU integration with the price convergence and make studies of the policy harmonization.

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EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

REFERENCES

Anderson, K., & Swinnen, J. F. M. (2008). *Distortions to Agricultural Incentives in Europe's Transition Economies*. Washington, DC: The World Bank. doi:10.1596/978-0-8213-7419-1

Bajramović, S., & Nikolić, A. (2014). Institutional and Strategic Dilemmas of Agricultural Policy in Bosnia and Herzegovina. In *2014 International Congress* (No. 186675). European Association of Agricultural Economists.

Bajramović, S., Nikolić, A., & Butković, J. (2014). *Agriculture and Agricultural Policy in Bosnia and Herzegovina. In Agricultural Policy and European Integration in Southestern Europe* (p. 92). Budapest: FAO.

Bogdanov, N. (2007). *Međunarodna iskustva u tranziciji agrarnog sektora i ruralnih područja. In Monografija* (p. 11). Beograd: Daes.

Csaki, C. (2000). Agricultural reforms in Central and Eastern Europe and the former Soviet Union Status and perspectives★. *Agricultural Economics*, *22*(1), 37–54. doi:10.1111/j.1574-0862.2000.tb00004.x

Cvijanović, D., Simonović, Z., & Mihailović, B. (2011). Focus and objectives of the recent reform of cap and EU regional policy. *Ekonomika poljoprivrede*, *58*(3), 359-370.

Dimitrevski, D., Kotevska, A., Janeska Stamenovska, I., Tuna, E., & Nacka, M. S. (2014). Agriculture and Agricultural Policy in Former Yugoslav Republic of Macedonia. In Agricultural Policy and European Integration in Southeastern Europe. FAO.

Erjavec, E. (2008). The EU common agricultural policy and Western Balkans integration process and tasks. In *100th Seminar of the EAAE, Development of agriculture and rural areas in Central and Eastern Europe: Thematic proceedings, Regional Chamber of Commerce, Novi Sad*.

European Commission. (1997). *The Common Agricultural policy in Transition*. Brussels: Secretariat General, Directorate General for Communication.

European Commission Agriculture and Rural Development. (n.d.). Retrieved August 4, 2015, from http://ec.europa.eu/agriculture/analysis/external/applicant/synthesis_en.pdf

European Western Balkans. (n.d.). Retrieved August 4, 2015, from http://europeanwesternbalkans.com/2015/05/20/franc-bogovic-mep-development-of-agriculture-in-the-western-balkans-following-the-example-of-the-eu/

Fabris, N., & Pejović, I. (2012). Montenegrin agriculture: Diagnosis and policy recommendations. *Ekonomika poljoprivrede*, *59*(4), 657-673.

Gajić, M., & Tošin, M. (2008). Razvojne performanse poljoprivrednog sektora i ekonomski razvoj zemalja jugoistočne Evrope u tranziciji. Anali ekonomskog fakulteta u Subotici, 44(20).

Kumrić, O., & Franić, R. (2005). Using Slovenian experience in the Croatian agricultural policy adjustment to EU requirements *Agriculture Conspectus Scientifics, 70*(1), 29-36.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Lovre, K., & Trkulja, Đ. (2003). Integralna politika agrarnog i ruralnog razvoja Evropske unije i implikacije na agrarnu politiku zemalja u tranziciji. Anali ekonomskog fakulteta u Subotici, 39(9).

Lovre, K., & Zekić, S. (2008). Protivurečnost i komplementarnost agrarne politike i ruralnog razvoja, Anali ekonomskog fakulteta u Subotici, 44(20).

Marković, M. (2014). Agriculture and Agricultural Policy in Montenegro. In Agricultural Policy and European Integration in Southeastern Europe. FAO.

Mikuš, O. (2014). *Agriculture and Agricultural Policy in Croatia. In, Agricultural Policy and European Integration in Southestern Europe* (p. 95). Budapest: FAO.

OECD. (1999). *Agricultural Policies in Emerging and Transition*. Paris: OECD.

Prokopijević, M. (2009). Evropska unija. Službeni glasnik.

Report No. ACS5258. (2013). Macedonia, former Yugoslav Republic of Analysis of the Agricultural Support Programs.

Simonović, Z. (2014). Upravljanje agrarom Srbije u tranziciji, Institut za ekonomiku poljoprivrede. Beograd, 301.

Simonović, Z., Cvijanović, D., & Hamović, V. (2010). The role of agrarian sector in economic growth of Serbia. *Ekonomika*, *56*(4), 73–82.

Thomaj, E. (2015). Analysis of public expenditures in support of agriculture development in Albania. *European Scientific Journal*, *11*(1), 309–320.

Volk, T. (2004). Uticaj agrarne politike na razvoj poljoprivrede Slovenije u periodu tranzicije i priključenja Evropsku uniju. *DAES, Beograd*, *2004*, 20–21.

Volk T. (2010). *Agriculture in the Western Balkan Countries*. IAMO.

Volk, T., Erjavec, E., & Mortensen, K. (2014). *Agricultural policy and European integration in Southeastern Europe*. Budapest: FAO.

Zhllima, E., Gjeci, G., & Imami, D. (2014). *Agriculture and Agricultural Policy in Albania. In Agricultural Policy and European Integration in Southeastern Europe* (p. 68). Budapest: FAO.

ADDITIONAL READING

Agenda 2000 for a stronger and wider Union, COM (97) 2000 final VOL. I. Brussels: Commission of the European Communities, 15.07.1997.

Agriculture in the European Union Statistical and Economic Information 2008, European Union, Directorate General for Agriculture and Rural Development, Brussels, 2009.

Baldwin, R., & Wyplosz, C. (2010). Ekonomija evropskih integracija, Data status, Beograd.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Cvijanović, D., Simonović, Z., & Mihailović, B. (2011). The Commnon Agricultural Policy in the function of organic production development in EU, European Union Food Sector after the last enlargements – conclusion for the future CAP, Multi-annual programme: Competitiveness of the Polish food economy under the conditions of globalization and European integration, no 6.1. Warsaw 2011, 67-68.

Daugbjerg, C., & Swibank, A. (2004). The CAP and EU Enlargement: Prospects for an Alternative Strategy to Avoid the Lock-in of CAP Support, *JCMS. Journal of Common Market Studies*, *42*(1), 99–119. doi:10.1111/j.0021-9886.2004.00478.x

Đekić, S. (2005). *Ekonomika poljoprivrede*. Niš: Sven.

Đekić, S. (2010). Agrarni menadžment, Ekonomski fakultet, Niš.

Dinan, D. (2009). Sve bliža Unija, Službeni glasnik, Beograd.

European Commission. (1997). *The Common Agricultural policy in Transition*. Brussels: Secretariat General, Directorate General for Communication.

European Commission. (1999). Prospects for Agricultural market, Chapter II, Prospects for agricultural markets in the CEESs, Directorate-General for Agriculture, Brussels.

European Commission. (2005). *The Agricultural Situation in the European Union, 2003. Report*. European Communities Brussels Luxembourg.

European Commission Brussels 18 November 2010 (COM 2010) 672 final.

Grbić, V. (2005). Ekonomija Evropske unije, Megatrend univerzitet primenjenih nauka, Beograd.

Hiks, S. (2007). Politički sistem Evropske unije, Službeni glasnik, Beograd.

Ivanović, S., & Bogavac, V. (2003). Usaglašavanje agrarne politike Srbije sa Zajedničkom agrarnom politikom EU i STO, Institucionalne reforme i tranzicija agroprivrede u Republici Srbiji, Beograd.

Izmenjeni i dopunjeni nacionalni program za integraciju Republike Srbije u Evropsku uniju, Republika Srbija, Vlada, Beograd, 2009.

Kornai, J. (2006). The Great Transformation Of Central Eastern Europe: Success And Disappointment-First Published. *Montenegrin Journal of Economics*, *2*(4), 11–38.

Lekman, Z., Csaki, C., & Feder, G. (2002). *Land Policies and Evolving Farm structures in Transition Countries*. Washington: The World Bank.

Lekman, Z., Csaki, C., & Feder, G. (2004). *Agriculture in transition Land Policies and Evolving Farm Structures in Post-Soviet Countries*. Lanham: Lexington Books.

Lekrman, Z. (2001). Agriculture in transition economies: From common heritage to divergence. *Agricultural Economics*, *26*(2), 95–114. doi:10.1111/j.1574-0862.2001.tb00057.x

Leon, N., & Lindberg, L. N. (1963). *The political dynamics of Economic Integration*. Stanford, California: Stanford University Press.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Lovre, K., & Zekić, S. (2008). Protivurečnost i komplementarnost agrarne politike i ruralnog razvoja, Anali ekonomskog fakulteta u Subotici 44 (20), Subotica.

Mihailović, B., Paraušić, V., & Simonović, Z. (2007). Analiza faktora poslovnog ambijenta Srbije u završnoj fazi ekonomske tranzicije, Institut za ekonomiku poljoprivrede, Beograd.

Norton, R. D. (2004). *Agricultural Development Policy: concepts and experiences*. West Sussex: Food and Agricultural Organization of the United Nations, John Wiley&Sons Ltd.

OECD. (1999). *Agricultural Policies in Emerging and Transition*. Paris: OECD.

OECD. (2002). *Agricultural policies in transition Economies, trends in policies and suport*. Paris.

Pejanović, R., Njegovan, Z., & Tica, N. (2007). Tranzicija ruralni razvoj i agrarna politika, Poljoprivredni fakultet, Novi Sad.

Petit, M. (1989): Pressures on Europe's common agricultural policy, International food policy research Institute, Washington and Ecole Nationale superieure des scienses agronomiques appliquees, Dijon.

Republički zavod za statistiku. (1998). *Poljoprivreda Srbije 1947-1996 – pedesetgodišnje serije statističkih podataka*, Beograd.

Ševarlić, M., & Tomić, D. (2007). *Agrarna i ruralna politika u Srbiji: Kompatibilnost sa drugim zemljama, Agrarna i ruralna politika u Srbiji 1, Reforme u periodu tranzicije i predlog mera za 2008. godinu*. Beograd: DAES.

Simonović, D., & Simonović, Z. (2005). Problemi tranzicije Srbije i procesi integracije u Evropi, Ekonomske teme 45(1-2), Niš.

Simonović, D., & Simonović, Z. (2010). *Srbija bez seljaka, agrarni i ruralni eksodus*. Niš: Sven i Ekonomika.

Simonović, Z., Hamović, V., & Mihailović, B. (2012). Zadaci agrarne politike u harmonizaciji i pružanju interne podrške poljoprivredi Srbije, str. 547-556, *International Scientific Conference: Harmonizacija zakonodavstva Republike Srbije sa pravom Evropske Unije II, Institut za međunarodnu politiku i privredu, Institut za uporedno pravo, Hans Seidel Stiftung*.

Simonović Z., Jeločnik M., Subić J.: (2013). Tax policy in Serbian agriculture, *Ekonomika poljoprivrede/ Journal Economics of Agriculture, 60(3),* 637-651.

Simonović, Z., Mihailović, B., & Simonović, D. (2009). „Karakteristike kretanja poljoprivrednog stanovništva Beograda prema popisu iz 2002. Godine", Ekonomske teme 47 (2), Niš.

Simonović, Z., Paraušić, V., & Puškarić, A. (2009). Transformacija poljoprivredne proizvodnje Srbije i neki aspekti svetske ekonomske krize, Naučni skup, „Poslovno okruženje u Srbiji i svetska ekonomska kriza", Visoka poslovana škola strukovnih studija, Novi Sad.

Simonović, Z., & Simonović, D. (2010). *A Review of Agricultural Policy of Serbian in the Period of First Serbian Uprising to World War II (1804-1941)", Facta Universitatis, series Economics and Organization, 7(4)*. University of Nis.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Simonovic, Z., Simonovic, D., & Gligic, P. (2009). *Agrarian Regions in Serbia as Natural Foundation and Market in Circumstance of Transition, EAAE and IEA, 113 Seminar of EAAE, The role of Knowledge*. Belgrade: Innovation and Human Capital in Multifunctional Agriculture and Territorial Rural Development, Thematic Proceedings.

Stojanović, Ž. (2007). *Agrarna politika kao pratilac tržišnih zakonitosti, Agrarna i ruralna politika u Srbiji 1," Reforme u periodu tranzicije i predlog mera za 2008. godinu, Tematski zbornik*. Beograd: DAES.

Tangernann, S. (2011). *Direct Payments in the CAP post 2013*. Directorate General for Internal Policies, European Parliament Brussels.

Vujičić, M. i Ristić L. (2006). Ekonomika poljoprivrede, Kragujevac.

Zekić, S. (2008). Reforma agrarnih politika i restruktuiranje poljoprivrede zemalja Jugoistočne evrope u procesu evropskih integracija, Doktorska disertacija, Subotica.

Zekić, S., & Lovre, K. (2004). Transformacioni procesi u poljoprivredi zemalja jugoistočne Evrope, Anali Ekonomskog fakulteta u Subotici, 39(12), Subotica, 2004.

KEY TERMS AND DEFINITIONS

Agricultural Policy: Agricultural policy is a set of economic policy measures, which includes the whole activity of censors directed towards agriculture. It consists of several interconnected elements – objectives of agricultural policies; means, measures, and methods of action; and bearers of agrarian policy. The objectives of agrarian policy can be long-term and short-term, and with regard to general and specific content. The efficiency of the agrarian policy largely depends on whether and how the objectives in terms of content and time-aligned. The means to achieve the objectives of agricultural policy can be economic, technical, legal and organizational. The most important economic resources are provided, investments, taxes and policy of exports and imports, and technical (mechanization, chemicals, farm measures, redistribution of land, redistribution of fields, crop rotation). Legal means to regulate the implementation of certain measures and actions in the production transport, in the possession relations and others. The organizational measures is relating to the organization of agricultural enterprises, and the forms of linkage in association of individual producers. Measures of agricultural policy according to the mode of implementation may be direct, i.e. voluntary and involuntary. As participants and holders of agricultural policy occur administrative and executive authorities, agricultural producers and their associations, political organizations, professional and scientific institutions.

Agriculture: A key sector in the Western Balkans. How important and so neglected in the transition process? In the Western Balkans country and agriculture is still very important economic factor. The relationship between agriculture and the total land varies from 23% in Croatia (it is arable land) to 66% in Serbia. In the European Union arable land is about 40%.

Common Agricultural Policy (CAP): The agricultural policy of the European Union. The importance of the Common Agricultural Policy is high. It is believed that there was no CAP there would be no EC. Perhaps this statement is pretentious, but the fact remains that economic organizations such as EFTA and NAFTA did not have the common agricultural policy and failed to survive. There is certainly

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the possibility that the Common Agricultural Policy could otherwise arrange for instance that the main principle is marketability rather than administrative measures.

European Union (EU): An intergovernmental and supranational union (the union) twenty-eight countries in Europe. Union takes its roots from the European Economic Community established by the Treaty of Rome in 1957 by six European countries. Since then, the European Union expanded the accession of new member states and gained more power. This community was formed under the present name of the Treaty on European Union (more known as the Maastricht Treaty) in 1992. Many aspects of the EU have existed even before the signing of this agreement, through the various organizations of established 50-ies of the twentieth century. Treaty of Lisbon signed in December 2007 provides for the amendment of the current agreement in order to redress the political and legal structure of the European Union. The ratification process of the Lisbon Treaty was completed in November 2009.

Southeast Europe: Region Southeast Europe geographically and politically in the Balkan Peninsula. Countries in the region are: Albania, Bosnia and Herzegovina, Macedonia, Croatia, Serbia and Montenegro. This region is also called the Western Balkans.

Stabilization and Association Process (SAP): A strategy that relates to the prospect of EU accession and is adjusted to the level of development of each of the countries concerned. This strategy is fact a substitute for the offer prospect of accession. To achieve that countries in the region are committed to fulfill the political and economic conditions that are given for all individual countries (Copenhagen criteria).

ENDNOTE

[1] The European Council approved the candidate status to Macedonia in December 2005, in Montenegro in December 2010, in Serbia in March 2012, and in Albania on 27 June 2014.

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Chapter 43
Trends and Transformations in European Agricultural Economy, Rural Communities and Food Sustainability in Context of New Common Agricultural Policy (CAP) Reforms

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ABSTRACT

Agriculture continues to be quite a debate for the last two and a half decades at least at the European level and for Romania Common Agricultural Policy (CAP) reforms has a big impact in developing the convergence to the European agricultural model. Agriculture becomes nowadays a multirole economic sector, with major implications on rural community's sustainability and on food security assurance. In this context, the transformations in European agricultural economy, rural communities and food sustainability in context of Common Agricultural Policy (CAP) reforms represent an important research topic in the context of EU-28 policy diversification from the larger context of Romanian approach.

INTRODUCTION

Refocusing economic activities towards high productivity sectors capable of generating a comparable standard of living and welfare for the population required a major reorientation of production structures, including resource allocation funding and resource mobilization work. In this context, agriculture has proven to be one of those sectors affected by these changes.

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Numerous studies have tried to highlight these transformations, starting from various parts of the analysis. Thus (Piotet et al., 2002; Kilian and Salhofer, 2008), Petrick and Zier, 2012), investigate the effects of direct payments and rural development measures of the EU's Common Agricultural Policy (CAP) on employment in agriculture. On the other side, (Luca, 2007; Montiel et al., 2014; Dwibedia and Chaudhurib, 2014) tries in their studies to provide a theoretical explanation why the agricultural subsidy policies fails in ensuring the well-being of the poor working families in terms of a three-sector general equilibrium. Ciutacu et al.2015 tries to identify and explain the similarities and dissimilarities between the EU agricultural and rural development model and Romanian agriculture.

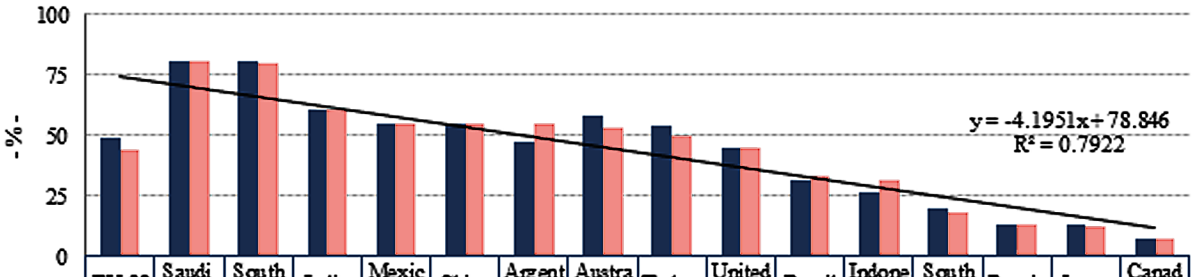
The changes occurred globally in the evolution of agricultural area, as share of land area demonstrates once again that interest towards increasing the agricultural potential, despite diminishing the agricultural area, is still a viable objective for most world economies, based on the need to increase the level of food security. Figure 1 illustrates the evolution of agricultural area as share of land area in some global economies, during 1992 – 2012.

From the analysis of Figure 1 it can be seen that during 1992-2012, the evolution of agricultural area as share of land area in some global economies was negative for most economies given. So it can be seen that the values of EU-28 decreased by 4.9%, while in other economies are recorded slight increases in resource consolidation of land used, as in Argentina (+ 7.4%), Brazil (+ 1.2%) and Mexico (+ 0.1%).

In spite of systematic transformations of the national economic structures due to increasing markets globalization and movements in productivity, rural areas continue to be an important component in the national economy of every state, mobilizing important and diverse resources. Taken from a sectorial perspective, rural areas are affected, at least at European level, by numerous and significant mutations which reflect both changes in agricultural policy and new approaches to integrated rural development and multifunctionality of agriculture.

Rural areas constitute a defining element in achieving economic and social governmental politics and by continuous reporting toward urban areas, dilute its significance, transforming rural areas in an amorphous space in which the only significant activity is agriculture. To erase these false premise comparisons between rural and urban areas has to stop and then, the accent has to be on outlining the multifunctional character of rural areas that can also be able to develop activities from secondary and tertiary sectors. From this perspective Figure 2 and Figure 3 analyzes the changes in the structure of the

Figure 1. Evolution of agricultural area as share of land area, in global economies, 1992-2012
Source: Authors based EUROSTAT (2015a)



	EU-28	Saudi Arabia	South Africa	India	Mexico	China	Argentina	Australia	Turkey	United States	Brazil	Indonesia	South Korea	Russia	Japan	Canada
1992	48.9	80.8	80.8	60.7	54.8	55.1	47.0	58.2	53.5	45.1	31.8	26.6	19.8	13.2	13.1	7.4
2012	44.0	80.7	79.4	60.3	54.9	54.7	54.4	52.8	49.9	44.7	33.0	31.2	18.4	13.1	12.5	7.2

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Figure 2. Change in the structure of the rural economy, in some EU-28 countries, 2008-2011
Source: Authors' own computation based on European Commission (2014)

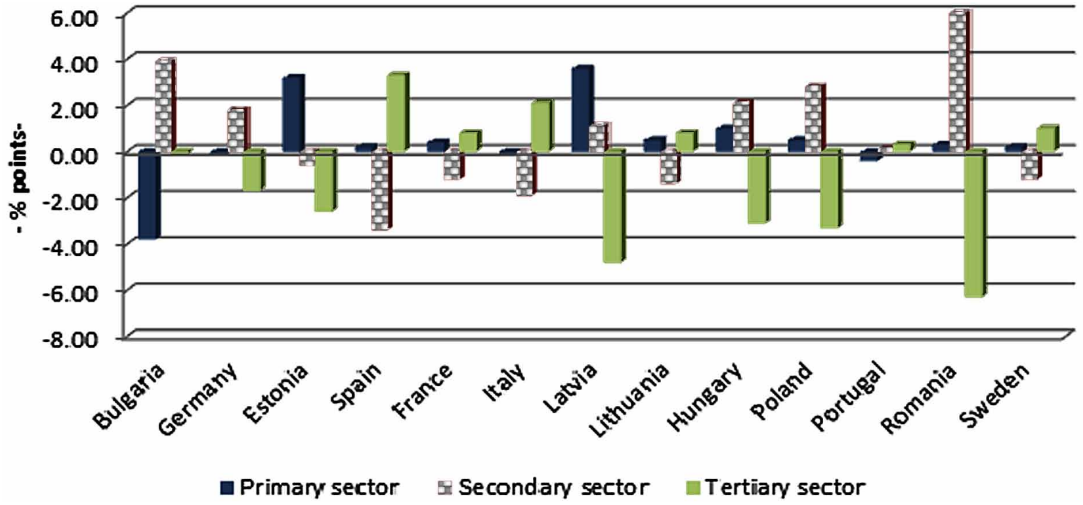
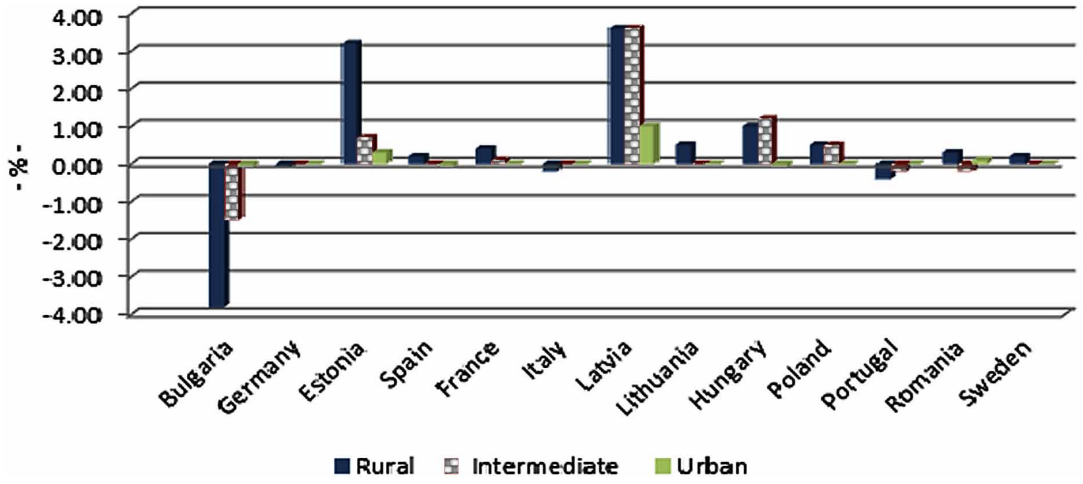


Figure 3. Change in the structure of the primary sector economy, in some EU-28 countries, 2008-2011
Source: Authors' own computation based on European Commission (2014)



rural economy, both sectorial (primary, secondary and tertiary) and from an environmental perspective (rural, intermediate and urban) in terms of weight and significance of the primary sector (agriculture).

From the perspective of the structure of the rural economy (Figure 2), for EU-28 in the cases of analyzed countries, it can be observed a noticeable decrease in the importance of the tertiary sector (services, infrastructure) in the rural areas, while the agriculture continues to represent the most important branch in these areas. The secondary sector, although it is poorly represented in the rural communities through small industries, recorded declines much lower than that of services.

Thus, regarding the evolution of the primary sector, it can be observed that in rural areas, the highest increase is registered in the case of countries such as Latvia (3.6%), Estonia (3.2%) and Hungary

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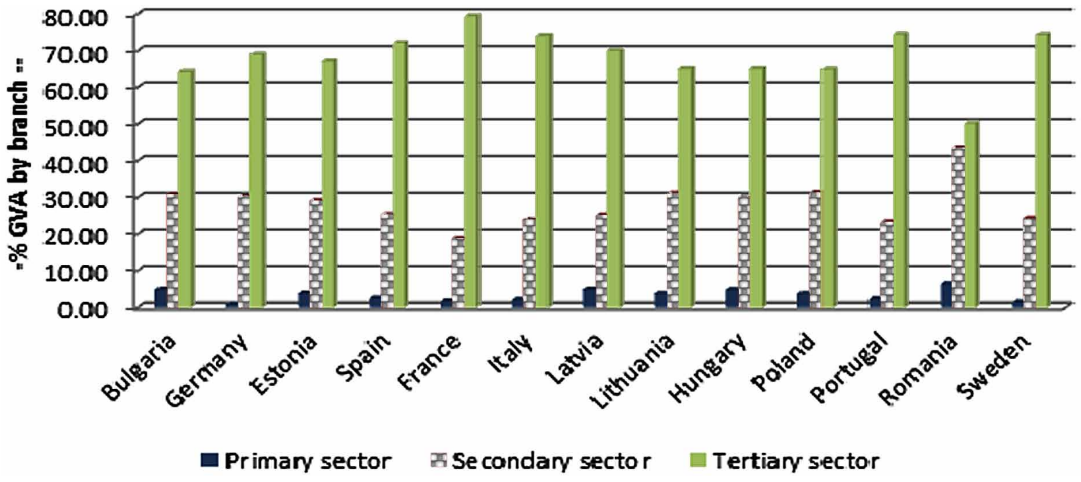
(1%). On the opposite side is Bulgaria with a drop of 3.8%, followed by Portugal with 0.4%, Italy with 0.2% and Germany which recorded a decrease of 0.1%. In the development and evolution of industry in rural areas, the highest increase is registered in Romania, with 6%, followed by Bulgaria with 3.9% and Poland with 2.8%. From this analysis, these trends can be seen as a sectorial evolution in opposite directions. In countries where agriculture recorded the highest increase it can be observed a decline in the secondary sector. Thus, Spain recorded the biggest drop with 3.4%, followed by Italy with 1.9%, France and Sweden with 1.2%.

Analyzing the tertiary sector, the largest decline is recorded in Romania (-6.30%), Latvia (-4.80%), followed by Poland (3.30%) and Hungary (3.10%). The only state that recorded growth in this area is Sweden (+1%). It may be noted that tertiary sector is sensitive to the influences and transformations of the rural economy and also that the tertiary division of the economy does not imply an automatic alignment of the primary sector to this phenomenon. The wish of extending and stimulating the tertiary sector in rural areas, as part of creating a multifunctional agriculture, continue to experience some difficulties, especially in the former socialist states that have joined EU-28.

The analyze of the change in the structure of the primary sector in the national economy, from 2008 to 2011 (Figure 3) pointed out that in terms of agriculture for each of the countries analyzed environmental, rural, urban and intermediary are registered increases in the Nordic countries and also in countries such as Spain, France, Romania, which has a significant agricultural potential and capabilities for sectorial development. The highest increases recorded are found in Latvia, closely followed by Estonia and Hungary. Although most countries analyzed records regarding agriculture increases for all 3 environments, Bulgaria is the only country that records a decline of 3.8% in rural areas, 1.5% in intermediary area and 0.1% in urban area.

The importance of the primary sector in the rural economy is evidenced by its ability to generate gross value added (GVA) and, thus to support the development of rural communities, which often have a high degree of sectorial dependence regarding the agriculture, by the fact that agricultural activities are the only activities that support the income of rural residents. In Figure 4 is presented the importance of the sectorial economy in some EU-28 countries in 2013, in terms of GVA.

Figure 4. Importance of the sectorial economy, in some EU-28 countries, 2013
Source: Authors' own computation based on European Commission (2014)



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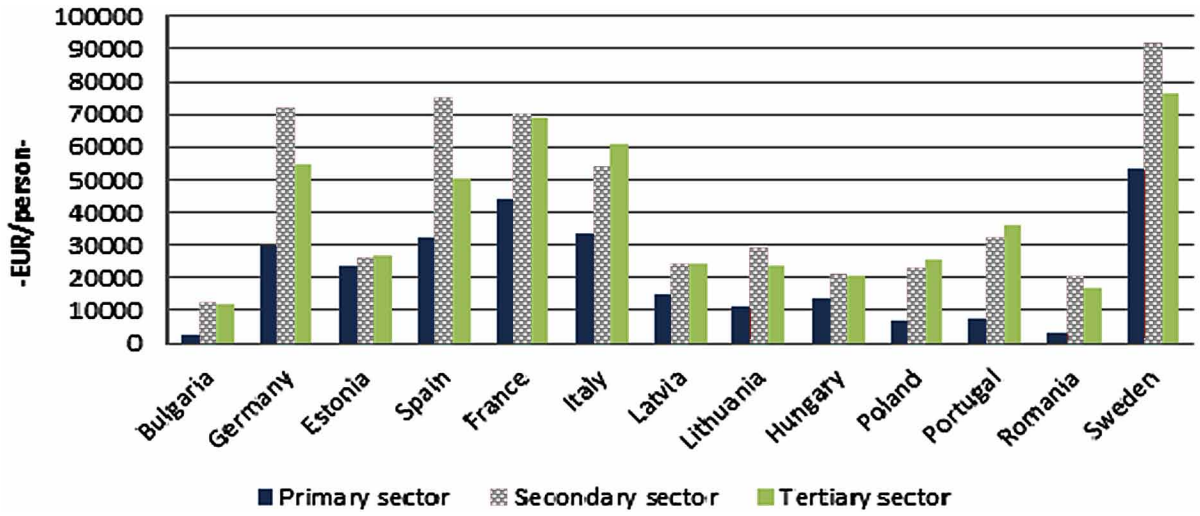
In Figure 4it can be seen that for the year 2013, the tertiary sector achieved the highest contribution to the GVA across all EU-28 Member States analyzed, confirming the tertiary division of the national economies and diminishing the importance of the primary sector (agriculture). Although the importance of agriculture in GVA formation decreased steadily over time in favor of the tertiary sector, it should not be neglected, at least in terms of ensuring its basic functions - providing food resources for the population. This trend can be explained by the level of productivity and resource allocations in the national economy. In Figure 5 is presented the labor productivity level by the economic branch in Some Countries EU-28 in 2013.

Significant differences recorded in labor productivity in the EU-28 Member States reflect a strong gap between the old Member States of the UE and those who have recently joined. In Figure 5 labor productivity is presented by branch in some Countries EU-28 in 2013. Thus from analysis we can see that in 2013, for which there is data (European Commission, 2014) the highest level of labor productivity is registered in the industrial sector, followed by the tertiary sector and in the primary sector are registered the lowest levels for this indicator.

From the Figure 5 it can be noticed that in rich countries are recorded the highest labor productivity values for all three sectors. The overall level of labor productivity recorded in the EU-28 in 2013 was 52.237 EUR/person, with significant differences between economic sectors, starting from a level of labor productivity that is lower than 20.000 EUR/person for agricultural sector and levels of over 50.000 EUR/person for labor productivity in industry and services sector.

It can be seen that the highest levels of labor productivity is registered in the economies of countries such as Sweden which records the higher labor productivity, 91.998 EUR/person obtained in industrial sector (secondary), 76.254 EUR/person for services and 53.166 EUR/person in the agricultural sector (primary), followed by Germany, France, Spain and Italy. However, it can be seen that labor productivity in agriculture and services in France, 44.305 EUR/person and 69.020 EUR/person exceeds the level in Germany, 29.550 EUR/person and 54.863 EUR/person. However, in terms of industry, even though Germany recorded higher values of labor productivity in this sector, the two countries have similar

Figure 5. Labor productivity by branch, in some EU-28 countries, in 2013
Source: Authors' own computation based on European Commission (2014)



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values, 71.733 EUR/person in Germany and 70.164 EUR/person in France, but is still topped by Spain with a value of 74.825 EUR/person.

At the opposite pole are the countries that joined later in the community area at which the values of labor productivity are very low compared with other countries of the EU-28. However, the agricultural sector recorded the lowest values from all, in Bulgaria (2.585EUR/person), followed by Romania (2.893 EUR/person), Poland (7.058 EUR/person) and Portugal (7.369 EUR/person).

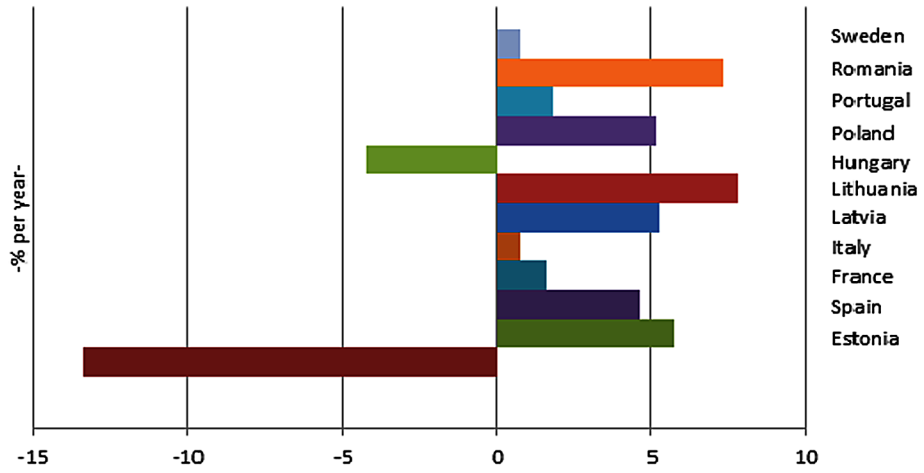
Labor productivity in this case is the most important factor in explaining the existing disparities in EU-28. With the exception of Italy (60.658 EUR/person) and Portugal (36.037 EUR/person) which records the highest level of labor productivity in the case of the tertiary sector, in the other states, the secondary sector defines the highest labor productivity.

AGRICULTURE AND ECONOMIC EFFICIENCY IN EUROPEAN AGRICULTURAL SECTOR: BEYOND CLASSICAL APPROACH

Returning to agriculture, the growth of labor productivity is a problem with major implications nationwide, its evolution influencing automatically the evolution of living standards and in general the competitiveness level of the European economy while in particular for national economies.

Labor productivity analysis involves understanding on how they are deployed, and on how labor resources are used in the national economy. Agriculture, through specific activities involved, mostly mobilize important human resources for members recently integrated in EU-28, faced with low-tech and a low rate of investment in this sector, and on the other hand, a decrease in the use of labor resources, if developed on states that the level of technical and technological resources have displaced labor, by increasing labor substitution ratio - capital in this sector. Therefore, analyzed from the perspective of economic efficiency, the developed countries will continue to record high levels of labor productivity, and in the states in transition to community space, agriculture will continue to be a place of sustenance for a rural population multiplied and devoid of possible investments. In Figure 6 is presented the change in labor productivity in agriculture in some EU-28 countries, from 2008 to 2013.

Figure 6. Change in labor productivity in agriculture in some EU-28 countries, 2008-2013
Source: Authors' own computation based on European Commission (2014)



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Regarding agriculture, the weight of labor productivity change in EU-28 for the period 2008-2013 shows in general an increasing trend for those countries that have low labor productivity in agriculture. Thus, although Germany has labor productivity in agriculture of 29948 EUR/AWU in 2008-2013 its weight in EU-28 it decreases by 13.4% per year, representing the biggest drop.

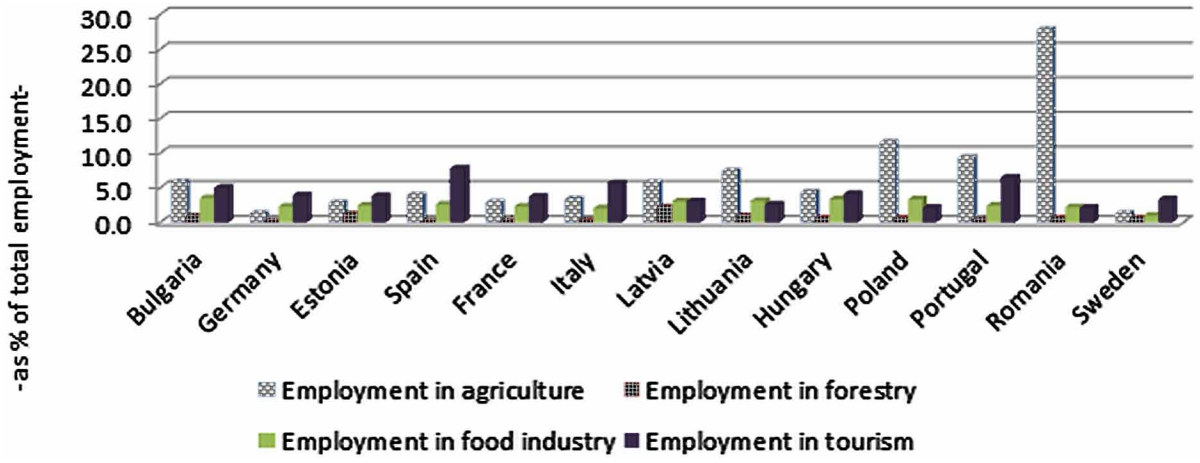
On the opposite pole, lies less developed countries in terms of industrial services with a low labor productivity in agriculture, which in the analyzed period, increased its weight productivity in agriculture in the EU-28, the largest increases being recorded in Lithuania with 7.8% per year, 7.3% per year in Romania and 5.7% per year in Estonia. Compared to these countries, the ones that present the highest level of productivity in agriculture such as France with 37.913 EUR/AWU, Spain 24.969 EUR/AWU and Italy, 23.804 EUR/AWU, record increases in low levels in 2008-2013, France 1.6% per year, Spain 4.6% per year and Italy 0.7% per year. This can be explained in terms of employment structure by economic activity. Therefore, in Figure 7 is shown the employment structure by economic activity in some countries EU-28 in 2013.

Regarding employment, in the Figure from above is seen that the highest level of employment in the EU-28 is registered in agriculture, 9.8577 million persons, followed by the 9.7274 million persons in touristic sector.

As level of the employment rate in 2013, the highest values are recorded in the case of agriculture and tourism. Regarding industrialized countries, it can be seen the rising rates of occupancy workforce relatively low in comparison to other countries. Thus, in Germany are recorded the lowest values, 1.3% in agriculture, 0.1% in forestry, 2.3% in food industry and 3.9% in tourism.

It can also be observed that in the same year, the occupancy workforce grows the most in agriculture, Romania registering the highest level of 27.8% of total, followed by Poland with 11.5% of total and Portugal 9.3% of total. The lowest values of employment in agriculture is registered in Germany and Sweden with 1.3% of total, followed by Estonia with 2.8% of total and France with 2.9% of total. From this perspective, agriculture continues to mobilize important work resources for ex-socialist countries such as Romania and Bulgaria which are facing an excess of occupancy in the agricultural sector and in the light of the relatively low technical and technological and practicing agriculture subsistence strong

Figure 7. Employment by economic activity in some EU-28 countries, in 2013
Source: Authors' own computation based on European Commission (2014)



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polarized holdings, with the exception of Portugal, the employment of labor force is 3.2 times higher than in France.

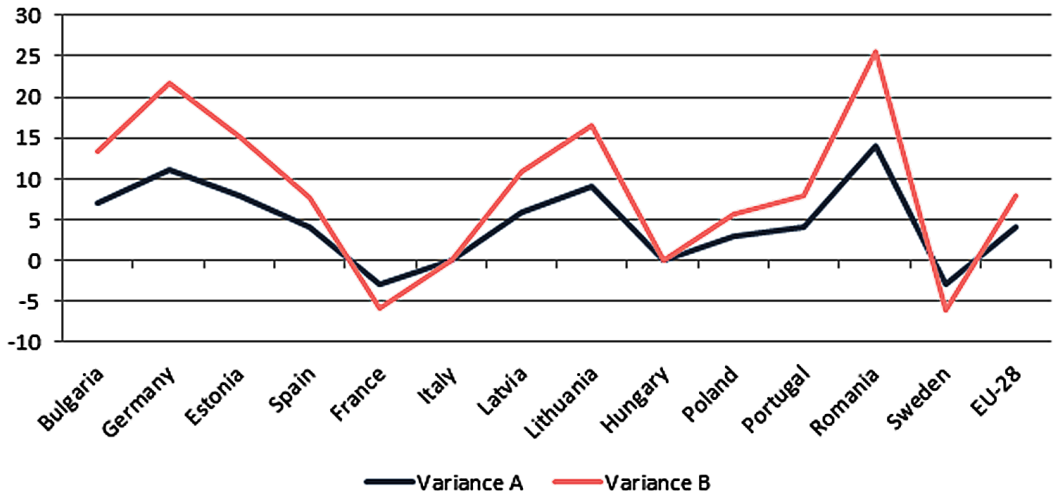
Regarding tourism, employment rate is lower than in the agricultural sector. The highest values are recorded in Spain with 7.8% of total and in Italy with 5.6%. In contrast, the lowest values are Romania and Poland with 2.1% of total, followed by Lithuania with 2.6% of total.

An important dimension in understanding the performance level of the European agrarian economy is represented by the total factor productivity indicator evolution in agriculture (TFT). The analysis of this indicator can explain the productivity differences between various agricultural sectors in the European economy.

Figure 8 reveals decreases in the value of total factor productivity in agriculture, both in terms of relative and absolute values during 2009-2013. Thus, it is observed that in some states such as France and Sweden are recorded decreased values up to 3% as viewed in absolute values. Viewed in relative terms, Sweden recorded the largest decrease of 3.00%, followed by France with a decrease of 2.91%. Also in other European countries are not recorded any significant increases, if we consider the case of Spain, which during 2009-2013 shows an increase of only 4% absolute and relative of 3.64%, while Italy and Hungary are the only countries that do not recorded changes during the referenced period, total factor productivity values remaining constant.

However, it is observed that in the case of Germany, a state with a strong level of industrialization, there is an absolute increase of 11% and a relative increase of 10.68%, this is also one of the largest increases. But it does not exceed the increases recorded in Romania, an absolute increase of 14% during 2009-2013 and a relative increase of 11.57%, indicating that the productivity in agriculture is growing. Bulgaria also recorded increases in the total factor productivity in agriculture during 2009-2013, increases of 7% in absolute terms and 6.42% in relative terms. Thus, it can be observed that in the case of Romania and Bulgaria, significant increases TFT does not show a significant reduction of productivity gaps compared to the EU-28 or to countries such as France, Germany, Poland or Italy.

Figure 8. Change in the total factor productivity in agriculture, 2009-2013
Source: Authors' own computation based on European Commission (2014)



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AGRICULTURAL HOLDINGS AND THEIR IMPORTANCE IN ACHIEVING SUSTAINABLE DEVELOPMENT IN EUROPEAN RURAL COMMUNITIES

Holdings are the main tools in the agricultural potential ensuring the mobilizing available resources of local communities and valorization of, perhaps, the most important existing resources - land resources. Holdings represent in the larger context of agricultural multifunctionality a pillar in ensuring national food security, especially in providing income support for rural population. Although in CAP financial perspective approach during 2014-2010 the focus is on the greening of agricultural policies and on a shift of the size of the from holdings production to greening by decoupling financial support structures of agricultural production will continue to fulfill their classic function of food provider for population and for animals.

Thus, in 2010, the final year for which is statistical data available in the EU-28 is 12,247,850 holdings of which 6,916,690 were holdings with livestock, which represented 56.5% (Eurostat, 2015d). The existence of a high number of holdings explains the importance of the agricultural sector in the EU-28 and, on the one hand, their importance in national and European economy, while on the other hand the importance in the economy of rural communities. In Table 1 and Figure 9 is presented the number of holdings and their distribution for some EU-28 states.

From Table 1 it can be seen that from over 12 million existing EU holdings, in Romania is recorded the largest number of 3,859,040 holdings. The only countries that recorded a higher number then 1 million holdings are either former communist countries such as Romania and Poland (1.506.620 holdings) which, following the agrarian reforms were seen facing accentuated fragmentation of land ownership and consequently the increasing number of holdings or countries such as Italy (1,620,880 holdings) in

Table 1. Number of holdings, in some EU-28 countries in 2010

Country	Total	Holdings with livestock
EU-27	12,247,850	6,916,690
Bulgaria	370,490	279,710
Germany	299,130	216,100
Estonia	19,610	9,680
Spain	989,800	245,160
France	516,100	309,370
Italy	1,620,880	217,330
Latvia	83,390	48,700
Lithuania	199,910	129,630
Hungary	576,810	381,650
Poland	1,506,620	918,870
Portugal	305,270	203,780
Romania	3,859,040	2,836,640
Sweden	71,090	40,360
UK	186,660	139,000

Source: Based on European Commission (2015b)

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which agriculture still mobilizes significant resources at rural communities level. The most important European countries with the most competitive economies record the lowest number of holdings, such as Germany (299.130 holdings), France (516.100 holdings), who despite their important size of agrarian economy manages coherent evolution of the numbers of holdings and not lastly UK (186.660 holdings). Holdings with livestock, as it can be seen from the data presented in the table above represents 56.5% or 6.916.690 units. An essential element in understanding the structure of EU holdings is their distribution at the level of the Community. Below, in Figure 9, is presented the distribution of total numbers of holdings in the EU-27.

Analyzing Figure 9 it may be remarked that holdings with livestock own the highest shares in total, which highlights the complex nature of farming as livestock is the most important for GVA growth at holding level. The weight of holdings with livestock exceeds 50% in all the analyzed countries, except Italy (13.4%), Spain (24.80) and Estonia (49.40%). Thus, the highest rates are recorded in countries such as Bulgaria (75.5%), UK (74.5%), Romania (73.5%), while in case of the majority of the other states registering values exceeding 60%. Instead, pure holdings, only focused on the exploitation of land resources, have a low share in the structure of the agricultural economy, the majority opting for integration of production livestock.

An important dimension in the analysis of the importance of holdings and their role is to understand the physical, economic and labor size of holdings. In Table 2 are presented these parameters, for analyzed states, in 2010.

From Table 2 it can be observed a correlation determined between two of the three dimensions considered, namely those states that have the largest agricultural areas also records the highest values in terms of economic size of the holding, reverse correlated with labor input.

For example, in the case of France for a physical size of the 27,837,290 ha of UAA there is an economic size of 50,733,216,720 EUR. In the case of ex-socialist member states are observed economic values of physical size, as in case of Bulgaria, Lithuania, Latvia or Romania. In Figure 10 are presented three key performance indicators when assessing physical size (UAA per holding), human resources (persons per holding) and using human resources from the perspective of labor productivity.

Figure 9. The distribution of the total number of holdings in the EU, 2010
Source: Authors based on European Commission (2015b)

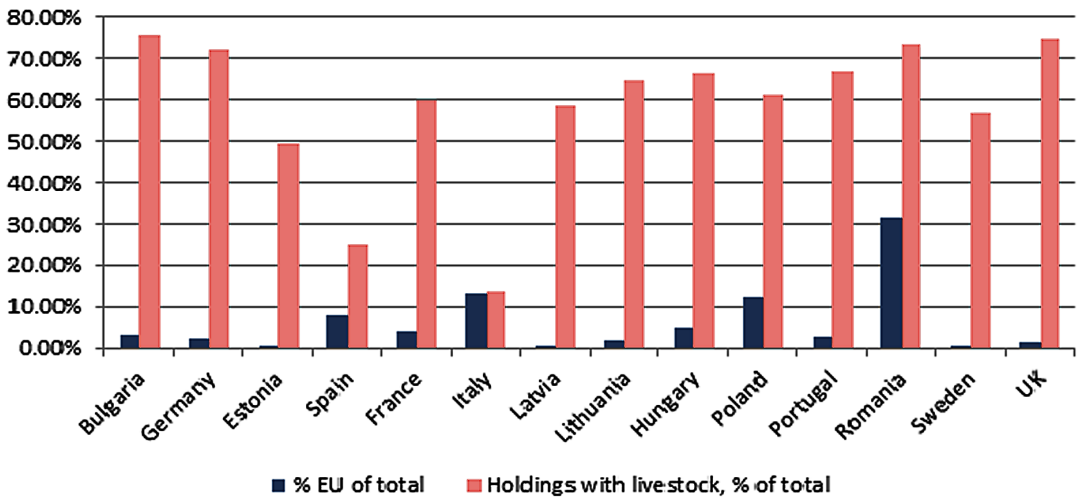

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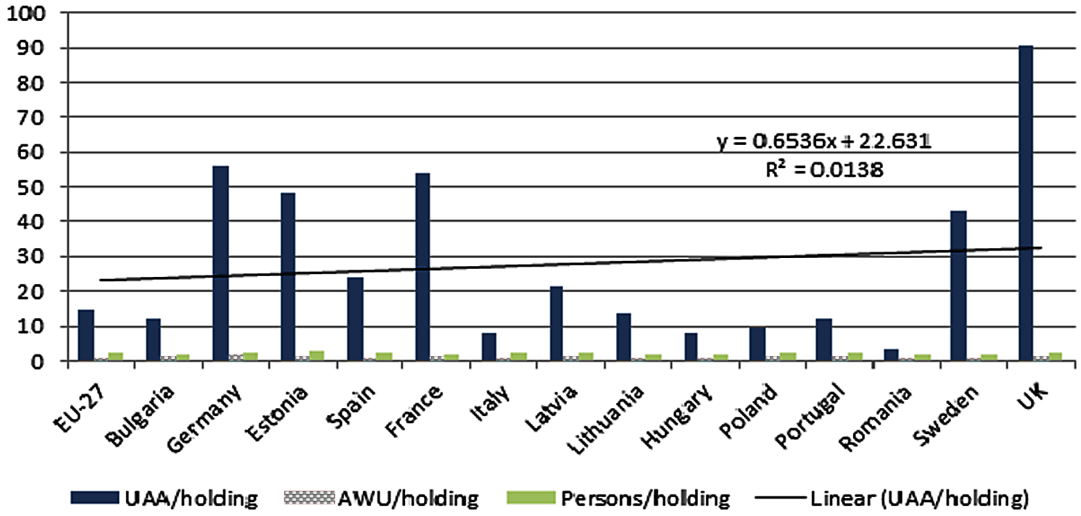
Table 2. Physical, labor and economic size of holdings in some EU states, 2010

Country	Physical Size (ha)	Economic Size (EUR)		Labor Size	
	UAA	SO	SO/Holding	Persons	AWU
EU-27	175,815,160	308,062,308,140	25,152.4	25,474,210.0	9,183,030
Bulgaria	4,475,530	2,536,665,610	6,846.8	738,900.0	389,110
Germany	16,704,040	41,494,097,650	138,715.9	749,740.0	489,660
Estonia	940,930	594,584,270	30,320.5	52,340.0	24,550
Spain	23,752,690	34,173,074,930	34,525.2	2,227,020.0	720,860
France	27,837,290	50,733,216,720	98,301.1	1,014,750.0	692,440
Italy	12,856,050	49,460,329,710	30,514.5	3,392,700.0	842,520
Latvia	1,796,290	777,190,960	9,320.0	180,990.0	84,640
Latvia	2,742,560	1,526,276,560	7,634.8	366,090.0	143,820
Hungary	4,686,340	5,241,037,240	9,086.2	1,143,500.0	402,970
Poland	14,447,290	18,987,070,900	12,602.4	3,802,590.0	1,869,420
Portugal	3,668,150	4,639,745,660	15,198.8	708,080.0	335,780
Romania	13,306,130	10,420,314,210	2,700.2	7,156,930.0	1,501,000
Sweden	3,066,320	3,733,311,440	52,515.3	141,530.0	53,580
UK	16,881,690	19,554,979,690	104,762.6	418,670.0	246,670

Source: Authors based on European Commission (2015b)

Figure 10. Resource efficiency of land and labor in some EU-27 countries in 2010
Source: Authors' own computation based on European Commission (2015b)



As it can be seen from the Figure 10 the highest values for the indicators considered in the assessment of the three sizes for the analyzed countries are registered on the economies of Germany, France and Italy. From this perspective is important to highlight the polarization of European agricultural economy. Thus in case of industrialized states is revealed a reduction in the workforce (AWU) and an increase in

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productivity while in the case of others economies, especially in the former communist countries, agriculture continues to mobilize the most important labor resources as a means of ensuring the existence of the rural people.

A decisive component in the capitalization of the agricultural potential and sectorial viability growth beyond its classic side is the size of agricultural holdings influence on the level of productivity and rural community life in general. In this regard, the size of agricultural holdings is a defining element in harnessing the potential of national agriculture having a direct impact on the value of productivity in agriculture sector. The distribution of holdings according to the utilized agricultural area reflects the effect of national and European policies, of support for the intensive production and the creation of large industrial holdings. Table 3 presents the agricultural size of holdings in some EU-27 countries in 2010.

From Table 3 it can be noted that of the 258 640 holdings with zero ha, more than half of them, respectively 134,710 are registered in Romania. A large number of holdings with zero ha is registered in countries such as Hungary (42.790 holdings), Spain (22.500 holdings), Bulgaria (13.150 holdings) and France (9.490 holdings). Small farms, with less than 2 hectares represent 5.759.760 holdings in EU-27, representing the predominant form of farm organization in realizing the exploitation potential of European agriculture. Also, it can be observed a polarization of European agricultural sector between small and very small farms on the one hand and industrial-type farms lower in number but which aggregate important land resources, on the other hand. Figure 11 shows the size distribution of agricultural holdings in some EU-27 countries in 2010, as total holdings.

Taken from an economic perspective, European farms, classified in category Zero EUR, register a slight decrease from the Zero agricultural hectares, 240.680 holdings, actually gratifying, considering that the holdings in this category are subsistence farms, corresponding to small properties land crumb.

Table 3. Agricultural size of holdings in some EU-27 countries, in 2010

	Zero ha	Less than 2 ha	From 2 to 4.9 ha	From 5 to 9.9 ha	From 10 to 19.9 ha	From 20 to 29.9 ha	From 30 to 49.9 ha	From 50 to 99.9 ha	100 ha and over
EU-27	258,640	5,759,760	2,474,030	1,337,660	916,570	382,560	399,160	393,890	325,860
Bulgaria	13,150	294,960	30,390	10,730	6,820	2,950	3,060	2,930	5,490
Germany	1,410	14,260	11,690	47,310	63,160	30,970	45,100	51,620	33,620
Estonia	150	2,210	4,250	4,070	3,470	1,480	1,170	1,090	1,720
Spain	22,500	270,280	232,800	141,850	110,960	53,010	54,730	52,470	51,190
France	9,490	66,580	62,690	46,640	50,150	33,280	55,240	97,780	94,250
Italy	5,290	819,360	357,670	186,150	120,120	46,690	40,920	29,210	15,490
Latvia	320	9,590	18,390	22,660	17,490	5,670	3,950	2,740	2,570
Lithuania	260	32,310	84,830	39,900	21,470	6,640	5,870	4,830	3,800
Hungary	42,790	412,740	46,060	26,540	19,430	7,950	7,440	6,410	7,450
Poland	7,960	355,220	468,200	334,950	218,510	59,970	35,310	16,840	9,650
Portugal	1,400	152,460	77,060	33,170	18,980	6,420	5,320	4,360	6,110
Romania	134,710	2,731,730	727,390	182,440	43,610	9,730	8,210	7,480	13,730
Sweden	740	560	7,630	15,820	14,180	7,140	8,030	9,070	7,930

Source: Authors based on European Commission (2015b),

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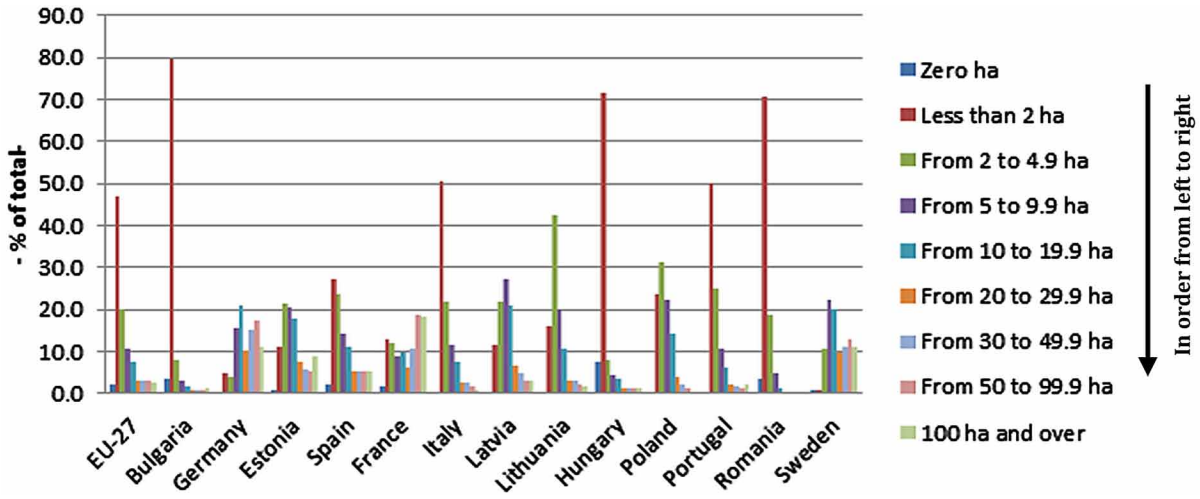
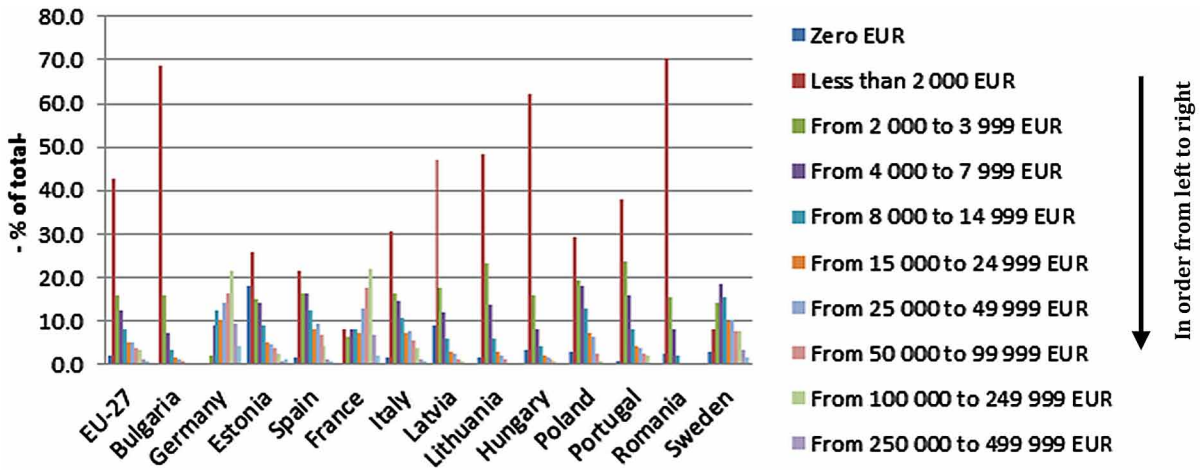
Figure 11. The distribution of holding by the agricultural size in some EU-27 countries, in 2010, (as total holdings)
Source: authors' own computation based on European Commission (2015b),



For comparison in Figure 12 is shown the economic size of holdings, as total holdings in some EU-27 countries in 2010.

By analyzing Figure 11 and Figure 12 it could be noticed a certain similarity in the distribution of holdings, both in terms of physical and economic perspectives, demonstrating the classical correlation of physical influence on holdings' economic performance. In Table 4 is shown in absolute values the size of holdings in some EU-27 countries in 2010. As it is shown in the below table, the economic size of holdings in some EU-27 countries reflect major disparities between the old EU member states and the new ones.

Figure 12. The economic size of holdings in some EU-27 countries, in 2010, (as total holdings)
Source: authors' own computation based on European Commission (2015b)



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According to de data (Table 4), Romania register 99,840 holdings with Zero EUR, which represents 41.48% form the total EU-27 (240,680 holdings). Also among the states with higher value of holdings with zero euro economic size could be mention Poland with 42,520 holdings, Italy (23,800 holdings), Hungary (19,900 holdings). Despite the evolution of the land structure consolidation, in Romania only 1,010 holdings have an economic size of 500 000 EUR or over, which could be barley compared with countries as: Germany (13,280 holdings), France (10,870 holdings), Italy (11,770 holdings) or Hungary (1,330 holdings). From this perspective it can be easily remarked the adaptive trend to the CAP tendencies and accentuating disparities in field of holding's consolidation perspective.

EVOLUTION OF AGRICULTURAL OUTPUT IN THE EU-28 IN CONTEXT OF AGRICULTURAL SECTOR TRANSFORMATIONS

With its classic function, agriculture must provide not only better utilization of available land resources, but it has to contribute significantly to improving the living standards of rural communities. Evolution of agricultural output during the years reflects more and more inclination of this sector towards the growth of production and increasing food security and thus to generate additional revenue for European farmers.

CAP reorientation towards greening agricultural industry, and shift from production support and funding on the surface that is boosting agri-environmental measures, was passed to an evolution of crop output syncope and a trend where animal ascendant output. In Table 5 is presented the evolution of agricultural output and gross value added at producer prices in some EU-28 states during 2010-2014 (in million EUR).

As it can be seen from Table 5, during 2010-2014, at EU-28 level there is an absolute increase in crop output of 12.128 million and 26.950 million EUR in the case of animal output. Also gross value added of the agricultural sector for the same period recorded an increase of 16.018 million euro. Spain is the only country that registered a decrease in crop output of 424 million euro. Among the countries with the largest increase in crop output is distinguished Poland (2.060 million euro), Italy (1,452 million euro), Germany (1,270 million euro) and Hungary (1,075million euro). In exchange regarding the evolution of gross value added of the agricultural sector in the same period it can be seen dramatic decreases in case of France (1.529 million euro) and slightly mitigated to some countries such as Spain (-454 million euro), Portugal (-135 million euro) and Latvia (-36 million euro).

Evolution of agricultural output and gross value added at producer prices in some EU-28 states during 2010-2014 highlights significant changes which have occurred in the European agricultural economy under CAP influence and the tendency of states to reform the structures of agricultural production by giving up some financial support. From this perspective, in Figure 13, is presented the evolution of subsidies and taxes in the agricultural sector in some EU-28 countries during 2010-2014.

Regarding subsidies and taxes in the agricultural sector in some EU-28 countries during 2010-2014 it can be noticed trends imposed by the modification of CAP paradigm. Thus the effect of the measures to reform CAP caused many of the subsidies to be eliminated or modified as structure and allocations during 2005-2006. As noted in (Eurostat, 2015c) „whereas production subsidies were more than 14 times as high as product subsidies in 2014, in 2005 they had only been 1.5 times as high. The net impact of these two types of subsidies less taxes in 2014 was to add an extra 31.4% to value added at producer prices; for comparison, in 2005 the increase due to subsidies less taxes was 34.5%"(Eurostat, 2015c).

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Table 4. Economic size of holdings in some EU-27 countries, 2010

	Zero EUR	Less than 2 000 EUR	From 2 000 to 3 999 EUR	From 4 000 to 7 999 EUR	From 8 000 to 14 999 EUR	From 15 000 to 24 999 EUR	From 25 000 to 49 999 EUR	From 50 000 to 99 999 EUR	From 100 000 to 249 999 EUR	From 250 000 to 499 999 EUR	500 000 EUR or over
EU-27	240,680	5,220,970	1,939,160	1,528,830	981,790	602,070	627,140	466,510	411,810	148,600	80,610
Bulgaria	980	254,130	59,480	26,290	12,510	6,060	4,750	2,570	1,990	1,010	730
Germany	470	1,120	6,560	26,460	37,170	30,850	42,320	49,310	63,970	27,640	13,280
Estonia	3,520	5,080	2,940	2,750	1,750	1,020	940	720	500	170	230
Spain	17,380	211,250	163,210	163,070	125,130	82,430	93,750	68,070	43,160	13,850	8,510
France	2,110	41,740	32,470	41,760	42,280	38,390	66,560	90,440	113,890	35,600	10,870
Italy	23,800	494,590	263,770	236,340	177,020	119,510	128,590	88,660	59,440	17,410	11,770
Latvia	7,660	39,240	14,560	10,130	4,910	2,640	2,120	1,070	700	220	150
Lithuania	3,190	96,760	46,540	27,140	12,220	5,700	4,580	2,180	1,110	270	240
Hungary	19,900	358,690	91,000	46,460	25,350	13,000	10,520	5,920	3,590	1,080	1,330
Poland	42,520	442,880	290,340	274,240	195,020	112,890	94,620	35,710	12,830	3,390	2,180
Portugal	2,710	116,540	71,840	48,550	24,970	12,760	11,470	8,020	5,940	1,600	860
Romania	99,840	2,716,620	602,470	313,000	78,460	22,240	13,370	6,450	4,120	1,450	1,010
Sweden	2,200	5,710	9,990	13,190	10,960	7,080	7,450	5,540	5,570	2,260	1,150

Source: authors based on European Commission (2015), CAP monitoring and evaluation indicators 2014-2020, retrieved from: http://ec.europa.eu/agriculture/cap-indicators/context/index_en.htm

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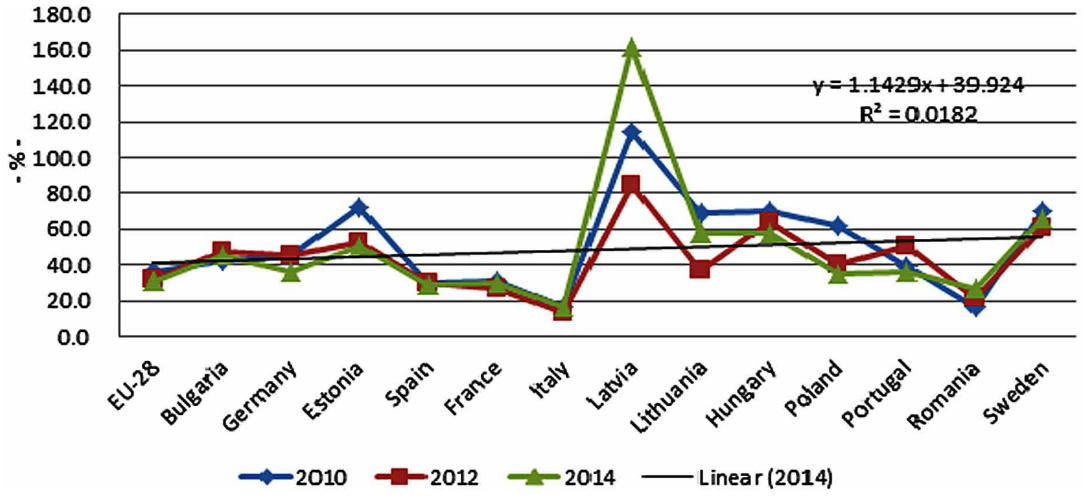
Table 5. Evolution of agricultural output and gross value added at producer prices, in some EU-28, 2010–2014

(Million EUR)	Crop Output				Animal Output				Gross value added of the agricultural sector			
Country	**2010**	**2012**	**2014**	**Δ 2010-14**	**2010**	**2012**	**2014**	**Δ 2010-14**	**2010**	**2012**	**2014**	**Δ 2010-14**
EU-28	189,685	210,979	201,814	12,128	140,928	163,094	167,878	26,950	143,817	157,020	159,835	16,018
Bulgaria	2,118	2,626	2,485	367	1,037	1,145	1,050	12	1,277	1,542	1,564	288
Germany	22,770	26,971	24,040	1,270	21,299	23,780	25,143	3,844	14,278	15,586	19,492	5,214
Estonia	274	429	383	109	317	380	425	107	231	356	332	100
Spain	24,587	23,754	24,163	-424	13,519	15,971	15,846	2,328	21,646	20,779	21,192	-454
France	38,809	44,303	39,420	611	22,329	25,244	26,116	3,787	26,686	29,090	25,156	-1,529
Italy	24,986	26,949	26,438	1,452	14,322	16,830	16,567	2,244	24,197	26,926	26,894	2,697
Latvia	474	750	602	128	371	451	495	124	223	314	186	-36
Lithuania	924	1,654	1,335	411	801	917	923	122	502	988	775	273
Hungary	3,473	4,335	4,548	1,075	2,111	2,546	2,605	494	1,910	2,482	3,008	1,099
Poland	8,782	11,290	10,842	2,060	9,115	10,497	11,260	2,145	6,498	8,229	8,702	2,204
Portugal	3,538	3,460	3,595	57	2,371	2,599	2,582	210	2,378	1,971	2,242	-135
Romania	10,311	9,008	10,938	627	3,592	3,993	3,888	297	6,534	6,209	6,783	249
Sweden	2,317	3,038	2,652	335	2,344	2,671	2,739	395	1,488	1,794	1,571	83

Source: authors based on Eurostat (2015b)

Figure 13. Subsidies and taxes in the agricultural sector, in some EU-28 countries, 2010–2014
Source: Authors based on Eurostat (2015c)



In terms of harvested production and area of production can be seen significant increases in the case for the main categories analyzed. From this perspective, in Table 6 and Table 7 are presented the harvested production and area of production of in some countries EU-28 for cereals in 2014 and of potatoes and sugar beet during 2007-2014.

Table 6. The harvested production and area of production of cereals, 2014

Country	Harvested production (thousand tonnes)						Area of production (thousand hectares)	
	Common wheat	Barley	Grain Maize	Rice	Total	Change 2007-2014 (%)	Total	Change 2007-2014 (%)
EU-28	149,918.9	60,716.5	78,079.0	2 878.3	334,182.3	27.8	58,074.0	1.6
Bulgaria	5,318.7	851.4	3,136.2	54.2	9,522.5	197.4	1,958.7	49.9
Germany	27,711.2	11,562.8	5,142.1	NA	52,010.4	28.0	6,468.6	- 1.6
Estonia	615.5	458.1	NA	NA	1,221.6	38.9	332.9	13.9
Spain	5,698.6	6,933.5	4,692.0	863.6	20,397.4	- 16.9	6,260.9	0.3
France	37,501.4	11,775.3	18,541.8	83.4	72,714.9	22.3	9,591.7	5.5
Italy	3,105.9	846.1	9,239.5	1 386.1	19,232.7	- 5.3	3,173.0	- 19.3
Latvia	1,467.5	418.8	NA	NA	2,227.2	45.1	638.8	22.4
Lithuania	3,230.6	1,018.5	115.0	NA	5,123.2	69.8	1,288.8	28.5
Hungary	5,169.3	1,278.9	9,168.8	8.9	16,448.2	70.4	2,811.8	1.7
Poland	11,635.6	3,274.6	4,468.4	NA	31,951.1	17.7	7,485.3	- 10.4
Portugal	84.7	36.6	933.1	167.3	1,348.6	26.5	302.9	- 2.9
Romania	7,769.4	1,834.0	12,040.5	45.4	22,438.9	187.1	5,521.7	8.1
Sweden	3,087.8	1,572.5	11.1	NA	5,790.4	14.5	1,025.1	4.4

Note: NA= no data available
Source: authors based on Eurostat (2015c)

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Table 7. Evolution of harvested production and area of production of potatoes and sugar beet, in some EU-28 countries, 2007-2014

	Potatoes						Sugar beet					
	Harvested production (thousand tonnes)			Area of production (thousand hectares)			Harvested production (thousand tonnes)			Area of production (thousand hectares)		
	2007	2014	2007-2014 (%)	2007	2014	2007-2014 (%)	2007	2014	2007-2014 (%)	2007 (2)	2014	2007-2014 (%)
EU-28	63,558.1	59,952.1	-5.7	2,205.2	1,682.6	-23.7	114,427.5	127,809.1	11.7	1,839.0	1,623.1	-11.7
Bulgaria	298.7	132.2	-55.7	22.4	10.2	-54.5	16.3	0.0	-100.0	1.3	0.0	-100.0
Germany	11,643.8	11,607.3	-0.3	275.0	244.8	-11.0	25,139.1	29,748.1	18.3	402.7	372.5	-7.5
Estonia	191.8	82.3	-57.1	11.1	4.4	-60.4	0.0	NA	NA	0.0	NA	NA
Spain	2,479.6	2,467.6	-0.5	85.7	75.8	-11.6	4,910.0	3,608.0	-26.5	68.2	38.4	-43.7
France	7,205.8	8,054.5	11.8	158.8	168.0	5.8	33,212.7	37,931.5	14.2	393.5	406.7	3.4
Italy	1,781.6	1,365.4	-23.4	69.5	52.3	-24.7	4,629.9	3,784.4	-18.3	85.6	52.0	-39.3
Latvia	630.0	209.9	-66.7	40.3	11.1	-72.5	11.1	NA	NA	0.3	NA	NA
Lithuania	571.5	460.9	-19.4	52.3	26.8	-48.8	799.9	1,014.4	26.8	16.9	17.0	0.6
Hungary	563.1	546.8	-2.9	25.1	20.8	-17.1	1,692.8	1,010.1	-40.3	41.2	15.3	-62.9
Poland	11 791.1	7,424.7	-37.0	549.4	267.1	-51.4	12,681.6	11,544.4	-9.0	247.4	191.4	-22.6
Portugal	621.5	534.2	-14.0	37.1	27.2	-26.7	251.6	13.3	-94.7	2.9	0.4	-86.2
Romania	3,712.4	3,520.3	-5.2	268.1	202.7	-24.4	748.8	1,357.3	81.3	28.7	30.6	6.6
Sweden	789.0	820.3	4.0	28.4	23.8	-16.2	2,137.7	2,056.2	-3.8	40.7	34.4	-15.5

Source: Eurostat (2015), Agricultural output, price indices and income, retrieved from: http://ec.europa.eu/eurostat/statistics-explained/index.php/Agricultural_output,_price_indices_and_income, accessed: 2015-07-16

From Table 6 it can be seen that at EU-28 level out of a total of 334,182.3 thousand tonnes of harvested production, 149,918.9 thousand tonnes were classified as common wheat, which represents the main production for most European countries. Thus in case of Romania out of a total of 22,438.9 thousand tonnes, 12,040.5 thousand tonnes were grain-maize and only 7.769.4 thousand tonnes common wheat. In the following table is presented harvested production and area of production of potatoes and sugar beet, EU-28, 2007-2014. In Figure 14 and Figure 15 are presented the yields/performance/productivity per hectare for wheat and corn.

Potato production and the sugar beet have undergone extensive reform measures in the EU-28, CAP significantly modifying production paradigm for these two products. Therefore in most countries analyzed it can be observed significant decreases both for the harvested production and for the area of production. As example, the table below presents the evolution of the harvested production and area of production of potatoes and sugar beet, in some EU-28, 2007-2014.

Figure 15. Corn production performance per hectare in some EU-28 countries, 2014
Source: authors' own computation based on NIS (2015)

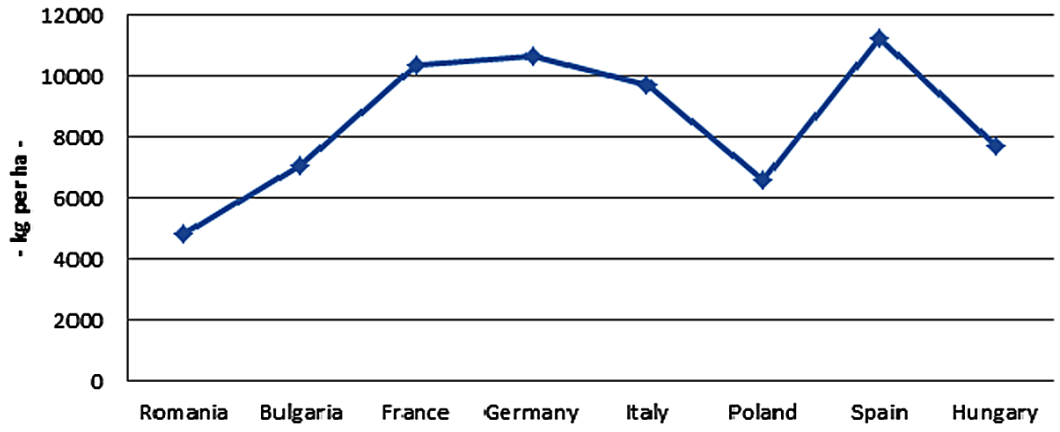
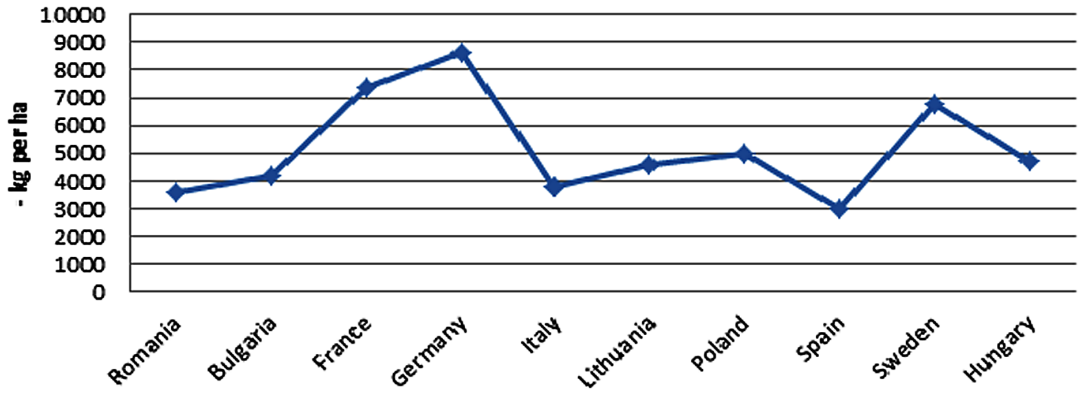


Figure 14. Wheat production performance per hectare in some EU-28 countries, 2014
Source: authors' own computation based on NIS (2015)



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CONCLUSION

Agriculture, despite significant transformations that have marked Europe's economy over the past two and a half decades continues to represent a broad economic sector with important implications, especially on rural communities. Being often the only source of income or achievement livelihoods, agriculture defines the evolution of rural communities, instilling in them a deep agricultural character.

Assuming that most of the time rural communities are facing on one side with large sectorial imbalances and the possibility to diversify non-agricultural activities remain sometimes the only goal when economies ex-socialist such as in Romania and Bulgaria, in this chapter, is attempted a radiography analyze by the European agricultural transformations in economy, rural communities and food sustainability in the context of Common Agricultural Policy Reforms.

Analyzed in sectorial terms and from the perspective of economic efficiency indicators, evolution of the European agricultural sector demonstrates the capability of appreciable levels of economic efficiency (TFT, labor productivity, agricultural GVA). In this context, the appreciation of the role and place that agriculture must play in the European economy is inextricably linked to the future of rural communities. General questions that research in this chapter tries to answer at: "It is the agricultural sector competitive enough to reduce the gaps between the other economic sectors at EU-28 and national level?" and "are rural communities strongly dependent on the evolution of the agricultural sector and what are the implications of this dependency?" are elements of continuity to understanding the mechanism of European rural economy as a whole.

REFERENCES

Andrei, J. V., Dusmanescu, D., & Mieila, M. (2015). The influences of the cultural models on agricultural production structures in Romania and some E-28 countries - a perspective. *Economics of Agriculture*, *62*(2), 293–307.

Andrei, J. V., & Gheorghe, P. (2014). Economy in Romania and the Need for Optimization of Agricultural Production Structures. Peter Lang GmbH. doi:10.3726/978-3-653-05012-7

Ciutacu, C., Chivu, L., & Andrei, J. V. (2015). Similarities and dissimilarities between the EU agricultural and rural development model and Romanian agriculture. Challenges and perspectives. *Land Use Policy*, (46): 258–266.

Dwibedia, J. K., & Chaudhuri, S. (2014). Agricultural subsidy policies fail to deal with child labour under agricultural dualism: What could be the alternative policies? *Research in Economics*, *68*(3), 277–291. doi:10.1016/j.rie.2014.05.003

European Commission. (2014). *CAP context indicators 2014-2020, Agriculture and Rural Development*. Retrieved from: http://ec.europa.eu/agriculture/cap-indicators/context/index_en.htm

European Commission. (2015b). *CAP monitoring and evaluation indicators 2014-2020*. Retrieved from: http://ec.europa.eu/agriculture/cap-indicators/context/index_en.htm

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Eurostat. (2015a). *The EU in the world - agriculture, forestry and fisheries*. Retrieved from: http://ec.europa.eu/eurostat/statistics-explained/index.php/The_EU_in_the_world_-_agriculture,_forestry_and_fisheries, accessed: 2015-10-04

Eurostat. (2015b). *Agricultural output, price indices and income*. Retrieved from: http://ec.europa.eu/eurostat/statistics-explained/index.php/Agricultural_output,_price_indices_and_income, accessed: 2015-07-16

Eurostat. (2015c). *Agricultural output, price indices and income*. Retrieved from: http://ec.europa.eu/eurostat/statistics-explained/index.php/Agricultural_output,_price_indices_and_income, accessed: 2015-07-16

Eurostat. (2015d). *Structure of agricultural holdings*. Retrieved from: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ef_r_farm&lang=en

Kilian, S., & Salhofer, K. (2008). Single payments of the CAP: Where do the rents go? *Agricultural Economics Research*, *9*, 96–106.

Latruffe, L., Dupuy, A., & Desjeux, Y. (2013). What would farmers' strategies be in a noCAP situation? An illustration from two regions in France. *Journal of Rural Studies*, *32*, 10–25. doi:10.1016/j.jrurstud.2013.04.003

Luca, L. (2007). Romania: Large Semi-subsitence Farm Sector, Result of Wrong Strategic Approach? *The 104th (joint) EAAE-IAAE Seminar Agricultural Economics and Transition: What was expected, what we observed, the lessons learned*. Corvinus University of Budapest.

Montiel, B. R., Colombo, S., & Salazar-Ordóñez, M. (2014). Social attitudes in southern Spain to shape EU agricultural policy. *Journal of Policy Modeling*, *36*(1), 156–171. doi:10.1016/j.jpolmod.2013.08.004

Petrick, M., & Zier, P. (2012). Common Agricultural Policy effects on dynamic labour use in agriculture. *Food Policy*, *37*(6), 671–678. doi:10.1016/j.foodpol.2012.07.004

Piotet, P., Leonte, J., Giurca, D., & Campeanu, V. (2002). *Politica Agricola Comuna - Consecinte asupra Romaniei, Institutul European din Romania – Studiul de impact in perioada de preaderare Nr.2, Bucureşti. NIS (2015), Productia agricola vegetala la principalele culturi, în anul 2014, (date provizorii), Comunicat de presa Nr. 75 din 31 martie 2015*. Bucuresti: Institutul National de Statistica.

ADDITIONAL READING

Anderson, K., Rausser, G., & Swinnen, J. (2013). Political economy of public policies: Insights from distortions to agricultural and food markets. *Journal of Economic Literature*, *51*(2), 423–477. doi:10.1257/jel.51.2.423

Badea, L., & Mieila, M. (2008). The economic efficiency of field crops cultivation in south Romania: Trends and actions for improvement. *Annales Universitatis Apulensis Series Oeconomica*, *1*(10), 328–336.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Bartolini, F., Viaggi, D., Ronchi, D., Gomez y Paloma, S., & Sammeth, F. (2011). Assessing the impact of future CAP reforms on the demand of production factors. In: *122nd Seminar EAAE* (European Association of Agricultural Economists), Ancona, Italy.

Borrell, B., & Hubbard, L. (2000). Global economic effects of the EU Common Agricultural Policy. *Economic Affairs*, *20*(2), 18–26. doi:10.1111/1468-0270.00218

Bougherara, D., & Latruffe, L. (2010). Potential impact of the EU 2003 CAP reform on land idling decisions of French landowners: Results from a survey of intentions. *Land Use Policy*, *27*(4), 1153–1159. doi:10.1016/j.landusepol.2010.03.005

Brady, M., Kellermann, K., Sahrbacher, C., & Jelinek, L. (2009). Impacts of decoupled agricultural support on farm structure, biodiversity and landscape mosaic: Some EU results. *Journal of Agricultural Economics*, *60*(3), 563–585. doi:10.1111/j.1477-9552.2009.00216.x

Cafiero, C., Capitanio, F., Cioffi, A., & Coppola, A. (2007). Risk and crisis management in the reformed European agricultural policy. Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie, 55(4), 419-441.

Ciaian, P., Kancs, A., & Swinnen, J. F. (2010). *EU Land Markets and the Common Agricultural Policy*. Brussels, Belgium: CEPS.

Ciaian, P., Swinnen, J.F.M. (2006). Land market imperfections and agricultural policy impacts in the new EU member states: a partial equilibrium analysis. *American Journal of Agricultural Economics*, *88*(4), 799–815. doi:10.1111/j.1467-8276.2006.00899.x

Ene, C (2013), *Food Traceability-Actual Coordinates at National, European and International Level*, Quality - Access to Success, 14(135):103-107.

European Commission. (2014). Cross-compliance. In: Agriculture and Rural Development. Policy areas, Retrieved from: http://ec.europa.eu/agriculture/direct-support/ cross-compliance/ accessed: 09.01 2014

Gohin, A., Latruffe, L. (2006). The Luxembourg Common Agricultural Policy reform and the European food industries: what's at stake?. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie, 54*(1), 175-194.

Gray, J. (2000). The Common Agricultural Policy and the re-invention of the rural in the European Community. *Sociologia Ruralis*, *40*(1), 30–52. doi:10.1111/1467-9523.00130

Hart, K., Baldock, D., Weingarten, P., Osterburg, B., Povellato, A., Vanni, F., . . . Boyes, A. (2011). *What Tools for the European Agricultural Policy to Encourage the Provision of Public Goods*, European Parliament, Directorate General for Internal Policies Policy Department B: Structural And Cohesion Policies, Brussels, June 2011, Retrieved from: http://www.ieep.eu/assets/835/PG_FINAL.pdf accessed: 2015-07-16

Latruffe, L., & Davidova, S. (2007). Common Agricultural Policy direct payments and distributional conflicts over rented land within corporate farms in the New Member States. *Land Use Policy*, *24*(2), 451–457. doi:10.1016/j.landusepol.2006.06.003

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Latruffe, L., & Le Mouël, C. (2009). Capitalization of governmental supporting agricultural land prices: What do we know? *Journal of Economic Surveys*, *23*(4), 659–691. doi:10.1111/j.1467-6419.2009.00575.x

Lee, K.-H., & Sivananthiran, A. (1996). Contract labour in Malaysia: Perspectives of principal employers, contractors and workers. *International Labour Review*, *135*(6), 75–91.

Manos, B., Bournaris, T., Papathanasiou, J., & Chatzinikolaou, P. (2009). Evaluation of tobacco cultivation alternatives under the EU Common Agricultural Policy (CAP). *Journal of Policy Modeling*, *31*(2), 225–238. doi:10.1016/j.jpolmod.2008.07.001

Matthews, A. (2011). Post-2013 EU Common Agricultural Policy, Trade and Development. A Review of Legislative Proposals. International Centre for Trade and Sustainable Development (ICTDS), Geneva http:// ictsd. org/downloads/2011/12/post-2013-eu-common-agricultural-policy-trade-and-development. Pdf

Matthews, K. B., Buchan, K., Miller, D. G., & Towers, W. (2013). Reforming the CAP—With area-based payments, who wins and who loses? *Land Use Policy*, *31*, 209–222. doi:10.1016/j.landusepol.2012.06.013

Moravec, J., & Zemeckis, R. (2007). Cross Compliance and Land Abandonment: A research paper of the Cross Compliance Network, February 2007. Mottet, A., Ladet, S., Coque, N., Gibon, A., 2006. Agricultural land-use change and its drivers in mountain landscapes: a case study in the Pyrenees. *Agriculture, Ecosystems & Environment*, *114*, 296–310.

Moyer, W., & Josling, T. (2002). *Agricultural policy reform: politics and process in the EU and US in the 1990s*. Ashgate Publishing Ltd.

Nedelcu, A., Subic, J., Tataru, A., & Kuzman, B. (2014). The Local Action Group. Local development model based on community. Case study - LGA „Land of Vineyards and wine. *Procedia Economics and Finance*, *2015*. doi:10.1016/S2212-5671(15)00290-7

Nedergaard, P. (2008). The reform of the 2003 Common Agricultural Policy: An advocacy coalition explanation.1. *Policy Studies*, *29*(2), 179–195. doi:10.1080/01442870802033464

Nowicki, P. (2002). European policy review: Mid-Term Review of the EU Common Agricultural Policy. *Journal for Nature Conservation*, *10*(3), 185–187.

Overmars, K. P., Verburg, P. H., & Veldkamp, T. (2007). Comparison of a deductive and an inductive approach to specify land suitability in a spatially explicit land use model. *Land Use Policy*, *24*(3), 584–599. doi:10.1016/j.landusepol.2005.09.008

Pokrivcak, J., Crombez, C., & Swinnen, J. F. (2006). The status quo bias and reform of the Common Agricultural Policy: Impact of voting rules, the European Commission and external changes. *European Review of Agriculture Economics*, *33*(4), 562–590. doi:10.1093/erae/jbl027

Popescu, G., & Andrei, J. V. (2015), Agricultural Management Strategies in a Changing Economy, Hershey, PA: IGI Global. doi:10.4018/978-1-4666-7521-6

Raggi, M., Sardonini, L., & Viaggi, D. (2013). The effects of the Common Agricultural Policy on exit strategies and land re-allocation. *Land Use Policy*, *31*, 114–125. doi:10.1016/j.landusepol.2011.12.009

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Roling, N. G., & Wagemakers, A. E. (2000). *Facilitating sustainable agriculture. Participatory Learning and Adaptive Management in Times of Environmental Uncertainty*. Cambridge University Press.

Schmid, E., & Sinabell, F. (2007). On the choice of farm management practices after the reform of the Common Agricultural Policy in 2003. *Journal of Environmental Management*, *82*(3), 332–340. doi:10.1016/j.jenvman.2005.12.027 PMID:17095138

Stoica, L. (2013). The Process of Collectivization Approached in Romanian Propagandistic Literature. *International Journal of Sustainable Economies Management*, *2*(1), 36–45. doi:10.4018/ijsem.2013010104

Topp, C. F. E., & Mitchell, M. (2003). Forecasting the environmental and socio-economic consequences of changes in the Common Agricultural Policy. *Agricultural Systems*, *76*(1), 227–252. doi:10.1016/S0308-521X(01)00113-5

Ungureanu, A. (2015). The importance of Romanian mountain tourism for the national economy. *Economics of Agriculture*, *62*(3), 849–868.

Viaggi, D., Raggi, M., & Paloma, S. G. (2011). Understanding the determinants of investment reactions to decoupling of the Common Agricultural Policy. *Land Use Policy*, *28*(3), 495–505. doi:10.1016/j.landusepol.2010.10.003

KEY TERMS AND DEFINITIONS

Agricultural Holding: The most common instrument in valuing the agricultural potential by combining in an optimum manner all the production factors – land, labour and capital.

Annual Work Unit (AWU): According to EUROSTAT definition, corresponds to the work performed by one person who is occupied on an agricultural holding on a full-time basis.

Common Agricultural Policy (CAP): A sectorial EU-28 policy concerning the agricultural sector. It consists of two pillars – common agricultural market and production organization (first pillar) and rural development (the second pillar).

Permanent Crops: Mainly ligneous crops and play an important role in shaping the rural landscape and it consists of orchards, vineyards and olive tree plantations.

Single Payment Scheme (SPS): Introduced in 2003 as common agricultural policy (CAP) reform, it disconnects the payments from the direct agricultural production by promoting cross-compliance.

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Chapter 44
The Use of Complementary Virtual and Real Scientific Models to Engage Students in Inquiry: Teaching and Learning Climate Change Science

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ABSTRACT

This chapter reports on a four-year study to change how climate change science is taught and learned in schools. The goal of the Climate Change Narrative Game Education (CHANGE) project is to take what is known about reform-based practices, incorporating students' lived experiences into the curriculum, and the integration of Information and Communications Technology (ICT) into the classroom. CHANGE uses the following: scientifically realistic text narratives (text stories with local characters, 50-100 years in the future, a local, place-based approach, a focus on the built environment, the use of simulations and games based on scientific data, and a web-based "intermedia" eBook narrative where sections of narrative text alternate with simulations and computer games. The chapter reports on the ways that we have used the above principles to connect classrooms and communities and school science with academic science to facilitate student inquiry into climate science by combining virtual serious educational games with in class, hands-on inquiry using scientific models.

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INTRODUCTION

It is an interesting time for science education. We are faced with global problems associated with advances in science and technology, while at the same time we seek solutions to them in new scientific knowledge and technological innovations. It is also a time in which there are massive changes in the ways that we share and use information as print and wired media are replaced by digital and wireless communications in the social sphere. All that said, classrooms in schools remain the familiar places in which the teaching and learning of science has changed little over the years. In particular, there are few visible effects of innovative uses of Information and Communications Technology (ICT) or the use of inquiry in the teaching and learning of science in schools.

The use of ICT has become ubiquitous in our contemporary lives. We see this in schools where students use it to write assignments, look up information, and communicate with teachers. Similarly, teachers use ICT to write lesson plans, handouts, quizzes and tests; to look up information; to present lessons; to record and calculate student grades; and to communicate with students, parents and administrators. For the most part these are examples of how ICT has replaced older technology, like printed books, paper and pencil, overhead projectors, calculators, and telephones. While there are teachers and students who engage with ICT in more innovative ways including the use of probeware, access to and analysis of real scientific data, and models and simulations, in the US, where we are located, these innovative uses of ICT are few and far between (e.g., Bang & Luft, 2013).

Similarly, the effects of a more than 50-year effort to transform the teaching of science to be more inquiry oriented are not common. In the mid 20th century governmental agencies around the world funded the development of courses and curriculum in which inquiry was central (e.g., Donahue, 1993; Nuffield Foundation, 2016; Tamir & Jungwirth, 1975). However, Stake and Easley (1978) found that in elementary schools there were only occasional efforts to do more than read about science topics, and that in secondary schools science was seldom taught as scientific inquiry and subjects were presented as what experts had found to be true. Twenty years later the National Science Education Standards (National Research Council, 1996) called again for the teaching of science as inquiry, and more efforts were made to transform teachers' practice (National Research Council, 2000). However, as with ICT, there is little visible evidence that teachers use inquiry oriented pedagogy.

There are many possible reasons why what happens in classrooms changes slowly if at all, including the negative effects of high stakes examinations, ill-prepared teachers, and the overall difficulty of enacting changes in large bureaucracies like school systems. There are also practical problems such as limited access to computers and other devices, and broadband access; and lack of scientific supplies and equipment. Another possible reason is that often the use of ICT and inquiry are presented as add-ons, rather than being incorporated into existing courses and curricula. In this chapter, we report on our efforts to change how climate change science is taught in schools within the context and structure of an existing high school course – Marine Science. We chose this course because many of the topics in its curriculum leant themselves to climate change science.

Our project -- the NSF-funded Climate Change Narrative Game Education (CHANGE)[1] project -- takes what we know about reform-based practices, the need to incorporate students' lived experiences into the curriculum, and the integration of Information and Communications Technology (ICT) to facilitate students' inquiry into climate science. Its aims are for students to gain a better understanding of the impacts of climate change on the natural environment and human-built world particularly within the place-based setting of the southeast US. It attempts to connect climate change and sea level rise

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to students' everyday lives so that they become motivated to learn about issues related to their region (Hallar, McCubbin, & Wright, 2011; Theobald, 2006). CHANGE does so by employing the following principles: (a) the use of scientifically realistic text narratives about future southeast US residents, (b) a local, place-based approach grounded in scientific data, (c) a focus on the built environment, (d) the use of simulations and games to help students learn principles of Global Climate Change (GCC), and (e) a web-based "intermedia" approach where sections of narrative text alternate with simulations and computer games. All CHANGE materials are available on our website (http://climatechange.usf.edu).

BACKGROUND

In this chapter we report on the how CHANGE uses serious educational games (SEGs) and hands-on activities in a complementary manner to engage students in inquiry through the use of models to learn climate change science. In the next sections we provide some background on global climate change, the teaching of climate change science, scientific inquiry, and serious educational games. We then provide examples of the CHANGE materials after which we present data from our pilot testing of them in classrooms.

Global Climate Change

The Earth's climate is rapidly changing as the concentration of atmospheric greenhouse gases increases. These heat-trapping gases, data show, raise global temperatures, which causes sea level to rise and can lead to an increase in the frequency of extreme weather events (IPCC, 2013; World Bank, 2012; UCAR, 2015). All this has a great impact on the built and natural environments (Jollands, Bernier, & Golubiewski, 2007). With more than 100 million Americans living within the areas directly affected by climate change and coastal flooding, the impact is being seen environmentally and economically in the destruction of coastal infrastructure and communities; the incursion of salt water into fresh water aquifers as the seas rise; the disruption and even destruction of beaches and natural coastal habitats, which are the breeding sites for large numbers of marine organisms; and coral bleaching.

Given the above, there are still significant numbers of people in the US who are ill informed and skeptical about climate change. Politicians, policy institutes, and television or radio commentators often misrepresent climate change as a highly controversial and debatable issue. This may be due in part to misinformation campaigns by energy companies like ExxonMobil (Brulle, 2014; Kaiser & Wasserman, 2016), which questions whether climate change is real and the authenticity of anthropogenically induced climate change (McCright & Dunlap, 2011). In addition, many people consider climate change to be a significant threat globally, but do not feel threatened personally (Leiserowitz, 2005). However, agreement among over 97% of scientists worldwide suggests that the globe is warming at an alarming rate, and that humans are largely to blame (IPCC, 2013).

Difficulty of Teaching and Learning Climate Science

An understanding of science, including its processes and methods for warranting knowledge, is fundamental to understanding the forces that produce climate change and its effects on coastal regions. Clearly students need to be better educated about climate change science if they are to make intelligent and

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reasonable decisions about what to do in response to its effects on their communities (Kohut, Doherty, Dimock, & Keeter, 2009; Maibach, Roser-Renouf, & Leiserowitz, 2009). This is particularly important for those living in coastal areas, such as those in Florida, who need to be prepared to make decisions about the future of coasts and infrastructure.

Putting climate change science into national science standards (NGSS Lead States, 2013a) is not enough. Teachers need to be able to teach it, and students need to be able to learn it. However, climate change is a difficult topic to teach because: (1) the science involved is complex and multidisciplinary, (2) people do not notice the changes in climate on a daily basis, and (3) the media portrays it in misleading ways.

Its multidisciplinary nature requires knowledge from different fields such as geography, geology, chemistry, physics, ecology, and marine science. Typically, these topics are taught in a disjointed way, for example, a unit on the carbon cycle, another on weather and climate, and others on environmental effects. Therefore, for students to gain a comprehensive understanding of climate change, researchers and educators agree that an interdisciplinary approach is necessary (Summers, Childs, & Corney, 2005).

The global nature of the problem makes climate change difficult to observe at the local level (Pruneau, Liboiron, Vrain, Gravel, Bourque, & Langis, 2001). While GCC is happening faster than ever before, its effects are incremental and noticeable over decades. Therefore, it is necessary to find ways to zoom in, from the global to the local level, and to somehow reduce the perception that it is a problem of the future, not of the present.

Finally, when an issue is controversial, it can affect teachers' instructional decisions due to, among other things, concern that instruction of the topic will lead to objection from stakeholders within the community (Boykoff & Boykoff, 2004). When this controversy is combined with teachers' lack of understanding of the complexities of climate science (Herman, Feldman, & Vernaza-Hernandez, 2015), teachers may opt out of including it in their enacted curriculum (Gehrke, Knapp, & Sirotnik, 1992). While many teachers believe that climate change is an important topic, discrepancies exist about which aspects of climate change should be taught and how much time to allocate to it (Liu, Roehrig, Bhattacharya, & Varma, 2015). There are clear motives as to why teachers avoid controversial topics in their classrooms, including the complexity of the science, opposition from stakeholders, and curricular constraints. However, teachers' report that the greatest challenge when teaching controversial issues is that students are misinformed, lack knowledge regarding the topic, and are therefore unable to actively engage in classroom discussions and activities (Kuş, 2015). This suggests that successful teaching and learning of climate change science in schools requires new and innovative approaches.

Inquiry, Models, and ICT

In this section we examine what it means to engage in inquiry, the various types of scientific models, and the use of serious educational games in school settings.

The Role of Inquiry in Science Education

The use of inquiry has been promoted as a way to engage students in science so that they develop conceptual understanding of science content and of the nature of science (National Research Council, 2000). While the use of inquiry should not be seen as a panacea, many research studies have shown that it can meet the stated goals of its use (e.g., Anderson, 2002; Crawford, 2007; Hofstein, Navon, Kipnis, & Mamlok-Naaman, 2005).

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What is meant by inquiry in the science education literature has been somewhat ambiguous. In this chapter we use it to mean what scientists actually do when they engage in science (Anderson, 2002; Bybee, 2006; National Research Council, 1996). For example, in their examination of the use of various forms of guidance to support virtual science laboratories, Zacharia et al. (2015) state that when students engage in inquiry, they do so in "an investigative process that resembles what scientists do" (p. 258), in order to develop scientific knowledge and skills as well as gaining an understanding of the nature of inquiry. In defining inquiry, they provide a list of skills and practices that is echoed by other researchers (e.g., Donnelly, O'Reilly, & McGarr, 2013; Linn, Clark, & Slotta, 2003; National Research Council, 2000), and have been included as the practices of science that all students are expected to be able to engage in according the Next Generation Science Standards (NGSS Lead States, 2013a) and the 2013 PISA draft framework (OECD, 2013). The CHANGE materials are designed so that students engage in these types of science practices, both with hands-on and virtual activities as part of SEGs.

Scientific inquiry in schools can also be enacted at different levels of complexity, depending upon how skilled students, and teachers, are in its practices. Level 1, Confirmation Inquiry is when students engage in an activity that confirms a scientific principle for which the results are known in advance. Level 2, Structured Inquiry, is when the teacher originates the question and students follow a prescribed procedure. Level 3, Guided Inquiry is when the question still comes from the teacher but the students design the procedures. The most complex is Level 4, Open Inquiry, in which students investigate questions that they formulate and devise ways to find answers to their questions (Bell, Smetana, & Binns, 2005).

Scientific Models

Climate change is difficult to teach and learn because it is global in scope and takes years to observe its effects. Therefore, climate change education materials need to rely on models to provide students with inquiry opportunities. As with inquiry, the term scientific model has been defined in multiple ways in the literature (e.g., NGSS Lead States, 2013b; Schwarz & Passmore, 2012). In this chapter, we rely on the list of attributes of scientific models laid out by Cartier, Rudolph, and Stewart (2001, pp. 2-5):

- Models are constituted by empirical or theoretical objects and the processes in which they participate.
- Models can be used to explain and predict natural phenomena.
- Models are consistently assessed on the basis of empirical and conceptual criteria.
- Models are useful as guides to future research.

Given the complexity of how we think about and use models, Harrison and Treagust (2000) developed a typology of models and how they are used in science teaching and learning. They divided models into four main categories: (1) *Scientific and teaching models* are used by teachers to explain entities not easily observed in the classroom. (2) *Pedagogical analogical models for conceptual knowledge* include symbolic models, like chemical formulae, mathematical models, and theoretical models designed to help students understand concepts. (3) *Models depicting multiple concepts and/or processes* include maps, diagrams and tables, concept-process models, and simulations. Concept-process models emphasize that scientific concepts, when often represented by nouns, are complex processes. Simulations are a type of model that can help students to understand the underlying processes through manipulation of the various

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factors that interact in the process. (4) *Personal models* include mental models and students' alternative conceptions that combine their intuitive mental models with accepted scientific models.

Feldman, Cooke, and Ellsworth (2010) provided a list of types of physical models based on how they can be used in scientific inquiry. A physical model 1 (PM1) can be used simply to represent a physical phenomenon in the form of a three-dimensional model, drawing, videos, or animation. PM1s can be used to teach or explain the phenomenon to students, but are not generally useful for inquiry. PM2s allow students to manipulate the model to explain and predict natural phenomena so that they can understand the processes inherent in the phenomena. A PM3 is a representation of the phenomenon that can be manipulated and used to test hypotheses, assess empirical and conceptual criteria, or guide future research (Cartier, Rudolph, & Stewart, 2001).

Feldman et al.'s (2010) typology of physical models can be applied to virtual models such as computer simulations or games. Simulations or games could simply represent the phenomenon (e.g., demonstrating how sea level rises when glaciers melt); students could manipulate them to show, for example, the rising of the seas due to thermal expansion; or they could include ways for students to manipulate them to test ideas that describe the natural phenomena that underlie climate change. We will refer to these as DM1-DM3 digital models (see Table 1). As we will show later in this chapter, when students engage in inquiry with CHANGE materials they are interacting with concept process models (Harrison & Treagust, 2000) that can be manipulated to test hypotheses (Feldman et al., 2010).

The Use of Digital Tools for Inquiry in STEM Learning

In this chapter we examine the ways in which students can use different types of ICT to help them engage in science inquiry activities. Rather than review the uses of ICT in a decontextualized manner, we do so in the context of the CHANGE project, with appropriate references to the literature. The CHANGE project uses a wide variety of forms of educational technology including computer simulations and models, serious educational games (SEGs) (Annetta et al., 2013), electronic measuring technologies, eBooks (G. G. Smith et al., 2013), and webquests (Subramaniam, 2012), among others.

These different forms of educational technology are used for different purposes in the CHANGE project. For example, CHANGE uses a web-based intermedia[2] eBook narrative where sections of narrative text alternate with simulations and computer games to tie together the units that are distributed through the marine science course. The narrative uses a place-based story-telling approach, situating climate change firmly in the west-central Florida Gulf Coast communities, where our high school students live, to make climate change feel more immediate to them (G. A. Smith, 2007). It consists of scientifically realistic, short stories about high school students in the future who grapple both with how climate change plays out in Florida (hurricanes, sea level rise, etc.) and typical issues high school students encounter such as concerns about grades, graduation and job prospects, friendships, and family issues. Each story includes at least one serious educational game (SEG), embodying some of the core climate change science content from the current unit.

SEGs are games "in which education (in its various forms) is the primary goal, rather than entertainment" (Michael & Chen, 2006, p. 17) and "use the artistic medium of games to deliver a message, teach a lesson, or provide an experience" (p. 23). Annetta, Cook, & Schultz (2007) argue that when students are immersed in well-designed SEGs, they engage in metacognition, learn new content, and revise existing schemata through the help of cognitive scaffolds built into the games. In addition, SEGs can provide

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students with lifelike experiences that are not possible to replicate in traditional classrooms or field trips and can be the site of problem-based learning activities.

CHANGE uses SEGs for several purposes including providing students with science content needed for classroom inquiry, introducing them to the use of actual instruments used by scientists in their research, and to engage in inquiry through a virtual field trip. It is important to note that the CHANGE SEGs are in fact games, and not simply simulations. We can see this for example, in a game called Water Gauge Warrior in which students engage in various activities to construct a tide gauge that can withstand a severe hurricane. Water Gauge Warrior has the key elements of computer games as, described by Malone (1981), Crawford (1982), and Gee (2003), i.e., (1) *rules based on the game play structure*: the player has to stay within their budget as they select parts for their water level gauge, (2) *a start state*: starting with no water level gauge built and no budget, (3) *a goal for winning*: with your budget, earned by answering questions on the topic, create a water level gauge that will withstand the ravages of a tropical storm, (3) *immediate feedback on progress towards the goal*: selecting a set of parts to build your water gauge that stays within your budget, (4) *a game play space with multiple options*: many possible choices to be made in building your water level gauge, (5) *competition*: against yourself, and implicit competition with classmates, and (6) *fantasy:* the storyline that you have been hired by the city of Tarpon Springs to build a water level gauge.

CHANGE also incorporates the use of ICT in its curriculum materials and its pedagogical approach. The materials are provided to teachers via the Internet (http://climatechange.usf.edu), and web-based surveys and other instruments, distributed using sites like SurveyMonkey, facilitate data collection for formative evaluation and research. Most of the background information is provided to teachers in PowerPoint files or MS Word documents, so that teachers can modify them to suit their educational situations.

EXAMPLES OF THE COMPLEMENTARY USE OF VIRTUAL AND REAL SCIENTIFIC MODELS TO PROMOTE LEARNING OF CLIMATE CHANGE SCIENCE IN CHANGE

The primary way that CHANGE engages students in inquiry is by combining SEGs and hands-on classroom laboratory activities. As the school year progresses the amounts and levels of inquiry in the SEGs and activities increases. In this section of the chapter we provide descriptions of the SEGs and hands-on activities for three CHANGE topics: sea level rise, coastal sediments, and harmful algal blooms. Each of these topics are part of a larger unit of the marine science course: ocean exploration, marine geology, and populations: producers, respectively.

Sea Level Rise

To see how global warming affects sea level, one needs to be able to measure it, for example with a tide gauge. Tide gauges are complex pieces of equipment, distributed throughout the world, that continuously measure and record the height of the sea at a fixed point. Modern ones have on-site computers, self-contained power supplies, and can transmit data remotely. To teach students how a tide gauge works and the importance of its different components, CHANGE developed an SEG called "Water Gauge Warrior" (Figure 1). In this game students are challenged to design a tide gauge that would withstand a category 5 hurricane. In the first level of the game, students answer questions about the purpose of the different

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Figure 1. Screenshots from the Water Gauge Warrior game

components to earn money to build their own tide gauge. As they design their gauge they need to make decisions about the cost and properties of the components that they assemble virtually for their gauge. Once completed, their gauge is "tested" to see whether it can withstand a large storm.

We see the Water Gauge Warrior game as an example of a type 2 digital model (DM2) because it does more than simply demonstrate how the tide gauge works, but does not allow for the testing of hypotheses (see Table 1). It is also what Harrison and Treagust (2000) call a concept-process model because it helps students to understand the complex processes that underlie the term sea level. We also see the game as an opportunity for students to engage in Level 2 inquiry because the students are given the problem and the methods with which to solve it.

While the Water Gauge Warrior game provides a way for students to learn about the workings of an actual piece of scientific equipment, we also want them to be able to inquire into how different factors affect sea level using a hands-on laboratory activity. It became clear to us that a physical model that mimics the operation of a tide gauge would either be too expensive, or too complicated to build using low-cost or found materials. We solved the problem by using the ubiquitous (in the U.S.) one-gallon plastic jug. The jug model exemplifies CHANGE's use of low cost of found materials in recognition of the limited budgets that teachers have for the purchase of equipment and supplies. As can be seen in Figure 2, the main part of the jug models the sea, and the hollow handle with a ruler, which is connected to the rest of the jug, models the tide gauge. In this way, the model distinguishes between the body of water and how its level is measured.

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Figure 2. Plastic jug that is used as a model for measuring sea level

The students use the jug model to investigate the effects of the melting of sea and continental ice, and of temperature changes on sea level. In this activity the inquiry questions are teacher generated, and students are provided with the tools and materials to investigate them. Hence, it an example of Level 2 inquiry. We see it as a physical model 3 (PM3) because students can manipulate it to the test their ideas about the relationships between the effects of global warming – the melting of sea and continental ice and warming of the oceans – on sea level (see Table 1). It is also what Harrison and Treagust (2000) call a concept-process model because, like the Water Gauge Warrior game, it helps to unpack the complex processes hidden in the noun phrase, *sea level rise*. In addition, this activity incorporates the CHANGE place-based approach. After the students investigate how GCC affects sea level, they then go to a website of the US National Oceanic and Atmospheric Administration (NOAA) (http://www.coast.noaa.gov/slr/) in which they can see predictions for sea level rise would affect their community where they live, as well as those of relatives and friends.

The combination of SEG and hands-on inquiry activity helps to solve a problem identified by Waight and Abd-El-Khalick (2011) in their article about the attempt to use the Biology Student Workbench (BSW), a student version of a web-based tool that enables scientists to model protein and nucleic acid

Table 1. Types of physical and digital models

Type of Physical Model	Type of Digital Model	Properties	Examples
PM1	DM1	Representation that can be used to teach or explain the phenomenon.	Three-dimensional models, drawings, videos, animations,
PM2	DM2	Representation that can be manipulated to explain and predict nature phenomena.	Physical models with moving parts, simulations, serious educational games
PM3	DM3	Representation of the phenomenon that can be manipulated and used to test hypotheses, assess empirical and conceptual criteria, or guide future research.	Bench-scale laboratory models, simulations, serious educational games

Based on Feldman, Cooke and Ellsworth (2010) and Cartier et al. (2001).

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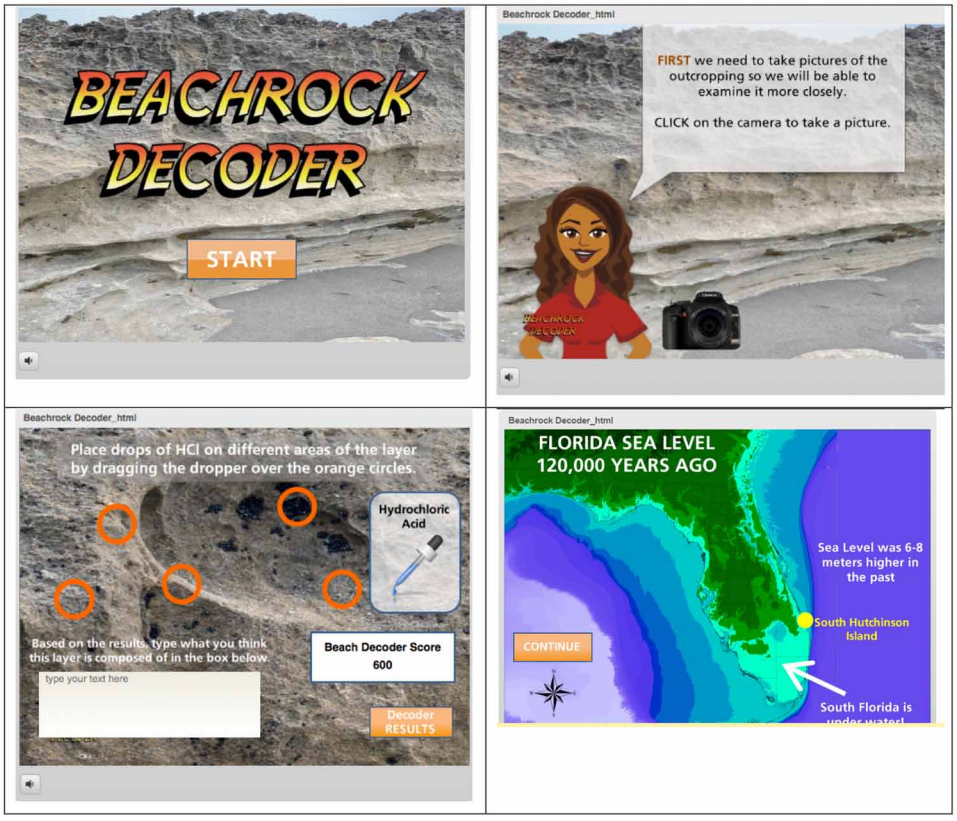
sequencing. They found that the BSW was not enacted in schools for two main reasons: 1) The difference between the ways in which the scientists who developed and used the Biology Workbench did science, and the teachers' beliefs about what constitutes school science. 2) While the BSW was significantly modified from the Biology Workbench, it still was not appropriate technology for the doing of science in school. In the CHANGE sea level activities, we dealt with these issues by having a simplified but accurate model of a tide gauge in the Water Gauge Warrior game, and used school appropriate materials for the hands-on activity. The structure of the hands-on activity helps to scaffold a change in teachers' beliefs, from lab activities that were purely conformational towards ones in which students can begin to inquire into natural phenomena.

Sediments

Students investigate the connection between coastal sediments and historical changes in sea level in the Beachrock Decoder SEG (Figure 3) and a classroom activity in which they investigate a teacher-presented question while using student designed and selected procedures.

In the game students participate in a virtual field trip to Hutchinson Island, Florida. Hutchinson Island has large beachrock outcroppings showing evidence of past sea level, estimated to be six to eight meters higher than it is today. The students travel virtually to the island with Dr. Ping Wang, the geologist on

Figure 3. Screenshots from the Beachrock Decoder game



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the CHANGE team, to investigate the properties of an outcropping by observing it through a magnifying glass and by testing it with acid to determine its composition. Later in the game, students examine an ancient sandbar and a sub-tidal worm reef, both of which were at one time located below sea level, but are now a few meters above it. These investigations lead the students to uncover clues related to the past sea level, concluding that the area's sea level was once six to eight meters higher than it currently is.

The Beachrock Decoder game engages the students in Level 2 structured inquiry because the students are presented with a question to investigate – "What do the observations of the beach rock outcroppings and the other formations tell us about Florida's past sea level?" – and they use the investigative methods built into the game. We also see it as a DM3 (see Table 1) because the students engage it to test hypotheses about the relationships of the characteristics of the swash zones, sandbar and worm reef, with sea level.

After students have completed the virtual field trip, they engage in a hands-on inquiry activity in which they examine the properties of sediment samples, including color, size, Wentworth classification, texture, sorting, and composition, that were collected from different sites around Florida. Using their observations and measurements they deduce the location of the collection site for each of the samples. The characteristics of the samples and where they were collected are then used to formulate hypotheses about Florida's past sea level and coastline. As with the Beachrock Decoder game, this is an example of Level 2 inquiry because students are given both the question and the methods to investigate them.

In this topic students engage in the science practices that Dr. Wang and his students use when they investigate the formations at Hutchinson Island and coastal sediments. In the game they use those practices in a virtual setting, while in the classroom they can work directly with the sediments to engage in structured inquiry. This combination provides an important opportunity for teachers to engage their students in the types of science practices described in the NGSS (NGSS Lead States, 2013) and by PISA (OECD, 2013).

Harmful Algal Blooms (HABs)

A third example from the CHANGE curriculum focuses on the study of Harmful Algal Blooms (HABs), which are often referred to as red tide. HABs are rapid growths of algae in marine or freshwater environments due to influxes of nutrients and warm water temperatures. They have major negative effects on the environment because they deplete the dissolved oxygen in water needed by fish and most other organisms. They can also be toxic to humans and other animals. It is believed that algal blooms will increase in frequency, and possibly in size, as a result of GCC because of both increases in water temperature and increased washing of nutrients in fertilizers used by farmers and homeowners, from the land to the water by larger storm events. Because the study of algae was already a part of the Marine Science curriculum, the CHANGE materials on HABs and climate change fit easily into what the teachers were already expected to cover as part of the course.

The SEG for this topic is Whack Algae (Figure 4) in which students gain information about HABs and the factors that contribute to their growth. It is a DM2 because students can manipulate the factors that cause HABs, but would find it difficult to use it to test hypotheses (see Table 1). We believe that it is generous to call it an inquiry activity because its primary purpose is for students to gain the knowledge of what factors can cause an HAB in Tampa Bay and how they are related to climate change. They then can use this knowledge when they engage in inquiry in the hands-on activity.

The HAB hands-on activity is CHANGE's most authentic use of science practices, modified to be appropriate for schools. The students are given instruction in how to set up a bioreactor — a vessel in

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Figure 4. Screenshot from Whack Algae game showing the factors that students can manipulate to cause a harmful algal bloom

which to grow algae. In the research laboratory at our university, bioreactors are usually custom-built containers constructed of glass or Plexiglas, costing hundreds of dollars. The students' bioreactors are clear plastic 20-ounce (~0.6L) water bottles. Instead of toxic marine algae, they grow a freshwater species provided to them by the university laboratory. At the university, the concentration of algae is measured using a method called fluorospectroscopy (Halfhide, Wilkie, & Ergas, 2016). In the classroom we provide the students with a color chart, which is a set of test tubes, each containing a different concentration of algae (Figure 5). The students match the color of their bioreactor against the colors in the photograph to estimate the concentration algae.

In the activity students make a control by adding fertilizer to a bottle containing the non-toxic algae species and distilled water. They then choose a variable to alter from the control to examine whether it will increase or decrease HAB growth over time. While the teacher provides students with supplies that can be used in their bioreactor, students are free to choose any variable they like that could be related to an effect of climate change. In the piloting of the activity, students have changed the amount of light,

Figure 5. Color chart for measuring the concentration of algae in the bioreactors

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fertilizer and salinity. They have also looked at the effect of temperature and even the presence of bacteria. For five days the students measure the concentration of the algae in the bioreactor using the color chart. They then use their data to draw conclusions about the relationship between their variable and the growth of algae. We see this as an example of Level 4: Open inquiry in which the students investigate topic-related questions that are student formulated through student designed and selected procedures.

Finally, we ask whether the HAB activity is an example of the use of a model. While the water bottle is a physical model of an actual bioreactor, we prefer to think of the whole activity as a scientific model that fits the criteria suggested by Cartier et al. (2001), and what we would call a DM3. In the HAB activity the students construct ideas that describe the process by which different factors associated with climate change can affect the growth of algae. It is an empirical model in which they make measurement of algae concentrations; they use it to explain and predict the phenomenon of HABs; they test their model against their empirical evidence; and although they are limited by the time constraints of the Marine Science curriculum, they could be used as guides for future research.

THE EFFECTS OF STUDENTS' ENGAGEMENT WITH VIRTUAL AND REAL SCIENTIFIC MODELS IN CHANGE

The CHANGE curriculum materials were developed and pilot-tested during the 2013-14, 2014-15, and 2015-16 academic years. In this section we describe the data collection and analysis methods that we used, and the findings from the pilot testing.

Data Collection

During the three pilot years we collected data to 1) provide formative information for the improvement of the CHANGE materials; and 2) test instruments that we would use in the full implementation year to determine the efficacy of the materials. We collected the data for the former through online surveys that were administered at the end of each unit of the marine science course (End of Unit Surveys). For the latter, we developed student pre- and post-surveys to determine their knowledge and beliefs about climate change (Nation, Feldman, Smith, Wang, & Lou, 2016), and multiple-choice items that were incorporated into the district-wide marine science midterm and final exams.

The end of unit (EOU) surveys were in two parts. The first included Likert-type questions about the materials. Students were also asked the following open-ended questions: In what specific way do you feel that the combination of eBook story, computer game, and hands-on lab in this unit helped you to learn climate change science better and/or increase your interest in this unit? Or are there other things that could be added to the combination that would help make the unit more interesting?

Data were also collected from online surveys, midterm, and final exam to measure student responses to the materials and further understanding of climate change science. The CHANGE student survey, which was administered at the beginning and end of the 2014-2015 and 2015-16 academic years asked students about the causes and implications of climate change, and students' likelihood to take mitigative actions to help reduce the impacts of climate change on the built and natural world. The midterm and final exam were distributed to all marine science students in the district, including those how had not participated in the piloting of CHANGE. An item analysis was performed to determine whether or not experience of the CHANGE curriculum had a significant impact on student understanding of climate

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change science. In addition to these surveys and exams, data were collected for formative purposes from classroom observations and focus groups made up of the pilot teachers.

Data Analysis

Quantitative data gathered from the CHANGE student survey, midterm, and final exam results were analyzed using SAS (Statistical Analysis System). For the CHANGE student survey analysis, t-tests were used to compare the means from the initial data with the end of year data. Results from the midterm and final exam were also analyzed using a t-test to examine the difference of scores between students who experienced the CHANGE curriculum and the students who did not.

Open-ended qualitative data from the EOU surveys were analyzed using thematic coding to determine how the students feel about the combination of eBook story, computer game, and hands-on lab. After similar codes were grouped together, frequency distributions were generated for the codes (Patton, 2015). Classroom observations and focus groups data were analyzed in a similar fashion. CHANGE project leadership and graduate students engaged in continuous review of data to improve the quality of the findings and conclusions throughout the data analysis.

RESULTS

End of unit (EOU) survey data were collected for all three of the CHANGE topics described in this chapter. However, because of a technical problem with the online survey, we do not have responses to the open-ended or content questions for the topic on HABs. The EOU survey for the piloting of the sea level materials indicated that on the average students (n=117) agreed with the following statements:

- Playing the computer game helped me to engage with the content of this unit.
- I found the computer game relevant to learning the content of the unit.
- The combination of hands-on lab, eBook story and computer game made the unit more relevant to me.
- I felt more engaged in learning this unit because of the combination of hands-on lab, eBook story and computer game.

In addition, more than 75% of the students demonstrated that they gained an understanding of the different effects of the melting of sea and continental ice on sea level. For the coastal sediments topic the EOU data indicated that the students (n=109), on the average, agreed with the statements above. In addition, about three-fourths of them correctly estimated the ancient sea level and knew what types of data geologists use to determine past sea level.

The EOU data from the HAB unit focused on the eBook and the games. Overall the students (n=137) found the games to be fun and informative. In addition, we have formative data from extensive observations that we made of the implementation of the unit in three different schools. The observation data suggest that the unit was successful in engaging the students in authentic research practices, and that they came to understand the relationships between GCC and HABs.

For sea level and coastal sediments, we used a grounded theory approach (Corbin & Strauss, 2015) to analyze the open-ended question in which we asked the students how the combination of SEGs and

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hands-on activities helped them to learn the topics. For the sea level topic, the students were overwhelmingly positive about the combination with only 22 of 121 respondents indicating any negative aspect at all. For example, one student wrote, "I'd rather just read about things instead of all the labs and games." Another responded, "It was a little helpful but should be more hands-on and directly related to the topics."

Of the positive responses about the sea level topic, we coded 32 responses in which students stated that the combination was fun (n=6), interesting (n=13), or simply that they liked it (n=13).[3] More elaborate reasons included that it helped them to learn (n=26), there was a real world connection (n=4), the combination provided them with a variety of learning experiences (n=10), and there were multiple modes for learning and learning styles (n=15). Exemplars for these codes can be found in Table 2.

We found similar results from the open-ended responses to the same question in the end of unit survey for the coastal sediments topic. In this case, 10 of the 99 responses were negative, such as "It honestly needs to be more appealing" and "More games that are for fun and not just lesson based". In addition, there were 15 responses that were either not relevant, unclear, or missing. The remainder of the coded responses were positive about the SEGs and hands-on activities (n=79). Of these, a total of 37 were that the combination was fun, interesting, or simply that they liked the combination. Students responded that the combination helped them to learn about the relationship between coastal sediments and climate change (n=8), it was engaging (n-9), or that it provided them with a variety of experiences that worked with multiple learning styles (n=13). Exemplars of these codes are in Table 3.

The remaining data that we analyzed relate more broadly to the implementation of the CHANGE curriculum materials. For example, in the beginning and end of the year surveys, students were asked, "How likely do you think it is that human actions have changed global climate?" We found that students were ranking humans as a likely contributor to climate change significantly higher ($p<0.01$) after experiencing the CHANGE curriculum. CHANGE items were added to the midterm and final exams of the marine science course for the 2014-15 and 2015-16 academic years. Therefore, all students enrolled in the course responded to those items. We analyzed the data for the midterm and final of 2014-15 and the midterm for 2015-16. The midterm for 2014-15 was used solely to test the items. For the final given that year we found that the students enrolled in the classes that used the CHANGE materials (n=176) scored significantly higher ($p<0.001$) than the students who did not experience the CHANGE materials

Table 2. Exemplars of codes used for analysis of sea level open-ended question from the EOU survey

Code	Exemplar	N
Multiple modes for learning, including learning styles	All the features put together gave me a diversity and variety of learning styles	25
Combination more engaging	I think it helped engage myself and other students because it offered different things to do throughout the lesson.	11
Real world connection	The combination of this trio helped me learn about climate change better because I could apply it to my everyday life	4
Helped me learn	All in all, I felt like I learned a lot about climate change in this unit	26
Positive (no reason given)	The combination was lovely.	13
Negative (various reasons)	I'd rather just read about things, instead of all the labs and games	22
Fun	It was fun and I could 'physically' engage in the unit.	6
Interesting	The mix of things made learning more interesting.	13

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Table 3. Exemplars of codes used for analysis of coastal sediments open-ended question from the EOU survey

Code	Exemplar	N
Multiple modes for learning, including learning styles	This combination overall worked really well to help learn the science of climate change as well as increase in the interest in the unit. This is because it reaches out to all types of learners. For example: visual, auditory, and kinesthetic learners. The combination together has a stronger impact.	23
Combination more engaging	I felt engaged in what I was doing. It made me feel that if someone needed help with something I would be able to assist them with my background knowledge on geology so it's successful.	7
Real world connection	The story along with the games gives an interesting real life situation.	
Helped me learn	I feel that the course was making a genuine interest in trying to help me learn, unlike most lessons where it's just a PowerPoint followed by a test.	14
Positive (no reason given)	I think the combination works just fine	11
Negative (various reasons)	It honestly needs to be more appealing.	10
Fun	We don't get bored half way through the lesson and we're always engaged in the unit.	1
Interesting	I became more interested because it helped me get a better understanding through a different method.	18

(n=789). For the 2015-16 midterm CHANGE students (n=312) performed significantly higher ($p<0.001$) than the non-CHANGE students (n=1502). The 2014-15 final exam included questions about the HAB topic and the 2015-16 midterm included questions about the sea level and coastal sediments topics.

In addition to the results from the student data reported above, our observations of classrooms suggest that independent of which was done first by the students – the SEG or the hands-on activity – they were better able to complete the second activity in the ways intended by the CHANGE project. In general, the students were more familiar with the content and methods, and were better able to make arguments in whichever came second. Finally, data from the teacher focus groups indicate that they believe that the combination of SEGs and hands-on activities improve student learning by reinforcing the science content.

FUTURE RESEARCH DIRECTIONS

In our introduction to this chapter we argued that there has been little change in the ways in which science is taught in the US and elsewhere even though there has been a concerted effort to implement inquiry teaching and learning methods, as well as the use of ICT. Our study supports our belief that this is due to several factors, including the demands of accountability systems, and the resilience of traditional conceptions of what counts as school science. However, outside of schools, people engage in inquiry and ICT has become an integral part of how they work, play and communicate with one another. The curriculum materials we describe in this chapter were designed to bring everyday activities like reading, playing games, and inquiring into local space into school science. Our study so far supports that it is possible to change how teachers teach and students learn within the context of an existing course by using ICT and inquiry to augment what is already happening in schools. However, there is still much

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research to be done. For example, we would like to gain a better understanding of how teachers' beliefs about what they teach, like climate change, affects their practice and what their students learn, believe and our willing to do. We would also like to uncover the cognitive mechanisms that connect the reading of a fictional eBook with embedded serious educational games and their interaction with hands-on activities, with the learning of science content and practices. Finally, all our research so far has been relatively short term. Can the types of changes that we have seen so far be sustained in schools? Will teachers continue to use the new methods and materials without our support? Will the school district continue to support the teaching of climate change given the new political landscape in the US? It is our plan to investigate these questions in our future research.

CONCLUSION

In the above three examples of CHANGE curriculum materials, we demonstrated the ways that SEGs and in-class hands-on activities can work together to promote inquiry using digital and physical models. The SEG for the sea level topic, which was a simulation and Type 2 digital model (DM2), engaged students in Level 2 inquiry to learn how an actual tide gauge works. This provided them with the knowledge that they needed to see and understand what the jug model was modeling. For the coastal sediments topic, the SEG allowed students to virtually experience what it is like to go on a geology field trip and examine specimens in situ. This provided them with the background to connect what they did in the lab with the sediment samples to how research is done in the field by geoscientists. The formative data from the piloting of both of these topics, as well as our other data, support the efficacy of the approach.

Finally, for the HAB topic, the SEG provides students with the necessary background information about how and why an HAB could occur in Tampa Bay. However, it did not provide the type of virtual experience that students had with the Water Gauge Warrior and Beach Rock Decoder games. We do not necessarily see this as a problem because in the HAB activity students engaged in a full range of science practices that include developing research questions and hypotheses, determining the best way to use their bioreactors to test their hypotheses, collecting and analyzing data, and coming to defensible conclusions. What is missing from the activity itself is the context and causes of HABs, which they get from the Whack Algae game. Although we did not have the same type of formative data as for the other topics, the exam results and classroom observations support the complementary nature of the SEGs and hands-on activity for the HAB topic.

During this academic year the CHANGE materials are being incorporated into the Marine Science courses in twenty-seven high schools in the district. All indications from our three years of developing and piloting the CHANGE materials suggest that if teachers use them as the pilot teachers did, there will be major changes in what happens in their classrooms. Because the CHANGE materials are only for about 15% of the class meetings we expect that much of their teaching would likely remain similar to what they have already been doing. However, we think that he would be excited to see how the SEGs and hands-on activities are integrated in the CHANGE curriculum materials, resulting in a transformation of how teachers teach and students learn science in their schools.

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REFERENCES

Anderson, R. (2002). Reforming science teaching: What research says about inquiry. *Journal of Science Teacher Education*, *13*(1), 1–12. doi:10.1023/A:1015171124982

Annetta, L. A., Cook, M., & Schultz, M. (2007). Video Games: A Vehicle for Problem-Based Learning. *e-Journal of Instructional Science and Technology, 10*(1).

Annetta, L. A., Frazier, W. M., Folta, E., Holmes, S., Lamb, R., & Cheng, M.-T. (2013). Science teacher efficacy and extrinsic factors toward professional development using video games in a design-based research model: The next generation of STEM learning. *Journal of Science Education and Technology*, *22*(1), 47–61. doi:10.100710956-012-9375-y

Bang, E., & Luft, J. A. (2013). Secondary Science Teachers Use of Technology in the Classroom during Their First 5 Years. *Journal of Digital Learning in Teacher Education*, *29*(4), 118–126. doi:10.1080/21532974.2013.10784715

Bank, T. W. (2012). Turn down the heat: why a 4 C warmer world must be avoided. The World Bank, 74455.

Bell, R. L., Smetana, L., & Binns, I. (2005). Simplifying inquiry instruction. *Science Teacher (Normal, Ill.)*, *72*(7), 30–33.

Boykoff, M. T., & Boykoff, J. M. (2004). Balance as bias: Global warming and the US prestige press. *Global Environmental Change*, *14*(2), 125–136. doi:10.1016/j.gloenvcha.2003.10.001

Brulle, R. J. (2014). Institutionalizing delay: Foundation funding and the creation of US climate change counter-movement organizations. *Climatic Change*, *122*(4), 681–694. doi:10.100710584-013-1018-7

Bybee, R. W. (2006). Scientific Inquiry And Science Teaching. In L. B. Flick & N. G. Lederman (Eds.), *Scientific Inquiry and Nature of Science: Implications for Teaching, Learning, and Teacher Education* (pp. 1–14). Dordrecht: Springer Netherlands.

Cartier, J., Rudolph, J., & Stewart, J. (2001). *The nature and structure of scientific models*. National Center for Improving Student Learning and Achievement in Mathematics and Science.

Corbin, J., & Strauss, A. C. (2015). *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory* (4th ed.). Thousand Oaks, CA: Sage Publications.

Crawford, B. A. (2007). Learning to teach science as inquiry in the rough and tumble of practice. *Journal of Research in Science Teaching*, *44*(4), 613–642. doi:10.1002/tea.20157

Crawford, C. (1984). *The art of computer game design*. Berkeley, CA: Osborne/McGraw-Hill.

Donahue, D. M. (1993). Serving Students, Science, or Society? The Secondary School Physics Curriculum in the United States, 193065. *History of Education Quarterly*, *33*(3), 321–352. doi:10.2307/368196

Donnelly, D., OReilly, J., & McGarr, O. (2013). Enhancing the Student Experiment Experience: Visible Scientific Inquiry through a Virtual Chemistry Laboratory. *Research in Science Education*, *43*(4), 1571–1592. doi:10.100711165-012-9322-1

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Feldman, A., Cooke, M. L., & Ellsworth, M. s. (2010). The Classroom Sandbox: A physical model for scientific inquiry. *Science Teacher (Normal, Ill.)*, *77*(9), 58–62.

Gee, J. P. (2003). *What video games have to teach us about learning and literacy*. New York: Palgrave Macmillan.

Gehrke, N. J., Knapp, M. S., & Sirotnik, K. A. (1992). In Search of the School Curriculum. *Review of Research in Education*, *18*, 51–110. doi:10.2307/1167297

Halfhide, T., Wilkie, A., & Ergas, S. (2016). *Indigenous Algal Growth on Municipal Sludge Centrate and Measuring Lipid Productivity Using Fluorospectroscopy and Gravimetric Analyses.* Paper presented at the Algal Biomass, Biofuels and Bioproducts (ABBB), San Diego, CA.

Hallar, A. G., McCubbin, I. B., & Wright, J. M. (2011). CHANGE: A place-based curriculum for understanding climate change at Storm Peak Laboratory, Colorado. *Bulletin of the American Meteorological Society*, *92*(7), 909–918. doi:10.1175/2011BAMS3026.1

Harrison, A. G., & Treagust, D. F. (2000). A typology of school science models. *International Journal of Science Education*, *22*(9), 1011–1026. doi:10.1080/095006900416884

Herman, B. C., Feldman, A., & Vernaza-Hernandez, V. (2015). Article. *International Journal of Science and Mathematics Education*, 1–21.

Higgins, D., & Higgins, H. (2001). Intermedia. *Leonardo, 34*(1), 49-54. Retrieved from Project MUSE database website: https://muse.jhu.edu/article/19618

Hofstein, A., Navon, O., Kipnis, M., & Mamlok-Naaman, R. (2005). Developing students ability to ask more and better questions resulting from inquiry-type chemistry laboratories. *Journal of Research in Science Teaching*, *42*(7), 791–806. doi:10.1002/tea.20072

IPCC. (2013). The physical science basis. Contribution of working group I to the fifth assessment report of the Intergovernmental Panel on Climate Change.

Jollands, N., Ruth, M., Bernier, C., & Golubiewski, N. (2005) Climate's long-term impacts on New Zealand infrastructure—a Hamilton City case study. In Proceedings ecological economics in action. New Zealand Centre for Ecological Economics.

Kaiser, D., & Wasserman, L. (2016). The Rockefeller Family Fund vs. Exxon. *The New York Review of Books*, *63*(19). Retrieved from http://www.nybooks.com/articles/2016/12/08/the-rockefeller-family-fund-vs-exxon/

Kohut, A., Keeter, S., Doherty, C., & Dimock, M. (2009). *Scientific achievements less prominent than a decade ago: Public praises science; scientists fault public, media*. Washington, DC: The Pew Research Center for the People & the Press. Retrieved from http://www. people-press. org/files/legacy-pdf/528. pdf

Kuş, Z. (2015). Science and social studies teachers' beliefs and practices about teaching controversial issues: Certain comparisons. *JSSE-Journal of Social Science Education*, *14*(3), 84–97.

Leiserowitz, A. A. (2005). American risk perceptions: Is climate change dangerous? *Risk Analysis*, *25*(6), 1433–1442. doi:10.1111/j.1540-6261.2005.00690.x PMID:16506973

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Linn, M. C., Clark, D., & Slotta, J. D. (2003). WISE design for knowledge integration. *Science Education*, *87*(4), 517–538. doi:10.1002ce.10086

Maibach, E., Roser-Renouf, C., & Leiserowitz, A. (2009). *Global Warming's Six Americas 2009: An Audience Segmentation Analysis. Yale Project on Climate Change*. New Haven, CT: Yale University and George Mason University.

McCright, A. M., & Dunlap, R. E. (2011). Cool dudes: The denial of climate change among conservative white males in the United States. *Global Environmental Change*, *21*(4), 1163–1172. doi:10.1016/j.gloenvcha.2011.06.003

Michael, D. R., & Chen, S. (2006). *Serious games: games that educate, train, and inform*. Boston, MA: Thomson Course Technology PTR.

Nation, M., Feldman, A., Smith, G. G., Wang, P., & Lou, Y. (2016). *Uncovering High School Students' Knowledge and Beliefs about Climate Change to Inform the Development of Embedded Curriculum Materials*. Paper presented at the Annual Meeting of the Association for Science Teacher Education, Reno, NV.

National Research Council. (1996). *National science education standards*. Washington, DC: National Association Press.

National Research Council. (2000). *Inquiry and the National Science Education Standards*. Washington, DC: National Association Press.

National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: National Academies Press.

NGSS Lead States. (2013a). *Next Generation Science Standards: For States, by States*. Washington, DC: The National Academies Press.

NGSS Lead States. (2013b). Next Generation Science Standards: For States, by States: Vol. 2. *Appendixes*. Washington, DC: The National Academies Press.

Nuffield Foundation. (2016). *A short history of curriculum development at the Nuffield Foundation*. Retrieved from http://www.nuffieldfoundation.org/short-history-curriculum-development-nuffield-foundation

OECD. (2013). *Draft PISA 2015 Science Framework.* Retrieved from http://www.oecd.org/pisa/pisaproducts/pisa2015draftframeworks.htm

Olson, J. (1981). Teacher influence in the classroom: A context for understanding curriculum translation. *Instructional Science*, *10*(3), 259–275. doi:10.1007/BF00139803

Patton, M. Q. (2015). *Qualitative Research and Evaluation Methods* (4th ed.). Thousand Oaks, CA: SAGE Publications, Inc.

Pruneau, D., Liboiron, L., Vrain, E., Gravel, H., Bourque, W., & Langis, J. (2001). People's idea about climate change: A source of inspiration for the creation of educational programs. *Canadian Journal of Environmental Education*, *6*, 121–138.

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Schwarz, C., & Passmore, C. (2012, July 14). *Preparing for NGSS: Developing and Using Models. NSTA Web Seminars*. Retrieved from http://learningcenter.nsta.org/products/symposia_seminars/ngss/files/PreparingforNGSS--DevelopingandUsingModels_9-25-2012.pdf

Smith, G. A. (2007). Place-based education: Breaking through the constraining regularities of public school. *Environmental Education Research*, *13*(2), 189–207. doi:10.1080/13504620701285180

Smith, G. G. (2012). Computer-Game Play as Imaginary Stage for Reading: Implicit Spatial Effects of Computer Games Embedded in Hard Copy Books. *Journal of Research in Reading*, *35*(1), 1–19.

Smith, G. G., Li, M., Drobisz, J., Park, H.-R., Kim, D., & Smith, S. D. (2013). Play games or study? Computer games in eBooks to learn English vocabulary. *Computers & Education*, *69*, 274–286. doi:10.1016/j.compedu.2013.07.015

Stake, R., & Easley, J. (1978). *Case studies in science education* (Vols. 1-2). Center for Instructional Research and Curriculum Evaluation, University of Illinois at Urbana-Champaign.

Subramaniam, K. (2012). How WebQuests Can Enhance Science Learning Principles in the Classroom. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, *85*(6), 237–242. doi:10.1080/00098655.2012.698323

Tamir, P., & Jungwirth, E. (1975). Students growth as a result of studying BSCS biology for several years. *Journal of Research in Science Teaching*, *12*(3), 263–279. doi:10.1002/tea.3660120309

University Corporation for Atmospheric Research (UCAR). (2015). *How much has the global temperature risen in the last 100 years?* Boulder, CO: University Corporation for Atmospheric Research.

Zacharia, Z. C., Manoli, C., Xenofontos, N., de Jong, T., Pedaste, M., van Riesen, S. A., & Tsourlidaki, E. (2015). Identifying potential types of guidance for supporting student inquiry when using virtual and remote labs in science: A literature review. *Educational Technology Research and Development*, *63*(2), 257–302. doi:10.100711423-015-9370-0

KEY TERMS AND DEFINITIONS

Climate: The average weather over a region of the earth over a long period of years.

Climate Change: Changes to the earth's climate, usually referring to the effects of increasing amounts of heat trapping gases in the atmosphere due to human actions.

Harmful Algal Blooms (HABs): A sudden increase in the amount of algae in a body of water that typically has negative effects of the health of human and other organisms.

Information and Communications Technology (ICT): An umbrella term that refers to contemporary electronic devices or applications that includes the Internet, mobile telephones, computers, videoconferencing, and so on.

Inquiry: In the context of this chapter, inquiry is the method used by scientists as they seek new knowledge about the natural world.

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Models: A representation of a phenomenon that can be physical, digital, or cognitive.

Sea Level Rise: The increase of the global mean sea level due to climate change.

Serious Educational Games (SEGs): Games in which education is the primary goal, rather than entertainment.

ENDNOTES

1 The acronym was derived from the title of the project, although it does not match the letters exactly.

2 The term "intermedia" was defined by Dick Higgins (Higgins & Higgins, 2001) as works of art that "fall conceptually between media that are already known" (p. 52).

3 The total n is greater than 121 because some responses received multiple codes.

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Chapter 45
The Temporal and Spatial Development of Organic Agriculture in Turkey

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ABSTRACT

The world's population is increasing rapidly and the food need for the increasing population has been growing also. In the 21st century, efforts for the sustainable use of the natural resources have been raised all around the world. Agriculture has always been on the center of discussions and developments as an activity carried out depending on the nature. Therefore, the sustainable agricultural systems have gained a considerable importance in recent years. This chapter will examine the temporal and spatial development of the organic agriculture in Turkey. The current situation of the agricultural sector in Turkey will be reviewed and the need for a sustainable agricultural system in Turkey be analyzed. The temporal and spatial change of the organic agricultural areas, numbers of producers and products, and organic production amounts in Turkey will be put forward. Also, the organic agricultural potential of Turkey will be evaluated and the reasons for not exploiting this potential will be investigated.

INTRODUCTION

Agriculture is a highly prominent strategic sector for almost all countries as it enables them to produce their basic foodstuff, provides raw materials to other industries, is an area of employment and brings about a foreign currency inflow to the country's economy through exporting activities. In the direction of the world's changing needs and circumstances, in the course of time, some important changes have been seen at the methods and policies applied for the agriculture. As a result of wars bursting out in the last century, and associated food supply problems, application of the technological innovations into agriculture and the rapid increase in the world's population have changed notably the expectations in the agricultural activities. Rapidly increasing population of the world has brought along many necessities, and the need for agricultural products has risen to meet increasing populations. At this stage, the main objective of the agricultural policies has become to raise the productivity and increase the production

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quantities (Grigg, 1995). Particularly with the policies applied in the 1960-1970s, high effectiveness and productivity have been reached. On the other hand, in obtaining high productivity, the fact that agriculture-related natural resources are limited has been ignored (Badgley & Perfecto, 2007). Agriculture itself has been managed for many years with the understanding that the natural resources are limitless. As a result of these policies, high productivity has been reached and agricultural economic development has been built, but it has been realized that such development is not sustainable any more (Park & Seaton, 1996).

Agriculture is an economic activity dependent on some fundamental natural resources such as soil, water and air. At the end of the 20th century, it was agreed that natural resources, the base of all agricultural production, are restricted and it was realized how important it is to use these natural resources sustainably (Pretty, 1995). At this stage, people have started searching for sustainable agricultural options without damaging the natural resources. Agricultural systems that promote sustainable production without damaging the natural resources as well as policies which support such systems have been brought to the forefront of the world's agenda.

Thanks to the understanding of sustainable agriculture, natural resources are protected and their productivity is guaranteed for a long term. The concept of sustainable agriculture implies a balanced economic, social and ecologic agricultural system. For people's access to sufficient and safe food, the raising of healthy future generations, enhancing rural development, economic improvement and a liveable environment, agricultural areas should be used in a sustainable manner. Today, the concept of sustainable agriculture has great importance. It is so important to create a society that could meet its necessities by not destroying the natural resources and by sustainable use of the existing natural resources especially in light of increasing populations (Grigg, 1995). For this reason, in order to reach a sustainable life and a sustainable agriculture, organic agriculture is gaining importance as an alternative agricultural method around the world.

Organic agriculture is one of several sustainable agricultural systems and it could be generally defined as a production method that is controlled and certified in all of its stages, aiming for protection of the natural resources, having a human and natural friendly understanding and free of synthetic chemical inputs including fertilizers. It is highly possible to protect the natural resources with organic agriculture at one side while to benefit from these resources to the utmost with a sustainable understanding of agriculture (Lotter, 2003). As compared to the conventional agricultural areas, the world's organic agricultural areas are still too small. However, it has been accepted that the world's need for food is increasing rapidly and that the developments happening on the agricultural fields threaten the future of human beings. Because of the awareness, sustainable use of agricultural areas has been raised across the world. Therefore, in the next years, organic agricultural applications will undoubtedly increase.

Turkey is one of the countries where the organic agriculture has gained importance in recent years all around the world. Turkey is an important agriculture country at the present time (Food and Agriculture Organization [FAO], 2014). In reference to the 2014 data, Turkey has the 7th largest agricultural economy of the world. This figure reveals clearly how the agricultural sector is important in Turkey's economic and social structure. Having a sustainable agriculture in Turkey is so important especially in light of the rapidly increasing population. The concept of organic agriculture started to come into the view in Turkey after 1984 and it has improved gradually within the period of time following 2000. Also, the European Union membership process has made a great contribution to the wide spreading organic agriculture in Turkey. Today, Turkey is one of the top ranked countries in the world with regards to organic agriculture areas, number of producers and products, and organic production amounts (Pugliese, Bteich, & Al-Bitar, 2014). Turkey's prominence in the world organic food market scales up day by day.

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The aim of this chapter is to examine the temporal and spatial development of organic agriculture in Turkey. Within this framework, the current situation of the agricultural sector in Turkey will be evaluated and the development process of organic agriculture will be reviewed. In addition, the existing challenges of Turkish agriculture and the necessity for sustainable agricultural systems in Turkey, will be studied. Moreover, the temporal and spatial change of the organic agricultural areas, numbers of producers and products, and organic production amounts in Turkey will also be examined.

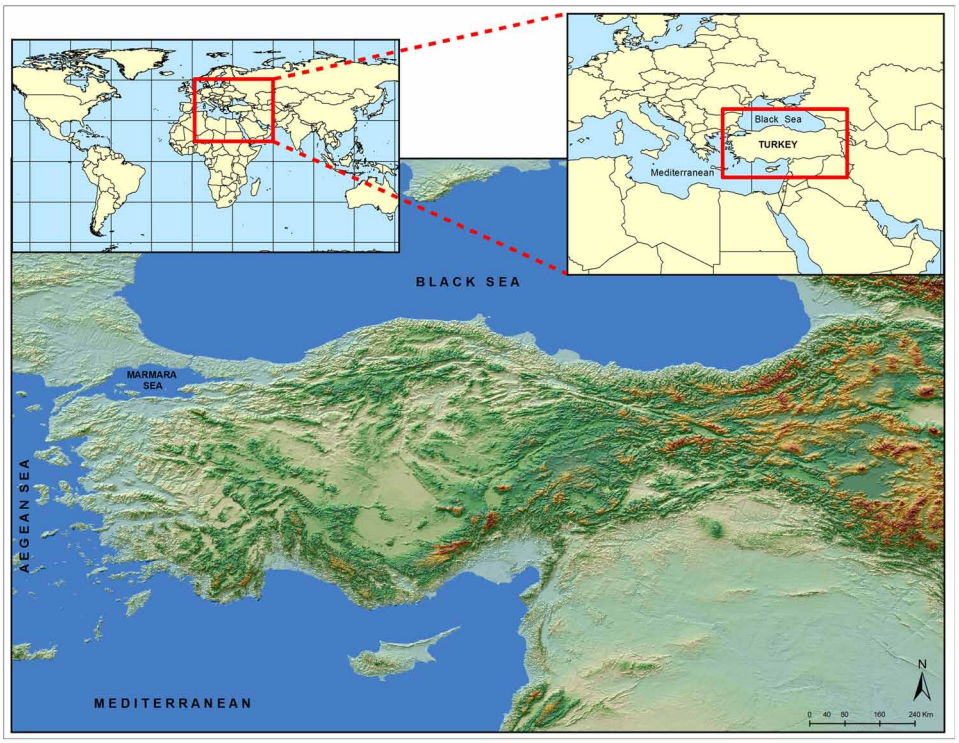
AGRICULTURE IN TURKEY AND THE POTENTIAL FOR ORGANIC AGRICULTURE

Agricultural Structure of Turkey

Turkey, which is the study area, is a country located at the northern hemisphere between the 25° 40' - 44° 49' eastern longitudes and the 35° 48' - 42° 06' northern latitude (Figure 1). The geographical and special position of the country has brought about different climatic types particularly the Mediterranean climate. Turkey has various characteristics in terms of climate, soil and morphologic features. Such variety has paved the way for a rich agriculture potential and a high importance on the agricultural activities of the country (Doğanay, 2007).

Turkey is one of the countries located on the Mediterranean Basin and the most important economic sector of the Mediterranean Basin is agriculture. At the present time, the agricultural sector uses most

Figure 1. Location map of Turkey



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of the land and water resources on the Mediterranean Basin and it provides employment for nearly half of the labor force of the basin (Makhzoumi & Pungetti, 1999). It is quite similar in Turkey as well that is located on the Mediterranean Basin and agriculture is one of the most fundamental economic sectors. Agricultural sector has played a very significant role for the economic and social development of Turkey, not only in the past but also in present times.

Agriculture is tightly coupled to the natural environmental features of the space. Natural environmental conditions have influences on the distribution of the agricultural areas, application of the agricultural systems and variety, type and quality of the agricultural products (Knowles & Wareing, 1983). Turkey's structure of land and accordingly changing climatic features has led to different geographic regions and the formation of various micro climates in these regions. Such diversity in the natural environmental features has brought along a rich agricultural potential. There are 7 geographic regions with different ecologic characteristics in Turkey and the production potentials of these regions are considerably different from each other.

Turkey's lands constitute a very old agricultural area. Looking through the historical development of the agricultural land use in Turkey, one can see substantial changes that have happened over time. Depending on the increasing population and developments happening in the agricultural mechanization, a notable increase was detected in the quantity of agricultural areas up to the early 1990s. From the period since 1990 up to our present day, a reduction has been noted in the quantity of agricultural areas and this is due to several different reasons.

Turkey has 78.534.700 hectares of surface area. While in 1928 only 6.6 million hectares was cultivated, it reached to 25.3 million hectares in 1950 and later on nearly 28 million hectares in the early 1990s (Minister of Development, 2014a). Following the end of 1990 the quantity of agricultural areas started to decrease. It dropped to 26.986.548 hectares in 1996 and finally 23.810.672 hectares in 2013. Within the short period of time, 3.175.876 hectares (-11.2 per cent) of agricultural areas have been lost because of different factors. Today, the proportion of the agricultural areas to the country's surface area is 30.3 per cent.

About 20.6 million hectares of the agricultural areas in Turkey consist of arable crops, fallow and vegetable lands in 2013. Nearly 3.2 million hectares of areas are covered with fruit gardens, vineyards and olive groves (Table 1, Figure 2). In about 66 per cent of the agricultural areas, grain products are cultivated while only 3.4 per cent of these areas are allocated for vegetables and in 8.1 per cent of agricultural lands, various fruits are produced. Vineyards constitute approximately 2 per cent of these agricultural areas while 3.4 of them are covered with olive groves. The proportion of fallow lands is 17.4 per cent by 2013, and in the same year, wheat and barley are the mostly cultivated grain products. Wheat is cultivated on 7.773.000 hectares of area and barley is produced on 2.721.000 hectares of area. By 2013, the areas that only wheat and barley are cultivated on, stand for the 44 per cent of the agricultural areas in Turkey.

The agricultural sector maintains its importance as a resource for employment and economic development in Turkey's economy. An examination of the distribution of country's employment to the sectors, revealed some important changes. In the early 1930s, 90 per cent of the working population was employed in the agricultural sector (Göney, 1979). Such proportion dropped back to 75 per cent in 1960 and up to 1990 agricultural sector was dominant over the employment of the country. After 1990, substantial changes took place in the distribution of country's employment to the sectors, (Table 2). In 1991, almost half (48 per cent) of the working population was employed in the agricultural sector. Depending upon the developments happening in the service and industrial sector since 1990 up to our present day, a notable decrease has been seen in the working population employed in the agricultural

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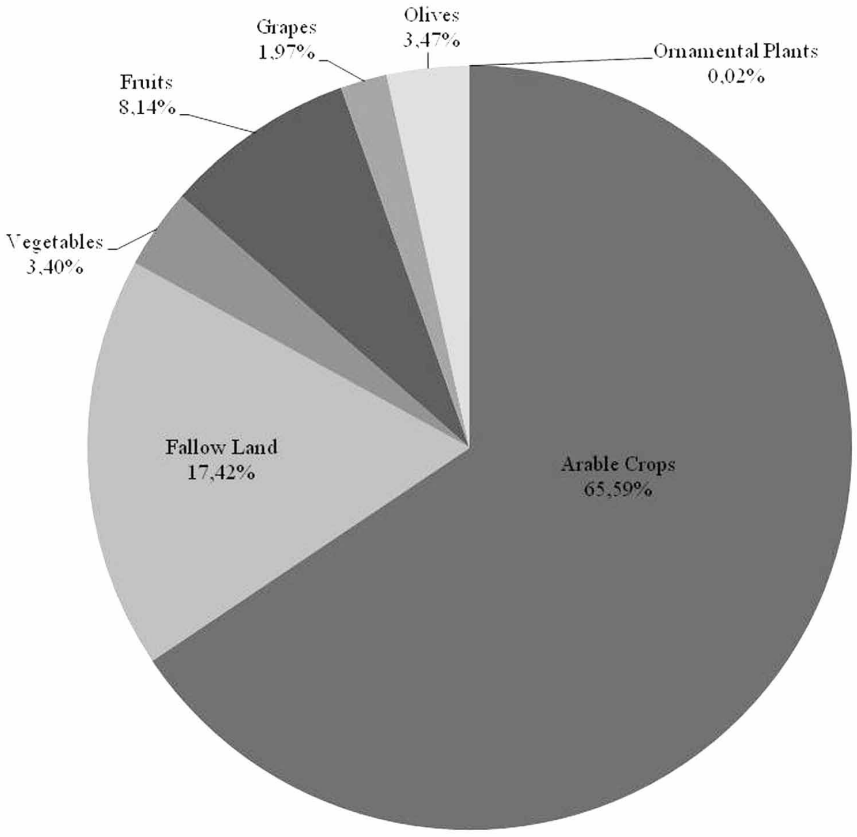
Table 1. Agricultural land use types in Turkey, 2013

Agricultural Land Use Types	Area (ha)	%
Arable crops	15.618.059	65.59
Fallow land	4.147.587	17.42
Vegetables	808.488	3.40
Fruits	1.937.416	8.14
Grapes	468.792	1.97
Olives	825.827	3.47
Ornamental plants	4.503	0.02
Total	23.810.672	100

(Turkish Statistical Institute [TUIK])

Figure 2. Distribution of agricultural area by land use types, 2013



sector and the percentage of the agricultural sector in the total employment has rapidly reduced. Now, the agricultural sector comprises 21 per cent of the total employment of the country. Although the percentage of the agricultural sector in the total employment has reduced, agricultural sector maintains its importance in the rural areas as the primary means of employment (FAO, 2014). Nearly 63 per cent

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Table 2. Employment by sectors

Years	Agriculture		Industry		Services		Total Labor Force
	Employed (thousand)	%	Employed (thousand)	%	Employed (thousand)	%	Employed (thousand)
1991	9.212	48	2.952	15	7.143	37	19.307
1995	9.080	44	3.295	16	8.212	40	20.587
2000	7.769	36	3.810	18	10.001	46	21.580
2005	5.154	26	4.178	21	10.735	53	20.067
2010	5.683	25	4.496	20	12.417	55	22.596
2013	5.204	21	5.101	21	14.297	58	24.602

(TUIK)

of the rural population of the country, in 2011, was employed in the agricultural sector (OECD, 2011). For this reason, to continue the agricultural activities in a sustainable manner is essential for the rural development in the country (Bakırcı, 2007). Apart from these figures, there is illegal employment as well in the agricultural sector of Turkey. In summary, today the agricultural sector maintains its role of being a prominent source of employment for Turkey.

In the development years of Turkey, the agricultural sector contributed a substantial proportion of the national income. In 1970s, the proportion of agricultural sector in Turkey's national income was 30 per cent. Such proportion dropped back to about 10 per cent in 2000, and has decreased to 8 per cent at the present time. Also, the agricultural proportion to total foreign trade has reduced. Agricultural sector constituted 85 per cent of Turkey's foreign trade in 1968 while it was 61 per cent by 1975 (Göney, 1979). The proportion of the agricultural sector in the foreign trade was 6 per cent in 2000 and dropped to 4.7 per cent 2005. In spite of the fact that the proportion of agricultural sector in foreign trade has reduced as compared to other sectors, agricultural sector still maintains its importance in foreign trade. Today, Turkey is one of the world's major agricultural producers and is an exporting country in many prominent agricultural products. In 2012, the agricultural sector in Turkey has 5.2 billion US dollars export volume and it corresponds to 3.4 per cent of country's total exportation.

The agricultural sector is an economic sector which is directly bonded to food production and nutrition of the country's population. Turkey's population is growing rapidly as well. In 1927, country's population was 13.648.270 people and the rural population was more dominant in the country. By 2015, the total population of the country increased to 78.741.053 people, so it means that the total population has increased 5-6 times since 1927. Within the development process of the population, highly important changes have taken place in rural and urban distribution of the population (Table 3). In 1927, 75.8 per cent of the total population lived in the rural areas and the other 24.2 lived in the cities while such percentage has become just the contrary at the present time; in 2012, only 22.8 per cent of the total population lived in the rural areas while the other 77.2 per cent lived in the cities. It is due to the rural-to-urban migration that working population employed in the agricultural sector decreases in spite of the increase in Turkey's total population. Unless such migration is reversed, the decrease in rural population will go on. Keeping the rural population in its place and employment of this population in the agricultural sector are of vital importance for a sustainable agriculture. Even though the rural population has reduced in time, as compared to other European countries, the percentage of rural population is still high in Turkey.

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Table 3. Turkey population by years

Years	Urban		Rural		Total
	Population	%	Population	%	
1927	3.305.879	24.2	10.342.391	75.8	13.648.270
1940	4.346.249	24.4	13.474.701	75.6	17.820.950
1950	5.244.337	25.0	15.702.851	75.0	20.947.188
1960	8.859.731	31.9	18.895.089	68.1	27.754.820
1970	13.691.101	38.5	21.914.075	61.5	35.605.176
1980	19.645.007	43.9	25.091.950	56.1	44.736.957
1990	33.326.351	59.0	23.146.684	41.0	56.473.035
2000	44.006.274	65.0	23.797.653	35.0	67.803.927
2012	58.448.431	77.2	17.178.953	22.8	75.627.384

(TUIK)

By 2012, the rural population of Turkey was 17.178.953 people. Today, the unique means of livelihood of Turkey's rural population is agriculture. Therefore, sustainable agriculture is more important for the rural population.

Agriculture plays an important role in providing the food needs of the increasing population. Every country makes efforts to be self-sufficient in the agricultural production. Providing the food needs of the increasing population requires an increase in production at the same time. Soils are used more intensely in order to satisfy the food needs of the increasing population. Agricultural mechanization, developments in the agricultural technologies and increase in use of chemicals and fertilizers brought about high productivity in Turkey, especially between 1970-1990. In this period, the increasing population triggered the motivation to increase production, however the negative effects on the soil and environment of conventional agricultural systems have come to the fore in recent times.

On the other hand, the rapid increase in population has brought along misuse of the lands. The need for new lands due to the pace of urbanization has been answered by opening the agricultural areas to settlement. Needs and tendencies of the rapidly growing cities to enlarge on the agricultural areas gradually threaten the availability of Turkey's fertile agricultural soils. Particularly in the last 15-20 years, the reduction of agricultural areas is highly related to the increase in non-agricultural usage (settlement, industry, tourism, mining and transportation etc.) of these lands. Along with the rapid urbanization in the country, fast growing tourism activities also threaten the agricultural areas as well. The fertile agricultural areas on the coastal regions are almost decimated because of tourism use. Urbanization and tourism activities are intensified generally on the coastal regions and the most productive agricultural areas of Turkey are located on these coastal regions. Data from 2013 show that 41.151.531 people live in the provinces located on Turkey's coastal regions. In these coastal provinces which constitute 28 per cent of Turkey's surface area, 54.4 per cent of country's total population lives. This fact brings into open the population pressure and threat on the productive agricultural areas located on the coastal regions.

Today, one of the other primary problems of Turkey's lands is erosion. Nearly in 79 per cent of the country's lands, there is medium or high level erosion problem. Moreover, there is an erosion problem in 59 per cent of the cultivated agricultural areas and 64 per cent of the pasture areas in Turkey. Such percentages reveal the huge threat to Turkey's soil resources. Erosion decreases the soil depth and removes

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the fertile upper layer of the soil. About 68 per cent of Turkey's soils are shallow (soil depth is between 0-50 cm). Erosion and consequently shallowness of the soils affect agricultural production. Apart from this, problems seen on the soils such as salinity and pollution threaten Turkey's agriculture more every passing day. In our present time, 4.2 million hectares of area have lost its productivity partially or completely owing to the changing salinity proportions (Minister of Development, 2014b).

Such changes in the physical, chemical and biologic structure of the soil diminish its productivity, and to raise the productivity and maintain an increase in production, much more chemical fertilizers are applied. By 2013, use of chemical fertilizers in Turkey's agriculture is 5.813.612 tons. Within such a short period of time since 2008 up to 2013, a 41 per cent of increase in chemical and fertilizer use has been noted. Within the period from 2012 till 2013, use of chemical fertilizers in the country has increased 9 per cent (Ministry of Food, Agriculture and Livestock, 2014). Although the use of chemical inputs and fertilizers has become more common in Turkey especially for recent years, overall amounts are not so high in comparison to other developed countries (Demiryürek, Stopes, & Güzel, 2008). Particularly in the Central Anatolia, Black Sea, Eastern Anatolia and South Eastern Anatolia regions of Turkey, where the conventional agriculture is more common, the soils have not been polluted so much. Usage of chemical fertilizers is however more intensified in the Marmara, Mediterranean and Aegean regions. The fact that a substantial part of the soils in Turkey is not polluted so much with chemical fertilizers is a definite advantage in its transition to a sustainable agriculture system.

It is highly essential for the countries to provide for the nutritional needs of the increasing population. In Turkey, the population has increased rapidly and the nutritional needs of the increasing population have intensified the pressures on agricultural areas. Population projections set forth that the increase in Turkey's population will continue. According to the estimations, Turkey's population will reach to 88.427.604 people by 2030 and 93.475.575 people by 2050 (TUIK). This will aggravate the pressure on agricultural areas. In order to satisfy the nutritional needs of the increasing population, the sustainable use of agricultural areas is required just the because of the fact that agricultural areas in Turkey has already pushed the limits and creating new agricultural areas is not possible any more. On the contrary, the existing agricultural areas could be lost because of natural and human factors such as erosion and misuse of lands. Consequently, the existing agricultural areas should be used in the most rational way. It is a fact that the agricultural areas in Turkey could not be increased, but it is not impossible to provide the needs of the increasing population through a well-planned and sustainable usage. For this reason, organic agricultural applications have started to gain prominence for the last years in Turkey just as in the other parts of the world.

Organic Agriculture in Turkey

The level that the agriculture sector in the world has come in the recent years shows that agriculture is not sustainable anymore and agricultural innovations are required. Natural resources needed for the agricultural production are not limitless. However, for many years all around the world, agricultural activities have been managed with the principle that these resources as limitless. It is a fact one cannot achieve sustainable development by damaging these limited resources and destroying the natural balance. Therefore, sustainable agricultural systems have become more important in last years. Sustainable agriculture embodies maintenance of production with environmental friendly techniques that protect the natural resources. Sustainable agriculture is defined as production systems that maintain continuous productivity and preserve social benefits (Pretty, 2008).

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Organic agriculture is one of the sustainable agricultural systems and it aims for rebuilding the natural balance destroyed because of the wrong applications in the ecologic system, as well as to once more bring the human and environmental friendly production systems to the fore. In this sense, organic agriculture stands for an agricultural system armed with an ecologic, social and economic balance (Topp, Stockdale, Watson, & Rees, 2007). Since it is sensitive to human health and nature, organic agriculture has gained much more prominence. In recent years, organic agriculture has been rapidly spreading across the world and global organic food market has been enlarging every passing day. By 2012 across the globe in 164 countries, 37.5 million hectares is under organic agriculture. Nevertheless, in comparison with the conventional agricultural areas, organic agricultural areas in the world are still a small amount (0.87%).

Turkey is one of the foremost countries that organic agricultural system is performed. Initial activities of the organic agriculture did not become with raising public awareness regarding the sustainable agriculture. Instead, organic agriculture was started completely with commercial motivations in Turkey. Organic agriculture in Turkey started in the 1984-1985 production season upon the organic products request of the European companies from Turkey (Istanbul Chamber Commerce, 2006). The first organic production was carried out with raisins and dried fig in the Aegean Region. Afterwards, these products were increased with the addition of dried apricot and hazelnut production in different regions (Ozkan, 2003). Although organic agriculture started quite late in Turkey, especially for the recent years, an important development has been made. However, this development is based mainly on vegetative production, and organic animal production in Turkey is not so common yet. For this reason, in this study, organic vegetative production of Turkey has been examined. Within time, organic vegetative production in Turkey has made notable progress both in terms of number of products and producers and production areas and quantities. In the following discussion, the temporal and spatial change of the organic agriculture in Turkey will be examined.

TEMPORAL AND SPATIAL DEVELOPMENT

Organic agriculture in Turkey has been subjected to notable changes with regards to both temporal and spatial distribution.

Temporal Development

Turkey has such a rich agricultural potential that many various products could be cultivated in its different geographic regions, territories and climates. Turkey has demonstrated its potential with its organic products variety within the last years. Apart from the arid climate plants, many different plant species including subtropical plants are cultivated in the country. In parallel with the enlargement of the world's organic product market in recent years, organic products cultivated in Turkey have become more diversified. The organic agricultural product range started with traditional products (such as fig, grape, apricot, hazelnut and cotton etc.) has since become varied every passing year. The number of organic products in 1990 was only 8. By 2000, number of organic products rose to 95 and in 2005, it reached to 205. By the year of 2013, the total number of certified organic products in Turkey is 213. As it is seen, within these 23 years, a substantial increase has been noted in the number of organic products.

As consumers' demands for organic agricultural products rise, so has the number of producers adopting organic agriculture. International trade has developed owing to the growth of this demand. All in

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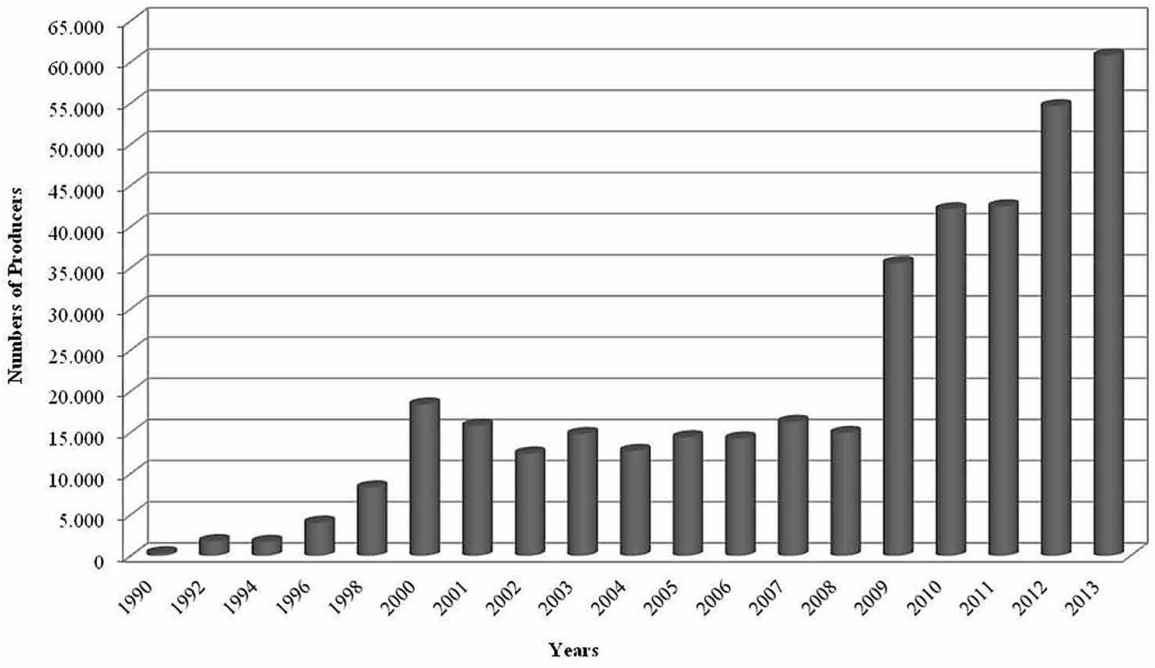
all, some countries have started to cultivate different organic products demanded from other parts of the world and export these products to these countries in spite of the fact that there is no domestic market or demand for the organic products in these countries. This situation is similarly in Turkey (Rehber & Turhan, 2002). Due to the rise in demand for the organic products in the world, the number of organic agricultural producers has increased.

Looking through the change in number of producers in Turkey, some important changes have been noted (Figure 3). Number of producers in Turkey was only 313 in 1990, and it rose up to 4.039 in 1996 and it reached to 18.385 by 2000. However, after 2000, a decrease has been seen in number of producers in Turkey. The economic crisis which occurred in 2001 in Turkey was responsible for the decrease in number of producers following 2000. On the other hand, after 2008, a substantial increase has been seen in number of producers. While the number of producers in 2008 was 14.926, it rose to 35.565 by 2009. In other words, only within 1 year, the number of producers increased almost 2.5 times. As to 2013, the number of producers reached to 60.797. By the year of 2012, there were 1.927.018 organic agriculture producers all around the world and Turkey became the 6th country with the largest number of producers. Also, Turkish producers now constitute 17 per cent of the total producers in Europe.

Both the temporal distribution of number of producers in Turkey and the spatial distribution of them have been subjected to substantial changes. There are 81 provinces in Turkey as per the civil administration structure. The data of provinces regarding the organic agriculture in Turkey is from 2004 and therefore on this data of 2004 will be used to compare the spatial changes of the organic agriculture.

An analysis of maps of 2004 and 2013 demonstrates some important changes in the spatial distribution of the organic agricultural producers. The total number of organic agricultural producers in 2004 was 12.751 and looking at the distribution of producers, no producers can be seen in 28 cities across

Figure 3. The number of producers in Turkey



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the whole country. This means that organic agriculture was not practised in 1 of every 3 cities and the cities without any organic agricultural activities are generally located in the Eastern Anatolia and South Eastern Anatolia regions (Figure 4). In 15 cities, number of producers was less than 10. In this way, we conclude that organic agriculture does not matter so much in more than half (43) of the cities. By 2004, the number of cities having more than 1.000 producers was only 6. These cities are respectively İzmir, Aydın, Erzurum, Kastamonu, Konya, and Çorum. As to the cities having 100 and more producers, they were intensified in the Western Anatolia Region and the city having the largest number of producers (1636) was İzmir in 2004.

A look at the map of 2013 shows that with respect to the spatial distribution of the organic agricultural producers, notable changes are seen at first glance as compared to 2004. Total number of producers reached to 60.797 by 2013 and there were only 2 cities (Siirt and Şırnak) without any producers in this year. This shows that organic agriculture has expanded all around the country since 2004 up to our present day. Cities with less producers are mostly concentrated in Central Anatolia Region (Figure 5). The most significant point drawing attention in both of the maps is the great increase in number of organic producers in Eastern Anatolia and Eastern Black Sea regions by 2013, where limited producers were once involved in organic agriculture activities in 2004. The number of cities having more than 1.000 producers rose to 13 in 2013. It is seen that these cities are intensified in Aegean, Eastern Anatolia and Eastern Black Sea regions. There are 5 cities in Turkey that has more than 4.000 producers and these cities are respectively Aydın, Rize, Van, Erzurum, and Kars. Aydın is the city having the largest number of producers (9.417) also in this year. Eventually, it is deduced from the examination of both maps showing the distribution of producers' number in 2004 and 2013, that the number of producers adopting organic agriculture has increased and it has started to spread over the country. Between 2004 and 2013, some notable changes have taken place in the distribution of the producers into the geographic regions.

Figure 4. The distribution map of producer in 2004

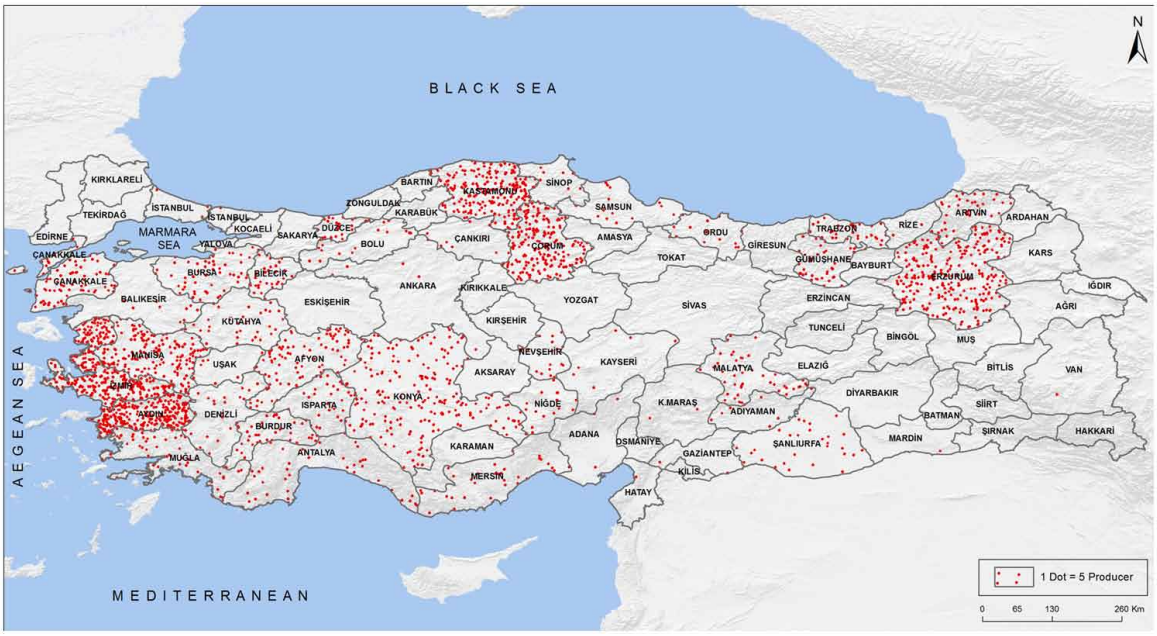

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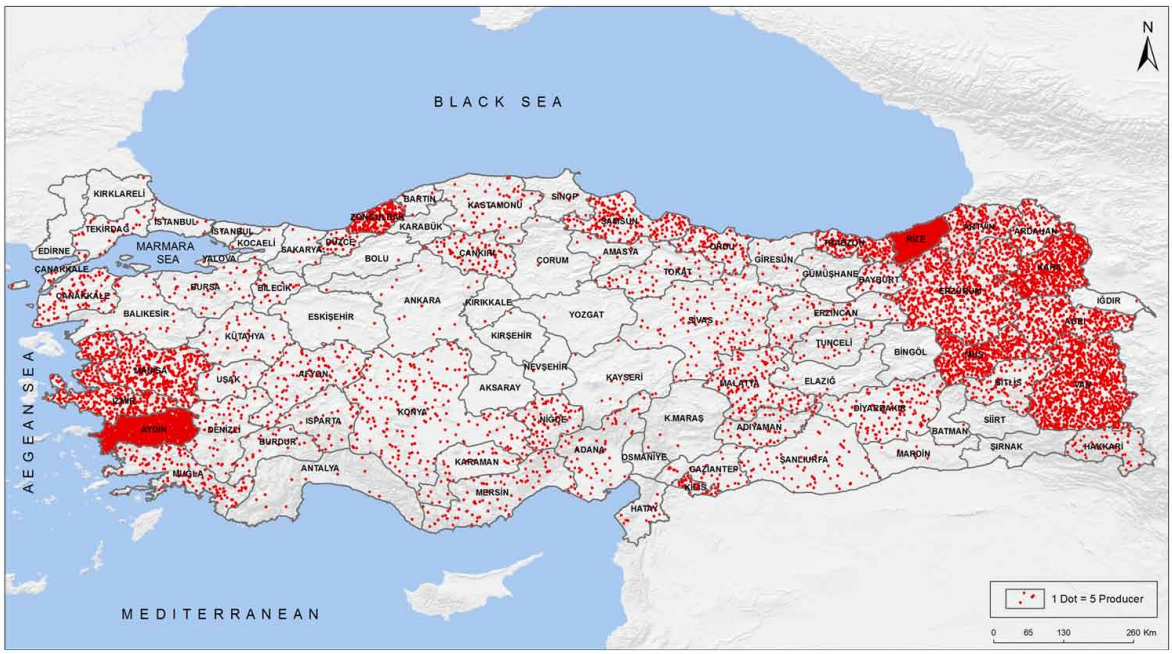
Figure 5. The distribution map of producer in 2013



Actually, in all of the regions, the total number of producers has increased between 2004 and 2013. Nevertheless, such increase rate is quite high in some of the regions. After all, the percentage of regions in total number of producers has been changed in time and the most significant change has happened in the Eastern Anatolia Region. While only 13 per cent of the total producers were located in the Eastern Anatolia Region, it has reached to 37 per cent by 2013 (Table 4).

Upon investigating on the temporal change of the organic agricultural areas in Turkey, we see quite important changes have taken place. Organic agricultural areas have been enlarged ever since the organic agriculture was firstly started in Turkey in 1984. Total area where organic vegetative production is made was solely 1.037 hectares in 1990 and organic agricultural areas were subjected to peaks and

Table 4. Distribution of producer by geographical regions

Geographical Region	2004		2013	
	Numbers of Producers	%	Numbers of Producers	%
Mediterranean Region	744	6	1.183	2
Eastern Anatolia Region	1.627	13	22.179	37
Aegean Region	4.884	38	15.825	26
Central Anatolia Region	1.317	10	2895	5
Black Sea Region	3.093	24	15.451	25
Marmara Region	897	7	1.184	2
Southeastern Anatolia Region	189	2	2.080	3

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troughs between 1990-2008. However, within this period of time, the general tendency of the organic agricultural areas was to enlarge. This enlargement was more rapid after 2008 (Figure 6) and the reason was the fact that organic agricultural policies were getting stronger. By 2012, total organic agricultural areas reached to 523.627 hectares between 2011-2012, a sizeable enlargement was seen. While Greece was the foremost country having the biggest expansion areal enlargement in organic agricultural areas in 2011-2012, Turkey became the fourth country (Willer & Lernoud, 2014). Organic agricultural areas have become enlarged 445 times in Turkey since 1990 up to 2013.

In the evaluation of the organic agricultural areas and natural collection areas in 2013 together, we see that total organic agricultural area in Turkey is 769.014 hectares (Table 5). 60 per cent (461.395 ha.) of this area is vegetative production area while 40 per cent (307.619 ha.) of it is for natural collection. Although the total organic area in Turkey shows fluctuations in some years, generally it tends to grow (Figure 7). In the case that such tendency in growth continues, in Turkey organic agricultural areas will enlarge much more in the coming years. By 2012, Turkey became the 15th country in the world and 8th country in Europe in terms of organic agricultural areas. These qualifications are the sign of Turkey's development in organic agriculture. As compared to the conventional agricultural areas, today organic agricultural areas in Turkey are not so large; they constitute 1.9 per cent of the total agricultural areas in the country. Such percentage shows how the organic agricultural areas are limited as compared to the total agricultural area in the country. On the other hand, in comparison with the past, we see that this percentage has grown. This proportion was 0.2 per cent in 2002, 0.4 per cent in 2008, 1.6 per cent in 2010 and 1.9 per cent at the present time. It is a proof that organic agriculture has been improving gradually within the Turkish agricultural system.

Figure 6. Organic agricultural lands in Turkey (ha)

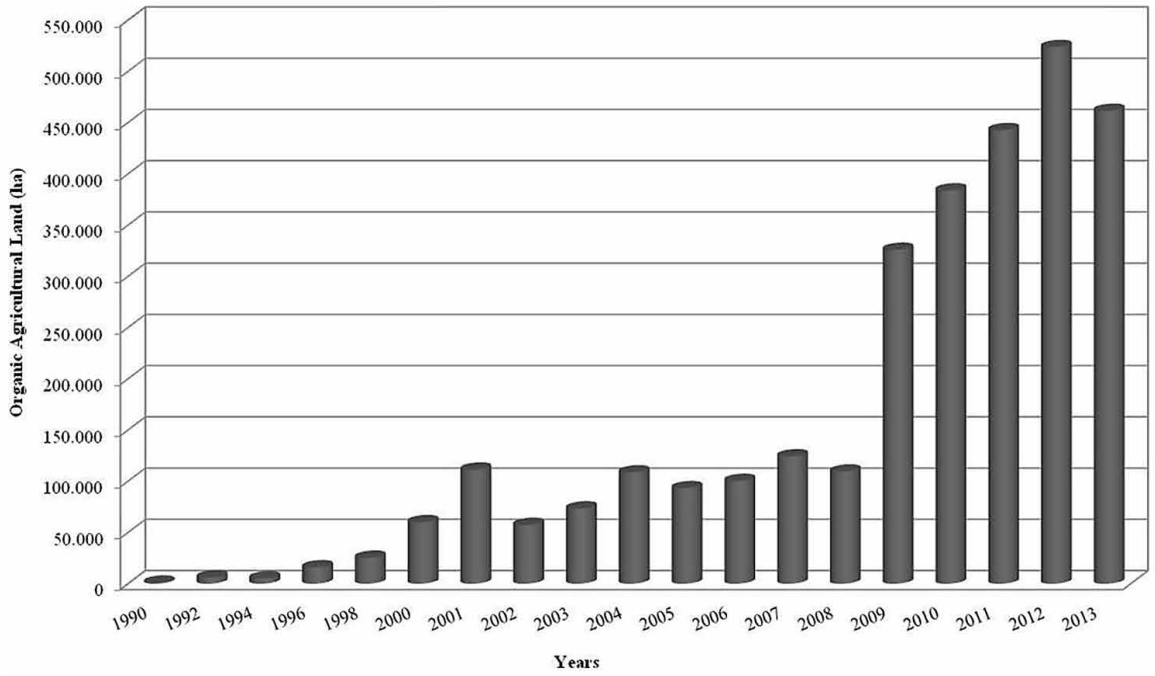

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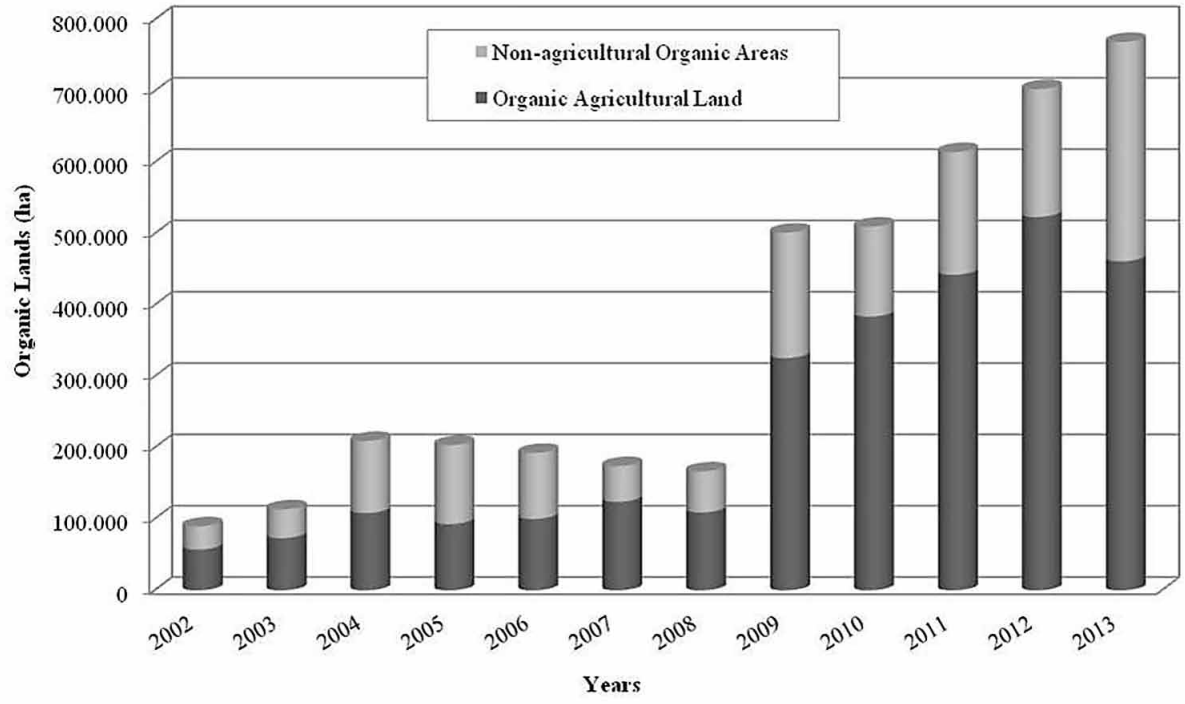
Table 5. Total organic lands in Turkey

Years	Organic Agricultural Land (ha)	%	Non-agricultural Organic Areas (ha) (Mainly wild collection)	%	Total Organic Lands (ha)
2002	57.365	63.9	32.462	36.1	89.827
2003	73.368	64.6	40.253	35.4	113.621
2004	108.598	51.8	100.975	48.2	209.573
2005	93.134	45.7	110.677	54.3	203.811
2006	100.275	52.0	92.514	48.0	192.789
2007	124.263	71.3	50.020	28.7	174.283
2008	109.387	65.5	57.496	34.5	166.883
2009	325.831	65.0	175.810	35.0	501.641
2010	383.782	75.2	126.251	24.8	510.033
2011	442.581	72.0	172.037	28.0	614.618
2012	523.627	74.5	179.282	25.5	702.909
2013	461.395	60.0	307.619	40.0	769.014

(TUIK, 2012; TUIK, 2014)

Figure 7. Total organic lands in Turkey (ha)



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Spatial Distribution

As it has been in the temporal development of the organic agricultural areas, some notable changes have seen in the spatial distribution of these areas. In 2004, the total organic area in Turkey was 209.573 hectares and nearly 52 per cent (108.598 ha) of it was agricultural area while the other 48 per cent (100.975 ha) was for the natural collection area. In the assessment of the map showing the distribution of the organic areas in 2004, it draws attention that there were significant gaps in the country (Figure 8). There was not any organic agricultural areas in 28 cities; mainly in the Eastern Anatolia Region and the eastern parts of the Central Anatolia Region. No data for 15 cities regarding organic land is available that is why no organic land is seen in the cities in the map such as Balıkesir, Bilecik, Erzurum, Eskişehir, Kocaeli, Konya, Nevşehir, Sakarya, Samsun, Tekirdağ, Tokat, Aksaray, Karaman, Iğdır, and Yalova. In 2004, organic production area was less than 1.000 hectares in nearly half (39) of the cities in Turkey and number of cities having a more than 1.000 hectares of organic area was 14. We see that these cities are intensified in the Aegean and Mediterranean regions and only 4 of these cities had more than 10.000 hectares of organic area; these cities are Antalya, Muğla, Şanlıurfa and İzmir. Antalya had 65.900 ha, Muğla had 21.790 ha, Şanlıurfa had 15.981 ha and İzmir had 10.995 ha of organic area. Total organic production area are in these 4 cities are 114.666 hectares. That is to say, almost 55 per cent of the total organic agricultural areas in Turkey are actually in only 4 cities. This suggests that in 2004 organic agriculture was not distributed equally in the country.

By 2013, there were some major changes in the distribution of the organic agricultural areas in the country (Figure 9). Total organic area in Turkey rose to 769.014 hectares in this year; 60 per cent (461.395 ha) of this area is the agricultural area while the other 40 per cent (307.619 ha) of it is for

Figure 8. The distribution map of organic lands in 2004

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Figure 9. The distribution map of organic lands in 2013

natural collection area. While looking at the map showing the distribution of the organic areas in the country in 2013, we see that there 2 cities without any organic agricultural area and these cities are Siirt and Şırnak. However, number of the cities without any organic agricultural areas in 2004 was 28 and the fact that it has decreased to only 2 cities by 2013 demonstrates that organic agriculture has started to spread over the country. (The data of 10 cities have not been obtained and these cities are Bingöl, Edirne, Elazığ, Kırklareli, Kırşehir, Kahramanmaraş, Zonguldak, Aksaray, Karabük and Osmaniye. For this reason, there are not organic any agricultural areas seen in these cities in the map. Nevertheless, it is known that organic agricultural area is quite small in these cities.) By 2013, number of the cities having more than 1.000 hectares of organic area has reached to 41 and it is seen that these cities are distributed almost equally over the country. As to the cities having a more than 10.000 hectares of organic area, the number of them has risen to 16 and these cities are mostly intensified in the Aegean, Eastern Anatolia and Mediterranean regions. The number of the cities with a more than 50.000 hectares of organic area is 6 and these cities are Mersin, Kastamonu, Van, Erzurum, Aydın and Kars. Mersin has 111.868 ha, Kastamonu has 83.714 ha, Van has 67.496 ha, Erzurum has 55.708 ha, Aydın has 52.759 ha and Kars has 52.622 ha of organic area. Between the years of 2004 and 2013, some notable changes have taken place in the distribution of the organic agricultural areas into the geographic regions. In fact, between these years, total organic areas has expanded in all the regions but such expansion rate is quite higher in some regions. This has changed the percentages of the regions in the total organic area of the country within time. We see the most substantial changes happening in the Eastern Anatolia Region (Table 6). While only 4 per cent of the total organic area in the country was in the Eastern Anatolia Region; this percentage reached to 38 per cent in 2013. Consequently, an evaluation of the spatial distribution of the organic agricultural areas in Turkey between 2004 and 2013 shows that organic agricultural areas in Turkey have become larger and they have expanded over the country in time.

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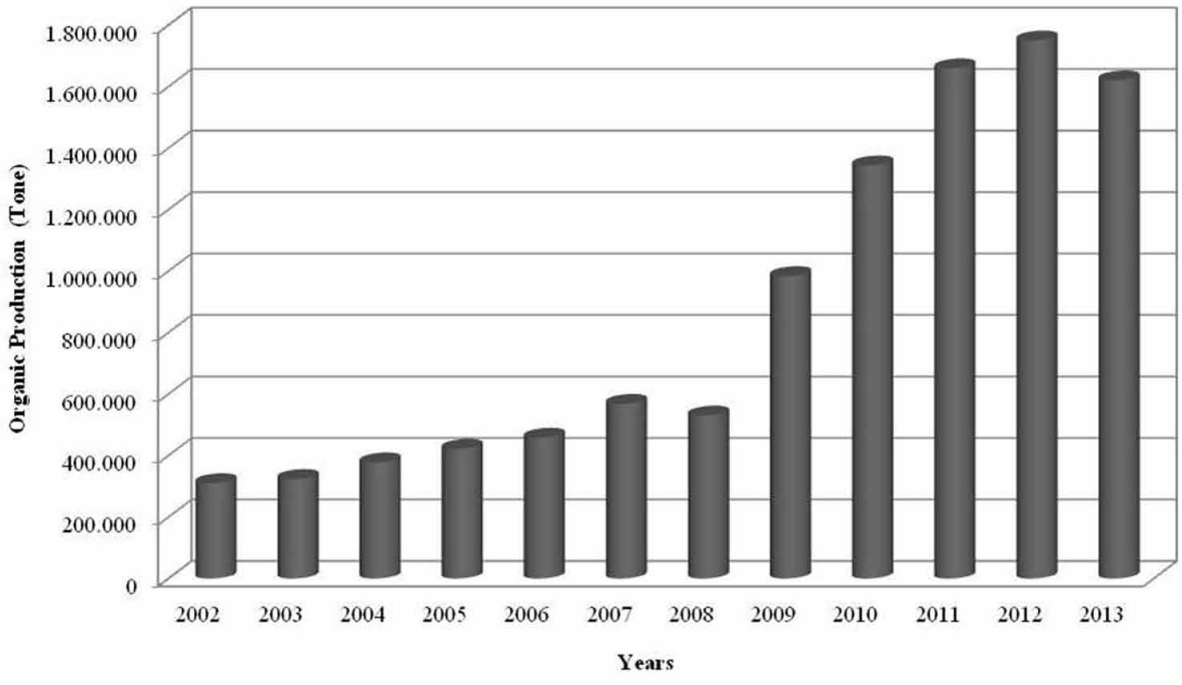
Table 6. Distribution of organic lands by geographical regions

Geographical Region	2004		2013	
	Total Organic Lands (ha)	%	Total Organic Lands (ha)	%
Mediterranean Region	77.341	47	161.322	21
Eastern Anatolia Region	6.115	4	288.993	38
Aegean Region	49.441	30	98.429	13
Central Anatolia Region	1.297	1	23.459	3
Black Sea Region	7.841	5	110.991	14
Marmara Region	2.718	2	54.296	7
Southeastern Anatolia Region	19.089	11	27.402	4

Depending on the increase in number of farmers and production area, the organic vegetative production quantity in Turkey has gotten bigger. We see some important temporal changes happening in the amount of organic production and the general trend of this change is in the direction of increasing. Organic vegetative production quantity, being only 310.125 tons in 2002, rose to 530.224 tons in 2008. Particularly after 2008, a great increase was noted in the organic production (Figure 10). An increase in the number of producers and production area between 2008-2009 is reflected in the production quantity that reached to 983.715 tons by 2009. In other words, organic production quantity increased by about 85 per cent just within 1 year. Aid given to the organic agricultural producers since 2009 gave a boost to the organic production in forage plants and grains and this led to an overall increase in the total produc-

Figure 10. Organic production (Tons)



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tion (The Union of Chambers and Commodity Exchanges of Turkey, 2013). By 2013, the total organic production quantity has reached to 1.620.466 tons. Organic production quantity in Turkey is shaped by the foreign demands. Since Turkey makes export-based organic production, mostly it is the world market that decides the production quantity. However, owing to the rising demands for organic products in the domestic market, the organic production quantity in Turkey is expected to rise as well.

Some notable changes have also taken place in the spatial distribution of the organic production. In 2004, organic production in Turkey was 377.615 tons. Looking at the spatial distribution of production in 2004, one can see 28 cities without any organic production. There were 26 cities having more than 1.000 tons of production and 10 cities having more than 10.000 tons of production and we see that these cities are intensified in the Western Anatolia. There were only 3 cities having more than 20.000 tons of production which are İzmir, Aydın and Şanlıurfa. Production quantity in İzmir was 26.174 tons, it was 39.787 tons in Aydın and 54.198 tons in Şanlıurfa. It shows that in 2004 organic production was intensified in some certain regions of the country (Figure 11). Organic products at that time were the traditional products that were of vital importance in Turkey's agricultural structure; these were grape, fig, apricot, hazelnut, olive, cotton and citrus fruits.

By 2013, the organic production quantity in Turkey rose to 1.620.466 tons and in this year, some substantial changes have been seen in the distribution of the organic production according to the cities (Figure 12). An examination of the map showing the distribution of the organic production into the country in 2013, shows that there are 2 cities without any organic production which are Siirt and Şırnak. (In 2013, we have not accessed to the data of 10 cities regarding the organic production. Therefore, there is no organic production seen in these cities in this map which are Bingöl, Edirne, Elazığ, Kırklareli, Kırşehir, Kahramanmaraş, Zonguldak, Aksaray, Karabük and Osmaniye. However, it is known that there

Figure 11. The distribution map of organic production in 2004

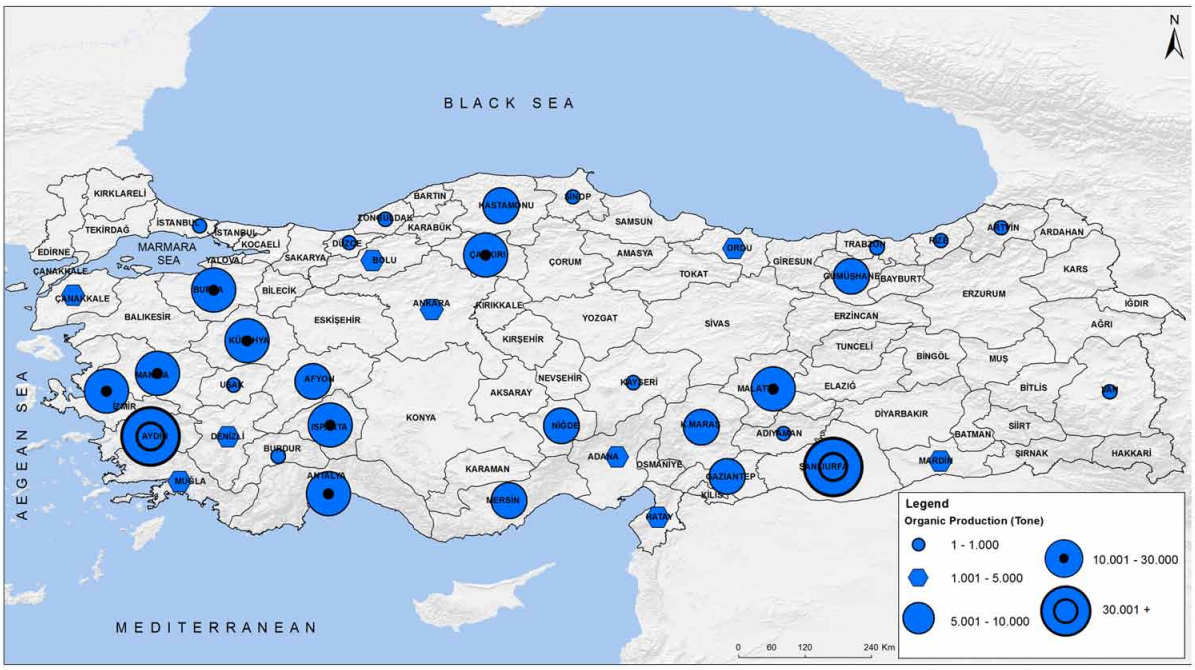

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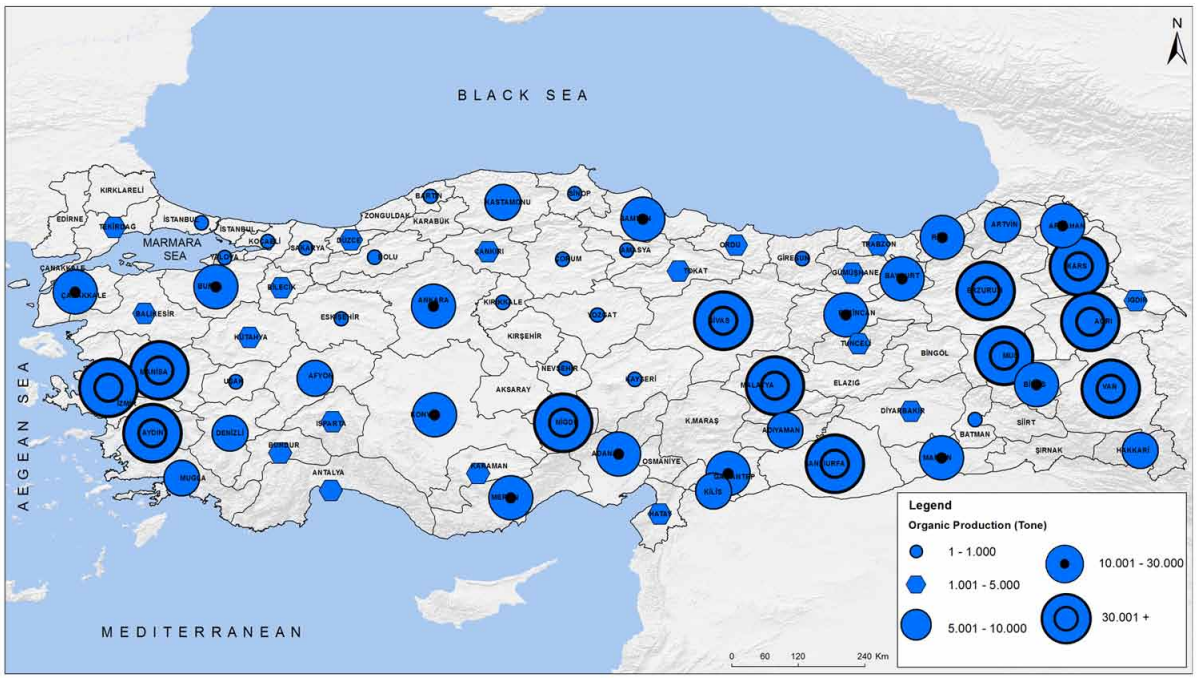
Figure 12. The distribution map of organic production in 2013



is too small organic production in the aforesaid cities). There are 52 cities having more than 1.000 tons of production. It is possible to conclude that organic production has expanded over the country because organic production is done in most of the cities. The number of the cities having more than 10.000 tons of production is 26 and those having more than 20.000 tons of production are 16. On the contrary, this was limited to 3 cities in 2004. Moreover, there are 12 cities in Turkey having more than 30.000 tons of production and these cities seem to be intensified in the Eastern Anatolia and Aegean regions. In this year, number of the cities having more than 100.000 tons of production is 5 and these cities are respectively Erzurum, Van, Aydın, Kars and Ağrı. The production quantity in Erzurum is 233.408 tons, 198.738 tons in Van, 154.760 tons in Aydın, 137.040 tons in Kars and 135.917 tons in Ağrı. Apart from Aydın, in the rest of the cities, grain production is more dominant. Looking through the maps shows the spatial distribution of the production in 2004 and 2013. At first glance, one can observe that substantial changes have occurred in the spatial distribution of the production within the period of these 10 years, and organic production has expanded all around the country. As to the regional distribution of the organic production, we see a growth in all the regions but there is an extreme growth in the Eastern Anatolia Region (Table 7). In 2004, the organic production in the Eastern Anatolia Region constituted solely 5 per cent of the total production of the country, while it has reached to 57 per cent by 2013. Despite the increase in the organic production in the Aegean Region, the percentage of the Aegean Region within the total production has decreased. A considerable difference can be observed between the Eastern Anatolia and Aegean regions with regards to organic production quantity in 2013. On the other hand, trade volume and organic market value of the products cultivated in the Aegean Region are much more. In the Eastern Anatolia Region, grains are generally cultivated.

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Table 7. Distribution of organic production by geographical regions

Geographical Region	2004		2013	
	Organic Production (Tons)	%	Organic Production (Tons)	%
Mediterranean Region	50.301	17	56.982	4
Eastern Anatolia Region	16.012	5	913.828	57
Aegean Region	111.722	37	303.014	19
Central Anatolia Region	21.501	7	109.879	7
Black Sea Region	20.490	7	72.688	4
Marmara Region	16.210	5	38.351	2
Southeastern Anatolia Region	65.074	22	116.033	7

Organic agriculture in Turkey develops depending on the export market (Leeuwen, Voort, Sukkel, & Balci, 2008). Almost all the organic production are exported to the developed countries especially EU countries, the USA and Japan. EU countries stand for the most important exportation market of Turkey between these markets and Germany, France and England are the most prominent exportation markets of Turkey within these EU countries (Gök, 2008). A large part of the exported products is dry and dried fruits and later on fresh fruits and field crops. From 19.4 million US dollars in 1998, organic products exportation rose to 26.3 million US dollars in 2005, but it dropped to 15 million US dollars between 2010 and 2011. Such reduction is associated with the global economic crisis in that time. Following the recovery of the markets after the crisis, organic products exportation rose to 24.7 million US dollars in 2012 while it has reached to 46 million US dollars in 2013. Although the exportation values grade up every passing day, the proportion of Turkey in the world organic agricultural market is still too little. In the evaluation of the product groups, it is noted that Turkey has gained the most foreign currency income from organic hazelnut, fig, apricot, grape, strawberry, olive, cotton and fruit juices. The organic agricultural market, which is growing rapidly in the world, was 63.8 billion US dollars in 2012. Considering the total market value of the world's organic agriculture, the revenue that Turkey gains from this market is still very small. Within the 2023 year targets of Turkey, there is an objective as well to raise the organic agricultural exportation to 2.5 billion US dollars. Turkey has the potential to realize this objective as well as to make agricultural the policies needed to stimulate its potential (Ministry of Food, Agriculture and Livestock, 2012).

In order for the organic agriculture to become widespread in Turkey, the domestic market of organic products needs to grow as well. For the time being, Turkey has an export-oriented organic production. Consumption of organic products is too small in the domestic market of Turkey. It is estimated that the domestic market of organic products of Turkey is around 14 million US dollars. As compared to other countries, this figure shows how much restricted is the domestic market of organic products in Turkey (Demiryürek, 2011). By 2012, consumption value of the organic food per capita in Turkey was 0.16 US dollar. In other words, consumption value of the organic food per capita is not even one US dollar. On the contrary, in the same year, across the globe, average consumption value of the organic food per capita was 9.08 US dollars. It reveals that in Turkey consumption of organic value is very little and Turkey has a lower consumption value of the organic food in comparison with the other parts of the world. If it is desired for the organic agriculture to become more widespread, domestic consumption should be increased. In the recent years, to increase the organic products consumption in the domestic market, some

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organic products stores, organic products sections in the supermarkets and organic open-air markets in some days of the week have been opened. Particularly in İstanbul, Ankara and İzmir, organic open-air markets are established at 15 points in the country. There are 7 organic open-air markets in İstanbul. İzmir and Ankara have 2 organic open-air markets and Antalya, Bursa, Eskişehir and Samsun have one organic open-air market each. Domestic consumption has been growing gradually thanks to the recent activities. People have started to hear the concepts of organic agriculture and organic products much more. Along with exports, increased domestic consumption of organic products will make the organic agriculture widespread in the country.

BENEFITS OF ORGANIC AGRICULTURE TO TURKEY

Agriculture is one of the sectors that has always maintained its importance in the economic and social development in Turkey from past to present. Turkey has a very prominent agricultural potential such that apart from arid climate plants, many other plant species could be cultivated including subtropical plants. Making optimal use of Turkey's agricultural potential is possible only with the rational use of its natural resources. Turkey is in need of sustainable agricultural systems that do not decimate its natural resources, pollute or destroy them. Sustainable agricultural production could be applied; systems which do not use up its natural resources and eventually cause to the deterioration of these resources, but rather systems which use these resources effectively so that they could be passed on to the next generations. For this reason, start of organic agriculture and its spread in Turkey in recent years are important steps for sustainable agriculture.

Turkey has made notable progress regarding organic agriculture within the last 20 years. By 2013, Turkey has made a 1.620.466 tons of organic production on a 769.014 hectares of area together with 60.797 producers. Turkey has become the 6th country in the world as having the largest number of producers and the 15th country in terms of its organic agricultural areas. Between 1990-2013, the number of producers has increased 195 times more and organic agricultural area has enlarged 445 times more, and between 2002-2013 organic production quantity has grown 5.2 times more. In spite of all these developments, today Turkey still uses only a very small part of its organic agricultural potential. Turkey is a country with a high organic agriculture potential, but these potentials are not evaluated sufficiently. Here are some of the potentials Turkey enjoys concerning organic agriculture.

- Turkey has different ecologic conditions and such diversity in the ecologic conditions make it possible to cultivate many agricultural products in the country. At one side, arid climate plants are cultivated while mild and sub-tropical plants could be cultivated at the same time. It gives an advantage to Turkey for the variety of products.
- Turkey has a biologic richness and diversity.
- Turkey has adequate and productive agricultural areas. The proportion of the agricultural areas in the surface area of Turkey is 30.3 per cent.
- Turkey has sufficient water resources.
- Turkey has thousands years of agricultural knowledge and experience.
- Turkey has adequate labor force. Researches done in this field have revealed that organic agriculture required much labor force as compared to the conventional agriculture (Turhan, 2005). Having a large, young population in Turkey is an advantage for a cost-effective labor force.

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- Another potential is the country's geographical position. Turkey is close to foreign markets and Turkey is especially advantageous due to it being so close to the European Union market.
- Turkey is an important player in terms of transportation systems in the international trade. Apart from the land and air transportation systems, marine transportation is an advantage as well for Turkey because it has outstanding mercantile ports (such as İstanbul, İzmir, Mersin).
- Turkey is the leading producer in some certain products (such as hazelnut, fig, grape, apricot etc.) in the world's agriculture and it has the chance to continue this advantage along with the organic production.
- In comparison with the industrialized countries, the amount of chemical input in the agricultural areas is lower in Turkey. Therefore, chemical pollution is not so dense in Turkey's soils. This will make the transition easier to organic agriculture.
- It is an advantage as well that Turkey has built the fundamental education required for solving the qualified labor force in the organic agriculture. Some 21 Organic Agriculture Departments have been established in 19 universities in order to support the organic agricultural development.
- Having a national legislation for organic agriculture is another advantage. By 2012, Turkey is one of the countries in the world that fulfilled the necessary regulations regarding the organic agriculture (Willer & Lernoud, 2014).

Embracing organic agriculture in the country will provide additional national benefits. Some of these are:

- Since the organic agriculture is an agricultural system that is sensitive to the environment, it will maintain the sustainable usage of natural resources. Turkey will both protect its natural resources and it will get the maximum benefit from these resources as well.
- Erosion intensity, one of the significant problems in Turkey's agriculture, will be diminished.
- Turkey will satisfy the food needs of the increasing population sustainably with organic agriculture.
- Health food supply with organic agriculture will make contribution to raising healthy generations of people.
- Organic agriculture will find solutions for the employment problems of the large rural population to a considerable extent.
- Rural-to-urban migration will be reduced as organic agriculture will contribute to the rural development.
- Wide spreading of the organic agriculture will increase the agricultural employment.
- Producers will be given guarantee thanks to the contracted agriculture.
- Percentage contribution of agriculture in the national income will again increase.
- Turkey will make good use of its potential in the diversity of organic products and will promote its competitive capacity in the international markets.
- Its agricultural exportation revenues will increase. Reduced percentage of the agriculture in the foreign trade will again raise.
- Increasing the foreign trade of the organic agricultural products will provide a substantial foreign currency inflow to the country. It will make contribution as well to the importation-exportation balance.

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- High values of the organic products in the market will enable producers to obtain high revenues.
- Use of chemical inputs including fertilizers in the agriculture will be diminished thanks to the wide spread use of organic agriculture, and accordingly farmers will get rid of additional expenses.
- In case of a reduction in the use of the agricultural chemicals and fertilizers, importation expenses of the country will become less since most of them are imported.
- Every year in Turkey, a considerable amount of the agricultural areas remain fallow. Thanks to the organic agriculture, these areas will become smaller, and more agricultural areas could be used for the production.
- It will make a contribution to the regional development and especially to the development of the Eastern and South Eastern Anatolia regions.
- As organic agriculture becomes more common in Turkey, this will contribute positively to the agricultural negotiations in the membership process of the EU (Bakırcı, 2005).

RECOMMENDATIONS

Future agricultural systems will be those that prioritize the principle of sustainability, and the countries having these systems in-house will enjoy sustainable agricultural development. In this sense, if Turkey has expanded the organic agriculture system as soon as possible, it will be a shining example for the future. We have hereby shared our recommendations regarding the sustainable agriculture:

- A sustainable development in the agricultural production will be only succeed with the coherent use of various agricultural technologies. For this reason, Turkey should benefit much more from the agricultural information technologies.
- Geographic Information Systems (GIS) is an effective tool that should be used for the sustainable agriculture. Use of GIS has increased in the sustainable agriculture applications in the world in recent years. GIS helps in forming the sustainable agricultural applications by storing, managing, analyzing, reporting and monitoring agricultural data in huge numbers (Esri, 2008). Therefore, the first priority of Turkey should be establishing agricultural data bases and such data bases should include environmental information, cadastral information, infrastructural and socio-economic information. In Turkey, these data bases should be city-based. The most important factor of the agriculture is soil, but there is not any significant data base of soils yet. For this reason, activities of preparing agricultural data bases should be accelerated.
- Turkey has different ecologic conditions. Therefore, Turkey should consider agro-ecological zoning for sustainable agriculture. By this way, more effective agricultural programs could be prepared for each of the agro-ecologic zones. For an agro-ecological zoning, primary data bases should be developed, that is to say, necessary foundations should be built.
- The most fundamental deficiency concerning the sustainable agriculture is that Turkey lacks for the agricultural data bases. Therefore, information technologies and information management systems should be considered and the relevant studies should be accelerated. Consequently, without sufficient information regarding the physical and human characteristics of the natural environment, a healthy agricultural planning cannot be made.

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- Agricultural policies should be based on the concept of sustainability and oriented towards organic agriculture.
- Organic agriculture should be given more priorities in the agricultural development plans.
- The situation of the Turkish farmers should once again be evaluated and in accordance with the local conditions, new agricultural policies should be created.
- Agricultural areas in Turkey are small and partial. Land consolidation of the agricultural areas should be considered and agricultural enterprise areas should be enlarged.
- Support for organic agriculture should be increased.
- Model agricultural applications should be promoted with government aid.
- In order to raise awareness among producers and people, some public service announcements should be prepared.
- Apart from the organic vegetative production, organic animal production should be considered as well and some actions should be taken to improve the production. Large grass and pasture lands (14.617.000 ha) are an advantage that will make it possible an organic animal breeding development in Turkey.
- The entrepreneurs should be encouraged for the organic agriculture and agricultural industrial integration. The number of high value processed organic products should be increased along with the organic raw materials. Thus, the revenue of organic products exports will grow.
- Not only the foreign market but also the domestic markets should be developed.
- An effective and continuous government policy is required for the organic agricultural development in Turkey but the re-shaping of the agricultural policies with every new government will cause instability and slow down organic agriculture development.

CONCLUSION

Nowadays, it has been understood that natural resources are restricted and sustainable use of these resources is highly important. For this reason, future agricultural systems will be those giving priority to the "principle of sustainable agriculture". Organic agriculture, one of the sustainable agricultural systems, has gained considerable importance in the world for recent years. Countries having widespread organic agriculture will enjoy sustainable economic development. Turkey has made substantial progress regarding the organic agriculture for the last 20 years. Moreover, the developments in organic agriculture in the last 5 years are show a lot of promise for the future.

Organic agriculture in Turkey has made notable progress in terms of both number of producers and products and production area and quantity. The number of producers has increased 195 times more and organic agricultural areas have enlarged 445 times more between 1990-2013. Also, organic production quantity has grown 5.2 times more between 2002-2013. Apart from the temporal changes in the organic agriculture of Turkey, some important spatial changes have been noted as well. Intensified in the certain parts of the country at the beginning, the organic agriculture has expanded over the country at the present time. In spite of all these developments, Turkey, today, could not benefit from the potentials and advantages adequately that it has in the organic agriculture. In order for the organic agriculture to be widespread in Turkey, a stable government policy should be developed and applied. Moreover, agricultural information system and management technologies should be considered to aid the sustainable agricultural development in Turkey. Organic agriculture will make great contributions to Turkey's

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economic development and regional improvement inside the country. Organic agriculture is an important necessity for a sustainable life and a sustainable agriculture. For this reason, it is of essence to spread much wider the organic agriculture in Turkey and all over the world for the sake of bequeathing a livable world to the next generations.

REFERENCES

Badgley, C., & Perfecto, I. (2007). Can organic agriculture feed the world? *Renewable Agriculture and Food Systems*, *22*(2), 80–85. doi:10.1017/S1742170507001986

Bakırcı, M. (2005). The future of organic farming in Turkey and its effects to the agricultural negotiations between Turkey and European Union. *Istanbul University Geographical Review*, *13*, 67–83.

Bakırcı, M. (2007). *Rural development in Turkey: Concepts, policies, practices*. Ankara, Turkey: Nobel Press.

Demiryürek, K. (2011). The concept of organic farming and the situation of organic farming in the world and Turkey. *Journal of Agricultural Faculty of Gaziosmanpasa University*, *28*(1), 27–36.

Demiryürek, K., Stopes, C., & Güzel, C. (2008). Organic agriculture: The case of Turkey. *Outlook on Agriculture*, *37*(4), 261–267. doi:10.5367/000000008787167754

Doğanay, H. (2007). *Agricultural geography*. Erzurum, Turkey: Aktif Press.

Esri. (2008). *GIS for sustainable agriculture* [PDF document]. Retrieved from http://www.esri.com/library/bestpractices/sustainable-agriculture.pdf

Food and Agriculture Organization of the United Nations (FAO). (2014). *Statistical yearbook 2014: Europe and Central Asia food and agriculture*. Retrieved from http://www.fao.org/3/a-i3621e.pdf

Gök, S. A. (2008). *An assessment of trade in Turkish organic products in the expanding market of European Union*. (Expertise thesis). Retrieved from Republic of Turkey Ministry of Food, Agriculture and Livestock expertise thesis database. (50)

Göney, S. (1979). *Geographical essentials of Turkey's agriculture*. Istanbul, Turkey: Istanbul University Press.

Grigg, D. (1995). *An introduction to agricultural geography*. London: Routledge.

Istanbul Chamber Commerce. (2006). *Analysis of organic agriculture and EU market opportunity*. Istanbul, Turkey: Birlik Press.

Knowles, R., & Wareing, J. (1983). *Economic and social geography*. London: Heinemann.

Lotter, D. W. (2003). Organic Agriculture. *Journal of Sustainable Agriculture*, *21*(4), 59–128. doi:10.1300/J064v21n04_06

Makhzoumi, J., & Pungetti, G. (1999). *Ecological landscape design and planning: The Mediterranean context*. London: Spon Press. doi:10.4324/9780203223253

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Minister of Development. (2014a). *Tenth development plan (2014-2018): Specialization commission report about agricultural structure and food security*. Retrieved from http://www.kalkinma.gov.tr

Minister of Development. (2014b). *Tenth development plan (2014-2018): Working group report about sustainable agricultural land use.* Retrieved from http://www.kalkinma.gov.tr

Ministry of Food, Agriculture, and Livestock. (2012). *Strategic plan for organic farming in Turkey (2012-2016)*. Retrieved from http://www.trakya2023.com/uploads/docs/2806201331nTii.pdf

Ministry of Food, Agriculture, and Livestock. (2014). *Activities of general directorate of vegetative production* [PDF document]. Retrieved from http://www.tarim.gov.tr/sgb/Belgeler/SagMenuVeriler

Organisation for Economic Co-operation and Development (OECD). (2011). *Evaluation of agricultural policy reforms in Turkey*. . doi:10.1787/9789264113220-en

Ozkan, M. (2003). Organic agriculture and national legislation in Turkey. In Organic agriculture: Sustainability, markets and policies (pp. 289-294). Wallingford, UK: CABI Publishing.

Park, J., & Seaton, R. A. F. (1996). Integrative research and sustainable agriculture. *Agricultural Systems*, *50*(1), 81–100. doi:10.1016/0308-521X(94)00050-2

Pretty, J. (2008). Agricultural sustainability: Concepts, principles and evidence. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *363*(1491), 447–465. doi:10.1098/rstb.2007.2163 PMID:17652074

Pretty, J. N. (1995). Participatory learning for sustainable agriculture. *World Development*, *23*(8), 1247–1263. doi:10.1016/0305-750X(95)00046-F

Pugliese, P., Bteich, M. R., & Al-Bitar, L. (2014). *Mediterranean organic agriculture: Key features, recent facts, latest figures Report 2014*. Retrieved from http://moan.iamb.it/

Rehber, E., & Turhan, Ş. (2002). Prospects and challenges for developing countries in trade and production of organic food and fibers: The case of Turkey. *British Food Journal*, *104*(3/4/5), 371-390. doi:10.1108/00070700210435380

The Union of Chambers and Commodity Exchanges of Turkey. (2013). *Agricultural sector report of Turkey*. Ankara, Turkey: Afşaroğlu Publishing.

Topp, C. F. E., Stockdale, E. A., Watson, C. A., & Rees, R. M. (2007). Estimating resource use efficiencies in organic agriculture: A review of budgeting approaches used. *Journal of the Science of Food and Agriculture*, *87*(15), 2782–2790. doi:10.1002/jsfa.3059

Turhan, Ş. (2005). Sustainability in agriculture and organic farming. *Turkish Journal of Agricultural Economics*, *11*(1), 13–24.

Turkish Statistical Institute. (2012). *The summary of agricultural statistics 2011*. Ankara, Turkey: Turkish Statistical Institute Press.

Turkish Statistical Institute. (2014). *Turkey in statistics 2013*. Ankara, Turkey: Turkish Statistical Institute Press.

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Turkish Statistical Institute (TUIK) Databases. (n.d.). Retrieved from http://www.turkstat.gov.tr

van Leeuwen, M. A. E., van der Voort, M. P. J., Sukkel, W., & Balci, S. (2008). *Organic agriculture in Turkey: trade opportunities for organic fruit and vegetables*. Retrieved from http://edepot.wur.nl/29925

Willer, H., & Lernoud, J. (Eds.). (2014). *The world of organic agriculture: Statistics and emerging trends 2014*. Retrieved from https://www.fibl.org/fileadmin/documents/shop/1636-organic-world-2014.pdf

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Chapter 46
Climate Change and Land Suitability for Potato Cultivation in India

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ABSTRACT

Potato is one of the most important vegetable crops in India accounting for 20-25% of area under cultivation of vegetables and grown in a wide range of climatic conditions. It is grown in almost all states under diversified agro-climatic conditions. Nearly 80% of the crop is grown in Indo- Gangetic plains comprising Uttar Pradesh, West Bengal, Punjab, Haryana, Bihar and other parts of India like Gujarat and Karnataka. Moreover, within the country, there is a lot of heterogeneity in potato productivity depending upon mostly on management and climatic conditions. The viability of commercial potato production is influenced by spatial and temporal variability in soils, agro climate, and the availability of water resources. The inter and intra-regional variations in productivity within the country are attributed to the variations in bio-physical factors vis-a-vis specific soil-climatic requirements of the crop. The present chapter discusses the impact of climate change on the land resources requirement for potato crop with reference to Indian context.

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INTRODUCTION

Potato (*Solanum tuberosum* L.) plays an important role in global food and nutritional security especially for the poor (Thiele et al., 2010). It is commonly known as 'The king of vegetables and it has emerged as fourth most important food crop in India after rice, wheat and maize. Indian vegetable basket is incomplete without Potato. It is an annual, herbaceous, dicotyledonous and vegetatively propagated plant. The dry matter, edible energy and edible protein content of potato make it nutritionally superior vegetable as well as staple food. Potato is a highly nutritious, easily digestible, wholesome food containing carbohydrates, proteins, minerals, vitamins and high quality dietary fiber. Fresh potato contains about 80 per cent water and 20 per cent dry matter of which 60- 80 per cent is starch. It has low fat content and high vitamin C. A single potato of 150 g can meet 100 mg of vitamin C requirement. Potato is also a good source of iron, vitamins B1, B3 and B6 and important minerals. It also contains dietary fibers, which benefit human health. (Jha, 2015). It produces more quantity of dry matter, edible energy and edible protein in lesser duration of time than cereals like rice and wheat. The crop has also shown better economic viability during the current trend of diversification from cereals to horticultural/vegetable crops. However impending global climate changes are set to alter the potato production systems in the country and hence it is imperative to examine its consequences.

Global warming also termed as greenhouse effect is the result of accelerated emission of greenhouse gases (GHGs) *viz.* carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) in to the atmosphere due to anthropogenic activities. Global warming also termed as greenhouse effect is the result of accelerated emission of greenhouse gases (GHGs) *viz.* carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) in to the atmosphere due to anthropogenic activities. Atmospheric CH_4 and $N_2O$are attributed to crop cultivation forestry and other land uses. Whereas rise in concentration of CO_2 is attributed to fossil fuel combustion. Agriculture has a minor role in contribution of CO_2 to the atmosphere. It is now established that the global atmospheric concentrations of CO_2, CH4and N_2O have increased markedly as a result of human activities since 1750. The increase in GHGs has resulted in warming of the climate system by 0.74°C between 1906 and 2005. The rate of warming has been much higher in recent decades (Dua et al., 2013).

Although increase in atmospheric CO_2 has a fertilization effect on crops with C_3 photosynthetic pathway and thus promotes their growth and productivity, on the other hand, it can reduce crop duration. Report of Working Group II of Inter-Governmental Panel on Climate Change (IPCC) and a few other global studies (Aggarwal, 2008) indicated a probability of 10–40% loss in crop production in India with increase in temperature by 2080–2100. The discussion in this chapter pertains to potato cultivation in the wake of climate changes.

Global Potato Production Scenario

The potato is the most popular food crop cultivated in the world and area under its cultivation is 4th largest following rice, wheat and maize. The major potato producing countries in the world are China, Russia, India, Poland, U.S.A., Germany and Spain. Presently, China is the biggest potato producer in the world and almost one third of all potatoes harvested globally come from China and India.

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Potato Production in India

Potato is an important food crop of India and comes third after rice and wheat in terms of production and food security (Dua et al., 2015). India has made tremendous progress in potato production and the per capita availability of potato has increased from 4.37 kg in 1950 to 21.52 kg in 2012 (National Horticultural Board, 2012). India is the second largest producer of potato in the world after China and both the countries put together contribute nearly one third of the global potato production (Scott and Suarez, 2012). Potato is most important vegetable crop in India accounting for 20-25% of area under cultivation of vegetables. In India 46.609 million tons of potato production was obtained in the year 2013 - 2014 from an area of 2.032 million ha with an average productivity of 22.5 t/ha (Jha, 2015). In India, it is a major vegetable crop and is being grown in a wide range of climatic conditions (Pandit & Chandran, 2011). It is grown in almost all states under diversified agro-climatic conditions. Nearly 80% of the crop is grown in Indo- Gangetic plains comprising Uttar Pradesh, West Bengal, Punjab, Haryana, Bihar and Gujarat. The potato growing states and their distribution in different Agro-Ecological Regions (AER) and Agro-ecological sub regions (AESR) are presented in Table 1.

Though it is grown in all the three seasons with diversified soil-management practices, potato is grown largely in the *rabi* season in major production regions of Uttar Pradesh (UP) West Bengal (WB), Bihar, Gujarat and Punjab. The rainy season (*kharif*) potato production is taking place in Karnataka, Maharashtra and Chhattisgarh. However, the potato productivity in India is still very poor as compared to about 45 t/ha in many countries of Europe and U.S.A. (Bansal & Trehan, 2011). Moreover, within the country, there is a lot of heterogeneity in potato productivity depending upon mostly on nutritional management and climatic conditions (Table 2).

For example, Bihar is the 3rd largest potato growing and producing state of India accounting for nearly 9.8% of total potato area and 4.2% of the total potato production in the country, but with very

Table 1. Distribution of potato growing states in different AER and AESR in India

AER	AESR	States
5	5.2	Gujarat
9	9.2	Uttar Pradesh, Bihar
10	10.4	Madhya Pradesh, Maharashtra
11	-	Uttar Pradesh, Madhya Pradesh, Bihar
12	12.3	Bihar, West Bengal. Orissa
13	13.1	Uttar Pradesh, Bihar
14	14.3, 14.5	Himachal Pradesh, Uttar Pradesh
15	15.1, 15.2, 15.4	West Bengal. Assam
16	16.1, 16.2,16.3	West Bengal, Assam, Sikkim, Arunachal Pradesh
17	17.1, 17.2	Meghalaya, Assam. Nagaland, Arunchal Pradesh
18	18.2, 18.4, 18.5	Tamil Nadu, Andhra Pradesh, Orissa, West Bengal
19	19.2,19.3	Maharashtra, Goa, Karnataka, Kerala, Tamil Nadu

Source: Naidu et al., 2009

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Table 2. State wise area, production and productivity of Potato India (2012)

State	Area (000 ha	Production (000 MT)	Productivity (MT/ha)
Uttar Pradesh	603.76	14430.28	23.9
West Bengal	386.61	11591.30	30.0
Bihar	322.46	6640.55	20.6
Gujarat	81.27	2499.73	30.8
Madhya Pradesh	108.87	2299.00	21.1
Punjab	85.25	2132.31	25.0
Assam	99.77	975.27	9.8
Karnataka	44.40	698.30	15.7
Haryana	29.47	676.02	22.9
Jharkhand	47.21	659.61	14.0

Source: NHB, Database, 2013

poor productivity of 7.89 t/ha as compared to comparatively quite high productivity realized in the two neighboring states of UP (21.97 t/ha) and WB (24.7 t/ha). Similarly, productivity is very poor in Karnataka state as the climate is not very favorable for growing potato.

Potato can be grown on a wide range of soils, ranging from sandy loam to loam and best suited to acidic soils (Reddy & Shiva Prasad, 1999). It prefers friable, well aerated, fairly deep soils and well supplied with organic matter. Well-drained light soils are preferred for uniform tubers. The viability of commercial potato production is influenced by spatial and temporal variability in soils, agro climate, and the availability of water resources. Soil site characteristics and agro-climatic conditions greatly influence the choice of variety, land management practices and the economics of production. The inter and intra regional variations in productivity within the country are attributed to the variations in bio-physical factors *vis-a-vis* specific soil-climatic requirements of the crop. However, some researchers reported that the low use of fertilizers and severely imbalanced use of N, P and K fertilizers are some of the reasons responsible for low production of potato in many parts of the country (Bansal & Trehan, 2011). This study concentrates mainly on the land evaluation for growing potato crop in varied climatic conditions prevailing in India and simulation of likely impact because of climate change.

BACKGOUND

Indian agriculture has made tremendous progress in ensuring food security to its vast population with food grain production touching an on all-time record level of 263+ Mt in 2013-14 and estimated requirement in 2030 and 2050 is 345 and 494 Mt, respectively (Rattan, 2014). The country faces a daunting task of meeting future food demands and providing nutrition security to 17.5% of the global population and providing feed and fodder to 11% of the world's livestock population on 2.3% of the land and only 4% of the fresh water resources. The per capita arable land shall shrink from 0.34 ha in 1950-51 to 0.08 ha in 2025. Since, 1970, the net cultivated area has remained around 142 Mha and highly productive agricultural land has been lost due to urbanizaation, industrialization and other developmental activi-

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ties which implies that out of total 120.8 Mha of degraded land, more marginal and degraded lands are being progressively brought under cultivation. Natural resources viz. soil, water and biodiversity have been over exploited and have been consequentially degraded due to loss of organic matter, depletion of nutrients, over exploitation of ground water and depletion of carrying capacity of pastures, grazing land etc. posing severe health hazards which need immediate attention.

LAND EVALUATION AND SOIL-SITE REQUIREMENT FOR POTATO PRODUCTION

The natural resources (soil, climatic features and water) profoundly influence the cropping patterns and control crop productivity in specified region. It is well known that the adaptability of crops in one or the other area is the interaction between edaphic properties and existing climatic features. It is also well known that each plant species requires specific soil-site conditions for its optimum growth. Although, the State -Agricultural Universities and Research Institutes have generated voluminous data for crop production through experimentation, it has not been correlated adequately to work out soil-site suitability models for optimizing agricultural land use in the country (Naidu et al., 2009).

Of late, the importance of land evaluation for better land use options has been receiving greater importance. An efficient land use maintains agricultural sustainability. Land evaluation has been defined by FAO (1976) as "the process of assessment of land performance when used for specified purpose. It involves the execution and interpretation of surveys and the studies on landforms, soils, vegetation, climate and other related aspects of land for a comparison between the promising land use and/or specific land use". Soil - site suitability studies provide information on the choice of crops to be grown on best suited soil unit for maximizing crop production per unit of land, labour and inputs. The land suitability for defined use and the impact of the use on environment is determined by land conditions and land qualities (Table 3). The sustainable land use depends on soil resilience. It is a balance between soil restorative and soil degradation processes. Ecologically every factor of environment exerts directly or indirectly a specific effect on growth and development of the plant. The factors such as, the water, temperature, sunlight, soil aeration and availability of plant nutrients directly control the crop growth. However, it

Table 3. Important land qualities and related soil characteristics

Land quality	Land/Soil characteristics
Temperature and light energy for plant growth	Temperature (Max. and Min.), Sunshine hours and day length
Moisture availability in crop growing season	Rainfall, relative humidity frost. Potential evapotranspiration Soil depth and texture and length of growing period
Root development and anchorage	Soil depth, texture in root zone, structure and hard pans
Oxygen availability to roots	Drainage, depth of ground water table, frequency and period of flooding, moisture retention capacity of soils
Nutrient availability in root zone	Organic matter, CEC, base saturation, NPK status and pH
Sensitivity to Soil toxicity	pH, salinity, sodicity, $CaC0_3$, Al and heavy metals
Workability and management	Slope, surface stoniness/rockiness, moisture retention

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varies from habitat to habitat and determines the suitability of a plant to any particular environment. For planning and effective utilization of soil resources, the information relating to the soil-site characteristics for cultivation of crops is necessary.

Each plant species requires specific soil-site conditions for its optimum growth. For rationalizing land use, the soil-site suitability for different crops needs to be determined. The suitability models provide guidelines to decide the policy of growing most suitable crops, depending on the suitability/capability of each soil unit.

The adaptability of crops in the area is the interaction between existing edaphic conditions and fitness of the cultivar under these conditions. Plant growth requires a reasonable range of moisture and nutrient supply linked to rooting depth, photosynthesis and in turn the biomass production. Each crop has specific growth requirements. Some of the crop requirements are not always directly measurable in the field. They are to be derived from other associated observations. Many workers attempted (Sehgal et al., 1989; Sys et al., 1991; Davidson, 1992) to identify and specify the suitability criteria for different annual crops through land evaluation approach using multivariate regression models with the help of soil parameters and yield data.

The term Land Evaluation was first used in 1950 at the Amsterdam Congress of the International Society of Soil Science, where Visser (1950) presented a paper entitled, 'The trend of the development of land evaluation in the future'. Stewart (1968) then defined land evaluation as assessment of suitability of land for use in agriculture, forestry, engineering, hydrology, recreation, etc. According to Van Wambeke and Rossiter (1987) land evaluation is the ranking of the soil unit on the basis of its capabilities (under given management levels and socio-economic conditions) to provide optimum returns per unit area besides conserving the natural resources for future use. In other words, it is the process of estimating the potential of land for alternative kinds of use. The basic feature of it is the comparison of the requirements of a crop with the resources offered by the land (Dent & Young, 1981). The land evaluation thus is the assessment of land performance for a specific purpose. It involves the interpretation of basic data on the climate and the characteristics of land under the existing land use (Sehgal, 1991). The principal objective of land evaluation is to select the optimum land use for each defined land unit taking into account both physical and socio-economic considerations and the conservation of environmental resources for sustainable use (FAO, 1983).

The generally used methods for land evaluation are Storie index rating (Storie, 1933). Land and soil irrigability classification (USBR, 1953), USDA land capability classification (Klingebiel & Montgomery, 1961), Productivity Index (Requier et al. 1970) and land suitability classification (FAO, 1976; Sys 1985, 1993). These methods differ from each other in the original purpose for which they were proposed, in terms of terminology, in the number and kind of soil properties taken into account, and in the logic of the procedures followed to arrive at a suitability rating (Van Diepen et al. 1991). The Land Evaluation proposed by FAO (1976) defines the basic concepts and principles followed universally. The basic concepts include the land and its major use, utilization type, characteristics, qualities and diagnostic criteria. Land includes soil, vegetation, hydrology, landform and climate. The framework suggested the classification of land in to different categories viz., Orders, Classes, Subclasses and Units. There are two orders namely, 'S' for suitable lands, and 'N' for non- suitable lands; further, three classes (SI, S2, S3) within the order 'S' and two classes (N1, N2) under the order 'N' depending upon the degree of limitations with respect to specific land use. The appraisal of the classes, within the order is done according to the land limitations. The Subclasses reflect the kinds of limitations or major kinds of improvement

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measures required within these classes. They are indicated by the symbols using lower case letter following the Arabic numeral.

In the land evaluation, there are four steps namely:

1. Characterization of existing soil, climatic and land use conditions
2. Development of soil-site criteria or crop requirements
3. Matching of the crop requirements with the existing soil and climatic conditions and
4. Choosing of the best fit among the crops and selecting the same as alternative crop strategy.

Development of the Soil-Site Criteria

Among the above four steps given above the formulation of the soil-site criteria to meet the crop requirements forms a vital and important step. The land and soil-site characteristics considered in land evaluation are climate, topography and landscape, wetness conditions, physical and chemical soil conditions (texture, depth, CaC03, etc.) and soil fertility characteristics (CEC, BS, pH, EC and ESP). The soil-site characterization are expressed in terms of degree of limitations (0, I, 2, 3, or 4) as per their optimality with respect to specific land use (Table 4). Limitation '3' is considered critical at which the expected yields decline significantly (upto 50 per cent) and the cultivation is considered marginally economical. The degree of limitations as proposed by Sys (1985), ranging from 0 to 4 suggesting no limitation to severe limitation level was used for determining the criteria of the suitability classes. These soil-site criteria are to be matched with the land qualities of each mapping unit of a study area to arrive at land suitability class.

Matching Crop Growth Requirements With Environmental Data

It is an exercise of comparing existing climatic, soil and physiographic conditions with the soil-site criteria with respect to individual crop. The matching of land qualities with crop requirements exercise includes two steps viz. climatic and a soil-physiographic evaluation. Initially, the climate of the soil unit is compared with that of the crop requirements. For this the specific soil and crop-linked growing season is calculated, using rainfall data, in particular, consumptive use of water of the plant as obtained from the calculated potential evapotranspiration (PET), the crop factor and the soil moisture storage capacity.

Table 4. Climatic and soil-site limitations

Limitations	Symbol	Limitations	Symbol
Climatic hazard	c	Erosion hazard	e
Flood hazard	f	Gravelliness	g
Workability	k	Topography	t
Moisture availability	m	Nutrient availability	l
Crusting	p	Rooting condition	r
Texture	s	Drainage	w
Excess of salt / calcareousness	m		

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The second step refers to the comparison of the individual soil and physiographic properties with the crop requirements in terms of nutrient supply, rooting depth, susceptibility to toxic elements and workability. On the basis of the degree and number of limitations identified the suitability class is established, viz. highly suitable (SI), moderately suitable (S2), marginally suitable (S3) and unsuitable lands (N 1 and N2) for specific kind of land use. S 1 classes correspond to areas which have a yield potential above 80% of the maximal attainable harvest within the climatic area. This figure drops to 60% and 40% for classes S2, and S3 respectively. The soil-site requirement for optimum potato production under Indian conditions worked out by Reddy and Shiva Prasad (1999) is given in Table 5.

CLIMATE CHANGE AND ITS IMPACT ON LAND SUITABILITY AND POTATO CULTIVATION IN INDIA

Climate change is the largest threat ever faced by the world as it affects the earth's natural resources widely from tropical to arctic and from sea to land and atmosphere (Pant, 2009). According to IPCC (2007) reports, warming of the climate system is unequivocal and scientists are more than 90% certain that it is primarily caused by increasing concentrations of greenhouse gases (CO_2, CH_4, O_3, CFCs and N_2O) produced by human activities such as the burning of fossil fuels and deforestation.

Table 5. Soil-site suitability criteria (crop requirements) for potato

Soil-site characteristics			**Rating**			
		Unit	Highly suitable S1	Moderately suitable S2	Marginally suitable S3	Not suitable N
Climatic regime	Mean temperature in growing season	°C	16-25	26-30 13-15	31-32 10-12	>32 <10
Land quality	**Land characteristics**					
Oxygen availability to roots	Soil drainage	class	Well drained	Moderately /imperfectly drained	Poorly drained	Very poorly drained
Nutrient availability	Texture- surface	Class	sl, I, ls	s, scl	sil, cl	Heavy c
	Sub-surface texture	class	scl, sil	s, sil	s	Heavy c
	pH	1:2.5	5.5-6.5	6.6-8.2 5.0-5.4	>8 <5	
	CEC	C mol (p+)/kg	>16	<16	<5	
	OC	%	High	Medium	Low	
Rooting conditions	Effective soil depth	cm	75-100	50-75	25-50	<25
	Stoniness	%	0-10	10-15	15-35	>35
Soil toxicity	Salinity (Ece)	dSm^{-1}	>16	<16		
	Sodicity (ESP)	%	Non sodic	10-15	>15	
Erosion hazard	Slope	Hills %	<5	5-10	10-15	>15
		Plains %	<3	3-5	5-8	>8

Source: Reddy and Shiva Prasad, 1999

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The effects of climate change on crop production can be complex. Depending on the temperature regime and the crop, high temperatures can lead to low yields due to increased development rates and higher respiration. However, a short growth cycle can also be beneficial, e.g., to escape drought or frost, and the use of late-maturing cultivars could offset the effect of high development rates. In environments where low temperatures now limit production, global warming could lead to a beneficial lengthening of the growing season and temperatures close to optimal for assimilation. Moreover, global warming is related to the increase of atmospheric CO_2, con- centration, which is likely to increase crop yields, particularly when water limits crop production (Nonhebel, 1993). Increase in atmospheric CO_2 has a fertilization effect on crops with C_3 photosynthetic pathway as Rubisco, the primary enzyme in leaf photosynthesis of C_3 plants, competes better with dissolved O_2 for binding sites on the Rubisco protein when CO_2 concentration is higher and leads to increased photosynthesis and promotes growth and productivity (Allen & Prasad, 2004). However, on the other hand, it can reduce crop duration.

Potato is grown in many different environments, but it is best adapted to temperate climates. Increase in temperature above optimal is reported to decrease in crop yields, particularly due to increased respiration rate (Takashi et al., 2007). At high temperatures (above 17^0C; Stol et al. 1991) tuberization diminishes (Reynolds and Ewing, 1989a). Potato is also frost sensitive and severe damage may occur when temperature drops below 0^0C (Hijmmans et al. 2003). In this regard various reports on climate change have given their views on rise in temperature in the coming years. It is likely that the currently observed trend of global warming, which has been 0.6 °C $\pm$ 0.2 since 1900, will continue and that the average global temperature will increase by between 1.4 and 5.8 °C over the period 1990 to 2100 (Houghton et al. 2001). For the Indian region (south Asia), the IPCC, (2007) has projected 0.5-1.2°C rise in temperature by 2020, 0.88-3.16 °C by 2050 and 1.56-5.44 °C by 2080. Report of Working Group II of IPCC and a few other global studies (Aggarwal, 2008) indicate a probability of 10–40% loss in crop production in India with increase in temperature by 2080–2100. This would lead to more frequent heat extremes, floods, droughts, cyclones and gradual recession of glaciers, which in turn would result greater instability in food production (Aggarwal, 2008). Having look on these data on changes in temperature over the years, it seems that the classes of land suitability in respect of climatic region with special reference to mean temperature during growing season will go on changing and the lands categorized as highly suitable S1 class may become moderately suitable (S2), while moderately suitable S2 will become marginally suitable (S3) class and marginally suitable S3 class will change to unsuitable class up to 2080. As far as the rise in temperature during growing season is concerned in the coming years there will be great loss in potato production in the arid and semi arid regions of India compared to northern India. Increase in temperature and atmospheric CO_2, both are interlinked and occur simultaneously and the CO_2 enrichment does not appear to compensate for the detrimental effects of higher temperature on tuber yield (Singh *et al.*, 2010).

The climate model projections for the Fifth Assessment Report of the IPCC made using the newly developed representative concentration pathways (RCPs) under the Coupled Model Inter-comparison Project 5 (CMIP5) (Chaturvedi et al. 2012) reveals that surface air temperature including night time temperatures are expected to increase further. The all India rainfall and extreme rainfall events are also expected to increase in future. Under the business-as-usual scenario, mean warming over India is likely to be in the range of 1.7-2.0 °C by 2030s and 3.3-4.8 °C by 2080s relative to pre-industrial time. Likewise, all India precipitation is projected to increase by 4-5% by 2030s and by 6-14% by 2080s compared to the 1961-1990 baselines. There is consistent positive trend in frequency of extreme precipitation days (e.g. > 40 mm/day) for decades 2060s and beyond.

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Climate change impacts are variable in different parts of the country. Western Rajasthan, southern Gujarat, Madhya Pradesh, Maharashtra, northern Karnataka, northern Andhra Pradesh, and southern Bihar are likely to be more vulnerable in terms of extreme events (Mall et al. 2006). For every 1°C rise in temperature, yield of wheat, soybean, mustard, groundnut and potato are expected to decline by 3-7 percent (Agrawal, 2009).

Potato can be grown on a wide range of soils, ranging from sandy loam, silt loam, loam and clay soils. It prefers friable, well aerated, fairly deep soils well supplied with organic matter. Well-drained sandy loam and medium loam soils, rich in organic carbon are most suitable for potato. Light soils are preferred because they tend to promote more uniform tubers and make harvesting of the crop easier. Studies on climate change impact on soils of the US Great Plains (Follet et al. 2012) shows that soil carbon and nitrogen stocks are strongly negatively related mean annual temperature and positively related to the ratio of mean annual precipitation to potential evapo-transpiration, suggesting that they are equally vulnerable to increased temperature and decreasing water availability. Crop is well suited to acidic soils (pH 5.0-6.5).

Rising temperature and decease in precipitation would also lead to deterioration of water quality. In north east India under the business-as-usual scenario, soil acidification may further intensify under the influence of rising atmospheric CO_2 concentration. This possibility stems from a frequent experimental observation of increased CO_2 production in soil due to increased root and soil microbial respiration under elevated CO_2 atmosphere. As the CO_2 produced this way forms carbonic acid (H_2CO_3) in soil waters, which removes base cations from the soil systems after leaching and produce soil acidity, enhanced CO_2 production in soil under elevated CO_2 can increase carbonic acid leaching and therefore intensify the already existing acute problem of soil acidity in north east India (Kumar, 2011).

Majority of the Indian soils are unhealthy in terms of very low in organic matter content, nutrient status and degradation. About 120.8 Mha constituting 36.5% of total geographical area of the country are degraded due to soil erosion, salinity/alkalinity, soil acidity, waterlogging and other problems (NBSS & LUP, 2008). There is no doubt about climate change as it is happening very rapidly resulting in drastic effects on the environment, particularly on soil system. Soils are the outcome of different soil forming factors and processes which are directly linked to the atmospheric-climate system through exchange of various gases, solar radiation, temperature, hydrologic cycles (Brevik, 2012). Soil erosion rates, driven by the climatic variables like precipitation and number of rainy days and raining intensity, are sensitive to global climate changes. Soil erosion, major factor causing a decline in agricultural productivity and impairing environmental quality, reduces soil fertility and water availability. Direct impacts on soil erosion include changes in the erosive power of rainfall due to changes in rainfall amounts and intensities (Nearing, 2001); Indirect impacts suggest changes in soil erodibility and soil surface covers.

Increased precipitation will increase the surface runoff in hilly lands; increase infiltration and water storage within the soil in the flat lands; enhance ground water recharge in the highly permeable and well drained soils; and increase the evaporation on soils having low infiltration and transpiration in the case of well-developed canopies (Varallyay, 2007). Soil erosion due to water is the major cause of soil degradation (82.6 Mha) followed by chemical degradation (24.7 Mha). About 5.34 billion tonnes (Gt) of soil is eroded in India at an average rate of 16.3 t ha^{-1} yr^{-1} (Dhruvanarayana & Ram Babu, 1983). While 61% of eroded sediments get redistributed on land, nearly 29% are lost permanently to the sea. The remaining 10% are deposited in reservoirs reducing their holding capacity by 1 to 20% annually (Sharma & Singh, 2012).

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Rise in temperature will increase the potential evapo-transpiration and decrease the surface runoff, infiltration, water-storage and ground water recharge, especially if accompanied by low precipitation. The influence of global warming on soil processes is more complex and needs elaborate discussion.

FUTURE RESEARCH DIRECTIONS

There is uncertainty about the future climate on different parts of the globe which may have positive and negative impact on the agricultural production and food security. The crops like potato which are more sensitive to soil and climatic conditions may affect badly due to climate change. Better understanding of past, recent and possible future changes in the climate is an important element for developing suitable soil climatic criteria based suitability of cultivation. Further research is needed ideally be targeted at locally relevant climate impacts and risks. The information provided in the chapter is of value to a wide range of different stakeholders in potato production system eager to learn more about future weather and climate of the Earth and its consequences on potato cultivation. Nevertheless, there is broad agreement that the climate is set to shift significantly, and that new cultivation techniques are needed in order to meet the growing demand of potato. Further, research is needed on the improved varieties of potatoes suitable for wide range of soil and climatic conditions.

CONCLUSION

The world's climate is changing, and the changes will have an enormous impact on the globe. There is threat that climate change will impact potato availability, access, and utilization due to change in the climatic parameters like temperature, precipitation, CO_2.etc. It is also expected to increase soil salinity in many part of the globe which may reduce the suitability of potato cultivation on such soils. In addition, the change in environmental parameters may change availability of water for cultivation of this important crop. However, the demand and changing food demand of growing population is crucial and will exaggerate the problem to greater extent. The impact of non-availability of favorable conditions for potato cultivation will lead to more poverty and degradation of land resources. Though the aggregate impact of climate change on future potato cultivation is not fully understood. The changing climate is playing central role in availability of sufficient supply of potato and individual climatic parameters and their interactions are equally important. There is an emerging consensus that systematic soil site analysis will help farmers in decision making on potato cultivation.

REFERENCES

Aggarwal, P. K. (2008). Climate change: implications for Indian agriculture. In S. S. Lal, P. M. Govindakrishnan, V. K. Dua, J. F. Singh, & K. Pandey (Eds.), *Impact Assessment of Climate Change for Research Priority Planning in Horticultural Crops* (pp. 1–10). Central Potato Research Institute, Shimla. Retrieved August 17, 2016, from http://krishikosh.egranth.ac.in/bitstream/1/2054278/1/CPRI034.pdf

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Aggarwal, P. K. (2009). Global climate change and Indian agriculture: Case studies from ICAR network project. Indian Council of Agricultural Research.

Allen, L. H., Jr., & Prasad, P. V. (2004). Crop responses to elevated carbon dioxide. Encyclopedia of Plant and Crop Sci., 346-348.

Brevik, E. C. (2012). Soil and Climate Change: Gas Fluxes and Soil Processes. *Soil Horizons, 53*. Retrieved August 04, 2016, from https://www.researchgate.net/publication/262260059_Soils_and_Climate_Change_Gas_Fluxes_and_Soil_Processes

Chaturvedi, R. K., Joshi, J., Jayaraman, M., Bala, G., & Ravindranath, N. H. (2012). Multi-model climate change projections for India under representative concentration pathways. *Current Science*, *103*, 791–802.

Dua, V. K., Singh, B. P., Govindakrishnan, P. M., Kumar, S., & Lal, S. S. (2013). Impact of climate change on potato productivity in Punjab – a simulation study. *Current Science*, *105*(6), 787–794.

Haverkort, A. J. (1990). Ecology of potato cropping systems in relation to latitude and altitude. *Agricultural Systems*, *32*(3), 251–272. doi:10.1016/0308-521X(90)90004-A

Houghton, J. T., Ding, J., Griggs, D. J., Noguer, M., van der Linden, P. J., Xiaosu, D., & ... (2001). *The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University.

IPCC. (2007). *The Physical Science Basis Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press.

Kumar, M. (2011). North East India: Soil and water management imperatives for food security in a changing climate? *Current Science*, *101*, 1119.

NBSS & LUP. (2008). *Harmonization of Degraded lands/Wasteland Dataset of India- GIS- based Approach*. Nagpur: NBSS&LUP.

Nearing, M. A. (2001). Potential changes in rainfall erosivity in the U.S. with climate change during the 21st century. *Journal of Soil and Water Conservation*, *56*, 229–232.

Nonhebel, S. (1993). *The importance of weather data in crop growth sim- ulation models and assessment of climatic change effects* (Ph.D. thesis). Wageningen Agricultural University, Wageningen, The Netherlands.

Pant, K. P. (2009). Effects of Agriculture on Climate Change: A Cross Country Study of Factors Affecting Carbon Emissions. *J. Agric. Envi.*, *10*, 72–88.

Rattan, R. K. (2014). Soil processes and climate change. *Journal of the Indian Society of Soil Science*, *62*(Supplement), s5–s24.

Reynolds, M. P., & Ewing, E. E. (1989a). Effects of High Air and Soil Temperature Stress on Growth and Tuberization in *Solanum tuberosum. Annals of Botany*, *64*(3), 241–247. Retrieved from http://aob.oxfordjournals.org/content/64/3/241.short

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Sharma, P. D., & Singh, M. V. (2012). State of health of Indian soils. In N. N. Goswami, B. Singh, D. K. Pal, R. K. Rattan, & D. L. N. Rao (Eds.), *Soil Science in the Service of Nation* (pp. 191–213). New Delhi: Indian Society of Soil Science.

Singh, J. P., Lal, S. S., Govindakrishnan, P. M., Dua, V. K., & Pandey, S. K. (2008). Impact of climate change on potato. In S. S. Lal, P. M. Govindakrishnan, V. K. Dua, J. F., Singh, & K. Pandey (Eds.), *Impact Assessment of Climate Change for Research Priority Planning in Horticultural Crops* (pp. 125–136). Central Potato Research Institute, Shimla. Retrieved August 17, 2016, from http://krishikosh.egranth.ac.in/bitstream/1/2054278/1/CPRI034.pdf

Stol, W, de Koning, G. H. J., Haverkort, A. J., Kooman, P.L., van Keulen, H. & Penning de Vries, F. W. T. (1991). *Agro-ecological characterization for potato production. A simulation study at the request of the International Potato Center (CIP), Lima, Peru*. CABO-DLO, Report 155.

Varallyay, G. (2007). Potential impacts of climate change on agro-ecosystems. *Review Agriculturae Conspectus Scientificus*, *72*, 1–8.

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Chapter 47
Strengthening Food Security With Sustainable Practices by Smallholder Farmers in Lesser Developed Economies

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ABSTRACT

Smallholder farming has played a key role in reducing world hunger and the focus now turns to consolidating these gains. What practices and policies will enable smallholders to sustain their livelihoods and strengthen food security? Following a brief discussion of agricultural models, and the global shift to sustainable development goals, this chapter examines practices of smallholder farmers in St. Kitts with examples from elsewhere. Assessing what has worked and what barriers continue to limit smallholder success, the chapter offers a list of adaptive strategies, policy recommendations, and areas for future research that can maximize smallholder farming impact on food security. Suggested priorities include: focusing research and policies on individual farm enterprises; moving toward an integrated farm model; adopting best practices in marketing, distribution, and accounting; improving government support; and adapting education programs to include modernized curricula, non-formal education, and the use of ICTs for training and extension at all levels.

INTRODUCTION

Improved agricultural productivity, especially by small and family farmers, leads to important gains in hunger and poverty reduction. (Food and Agriculture Organization, 2015)

Beginning in 1980s, lesser-developed countries (LDCs) witnessed a trend of declining production of agricultural food products, both crops and livestock, while at the same time more developed countries

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(MDCs) experienced increased production. As such, LDCs became more dependent on imported food from MDCs. Because of this, and despite their former status as agrarian societies, emerging economies have had to divert scarce economic resources away from other imports, investments, and foreign debt payments to pay for imported food. Even worse, when a dependency syndrome combines with government instability and social conflict, the result has often been hunger, malnutrition, and even famine in extreme cases.

With these dynamics in mind, governmental and non-governmental entities have worked to combat world hunger within a comprehensive United Nations framework known as Millennium Development Goals (MDG). In 2015, the UN Food and Agriculture Organization reported that 79 out of 129 countries had met the MDG benchmark of reducing hunger by one half. Worldwide, hunger has fallen by almost 20% in the past decade with most of those gains happening in the developing world mainly through the increased productivity of smallholder farms, operated mostly as family enterprises. In order to understand this success, and to envision ways of enhancing it to address the problems of the 796 million people who remain in hunger worldwide, this chapter approaches the topic of food security in emerging economies from several angles. After briefly touching on how MDCs have transformed their agricultural sector to become competitive in world food production, the chapter focuses primarily on the concerns of food production and distribution facing the Caribbean and other emerging economies with the input factors of cultural, socio-politico-economic, technological, and environmental conditions, including climate change. The chapter proposes how such economies may be transformed so that food security may be achieved. It presents examples of best practices and scenarios using a simple model of decision-making based on this range of factors.

In exploring food production and distribution in emerging economies, a central claim is that agricultural diversification is essential to achieve local food security and that diversification rests on four pillars: productivity, flexibility, competitiveness, and sustainability. Therefore, this chapter will examine concerns about food security from the perspectives of these four pillars. While some areas may realize high productivity, there is scarcity in other areas, which prompts a concern with food distribution networks in the context of trade and marketing.

All of the concerns can be addressed systematically by the application of a model of the farming system adopted from Waugh (2009). The unit of analysis is the individual enterprise or individual farmer level. The proposition is that if individual enterprises are successful, then national and regional agricultural economies will be successful. The model will address the prevailing conditions in terms of input factors and what decisions can be made in those respects. It also recommends the evaluation of profit and/or loss and a feedback mechanism to the decision-making process.

Main Characteristics of Agriculture in MDCs

Virtually every industrialized nation, for example, Australia, France, Japan, and the United States, has experienced an agricultural revolution (Nebel and Wright, 1996). The agricultural revolution in such countries had one thing in common, that is, significantly higher utilization of farm machinery not only for land preparation but also for planting, application of fertilizers and pesticides, and harvesting. They brought additional land into production, increased the use of chemical fertilizers and pesticides, increased use of irrigation, and substituted new varieties of crops or hybrids. According to Nebel and Wright (1996), all these developments carried an environmental cost, and expanding production by those methods has reached or exceeded sustainable limits. With competitiveness resulting from such significant inputs by

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MDCs, there has been a worldwide trend since the 1970s in which food production in MDCs has been rapidly increasing while there has been a rapid decrease in LDCs, resulting in greater export of food from MDCs and higher import of food by LDCs.

From findings based on an analysis of 15 select countries using 5 variables (GDP per capita; Percentage of population engaged in agriculture; Percentage of GDP derived from Agriculture; Amount (kg) of fertilizer used per hectare of agricultural land; and Number of tractors per 100 ha of land) Waugh (2009) postulates that:

- The less developed a country, the greater the percentage of its population involved in agriculture.
- The less developed a country, the greater the percentage of its GDP/GNP is made up from agriculture.
- The less developed a country, the less fertilizer it will use.
- The less developed a country, the less mechanized will be its farming.

The lesson here is that MDCs have transformed their agricultural sector with the incorporation of high capital input for the use of improved technology and by bringing larger expanses of land under cultivation, which is in stark contrast to the input made by LDCs. It also indicates that MDCs generally thrust forward with economic development as a priority over the environment, resulting in larger impact of climate change events and environmental degradation. Once the industry is developed, such countries then place increasing emphasis on environmental integrity.

It is not proposed here that LDCs require the same transformations that MDCs have gone through. Nonetheless, with changing conditions and under different circumstances, it is proposed that LDCs build adaptive capacities, while introducing locally innovative, sustainable, and appropriate technologies for mechanization, irrigation, plant science, and non-traditional growing systems to increase their food security as a high priority. Within this scenario, there are opportunities to satisfy local market demands while building niche markets that enable producers to enter the global market.

Main Characteristics of Agriculture in LDCs

Numerous scholars, economists, and leaders of LDCs have lamented the various ways in which the plantation system, imposed under colonialism, has hindered the development of local food production. As such, some main characteristics of agriculture in LDCs are as follows:

- Small-sized farms (less than 5 acres, with the majority being 2 acres or less).
- Parcels are fragmented.
- Land is marginal, on the periphery of former plantations.
- Population is mainly rural-based peasantry.
- Land tenure is such that the majority of farmers are “landless.”

While acknowledging the lasting impact of plantation systems, this section focuses less on that legacy and more on the current availability of land during the past four to five decades or so since many countries have become independent of colonial rule. In general, LDCs have not had transformations in their agricultural sector as did MDCs. This is perhaps in part due to the lack of comparative advantage, vis-à-vis

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their "later arrival on the scene" and having to compete with an already advanced agricultural economy in MDCs. Moreover, such transformation requires high capital input that is essentially scarce in LDCs.

With rising food prices and increasing impacts of climate change on food production, LDCs are increasingly challenged to maintain basic nutrition from food, alleviate poverty in rural communities, and reduce their relatively high food import bill. Food security has emerged in recent years as a high priority in LDCs and is often tied to building resilience to the effects of climate change. A hypothesis proposed is that the better the livelihoods of people in communities, the more resilient they would be to the vagaries of climate change and environmental degradation.

According to the CARIBSAVE Partnership, based on participation in CARIBSAVE National Consultation Workshops in Caribbean countries, LDCs' needs are ranked as follows, with food security as the highest priority (CARIBSAVE, 2011):

1. Food security (agriculture with improved methods; less dependent on weather – floods and drought, higher productivity on less land; more reliability of production, less impact on environment).
2. Water supply (rationing already exists in some places).
3. Medical supplies and facilities.
4. Education and awareness (at all levels).
5. Food storage (for extended periods of time).
6. Water harvesting and storage and replenishment of aquifers (cisterns, reforestation, conservation).
7. Shelters and Institutional support (some organizations, public services, and disaster management plans already in place).
8. Political will (not only from leaders but also from citizenry – building consensus - can draw political salience and influence public agenda).
9. Legislation enforcement (appears that legislation is already in place).
10. Reduce sedimentation by reforestation and by limiting construction sites near the sea.
11. Avoid building in high risk areas.
12. Fuel storage and alternative sources of energy (solar, wind, geothermal).
13. Fish sanctuaries and fish farms.

Small Island Developing States (SIDS) are perhaps the most vulnerable to the effects of climate change and sea-level rise, given that their populations are largely located on low-lying, coastal communities, and their relatively large percentage of rural populations are living in poverty and engaged in subsistence agriculture. The observations and predictions are pointing to the Caribbean as an area among the most vulnerable to the effects of climate change. Other SIDS in the South Pacific and Indian Ocean are equally vulnerable with respect to geographical characteristics. Food security goals are seriously at risk!

The climate in SIDS and LDCs is mainly tropical, with some variations from equatorial to tropical maritime, and sometimes with a Mediterranean-type effect. More importantly, it is characterized by high rainfall and hot conditions. Heavy rainfall often results in flooding, but also renders our soils vulnerable to leaching and erosion. Higher rainfall and higher temperatures result in higher rates of bio-decay. It is a misconception to think that tropical soils are the richest; this is perhaps due to the year-round and lush vegetation, and also to its history of agriculture as the main source of GDP. Compared to chernozem and peat soils in temperate regions, tropical soils are relatively impoverished. While there are greater opportunities for reforestation in temperate regions, a critical need exists for soil conservation or soil production, for example, by composting or integrated crop-livestock farming, in the tropics in order to

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maintain optimum nutrients in soils for cultivation. Volcanic ash contributes to high soil fertility, but this component also makes these soils easily drained and thus prone to excessive drying in drought conditions.

In light of these characteristics, many of which the Caribbean shares with other developing societies, we can also outline a set of specific vulnerabilities and opportunities for enhancing food production and food security in emerging economies. These areas are examined in more detail in the next section in the context of translating them into "Areas for Strategic Improvement". Additionally, concrete recommendations are given for smallholder farming. Two mini-case studies that highlight what may be termed a dialectic of vulnerability and opportunity are presented. As these two examples make clear, vulnerabilities often create related opportunities that stakeholders of many interests must strive to understand and are challenged to use for individual and collective advantage.

Example

Nigeria: Government Regulation as Barrier and Incentive

In Nigeria between 1970 and 1985, the government implemented a system of complex bureaucratic requirements that made it difficult for businesses to expand (Balogun, 2003). Furthermore, in the early 2000s, regional Nigerian governors established arbitrary areas where business activity was restricted (Ewah & Ekeng, 2009).

In spite of all the difficulties of business management in developing areas, these regions offer several opportunities and benefits to new firms, including undiscovered markets, government subsidies, a burgeoning middle class, and cheap production inputs (Ewah & Ekeng, 2009).

- Population growth. The size and growth of populations in developing countries presents a huge potential market for local businesses, and a ripe opportunity for marketing to help overcome the preference for foreign goods.
- Absence of competition. Due to their underdevelopment and large populations, developing countries have substantial undiscovered or partially served markets. Often these markets are so large that concerns about competition are nearly nonexistent because there is room for so many entrants.
- Government incentives. Developing countries often provide welcoming business environments through lenient tax codes and subsidies for local enterprise.
- Growing middle class. Incomes are rising in numerous developing countries, bringing with them increased consumption and marketing opportunities.
- Cheap production inputs. Labor and raw materials are usually cheaper in developing countries, making it easier to market and operate local businesses (Ewah and Ekeng, 2009).

Example

Latin America: Supermarkets as Threats to Smallholders and Catalysts for Increased Local Demand

The rise of Latin American supermarkets provides an example of the two-sided nature of marketing in developing countries. Grocery stores and markets emerged as dominant players in Latin America over just ten years, increasing from a population-weighted average of about 10 percent in 1990 to over 50 percent in 2000. This can be compared to the transformation in the U.S. that took over 50 years. Large

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scale supermarkets and manufacturers' entrance into agrifood markets excluded small Latin American farms because bulk purchase methods lowered the farmers' margins. As a result, only farms with sufficient production to reach substantial economies of scale remained profitable. However, the rise of supermarkets provided opportunities as well, in terms of increased local demand and changing consumer patterns (Reardon & Berdegué, 2002).

SUSTAINABLE FOOD PRODUCTION

Sustainability

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987)

This quote from the 1987 Bruntland Report, while greeted with controversy by some, is still the most popular general definition of sustainable development. How, though, does the key concept of *sustainability* apply more specifically to food security, smallholder farming, and adaptations in the Caribbean and other developing regions? In assessing the progress made toward meeting the Millennium Development Goals, the UN Food and Agriculture Organization noted several trends that affect developing societies broadly and the Caribbean specifically. For instance, much of the success in reducing world hunger during the MDG period (2000-2015) was attributed to gains in productivity among smaller farms similar to those that define Caribbean agriculture today. The FAO report also noted that growth in hunger eradication was steady but slower in the Caribbean region. This report correlates with the emphasis on smaller compared to large-scale farming that generates growth through a multiplier effect. The report notes as well, a lengthy transition process from former plantation economies to newer systems where stakeholders search for the right balance in allocating resources among local food production, tourism and other services.

As the millennium development goals are superceded by a new set of 17 interlocking benchmarks known as the Sustainable Development Goals (SDG), food security remains a top priority, with "zero hunger" listed as SDG2. The FAO calls for continued emphasis on smallholder and family farms, social protection for small-scale farming such as government purchase of food supplies, easier access to credit and land, and inclusive growth. Effectively meeting these goals depends on gathering more concrete information about what smallholders are actually doing, and identifying recent innovations that have been more (as well as less) successful. Information should also ascertain the next-step scenarios that seem promising based on a review of actually existing practices, and what policy decisions will best protect, support, and spur the sustainable growth of small-scale Caribbean farming.

The next section will highlight current practices with examples drawn mainly from the Eastern Caribbean. This is, followed by discussion of areas for strategic improvement that can immediately begin to enhance smallholder production. A series of policy recommendations and suggestions for future research needs is presented after the discussion.

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Smallholder Practices

According to the FAO, "the term 'smallholder' refers to their limited resource endowments relative to other farmers in the sector" (Dixon et al., 2004). Globally, there are about 2.5 billion people who rely on these farms for their livelihoods. Moreover, smallholders produce over 80 percent of the food in parts of the developing world, specifically Southern Asia and sub-Saharan Africa (IFAD, 2013).

New pathways to sustainable food production demand a holistic approach to understanding sustainability at the local and livelihood level. However, any appreciation of the importance of transforming current agricultural livelihoods into sustainable food production systems must include a deeper understanding and appreciation of the role of major assets in transforming the lives of farmers and their households. Financial capital, land, and knowledge of modern farming techniques are key variables and assets for successful application of small-scale back yard gardening. According to the FAO (A Tool for Gender-Sensitive Agriculture and Rural Development, 2013), inequalities in distribution is linked to women's underperformance in agriculture, but increased investment in smallholder farmers (women in particular) is a pathway out of poverty.

Home Food Production: St. Kitts-Nevis Case Study

A 2010 survey of former sugar workers in St. Kitts-Nevis (five years after sugarcane production ceased) revealed that the best route to alleviating poverty amongst the vulnerable grouping was to reconsider land distribution options and to promote backyard farming as a viable option for food security and livelihood resilience (Clarke, 2013; Naraine, 2005). Former sugarcane workers presented a unique opportunity for understanding how deeply engrained cultures of resource distribution can affect use of land and potential vulnerability.

The growing concerns for land are not only shared by those with livelihoods directly dependent on the asset, but also by the population at large. The former female sugarcane workers were also assigned to farms. The success of this program was short lived with many women distrusting the process of large scale group farming. It is clear that campaigns at the end of sugarcane production which sought to distribute land to every Kittitian did not do much to solve the problem of vulnerability amongst former workers. Larger plots of land distributed to women were burdensome and demanded help, money and access to social capital that was weak or non-existent in their households and extended community networks. Land as a route to diversification and resilience was therefore seen as a burden, not an asset. Increased access to land did not equate with a reduction in vulnerability or an increase in the sustainability profile of livelihoods or production systems, since land was not put to productive use. The lesson learnt was that land resources, a crucial asset in sustainable production and livelihoods, must be distributed according to capital access that makes for optimum use. Based on this, recommendations were made for backyard farming as a viable option.

A sustainable approach to backyard farming starts with a food security oriented approach to land distribution. The FAO (2013) outlined clearly that women face a range of constraints in their access to productive resources such as land, inputs, training and financial services. Giving them access will very well translate into lifting millions out of food insecurity! Land distribution policy must, therefore, include distribution of larger sized residential plots at reasonable rates to provide ample room for backyard gardening.

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Backyard gardening must be carefully and delicately guided through instruction in using small spaces for growing vegetables and other food crops. However, backyard gardening can harness all the techniques and skills of the local population without heavy reliance on external inputs. This may encourage more organic approaches to food crop management, as well as non-traditional agricultural systems (for example, hydroponics, organoponics, aquaponics, and hybridponics) which are adaptable to rural, sub-urban and even urban areas.

Protected Agriculture: Shadehouse Model

Protected agriculture has been reintroduced recently into the Caribbean region with the construction and commissioning of tropical shadehouses and greenhouses to increase year-round local production and in an effort to reduce imports.

At the Clarence Fitzroy Bryant College (CFBC) in St. Kitts, researchers, students, government agencies, NGOs, business and community-based stakeholders have partnered to develop a new Climate-Smart System that blends shadehouse protected agriculture with a combination of hydroponics, organoponics, and hybridponics growing systems. The term hybridponics was coined to describe a system in which a seedling is removed from a hydroponic system and transplanted in an organoponics system to complete the growth process. Proven benefits from the Climate-Smart System include the following: year round rather than seasonal production; no leaching of nutrients to the environment; no use of pesticides; no weeds; high nutritional values; maximum production in confined areas; efficient use of water; less labor intensive; can be used in any local location; sustainable; and promotes gender equity. Subsequent to developing a best-practices routine, and commercialization model for a 24' x 20' enclosure, the CFBC system was funded by the Organization of American States for implementation in Guyana, Haiti, Barbados, Trinidad and Nevis.

Pig Farming

Over the years Caribbean pig farmers (for example, Bounty Farms, Guyana; St. Catherine, Jamaica; Plum Tree Farms, St. Kitts) have witnessed a slow but needed transition from poorly kept operations in backyards where pigs were left outdoors in muddy pens to formal operations with enclosed housing complete with concrete floors (see Figures 1-3).

This transition has seen the improvement in techniques for waste management including, use of sewer systems, and heavy reliance on water pumped to the farm site for washing pens.

Local breeds of pigs have been known to mature with a high fat content. The introduction of Yorkshire White and the Duroc (and cross-breeding of the two for meat quality) has drastically increased stock and stock quality. Along with the improvement on stock is the improvement in the variety of pig rations to include starter and grower ration. These upgrades are supplemented with regular visits by Veterinarians to the farmers, especially for disease control, breeding and farrowing. Agricultural staff undergo continued training in disease monitoring and controls. These key inputs have been integral in the cycle of sustainable livestock production.

As these practices make evident, even accounting for the systemic challenges associated with emerging economies, important opportunities exist for smallholder farmers to position themselves more favorably,

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Figure 1. Outdoor pig pen

Figure 2. Sewage and drainage system

Figure 3. Old style of pig housing

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particularly with strategic assistance from government agencies. In this dynamic, based on sustainable agricultural practices, more consumers of food become producers, and food security is increasingly based on a "many-to-many relationship," with the many feeding the many.

AREAS FOR STRATEGIC IMPROVEMENT

Vulnerabilities and Opportunities for Food Security in Emerging Economies

Sound fundamental business practices are key to building successful agricultural operations. In preceding sections, this chapter explored sustainability, integration of different farm components, and efficiency as they relate to agricultural development. However, creating and managing profitable farms requires additional considerations outside the scope of these internal elements. Here, the conversation turns to the role of basic economic and financial concerns, with an emphasis on marketing and distribution.

Before delving into areas for strategic improvement of smallholder business practices, it is important to better understand the context of operating in a developing economy. Developing economies exhibit three principal characteristics: low incomes, high variance in consumer preferences and infrastructure quality, and relatively cheap labor costs, leading to substitution of labor for capital (Dawar & Chattopadhyay, 2002). Managing a farm in these countries raises unique challenges that revolve around the local social, political, economic, and cultural factors. Specifically, these operational obstacles include low business education, preferences for imported goods, deficient infrastructure, strict government regulations and interference, political instability, and social conflict (Ewah & Ekeng, 2009).

Although there are inevitably several challenges to doing business in developing areas, these regions also offer several opportunities and benefits to small farmers. Consider, for example, that 70 percent of the global poor live in rural areas and rely on agriculture for income and employment (World Bank, 2015). In spite of this gloomy statistic, local farmers are in a unique position to be successful due to their self-employment (free labor), agricultural expertise, and familiarity with the local environment (FAO, Trends and Impacts, 2012). Several of these vulnerabilities and opportunities are now discussed with a focus on identifying concrete recommendations for strengthening food security in emerging economies.

Marketing and Distribution

The act of marketing a good or service is prevalent in nearly all aspects of life. The American Marketing Association (2005) defines marketing as "the activity, set of institutions, and processes for creating, communicating, delivering, and exchanging offerings that have value for customers, clients, partners, and society at large." Marketing helps farmers to find the customers who need their product most (efficient resource allocation), and enables two-way signaling between farmers and customers so that both sides can communicate needs and offerings (Timmer et al. 1983).

Although marketing is a crucial step in the communication between potential producers and consumers, sales cannot occur without the physical distribution of produce. To understand how agricultural firms transport their goods from the farm to shelves or tables, it is important to appreciate the role of distribution in the larger context of food security.

Food security literature focuses on resource access, distribution, and closer connections between producers and consumers as principal issues of concern (Vervisch et al. 2013; Murphy, 2001; Edelman,

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2014; Kelly & Schulschenk, 2011; McKenzie & Woodruff, 2015). Several factors help determine the efficacy of distribution, including markets, transportation infrastructure, patterns in consumer demand, and the characteristics of supply. Governments in developing countries have traditionally intervened in food distribution networks by purchasing produce from growers and selling it to consumers nationwide, often at subsidized prices.

Government involvement in production and distribution had both positive and negative effects on farmers. For instance, African governments had interfered with farmers for years by purchasing agricultural produce at less than the cost of production in order to provide cheap food to nearby urban centers. When reforms disbanded this handout program, farmers were initially grateful. However, growers soon realized the restructuring of government activity left them in a void with no alternative to the state-run marketing and distribution arrangement. As a result, farmers either were unable to take their products to market or were forced to rely on private companies to fulfill all the functions previously managed by the government (Murphy, 2001).

Example: The Internet

The Internet not only simplifies distribution for both producers and consumers, but also other market stakeholders including food processors, restaurants, and retailers. Online connectivity helps the entire agribusiness market chain to stay abreast of price changes and production estimates. Furthermore, the Internet facilitates cooperation among farmers, helping them to protect their interests even when separated geographically. As a result, developing countries have seen the emergence of farmer-collaboratives that depend on web marketing to connect directly with consumers (Murphy 2001).

Farmers in South Africa's Stellenbosch region used virtual networks and communication to develop a stronger local food structure by helping local farmers produce more of what was actually needed, and closing the gap between consumers and producers. Moreover, food networks that operate at a community level, including community supported agriculture initiatives (CSAs), farmers' markets, consumer cooperatives, and local distribution centers, can shorten the value chain and help farmers retain more of the retail price (Kelly & Schulschenk, 2011).

Local communities are more receptive to direct marketing, but many poor consumers are not aware of the nutritional content of their food and produce. They also lack knowledge on how to prepare and incorporate new ingredients into meals. Thus, education is an important part of marketing in developing countries. Offering classes on cooking with healthy ingredients, providing free samples, and suggesting convenient recipe ideas are creative ways to persuade local customers to incorporate less familiar fruits and vegetables as ingredients in their diets (Hu et al. 2013).

Smallholder distributors might also consider the existing social network as a favorable marketing prospect. These avenues allow farmers to interact with larger groups and build a sense of pride around locally grown food. For example, small farmers working to attract potential clients can use community centered events as great venues to showcase their produce in educational and interactive ways. Farmers' markets also provide excellent social opportunities for farmers to engage customers and discuss their products, growing methods, and food preparation ideas (Hu et al. 2013).

On a smaller-scale, farmers can take advantage of the fact that community leaders and older citizens are often influential voices for younger generations. Utilizing these groups as marketing allies, lends credibility to the case for healthy eating. Furthermore, these members are in a unique position to model healthy lifestyles for younger generations that would otherwise be unresponsive to these lifestyles. Build-

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ing support among younger generations adds a new level of consumers that will continue to purchase goods into the future. Moreover, they broaden the word-of-mouth marketing team and help to access a new segment of local consumers (Hu et al. 2013).

Convenient distribution plays a significant role in augmenting innovative marketing efforts. Anticipation for products builds in direct correlation with a farmer's ability to demonstrate affordable pricing, appropriate location, and high frequency. In their surveys of poor areas, Hu et al. (2013) found many participants to be interested in a wide variety of mobile distribution mechanisms, for example, food carts, farm stands. Local customers also identified consistency, price-competitiveness, and frequent advertisements as contributing to their reasons for patronizing particular sellers. According to buyers, there was a huge benefit to knowing in advance what produce would be offered by which farmers (Hu et al. 2013).

Case studies focusing on horticultural marketing abound, and readers interested in the more detailed analysis based on a range of cases can access the references cited in this chapter. For summary purposes, several common threads unify the discussion about marketing for small farmers:

1. Perform basic market research and incorporate the results into decisions made about production and distribution. Dixie (2005) and Mafaru et al. (2007) both offered extensive commentaries on how farmers and farmer co-operatives in Bangladesh, India, Mozambique, South Africa, Tanzania, Yemen, and elsewhere effectively analyzed market conditions across a range of products and scales.
2. Cooperate in order to pool resources and experience, achieve economies of scale, ensure smooth supply, and increase market negotiating strength. Efforts of women farmers and craft workers in Bangladesh are detailed by Dixie (2005).
3. Innovation and forward thinking. Mafaru et al. (2007) provided details on the ability of Tanzanian farmers to effectively control and optimize sales of tomatoes and other crops to local and regional hotels. This was achieved by assigning leadership roles and building an organizational structure. A case study from Uganda provides a discussion of effective tribal leadership resulting in improved onion production in Yemen (Alimuga et al. 2007; Dixie 2005).
4. Cut out middlemen and engage in direct sales whenever possible. Dixie (2005), in his discussion of onion farming in Yemen, provided an insightful discussion of how to increase and benefit from direct sales.

Agro-Processing

After all costs have been paid for land preparation, irrigation, planting, maintenance, and harvesting, and such like, an enterprise is expected to achieve profits from the sale of produce. Post-harvest loss continues to pose high risk to farmers when produce is not sold due to lower market demand. One way to reduce post-harvest loss is by processing of produce, while adding value to the items. It appears that locally packaged produce are not competitive and the perception of farmers or entrepreneurs is that they have to lower their prices to compete with imported packaged foods. However, indications by agro-processors in some Caribbean island nations are that there is a demand for locally packaged foods with growing preference by tourists and local residents alike. Moreover, they are likely to be more "fresh" than the imported packaged foods which have generally longer shelf-life and higher quantities of preservatives.

Furthermore, when foods that can otherwise be produced locally are imported, the local economy loses out on the multiplier effect of farming activities. Therefore, it is prudent to build an economy around the primary sector, with import substitutes where possible, while reducing dependency on imported foods.

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Although many emerging economies have had their primary products as raw materials for trade, agro-processing adds value to primary products either for local consumption or for exporting.

Food processing is an extension of the postmodern agricultural industry that involves different sectors such as; research and development, equipment investment, production and marketing management. The processing industry needs to integrate different technologies and production equipment to make mass production possible. Data from the Agro-processing Unit, St. Kitts, show that juices and snacks have a high market demand. The juice revenue ratio is 37.2%, while that of snack foods is 29.2%. The St. Kitts and Nevis food service sector country report of 2006 stated that snack food is the third largest imported food in terms of volume and juices are the fifth (the sequence is; meat, seafood, snack food, processed fruits and vegetables, and juices). Based on this information, there is an opportunity to create economies of scale in juices and snacks in St. Kitts and Nevis.

The St. Kitts-Nevis experience in agro-processing, with infrastructural and technical support from the Republic of China (Taiwan), has been growing steadily over the past few years and still has significant room to grow the meet local demand. There is potential to grow multiple times even with local demand.

ADDITIONAL CHALLENGES AND ADAPTIVE STRATEGIES: TOWARDS A MODEL FOR SUCCESSFUL SMALLHOLDER FARMING

In a 2005 study in the Caribbean small island nation of St. Kitts-Nevis it was found that the characteristics of farmers are representative of SIDS (Naraine, 2005). These findings are detailed below under three general headings: A model for smallholder farming that is 1) diversified and scalable; 2) operational adaptations; and 3) educational and organizational adaptations. Each individual finding will be followed by an adaptive strategy or strategies taken from case study findings of best practices.

Diversified and Scalable

Finding: *Of all commercial farmers, 60% operate on a part-time or seasonal basis.*
Finding: *Farming households are generally larger (about 65% between 3-5 persons) as compared to the national average of 3 per household.*
Finding: *About 60% of farmers operate individually, not as part of a company.*

The first data point indicates that a majority of farmers are not fully-involved in farming and therefore are not likely to depend on farming alone as a source of income. Related to that finding, 30% of all farmers have other occupations. Instead, there is a growing trend in "backyard" and urban gardening on a small scale requiring less time for operation. Production can be in containers where land is not available. It will also maximize productivity with minimal time and with optimum soil nutrients, moisture, and solar radiation (lighting and heat intensity) in the containers. Such a growing system is referred to as organoponics (Naraine, 2005). It can further save time through less weeding and tillage and can adapt to varying weather conditions. It can also expand to varying scales with some not requiring shade, or shade can be introduced by trees. Organoponics can progress to full time farming with the greater attributes and benefits than on a small scale, such as the opportunity to diversify crop types. As it increases in scale, the advantage will grow exponentially, as in the case study of ALT enterprise in St. Kitts, an integrated system with livestock to produce manure and recycling of nutrients among crops and livestock. Scaling

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up still higher towards commercial and more diversified cropping, a mix of farming types and systems can be introduced, for example, hydroponics, hybridponics, open-air organoponics, and low tillage and point tillage. This facilitates increased sustainability, flexibility, efficiency, productivity and risk reduction. Sustainability and flexibility are key features of adaptation to effects of climate change. A more diversified system is also suitable for natural-biological pest control mechanisms by promoting a farm ecosystem with natural predator-prey relationships and symbiotic feeding relationships. It also promotes the recycling/reusing of water for various farming activities. Moreover, the housing for livestock can be utilized for water harvesting. Many organic materials, whether from crops or livestock, can be composted or processed into ground cover to enhance soil water retention capacity. Compost has the unique ability to improve the chemical (nutritional), physical (structural) and biological characteristics of the soil or growing media which is beneficial to plant growth.

With higher productivity and less labor input required in non-traditional agricultural system, this will enable the formation of true family farms with small households. Higher productivity can also attract other household labor or business partners for shared benefits. The data shows a 60% preference for individual enterprise, which may in fact be due to inadequate training in business techniques. Notwithstanding this, the ALT enterprise in St. Kitts teams up with young entrepreneurs, for example, Standard Hydro, to introduce a hydroponics facility as an addition to its already integrated farming concept. Existing employees partner with others in the various activities or aspects of the total enterprise. In such a partnership, all parties benefit from training in business techniques, including marketing and entrepreneurship.

The Diversity of Jobs and the Multiplier Effect

Finding: *Among the almost 150 farms surveyed, only about 50 persons are employed on about 30 of those farms. There is an almost even distribution of male and female employees working on an occasional basis among those 30 farms.*

Farms should not be viewed only for employment directly on farms. The economy around farming has a multiplier effect in which employment and commerce is created for related businesses, whether directly or indirectly, for example, insurance, retail and/or wholesale shops, traders, and transportation. Oftentimes, food supply is not always the problem for food security and availability, but the problem is marketing and distribution of produce. There is a great potential, based on the results of a needs' assessment conducted in St. Kitts-Nevis, Dominica, and St. Lucia, for labour market information (LMI) to inform the introduction of a new agri-business curriculum at local colleges. The LMI indicated a need for entrepreneurs devoted to marketing and distribution, while creating more employment related to the agricultural sector.

Income and Livelihoods

Finding: *Over 80% of all farmers reported annual household income of less than EC$35,000 (USD$12,900) consistent with the national median income of about $20,000 (USD$7,400) per person with two persons in the household employed.*

Finding: *About 70% of all farmers indicated that less than 25% of their household income is attributed to farming activities.*

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Backyard gardening and non-traditional growing systems on a small scale are excellent for increasing household income, given the part-time nature of farming activities on a small scale. An important consideration in the income equation is that household food bills are reduced when they can supplement their diet with food produced by themselves or bartered with other growers. Moreover, it is a way of building resilience to climate change through better livelihoods.

Operational Adaptations

Land Tenure and Use

Finding: *Very significant is that about 75% of land occupied by farmers is government owned (they are illegal occupiers).*

This is perhaps the most challenging problem for farming to achieve food security in the Caribbean region. Simply put, land is tied to politics. With all the adaptive strategies that farmers use to reduce dependence on land by increasing productivity using non-traditional growing systems, that alone is not sufficient to achieve food security and make agriculture a viable economic activity. Ultimately, agriculture requires more land under production and the development of irrigation. Farmers are less likely to invest in infrastructure and technology when they do not own the land or have secure tenancy agreements. It is also the case that some farmers have the mindset that if they acquire land either by renting or illegal occupation that they would eventually own the land or have infinite access when it may become regularized. There is widespread evidence that some farmers hold onto relatively large parcels of farmland but with little farming activity. In this scenario government, on the one hand, has limitations to its land management policy and, on the other hand, with some farmers not utilizing farmland to the optimum when they have access. In some cases, farmlands remain totally unproductive for years and even decades. Moreover, prime agricultural land cannot compete with other land uses such as for tourism, housing, and manufacturing. Land-use planning would show that some of the best agricultural soils are not always used for farming. There are adequate policy tools and options available to government, but it is unequivocally a matter of choices that rests solely on the political will and ethical principles with regards to land management practices. Where such practices fail, the option for farmers is only with non-traditional growing systems, such as hydroponics, organoponics, and aquaponics, as adaptive strategies to increase productivity. Non-traditional systems can operate in diverse environments such as marginal land, low freshwater availability, backyards, and urban centers. This option when practiced on a small individual scale but on a more widespread basis can have a cumulative and positive impact on food security.

Housing and Losses from Theft, Nuisance, and Predators

Finding: *Many farmers do not live in the same parish as the farm location which poses a problem for surveillance, theft, security*.

Finding: *Monkeys, theft/praedial larceny, and stray roaming livestock, in addition to diseases and pests are significant problems for crop production, but dogs and theft are problems for livestock.*

Losses from theft, nuisance, and predators are perennial problems with smallholder agriculture, especially when the farmer's plot is located at a distance from home. Where government policies prevent

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housing of people on farms, this presents a barrier to preventing such losses. It is also not feasible for persons to build homes on land on which they are renting or illegally occupying. Backyard farming is definitely one way to combat the issue of theft and praedial larceny, but more extensive farming also has a role to play in food security. On larger smallholder farms, one way of increasing the human presence is to build temporary cabins where workers can dwell. This solution can help to lower living expenses of farm workers, while having mutual benefits to workers and owners if occupation is rent-free, in exchange for surveillance. Cabins have added benefits to their uses by providing a mechanism for water harvesting from rooftops. Additionally, living in cabins on the farm site gives the option of flexibility of work hours so that work can be performed in the cool hours of the morning and late afternoons, as well as on weekends when some routines have to be performed.

While small ruminants are vulnerable to dog attacks, poultry and pigs are protected in pens or cages. It is not feasible to raise ruminants on small plots of land, and this type of farming is more suitable for large operations or designated areas in small countries where they are protected and monitored.

Irrigation

Finding: *About 50% of all commercial farms are below 1 acre in size, with a combined total of about 70% being less than 3 acres, or 75% being less than 5 acres and are predominantly rain-fed or lack consistent water supply.*

Finding: *About 60% of all farms use irrigation and about 70% of these use overhead sprinklers. However, about 60% of those irrigating depend on rain-fed supply.*

In a traditional setting, those farm sizes are too small. It is also not feasible to make the input of costly infrastructure and irrigations systems when farms are small and fragmented. Followed by land availability, water is of utmost importance to increasing productivity and food security, and therefore, government support is essential on both fronts.

The introduction of non-traditional growing reduces the amount of land needed to be productive enough for both subsistence and production at higher scales. However, communal infrastructure may be beneficial to serve several farmers, for example, the system of empoldering found in Guyana and Suriname. Empoldering is essentially a technique of Dutch origin, involving irrigating large expanses of land (thousands of acres) with irrigation and drainage canals running in parallel but with varying levels. The water is supplied from lakes or conservancies (where lakes do not exist, dams can be introduced to form a conservancy) into the irrigation canals and utilized on farms. The spent water is discharged in the drainage canals that are at a lower level than the irrigation canals. The water is regulated by sluices at various intervals along the canals. An overseer for the commune or empoldered area monitors fairness in distribution and usage, with the added benefit of surveillance on farms. In environmental conditions where there is sloping land or porous soils that do not retain surface water, irrigation pipes with open-shut valves can be used to regulate water from artificial reservoirs in higher elevations where rainfall is available. Furthermore, in environments where freshwater is scarce or prone to drought, the problem is typically not a lack of water entering the drainage basin but insufficient water retention or harvesting. In SIDS, the water drains efficiently and rapidly into the sea. Artificial dams and reservoirs are required to increase water retention and availability to replace rain-fed agricultural practices that are prevalent in SIDS.

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Where freshwater supply is scarce, drip-irrigation is most effective to conserve water. Drip irrigation is focused on the root systems and minimizes evaporation that is higher when water sprinklers are used. Mulching is also recommended to minimize evapotranspiration, with the caution that plastic mulch also reduces utilization from direct rainfall from which some crops can benefit, although plastic mulch prevents leaching and erosion. Mulch from biomass has beneficial effects in water retention, and also in the control of certain pests. Using mulch is also a way of recycling nutrients from the farm, and it can also be added to compost and then utilized as organic fertilizer instead of mulch. A technique that is used on a large scale in arid and semi-arid conditions is the development of swales simply by creating a depression on the land and piling organic matter from plant cuttings. It is allowed to mature by decomposition and then used for planting of crops. Swales thus enhance soil water retention and increase available organic nutrients.

Livestock, Soil Maintenance, and Feed Supply

Finding: *Livestock are traditionally of five main types: cattle, goats, pigs, poultry, and sheep. Poultry is used mainly for eggs with an insignificant production of broilers resulting in a heavy dependence on imported chicken.*

Finding: *There is a prevailing high demand for food crops and livestock products, but typically an inadequate domestic supply. As such, there is hardly any difficulty in finding a market or needing long-term storage.*

Mixed farming with integration of crops and livestock are found to be more successful (Naraine, 2005). The key to their success is the mutually beneficial effects with recycling of nutrients by which crops benefit from organic fertilizers and livestock benefit from plant matter or unsold produce. As noted previously, in item #1, such farms have achieved optimum diversification with as many as 5 types of crops and livestock combined. Diversification reduces risk.

There are opportunities on mixed farms to produce soil and reduce the need to buy fertilizers. Additionally, aquaponics or fish ponds on farms are excellent for irrigation of plants instead of using chemical fertilizers, while productivity is increased with fish supply, for example, tilapia as a source of protein in our diet. It is not unusual to see soil imported from MDCs for use in LDCs, a practice that is appalling in view of the high feasibility of producing soils locally. Mixed farming is one way to produce soils on a small scale, but there is also the potential in LDCs to produce soils on a large scale, considering that biomass and topsoil from clearing land for construction of residential and commercial properties end up in landfills and dumpsites.

The major issue with production of pork and poultry is the cost of feed. In most cases, there is no local production of feed for pigs and poultry, and when it is produced there is a higher demand than supply. The cost associated with importation of feed, storage, and the short shelf-life before degradation, is essentially too high a risk to render it feasible for farmers. Some pig farmers utilize the spent grain from local breweries as a supplement to imported feed. Poultry for egg production is generally more feasible compared to broilers for meat that require high amounts of protein in a relatively shorter time span than for layers that continue to produce eggs well beyond their rapid growth stage. The production of feed remains more feasible in large countries, for example, Brazil, Guyana, and Suriname with large

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production of rice, corn, and soybeans. A better system of marketing and distribution is key to supplying SIDS with meat or raw materials from which countries can manufacture feed locally instead of importing feed for which shelf-life and transportation cost present challenges. The local production of feed, even if it were from imported ingredients, can be an opportunity to ensure reliability of fresh supply and higher-quality meat than those imported and frozen for extensive periods.

Capital Investment and Land

Finding: *With regards to farm assets, real property averages only about EC$12,000 (USD$4,444).*

This level of investment is very low in view of the importance of the role of local food production to achieve food security. Essentially, farmers are not willing to invest, maintain, or improve land that they do not own. However, this low level of investment is generally adequate for backyard gardening and non-traditional growing systems at small scales, particularly in small spaces that they own or lease long-term.

Capital Investment and Machinery

Finding: *Heavy equipment averages about $25,000 (USD$9,300) while light equipment averages about $3,000 (USD$1,100), with almost all farms having light equipment.*

Heavy machinery is typically owned and operated by government agriculture departments to give support to farmers. However, these operations are typically inefficient and their machines are often inoperable or in need of maintenance. Therefore, farms, both small and large scale, are not highly mechanized. In isolated instances, there are private owner-operators who contract with various farmers, but there is still a general scarcity of heavy machinery when needed. Where agriculture associations or co-operatives exist, there can be opportunities for community owned machinery with a fee structure that is proportionate to hours of use, but with the fees as primarily a means of covering operation, maintenance, and replacement costs.

Access to Credit

Finding: *Less than 15% of all farmers receive farm input credit, with the main source of credit being private lending institutions, with as much as 13% interest rate*.

Vulnerability in this aspect stems from lack of business skills. Education in business practices and entrepreneurship, addressed below, will lead to better outcomes with banks or other lenders or mechanisms. The Bangladesh model of micro-financing with the now controversial figure of Muhammad Yunnus has had extensive impact in bringing millions out of poverty. Each nation or community has its own circumstances and a solution in one area may not apply in other areas. The lesson to be learnt is that micro-financing is essential for development of communities practicing small-scale farming. Mechanisms can range from formal programs by banking institutions or development banks, to informal small circles of people in communities who pool monies and lend to members on a rotational basis.

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Educational and Organizational Adaptations

Agricultural Education and Youth Engagement

Finding: *About 70% of all farmers are between the ages of 35-54 years old, contrary to the literature that suggests most farmers in St. Kitts are older or retired and younger people are not interested in farming*.

However, youth involvement is not fully utilized and has a great potential with non-traditional growing systems such as hydroponics. This was noted in higher enrolments in college programs, for example, at the Clarence Fitzroy Bryant College, in St. Kitts and Nevis with emphasis on this increasingly popular technology. Youth engagement can be achieved by educating more persons to get better results and also by using social media to network farmers to share experiences and knowledge of best practices. According to Simoes et al. (2010), education is a key to adaptive capacity and building resilience through greater understanding of the natural environment and knowing how to develop sustainable systems to increase productivity. Furthermore, with formal and non-formal education, all age-groups, socio-economic groups, and women can be targeted so that a greater percentage of any human population can enter into economically productive activities. The OAS-funded project under the theme, "Transfer of knowledge in science and engineering, and the promotion of innovations and entrepreneurship" engages all age groups, male and female, from formal and non-formal educational backgrounds in non-traditional agricultural systems and is networked through social media. The non-traditional growing systems are suitable for greater inclusion of women, youths, and those physically challenged or with health issues. This is possible because of the lower physical stress required to operate such systems.

Popular Education and Vocational Training

Finding: *Less than 15% of all commercial farmers have attained technical and/or vocational training*.

The OAS-funded project, referred to previously, includes an educational response through a toolkit, a formal curriculum, and a non-formal educational documentary on non-traditional agricultural systems that can be delivered as a short-course with a competency-based approach.

Entrepreneurial Training

Finding: Economic: *About 80% of all farmers do not keep business records and over 90% do not have a farm business plan*.

Related to improved credit access, and arguably a more important adaptive strategy, is business education to do better planning and minimize risks. Formal and non-formal competency-based training with incubation support is prudent, irrespective of whether or not it is from micro-financing sources or self-funded enterprises.

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ICTs and Extension Services

Finding: *The majority of farmers by far, receive farming information from radio and other farmers; not from the Agriculture Department.*

With recent developments in smart phones and widespread availability and connectivity on the Internet, there is greater opportunity for information sharing and networking around farming interests. Agriculture Departments can utilize ICTs to disseminate quality information to farmers. One effective arrangement is to have a space in each local community or farming area designated for Extension Officers to set up on-going sessions for demonstrations, experimentation, information dissemination and training on current issues relevant to that area. Too often, Extension Officers spend more time at their offices at a central location, where they also conduct sessions.

Professional Organizations, Political Impact, and Extension Services

Finding: *About 90% of all farmers do not have any membership or affiliation with agricultural based organizations, and there is scarcely any organized farming group.*

With more education, people are more likely to understand the importance of organizing around agriculture. Formal and continuing non-formal education is perhaps the most effective strategy for engaging a generation of more knowledgeable farmers. Although there may be several registered organizations in some communities, membership is low and meetings are infrequent and not effectively organized around issues that are significant to the development of the sector. Encouraging more of such organizations is now likely to yield greater success if guided to overcome these constraints. For this reason, there is a greater need for government agriculture departments to play a more active supporting role and be held more accountable to farmers.

POLICY RECOMMENDATIONS

We yearn for economic systems within our control, within our comprehension and that once again provide space for human interaction – and yet we are constantly overwhelmed by finding ourselves trapped into vast global economic systems that are corrupting and corrupt. (Bunting)

Recommendation for Policy Design and Implementation Strategy

At the apex of the hierarchy of needs—and the most important ethical responsibility faced by policy makers in emerging economies—is food security. Efforts to achieve this goal must begin at the household or individual farm enterprise level to meet basic nutritional needs and to combat hunger and malnutrition. The issues, case studies and examples, and adaptive strategies detailed in the previous sections reveal that land reform is essential to transform agricultural economies.

Land reform in LDCs has not been getting traction either because there is no perceived prospect of competing with large agricultural economies in MDCs, or the power is in the hands of resistant private or public elites, or both. Numerous policies at regional and national levels as well as those outlining

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sectoral strategies have been formulated with attempts for improvement of this situation. However, they have generally not been fulfilled due to failures at implementation, primarily because of insufficient budgetary support for implementation at the individual farm level, compounded by poor management and governance at all levels.

There has been growing success of smallholder farmers and backyard gardening throughout emerging economies of the world. This phenomenon has had a significant positive impact on world hunger despite myriad challenges. Based on this, policies should be focused in support of adaptive strategies, at least in the short- to medium-term, so that the trend can be continued and multiplied.

The approach should be at the enterprise level where individual farms can be assessed in terms of sustainability along input factors of land tenure, culture, technology, economy and trade/markets, and environment. Consideration should also be given to their output in terms of household benefits such as nutritional requirements, livelihoods, and building resilience to climate-related vulnerabilities (Waugh, 2009). Incubation centers can be introduced as a mechanism to minimize risks of farms that are not successful as well as to support new (and hence vulnerable) farming enterprises. Extension efforts should be restructured in terms of location and delivery formats to aid implementation in this framework or model. Extension should also expose smallholders to the benefits of integrating additional components and supporting efforts to create more integrated enterprises through effective communication. There must be policies to incentivize cooperatives and other strategies for expanding the enterprise to the next level in scale of operations.

In the long-term, in the face of long-range forecasts about climate change impacts, farmers and communities need to continue their fight. They should make representation to their elected officials on the basis of ethical responsibilities for decisions to meet the basic needs of food and nutrition of the general citizenry. They require factors such as; land reform, freshwater catchments and irrigation, machinery, fertilizers, pesticides, transportation, and improved varieties of crops and breeds of livestock and improved storage facilities.

Future Research

In emerging economies, food security may well depend on the success of smaller individual farming enterprises. As such, all interested parties need to develop an awareness of different enterprise scales as they learn to understand and adapt larger-scale forms of agriculture to local conditions. For scholars, policy makers, smallholder farmers and other stakeholders, consolidating recent gains in hunger eradication will depend on future research that focuses on six related areas:

- Building a model for larger-scale integrated farm enterprises where individual farms can achieve sustainability, higher productivity, and flexibility.
- The effective and innovative use of information and communication technologies (ICTs) in extension work.
- The development of government policies that promote social protection for small-scale agriculture through regulation of land tenure, credit, state purchasing, and other factors that influence the success of smallholder farming.
- Quantitative assessments that measure the impact of projects in categories such as productivity, profitability, nutrition, and inclusive growth.

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- Qualitative assessments that measure factors such as stakeholder uptake of new approaches and techniques, local knowledge, and feedback about extension service and policies.
- Redefining key concepts such as sustainability, subsistence, adaptive capacity and resilience for emerging economies.

CONCLUSION

This chapter has outlined the challenges and opportunities facing smaller, emerging economies as they attempt to improve food security in an ever-changing global economy. While dealing with a range of agricultural sectors, including crop farming, livestock, fisheries, and integrated enterprises that combine elements of some or all of those sectors, several common threads unify the analysis.

First, emerging economies typically depend on smaller individually-owned enterprises and will continue to do so into the future. Research and policy-making must recognize and respond to this reality by seeking to better understand and support the success of smallholder farming in all its permutations.

Second, local, national, and regional governments need to do a better job of supporting individual agriculture enterprises, and educators. Additionally, extension agents need to effectively and creatively target such enterprises with a range of formal and non-formal training and information services. Farmers themselves need to treat their farming—in whatever sector—as a business. This means adopting and maintaining sound techniques in marketing, accounting, communications, and political advocacy. While it goes beyond the scope of this chapter, developing political will on the part of smallholder farmers and the public who rely on them is an essential driver for shaping policies that will benefit smallholder success and ensure food security in developing societies.

Third, there is an assumption in this chapter that smallholder farming successes have a multiplier effect. This idea is validated by the recent FAO report that largely attributes a 20% drop in world hunger to advances in smallholder production. This dynamic is even more important in Small Island Developing States, where individual successes can add up more quickly to positive changes. These can manifest in less vulnerability to food imports and climate variability, more positive indicators in livelihoods and nutrition, and overall strengthening of societal resilience.

As the next generation of agricultural producers and policy-makers takes shape in the Caribbean and across the globe, hopefully this chapter will play a part in highlighting the role of small-holder farmers in sustaining nutritional health and overall food security for emerging economies.

REFERENCES

Alimuga, L., Magala, D., & Lwasa, S. (2007). Regoverning Markets: Small-scale producers in modern agrifood markets, Uganda--The case of the Nyabyumba United Farmers Group in Kabale district. Uganda Agricultural Economics Association.

American Marketing Association. (2005). *Definition of Marketing.* American Marketing Association. Retrieved from https://www.ama.org/AboutAMA/Pages/Definition-of-Marketing.aspx

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Balogun, E. D. (2003). Foreign Private Investment in Nigeria. *Central Bank of Nigeria Economic and Financial Review*, *37*(2), 31-81. Retrieved from http://www.cenbank.org/OUT/PUBLICATIONS/EFR/RD/1999/EFRVOL37-2-3.PDF

Bunting, M. (2011). Small Is Beautiful—An Economic Idea that Has Sadly Been Forgotten. *Guardian UK*. Retrieved from http://www.theguardian.com/commentisfree/2011/nov/10/small-is-beautiful-economic-idea

CARIBSAVE. (2011). Caribbean Climate Change, Tourism & Livelihoods: A sectoral approach to vulnerability and resilience. The CARIBSAVE Climate Change Risk Atlas – St. Kitts Final Draft Country Risk Profile. The CARIBSAVE Partnership.

Clarke, J. (2013). *Sugar, Land and Sustainable Livelihoods: Global Change and Local Vulnerability in St. Kitts.* (Ph.D. Thesis). University of the West Indies, Mona Campus.

Dawar, N. & Chattopadhyay, A. (2002). Rethinking Marketing Programs for Emerging Markets. *Long Range Planning, 35*(5), 457–474. Retrieved from http://www.sciencedirect.com/science/journal/00246301

Dixie, G. (2005). *Horticultural Marketing*. Rome: Food and Agriculture Organization of the United Nations. Retrieved from http://www.fao.org/docrep/008/a0185e/a0185e05.htm#bm05

Dixon, J., Taniguchi, K., Wattenbach, H., & Tanyeri-Arbur, A. (2004). *Smallholders, Globalization and Policy Analysis*. Rome: Food and Agriculture Organization of the United Nations. Retrieved from http://www.fao.org/docrep/007/y5784e/y5784e02.htm

Edelman, M. (2014). Food Sovereignty: Forgotten Genealogies and Future Regulatory Challenges. *The Journal of Peasant Studies*, *41*(6), 959–978. doi:10.1080/03066150.2013.876998

Ewah, S. O. E., & Ekeng, A. B. (2009). Problems and Prospects of Marketing in Developing Economies: The Nigerian Experience. *International Journal of Business and Management*, *4*(9). doi:10.5539/ijbm.v4n9p187

FAO. (2012). *Trends and Impacts of Foreign Investment in Developing Country Agriculture*. Rome: FAO. Retrieved from http://www.fao.org/fileadmin/templates/est/INTERNATIONAL-TRADE/FDIs/Trends_publication_12_November_2012.pdf

FAO. (2013). *FAO Policy on Gender Equality: Attaining Food Security Goals in Agriculture and Rural Development*. Rome: FAO.

FAO. (2013). *A Tool for Gender-sensitive Agriculture and Rural Development Policy and Programme Formulation: Guidelines for Ministries of Agriculture and FAO*. Rome: FAO.

FAO. (2015). *Saint Kitts and Nevis and FAO.* Food and Agriculture Organization of the United Nations. Retrieved from http://www.fao.org/3/a-av273e.pdf

Hu, A., Acosta, A., McDaniel, A., & Gittelsohn, J. (2013, January). Community Perspectives on Barriers and Strategies for Promoting Locally Grown Produce from an Urban Agriculture Farm. *Health Promotion Practice*, *14*(1), 69–74. doi:10.1177/1524839911405849 PMID:22102602

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

IFAD. (2013). *Smallholder farmers key to lifting over one billion people out of poverty.* International Fund for Agricultural Development. Retrieved from http://www.ifad.org/media/press/2013/27.htm

Kelly, C., & Schulschenk, J. (2011). Assessing the vulnerability of Stellenbosch's food system and possibilities for a local food economy. *Development Southern Africa*, *28*(4), 563–578. doi:10.1080/0376835X.2011.605575

Mafuru, J. M., Babu, A. K., & Matutu, T. F. (2007). Tanzania: The impact of market links on horticultural production in the Mara region. *Regoverning Markets.* Lake Zone Agricultural Research and Development Institute. Retrieved from <http://pubs.iied.org/pdfs/G03265.pdf>

McKenzie & Woodruff. (2015). Business Practices in Small Firms in Developing Countries. *International Labour Organization*. Retrieved from http://www.ilo.org/wcmsp5/groups/public/---ed_emp/documents/publication/wcms_360368.pdf

Murphy, S. (2001). The Global Food Basket. *Forum for Applied Research and Public Policy*, *16*(2), 36–42.

Naraine, L. (2005). *Agricultural Diversification in St. Kitts: Policy and Implementation. St. Kitts-Nevis*, Department of Agriculture.

Nebel, B., & Wright, R. (1996). *Environmental Science: The Way the World Works*. Upper Saddle River, NJ: Prentice Hall.

Reardon, T., & Berdeagué, J. A. (2002). The Rapid Rise of Supermarkets in Latin America: Challenges and Opportunities for Development. *Overseas Development Institute: Development Policy Review*, *20*(4), 371–388.

Simoes, A. (2010). Enhancing adaptive capacity to climate change: The case of smallholder farmers in the Brazilian semi-arid region. *Environmental Science and Policy,* (13), 801-808. Retrieved from www.sciencedirect.com

Timmer, C. P., Falcon, W. P., & Pearson, S. R. (1983). *Food Policy Analysis*. The John's Hopkins University Press. Retrieved from http://web.stanford.edu/group/FRI/indonesia/documents/foodpolicy/chapt4.fm.html

Vervisch, T. G. A., Vlassenroot, K., & Braeckman, J. (2013). Livelihoods, power, and food insecurity: Adaptation of social capital portfolios in protracted crises—case study Burundi. *Disasters*, *37*(2), 267–292. doi:10.1111/j.1467-7717.2012.01301.x PMID:23278356

Waugh, D. (2009). *Geography: An Integrated Approach*. Cheltenham, UK: Nelson Thornes.

World Bank. (2010). *Enterprise Survey: Saint Kitts and Nevis.* The World Bank. Retrieved from http://www.caribank.org/uploads/2014/11/2014-St.-Kitts-and-Nevis-PSAR.pdf

World Bank. (2015). *Data: Agriculture and Rural Development.* The World Bank. Retrieved from http://data.worldbank.org/topic/agriculture-and-rural-development

World Commission on Environment and Development. (1987). *The Bruntland Report: Our Common Future*. Oxford, UK: Oxford University Press.

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KEY TERMS AND DEFINITIONS

Emerging Economy: Economies that have passed their early growth stage, i.e. from their primary-based economy, and rapidly expanding to an industrialized base to become more developed. Some economies that have not become industrialized may rapidly expand into the service-based economy through tourism and/or offshore banking.

Food Security: The ability of a country to meet its basic food requirements from local agricultural production and without heavy dependence on imported foods.

Resilience: The ability of a community to recover from natural and technological disasters, and external shocks relating to commerce and trade. The better the livelihood of people in communities, the more resilient they are to disasters and external shocks.

Small Island Developing States (SIDS): A category of lesser-developed countries of the world that is mostly located in the tropics, such as the Caribbean Sea, Indian Ocean, and the Pacific Ocean. Their communities are primarily located in low-lying coastal areas and are susceptible to natural disasters, including volcanoes, as well as tropical storms and sea-level rise that have intensified due to climate change.

Smallholder: A farmer who operates a farm of no more than 5 acres on either a subsistence level or semi-commercial level. At such level, the farm is usually not highly mechanized.

Sustainability: In the context of the environment, it is the ability to utilize natural resources without exceeding the capacity to regenerate themselves to meet current needs of a community and without compromising the needs of future generations.

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Chapter 48
A Study of Different Color Segmentation Techniques for Crop Bunch in Arecanut

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ABSTRACT

Arecanut is an important cash crop of India and ranks first in the production. Arecanut crop bunch segmentation plays very vital role in the process of harvesting. Work on arecanut crop bunch segmentation is of first kind in the literature and this chapter mainly focuses on exploring different color segmentation techniques such as Thresholding, K-means clustering, Fuzzy C Means (FCM), Fast Fuzzy C Means clustering (FFCM), Watershed and Maximum Similarity based Region Merging (MSRM). The effectiveness of the segmentation methods are evaluated on our own collection of Arecanut image dataset of size 200.

INTRODUCTION

Agriculture plays a major role in any nation's economy and it is the primary livelihood of the mankind. Indian economy is based on agriculture as it is a traditional occupation. A stable agricultural industry ensures a country with food security, source of income and source of employment. This could be achieved by improving agriculture production and its quality by practicing precision agriculture. Precision agriculture, as a crop management concept, could meet much of the increasing environmental, economic, market and public pressures (Stafford 2000). The impact of precision agriculture technologies on agricultural production is expected in two areas: profitability for the producers and ecological and environmental benefits to the public (Zhang et al. 2002). The objectives of precision agriculture

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are profit maximization, its input rationalization and environmental damage reduction, by adjusting the agriculture practices to the site demands.

In the field of precision agriculture considerably quite a large effort on research has been focused. This leads the agricultural and engineering companies for manufacturing advanced machine vision devices to facilitate the practice of precision agriculture (Scarlet 2001). The spatial and temporal soil variability and crop management within a farm has been admired for centuries. In the past, the fields are small in size and their demarcations are defined by natural boundaries, like soil type and water courses. This made farmers to change their soil and crop treatments manually. With the enhancement in the area of field, the crop production was substantially increased and to cope up with the large scale of crop production automation coined more importance in the later part of the previous century (Godwin and Miller 2003). Without incorporating and developing the new technology for filed spatial variability and crop management (Goense et al. 1996), it was impossible automate the precision agriculture. With the advancement in technology which vitally made the impact for the development of the precision agriculture concept, in the late 1970s, the Global Positioning System (GPS) using satellites placed in orbit by the Department of Defense in the US. This system helped in locating any position on earth using latitude, longitude and altitude, 24 hours a day, up to the perfect accuracy of a few centimeters. With this information available to machines in the field, the treatment for the crops can be applied locally at the time of field operations within the field for the required amount of area (Stafford 1994). Precision agriculture is the future way ahead for formers to produce quality crop for the millennium. This is because the production of crop become more and more precise, the technologies are highly optimized which results in cost reduction and impact over the environment (Stafford et al. 1996).

Three main obstructions which needed to overcome during the implementation of precision agriculture (Matthews 1983; Stafford 2000)

1. Precision agriculture deals with intensive information related to mapping of different types of soil, crop and factors related to environment of the field. This produces huge data quantities which would be processed by the user. Along with the field data some more data is added based on the experience like weather and market information data. This overload of data has to be maintained and managed properly by suitable data integration, expert and decision support systems (Stafford 1994). To achieve this development some standardization of data formats and transfer protocols need to be followed.
2. There is an absence of balanced systems and methods for deciding application necessities on a restricted premise and a parallel absence of experimentally approved evidences for the benefits guaranteed for the concept. Both of these must be addressed by researching in the area of soil, crop science and agronomic exploration and experimentation.
3. Although information needed on soil, yield and ecological elements can be obtained, most strategies are expensive and intense labor-oriented, (like laboratory set up and subject expert for the analysis of soil). The information can be created through programmed sensor frameworks sensing particular components or suitable substitutes.

Accordingly, improvement of quick sensing frameworks must be needed before practicing precision agriculture. With the improvement of frameworks that can give information at fine spatial determination, the advancement of more exact application innovations and exact and dependable position reckoning has ended up important. Agricultural engineers must take a lead in overcoming the first and third hindrances

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however, in the most recent decade of research in precision agriculture has demonstrated, that the topic is multidisciplinary thus the inter disciplinary groups are expected to develop solutions for these issues (Stafford 2000).

Precision agriculture is an integrated crop management system that endeavors to match the sort and amount of inputs with the genuine product requirements for small regions within the farm field area. The benefits of precision agriculture in relation with economy and environmental could be envisioned through decreased utilization of water, fertilizers, herbicides and pesticides along with farm equipments. This avoids in managing the entire field based on some theoretical condition, which may not exist anyplace in the field (Godwin and Miller 2003). A precision agriculture approach perceives site-particular differences inside fields and adjusts the management procedures as needed (Goovaerts 2000).

Precision agriculture plays a vital role in cropping systems like yield monitoring, its variability, crop variety comparisons, yield damage reports, and field efficiency (Koch and Khosla 2003). In recent years, with the advancement in machine vision, applications of digital image processing and pattern recognition approaches have become powerful and essential in the field of precision agriculture, which involves computation and processing of intense data in order to provide timely and accurate information (Cox 2002).

With advancement in machine vision in the field of precision agriculture minimizes the human intervention and provides proper information for decision making process. The main problem in machine vision is in determining the presence of particular object, feature or activity in the image data. Even this can normally solved without human intervention, but the outcome results are not as per the expectation (Cox 2002). The available approaches for this problem can be solved for only specific objects, like simple geometric objects, human faces, printed or hand-written characters, or vehicles, and in particular for specific situations, where the images are captured in a well-defined illumination, background, and the direction of the object relative to the camera.

Agricultural automation may take advantage of machine vision resources, which can be applied to a number of different tasks, such as inspection, classification of plants, estimated production, automated collection and guidance of autonomous machines. Crop image segmentation issue on colour difference between mature crops and backgrounds under natural illumination condition is an important and difficult content of crop-harvesting machine vision.

Dealing with voluminous data and detection of proper crop bunch is very much desired in the process of harvesting. Machine vision approaches have been implemented in precision agriculture for various applications. The research works have been also done for harvesting, disease detection in case of crops like Tobacco (Guru et al. 2012), Tomato (Schillaci et al. 2012; Yin et al.2009), Potato (Hassankhani and Navid 2012), Coffee (Johnson et al. 2004), Tea (Singh and Kamal 2013), Mango (Chhabra et al. 2012) etc. Only a few attempts have been made for crops like Arecanut for classification, harvesting, grading and disease detection. Arecanut or Betelnut (Areca catechu L.,) is an important cash crop in the Western Ghats, Eastern Ghats, East and North Eastern regions of India. India ranks first in terms of both area (47%) and production (47%) of Arecanut. Indian productivity is also on par with the world productivity at 1.27 tonnes/ha (Gracy et al. 2010). Mainly, Arecanut is an important component of the religious, social and cultural celebrations and economic life of people in India. Also Arecanut is also used in Ayurvedic and Veterinary medicines.

Crop harvesting is the process of extraction of matured crops from the plant. The selection of right time and right maturity of crop adds quality to the crop. The assessment of proper crop for harvesting is a crucial decision making process. Automating the process mainly needs a solid machine vision model

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which helps in selecting the crop from the plant. This selection and extraction of crops from the plant can be carried out using image segmentation techniques.

From the literature survey it is evident that very few works have been done on crop segmentation part and in case of arecanut only few works have been done and those involves segmentation of a single nut from the background. So automatic segmentation (Gao et al. 2001) of crop bunches from the arecanut crops are very much needed as the plants are tall and needs skilled labor for harvesting. This increased labor cost in harvesting made small and middle level farmers life very tough. Also it is very dangerous for the labors who involved in harvesting; several cases have been reported by farmers that so many labors got injured by falling from the tree. This is due to the reason that, areca trees trunks are very thin and it grows to the height of 20-30 feet. This triggers us for proposing an automated harvesting process and this basically works based on the machine vision technique. This creates a huge scope for detecting and extraction of crop bunch from the plant using some solid color image segmentation techniques.

Color image segmentation is a prime and very important task in most of the machine vision problems. Color image segmentation is very much needed in the field of precision agriculture especially for harvesting process. One of the main problem with color segmentation in arecanut crop bunch is the complex background i.e., the background consists of other trees or leaves, flowers etc. of these some may have the same color as the crop bunch. Separation of areca crop bunches from the background is very challenging task.

This chapter initiates the exploration of various color segmentation methods (Sridevi and Mala 2012; Elbalaoui et al. 2013) and studies the effectiveness for areca crop bunch segmentation which are based on feature, image domain and edge (Lucchese and Mitra 2001; Pratt 2008). Under these different color segmentation techniques like Threshold (Pratt 2008; Sridevi and Mala 2012), K-Means clustering (Vijay et al 2014), Fuzzy C Means clustering (Cheng 1995; Pantofaru and Herbert 2005; Gonzalez and Woods 2009; Muthukannan and Latha 2012), Fast Fuzzy C Means clustering (Bhoyar and Kakde 2010; Singh and Singh 2010), Watershed segmentation (Belaid and Mourou 2009; Sridevi and Mala 2012), and Maximum Similarity based Region Merging (Ning et al 2009).

BACKGROUND

A novel and robust color space conversion and color index distribution analysis technique for automated date maturity evaluation for harvesting the date fruits was proposed (Lee et al. 2008b). Also Computer vision technology for detecting fruit size, color, bruise, and surface defects evaluation of fruit for the overall quality were discussed. Image analysis and color quantization techniques are used in evaluating fruit maturity for the harvesting process is demonstrated using Medjool date samples collected from field testing (Lee et al. 2008a).

Another system was developed using a genetic algorithm based neural network detecting technique for evaluating maturity of strawberry fruits during harvesting procedure (Xu 2009). A robust and an intelligent algorithm operated on the multispectral images for the estimatation of accurate percentages of green (under-ripe), yellow (proper ripe), and brown (over-ripe) colored coffee cherries displayed on the canopy surface (Furfaro et al. 2007). From the airborne multispectral imagery a feasibility of monitoring the coffee field ripeness was proposed and different approaches are discussed (Johnson et al. 2004).A multivariate based three class problem was incorporated considering a Bayesian classifier for data fusion to classify fresh non damaged tomatoes based on their ripening stages (Baltazar et al. 2008).

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Attempts have been made using machine vision in several crop management activities like crop to soil mapping, weed and disease detection, crop grading, and classification for harvesting. A machine vision–based guidance system was developed for grain harvesting (Benson et al. 2003; Mondal and Tiwari 2007). This system involve some stages like image acquisition from the sensor, digitization of the image, segmentation using adaptive using gray level histogram based techniques. Post segmentation process involves filtering using low-pass filters to remove noise. Blob analysis is done for classifying the connected pixels of the same image as a single object.

An automatic classification method for Betelnut/Arecanut is proposed in (Liu et al. 2009). The classification is done by extracting color, shape and texture features of Arecanut. The segmentation of the individual arecanut is done as preprocessing step using bilinear interpolation and wavelet decomposition. Arecanut image has been captured using CCD camera with YCbCr color mode. The image captured by keeping the arecanuts in white background to increase the contrast between object and the background region. As preprocessing mainly works on Y component, the arecanut is segmented based on Y component. Segmentation is achieved by considering only the low frequency image as the expected image and removing the high frequency components.

A method proposed for classification of Arecanut into two classes based on color (Danti and Suresha 2012b). The proposed method has three steps, segmentation, masking and classification. Three sigma control limits are used on the YCBCR image for the effective segmentation of Arecanuts. Classification is made based on the red and green color components of the segmented region of the Arecanuts. The segmentation is on individual arecanut images. The RGB image is first converted to YCBCR mode, the red and blue components from the arecanut image cropped manually for determining the lower and upper control limits of the red and blue colors. Shadow was removed using 3 sigma controls by setting the background color as black. Morphological operations are used for removing the noise on the binary image which was converted by segmented image.

Use of texture features have also been studied for classification of Arecanut (Danti and Suresha 2012c). The segmentation of arecanut from its background is the first step. This is done by converting the RGB image to HIS and YCbCr color model and then the saturation channel from HSI color model is extracted. Threshold based segmentation is carried out based on global image threshold using Otsu method is used. Classification is done using mean around features, gray level co-occurrence matrix (GLCM) features and combined (Mean around & GLCM) features.

Decision trees classifier is used for classification purpose. An approach has been proposed for grading of Arecanuts (Danti and Suresha 2012a). Three sigma control limits on color features are determined for effective segmentation of Arecanuts. Color features are used for the grading of Arecanuts with the help of support vector machines (SVMs) into two grades i.e. boiling and Non-boiling nuts. In the above mentioned work, the segmentation is again done for individual Arecanuts.

An application was developed by neural networks and image processing techniques for detecting and classifying the quality of Arecanuts. Defects with diseases or insects of Arecanuts were segmented by a detection line (DL) method. Six geometric features, three color features, and defect areas were used in the classification procedure. A back-propagation neural network classifier was employed to sort the quality of Arecanuts. Here the segmentation work is done for detecting the diseases spots on the Arecanuts (Huang 2012).

From the above literature survey, it is quite evident that few work has been carried out on segmentation of Arecanut is inadequate and fragmentary. It also reveals that no attempts have been made for segmentation of crop bunches of Arecanut.

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Among these the segmentation of Arecanut bunch crops it's of first kind in the literature.

NEED FOR MACHINE VISION IN HARVESTING

Harvesting is a vital and very important stage in production of any crop. If the crop production is qualitative then it should follow a selective harvesting process. Selective harvesting deals with the collection of only proper ripe crops from the plant. Hence, before the process of harvesting a crop, farmers should consider proper and accurate factors like unripe, ripe and over-ripe of crops. Due the human sensory limitations, the manual judgment of crop ripeness by human will not guarantee the accurate and precise result. Also the variability of lighting condition will minimize the efficiency in evaluating crop ripeness over the time. Therefore with these issues, there is a need to develop a robust model against ecological conditions (sunny, cloudy and rainy) to evaluate ripeness of crop during the harvesting process. The visual properties of crop like color, shape and textures need to be exploited for the evaluation of the ripeness of crop for harvesting process.

With this backdrop, there is need for exploring machine vision based algorithmic models for crop bunch segmentation of arecanut crop. The prime applications of arecanut crop bunch segmentation include monitoring and mapping crop yields. Crop-yield monitors to watch both quantitative and qualitative parameters, a great need of timely harvesting based on crop ripeness. Due to the excessive labor cost and chances of making wrong decision at the time crop selection, harvesting and grading, there is an increasing demand for machine vision based technology. Implementation of suitable machine vision techniques in precision agriculture for proper crop management helps farmers to serve the society by providing quality crops (Lee et al. 2011).

Arecanut harvesting is done manually in present scenario and is very cumbersome and dangerous process in case for non-expertise labors. Automation of harvesting process mainly concentrates on extraction or segmentation the crop bunch from the arecanut tree image. Image segmentation is a process of partitioning an image into its constituent regions to extract data from the attributes of the image. A good segmentation should result in regions in which the image elements should have uniform properties in terms of brightness, color or texture etc. Though the image is to be portioned into regions, the considerable changes within the regions should be observable visually. The quality of the segmentation can be measured by the elements of the same region should be similar and should have clear difference between elements of the other regions.

Now there are a number of wide varieties of image segmentation techniques are available, among these some are for general purpose and some are designed for specific types of images for the specific filed. Mainly the techniques were classified as: spatial clustering with measurement space guide, region growing schemes based on single linkage, region growing schemes based on hybrid linkage, region growing schemes with centroid linkage, spatial clustering techniques, and split-and-merge methods (Haralick and Shapiro 1985).

The proposed work concentrates at extracting the crop bunch of arecanut from the given image using different color segmentation approaches which are classified mainly into three classes based on

1. Feature space,
2. Image domain, and
3. Edge-based (Fu and Mui 1981; Lucchese and Mitra 2001 ; (Pantofaru and Herbert 2005).

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The feature-space based method is composed of two steps, feature extraction and clustering. Feature extraction is the process to find some characteristics of each pixel or of the region around each pixel, pixel value, pixel color component, windowed average pixel value, windowed variance etc. After we get some typical properties around every pixel, clustering procedure is executed to divide the image into compelling parts focused around these properties. Image space based technique experiences the image and finds the border between segments by few rules. The primary attention to separate two pixels into specific segment is the pixel value differences, so this sort of routines couldn't manage textures well. The main methods in this class are split and merge, region growing, and watershed. The third class is edge-based image segmentation method, which has edge detection and edge linking techniques (Haralick and Shapiro 1985; Lucchese and Mitra 2001).

In spite of the fact that there have been numerous sorts of existed strategies, some basic issue still can't be solved. For class (1), the exact boundaries between segments are still difficult to focus on the grounds that features take properties around however not precisely on every pixel. Class (2) just uses the pixel value, which may bring about over-segmentation on texture regions. The edge detection makes class (3) ends up with over-segmentation issue. The segmentation process can be divided into different category based on the attributes selected like pixel intensity, homogeneity, discontinuity, cluster data, topology etc. Each approach has its own advantages and disadvantages. The result of one approach may not be the same as compared with other. Methods that are specialized to particular applications can often achieve better performance. Selection of an appropriate method to a segmentation problem is very challenging dilemma.

The segmentation procedures can be semi-interactive or automatic. With the major difficulty of ill-posed nature of segmentation it is hard to obtain single answer for segmentation of given image as the interpretation varies from individual approaches. In some cases manual interaction to segment the image may be error-prone (for example, in case of seed selection) while the fully automated approach can give error output (for example in case of watershed segmentation)and in some cases interactive methods can be laborious and time consuming. So a single approach to segment all variety of images may be practical unachievable. The prior knowledge on the image can give better results and gives user the choice to decide proper method to segment the image.

DATASET CREATION

Creation of a suitable dataset is crucial for any research as the dataset is the primary thing for designing and testing the system. A newly designed system has to be empirically tested for various characteristics to assess its effectiveness in meeting requirements. Automation of any stage of precision agriculture for any crop has to be empirically tested for its various characteristics to assess its effectiveness in meeting the requirements for which it has been designed. The arecanut image data set is not readily available. This scarcity is mainly due to the huge manual effort required to collect a sufficiently large number of arecanut images. Due to the non-availability of a sufficiently large benchmarking dataset of arecanut images, it is difficult to compare the performances of different systems. In view of this, we have made an attempt to create a dataset of 200 arecanut images. These images are collected across the Karnataka state by visiting few districts and the images are captured from the ground by focusing the areca nut crop bunch at the top of the tree. This is very laborious process. The images were captured from the ground using NIKON COOLPIX L810 Digital camera with 26X Zoom. The input arecanut image, which has

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crop bunch along with different parts of arecanut plant like leaves, branches, stem and other tress in the background. Extracting the region of interest i.e., the crop bunch is a really very challenging task. To evaluate the performance of the segmentation techniques, one need to compare the segmented output samples with the ground truth samples. Performance evaluation of the segmentation algorithm is very important step in deciding which method is better by comparing with other methods. In the present case, due to the non availability of arecanut ground truth image dataset, we have created the ground truth dataset and did the performance comparison with other methods.

EXPLORATION OF DIFFERENT SEGMENTATION METHODS

Threshold Method

Intensity is the property shared by the pixels of a region. These regions can be naturally segmented through thresholding, which separates the regions with light and dark pixels.

Threshold based segmentation is the simplest segmentation technique which partitions different regions with different intensity levels based on the threshold value given. Thresholding algorithms are selected manually based on the priori knowledge or automatically by image information. These algorithms further classified based on edge, region and hybrid methods. Segmentation of image using thresholding is simple and promising for segmentation in case of images having light objects with dark background. Thresholding operation converts a multilevel image into a gray scale image and for the selection of a proper threshold *T,* further it divide the pixels of image into different regions and separate the light and useful objects from background. Any pixel (*x, y)* considered as a part of object only when its intensity exceed or in the range of the threshold value, given by, $f\left(x,y\right) \geq T$ otherwise the pixel belongs to background. Thresholding technique can be mathematically represented by (Gonzalez and Woods 2009),

$$T = \left\{x, y, L(x,y), f(x,y)\right\} \tag{1}$$

where (x,y) is the pixel location, $L(x,y)$ is the local property of the input image and $f(x,y)$ is the intensity value of the pixel (x,y).

Based on the selected threshold value, two classes are there, global and local thresholding. Global thresholding method has a fixed threshold value *T*. The threshold value should be proper to get an appropriate Region of Interest (ROI) of the image (Sridevi and Mala 2012). The output image g for the given input image f is obtained using the following (Gonzalez and Woods 2009),

$$g(x,y) = \begin{cases} 1, & \nabla f(x,y) \geq T \\ 0, & otherwise \end{cases} \tag{2}$$

Global threshold method will work only with images having even background illumination.

To overcome the issue with global thresholding method for non uniform background illumination, local thresholding was adopted using mean and standard deviation (SD) of the neighborhood pixels. It

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selects the threshold value based on the calculating the mean $\left(m_{xy}\right)$ and standard deviation σ_{xy}. The output image g for the given input image f is obtained using the following (Gonzalez and Woods 2009),

$$g(x,y) = \begin{cases} 1, & f(x,y) \geq a\sigma_{xy} + f(x,y) > bm_{xy} \\ 0, & otherwise \end{cases} \tag{3}$$

Local thresholding method uses multiple threshold values to manage the uneven illumination (Agarwal and Xaxa 2014).

In the case of crop bunch segmentation, the image is a color image. In this image each pixel is characterized by three RGB values. Hence 3D histogram has been constructed and is analogous to the method used for one variable. Histograms are plotted for each of color values the red, green and blue and the threshold point are found. The object in the segmented image is distinguished by assigning the average pixel value to the regions separated by thresholds.

Major issue with this method is, it considers only the intensity and does not draw any relation between the pixels. So there is no confirmation that the pixels selected by this are neighbor to one another. Also this nature of this method can introduces unrelated pixels within the same region i.e. nearby the boundaries. Due to this the noise will be maximized due to the variation of intensities of pixels within the region. This sometimes results in either under segmentation or over segmentation issues. This issue is very obvious when dealing with natural images.

From the experimentation and the result it is observed that the results are not as per the expectation. Here the complexity arises in selection of proper threshold values which separates the background from foreground. In the proposed case, it is very difficult to get the proper threshold value as the background is complex, as it consists of leaves, flowers which are having similar color compared to the arecanut crop bunch.

The Segmentation results of arecanut crop bunch using Thresholding are shown in Figure 1 and the performance of this technique is shown in Table-1.

K-Means Clustering

Clustering is a normally a techniques used for classification of samples. Given a vector of N measurements depicting every pixel or collection of pixels (i.e., district) in an image, a similarity of the measurement vectors and in this manner their grouping in the N-dimensional estimation space infers comparability of the similar pixels or pixel groups. Thus, clustering in measurement space indicates the similar regions of an image, and may be used for segmentation purposes.

The measurement vectors describe some useful features of the image and are also known as a feature vectors. Similarity between regions of the image or pixels implies in the feature space. Clustering methods are some of the earliest data segmentation techniques to be developed (Vijay et al 2014).

Normally the clustering algorithms suffer from two major issues

1. Predefinition of number of clusters, which makes inadequate using a huge image data base during batch processing.

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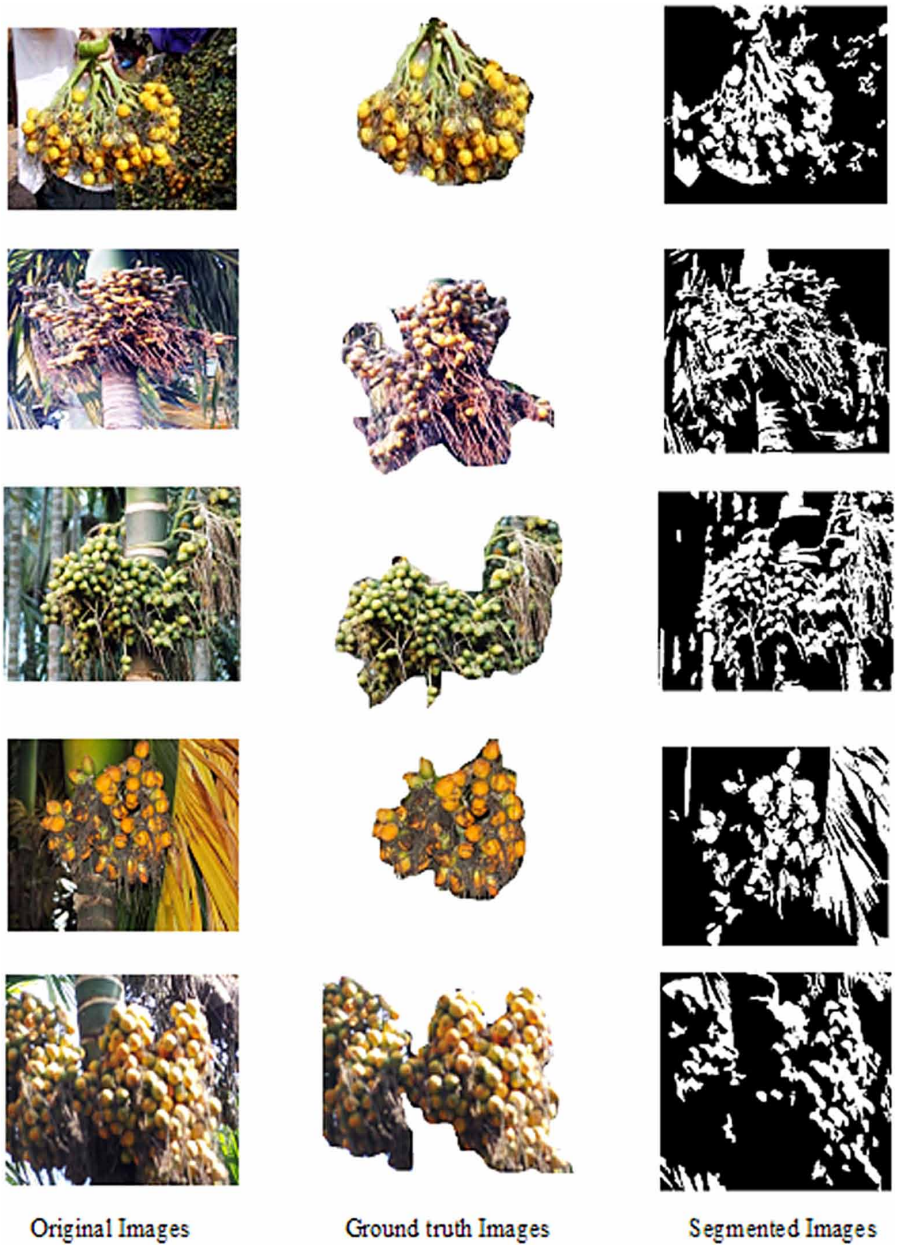
Figure 1. Results of Arecanut crop bunch segmentation using Threshold method



2. Representation of clusters by their centroid and built based on Euclidean distance inducing a hyper sphere cluster shape, which is incapable of capturing the actual structure of the data. This is especially arises during the case of color clustering with arbitrarily shaped clusters (Celenk 1990; Xi et al.2007).

The K-Means clustering method is one of the well-known methodologies connected to comprehend low-level image segmentation. In K-Means clustering a specific number of disjoint, flat (non-hierarchical)

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Table 1. Comparison and evaluation of different segmentation methods

Evaluation Parameters	Threshold					K-Means				
	1	2	3	4	5	1	2	3	4	5
Correlation	-0.29	-0.09	-0.15	-0.12	0.112	0.03	-0.16	-0.09	0.04	-0.20
RSME	13.61	13.15	12.88	12.99	13.94	11.89	11.76	11.55	13.18	11.02
Jaccard Coefficient	0.545	0.651	0.691	0.623	0.538	0.09	0.610	0.677	0.565	0.632
Dice Coefficient	0.004	0.005	0.005	0.005	0.004	0.005	0.004	0.004	0.004	0.004
Evaluation Parameters	**FCM**					**FFCM**				
	1	2	3	4	5	1	2	3	4	5
Correlation	-0.18	-0.06	0.07	-0.11	0.05	0.039	0.002	0.05	0.02	0.003
RSME	13.38	13.04	12.14	13.08	13.19	13.72	13.75	13.43	13.49	12.46
Jaccard Coefficient	0.601	0.659	0.730	0.605	0.603	0.999	1.000	0.999	0.999	1.000
Dice Coefficient	0.005	0.005	0.005	0.005	0.005	0.007	0.007	0.007	0.008	0.008

Evaluation Parameters	MSRM				
	1	2	3	4	5
Correlation	0.430	0.330	0.400	0.300	0.600
RSME	5.690	5.180	8.530	5.800	7.820
Jaccard Coefficient	0.990	1.000	0.990	0.990	1.000
Dice Coefficient	0.005	0.005	0.006	0.005	0.006

clusters were generated. It is well suits to the situation related to globular cluster generation. It is an unsupervised, numerical, iterative and non-deterministic method.

This algorithm is joined and its point is to optimize the partitioning choices focused around a user defined initial set of clusters. The applications of the clustering algorithms to division of complex color textured images are confined by two issues. The main issue is created by the beginning condition (the initialization of the initial cluster), while the second is produced by the way that no spatial (regional) attachment is connected amid the space partitioning procedure.

There are two preprocessing steps that are required for the implementation of K-means clustering algorithm: The stage begins first by making device independent color space transformation structure. Device independent color space, the coordinates used to point out the color will deliver the same shade regardless of the device used to draw it. Hence, making the color change structure that characterizes the shade space transformation is needed. At that point, the connection of device independent color space change, which changes over the color values in the image to the color space defined in the color change structure. The color change structure determines different parameters of the change. A device color space is the one where the resultant color relies on upon the supplies used to create it. Case in point the color created utilizing pixel with a given RGB qualities will be adjusted as the splendor and differentiation on the presentation device utilized. Hence the RGB framework is a shade space that is reliant (Agarwal and Xaxa 2014).

Generally, iterative frameworks are used for implementing spatial partitioning methods for either minimizing the variation within the clusters or try to identify the optimal partitions on a set of Gaussian Mixture Models (Farnoosh and Zarpak 2008). It is a nonhierarchical clustering technique and has

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a simple process to classify the given data set through a number of K clusters known apriori. K-Means algorithm iteratively updates space partition of the input data, where the elements exchanged between clusters based on a predefined metric (Euclidian distance and the vector under analysis) for satisfying the criteria of minimization of variation inside each cluster and maximization of variation among the resulting K clusters. The *K*-means clustering is a partitioning method for combining objects to minimize the within-group variance. By minimizing dissimilarity of a local subset, the algorithm will yield an optimal dissimilarity of all subsets globally (Gonzalez and Woods 2009).

The algorithm has following steps to image threshold:

1. Initialize the (K) class centers. Use an unequal-distance method to define the initial class centers:

$$Cen_i^0 = GV_{\min} + \left[\left(\frac{\left(j - j/2\right)\left(GV_{\max} - GV_{\min}\right)}{K}\right)\right] \tag{1}$$

where $j = 1,2,....K$ and where Cen_i^0 is the initial class center for the jth class, $GV_{\max}$ and $GV_{\min}$ are the maximum and minimum of the gray value GV in the sample space.

2. Assign each point to its closest class center. The criterion to assign a point to a class is based on the Euclidean distance in the feature (*GV*) space using:

$$Dist_{i,j} = abs\left(GV_j - Cen_i\right) \tag{2}$$

where $i = 1,2,....M \; and \; j = 1,2,.....N$ and where $Dist_{i,j}$ is the distance from the jth point to the ith class, and *N* is the total number of points in the sample space.

3. Calculate the (K) new class centers from the mean of the points that are assigned to it. The new class centers are calculated by N_i

$$Cent_i^m = \frac{1}{N_j}\sum_{i=1}^{N_i} GV_j \tag{3}$$

where $j = 1,2,...K$ and where N_i, is the total number of points that are assigned to the ith class in step 2.

4. Repeat step 2 if any class centers change, otherwise end the circulation.
5. The threshold value is defined as the average of the Kth class center and the $(K-1)th$ class center:

$$Thresh = \frac{1}{2}\left[Cent_K + Cent(K-1)\right] \tag{4}$$

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This method is having some limitations; it is difficult to assume the value of K, it will not work well with global clusters, result may have different final clusters due to different initial partitions and this will not well suits to clusters of different size and density.

The result obtained by this technique is not better for segmentation purpose. This is due to the partitions created having similarities in color and to the complex background. This also fails in minimizing the within-group variance.

The Results of arecanut crop bunch segmentation using K-Means Clustering method with K=2 is shown in Figure 2 and the performance of this technique is shown in Table 1.

Figure 2. Results of Arecanut crop bunch segmentation using K-means with K=2

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Fuzzy C-Means (FCM) Method

In case of hard clustering, the sample data is partioned into distinct clusters, among those each data element belongs to specifically to only one cluster. Fuzzy clustering sometimes also known as soft clustering where, data elements can be grouped in to more than one cluster, and those associated with each element is the belongs to the set of membership levels. This highlights the strength of association between the particular data element with a specific cluster. During the process Fuzzy clustering assigns the different membership levels and later using these membership levels assigns the data elements to one or more clusters. Fuzzy c-means (FCM) algorithm incorporates the spatial information of the data into the membership function for clustering. The spatial function is arrived from the summation of the each pixel under consideration with its neighborhood as membership function (Chuang et al. 2006).

Fuzzy Segmentation is considered as one of the interest area of research. Most analytic fuzzy clustering approach is derived from the fuzzy C-means (FCM) algorithm (Chaabane et al. 2008; Muthukannan and Latha 2012). The segmentation carried out using the thresholding technique, while the fine segmentation assigns the unclassified pixels to the closet class using Fuzzy C means (Chaabane et al. 2008; Yang et al. 2005).

The algorithm can be given mathematically as follows,

$$J_m\left(X,Y\right)=\sum_{i=1}^{n}\sum_{j=1}^{c}u_{ji}^{m}d^2\left(p_i q_j\right) \tag{5}$$

with

$$\sum_{i=1}^{c}u_{ij}=1, 1\le i\le n\,,$$

$$u_{ij}\ge 0, 1\le i\le n, 1\le j\le c\,,$$

$$\sum_{i=1}^{n}u_{ij}>0, 1\le j\le c$$

where $P=\left\{p_1,p_2,....p_n\right\}\subset R^s$, s is the dimension of space, n is the number of unclassified pixels, c is the number of clusters $(1<c<n)$, m is the fuzzy factor .., $d_{ij}=\left\|p_i-q_j\right\|$ is the distance between sample p_i and clustering center q_j with $(1<j<c)$. p_{ij} is the membership of the j^{th} sample of the i^{th} cluster center. The segmentation results are as shown in Figure 3 and the performance of this technique is shown in Table 1.

The FCM algorithm utilizes shared distances to compute the fuzzy weights. At the point when a feature vector is of equal distance from two cluster centers, it weights the same on the two clusters regardless of what is the distribution of the clusters. It can't separate the two clusters with distinctive distributions of

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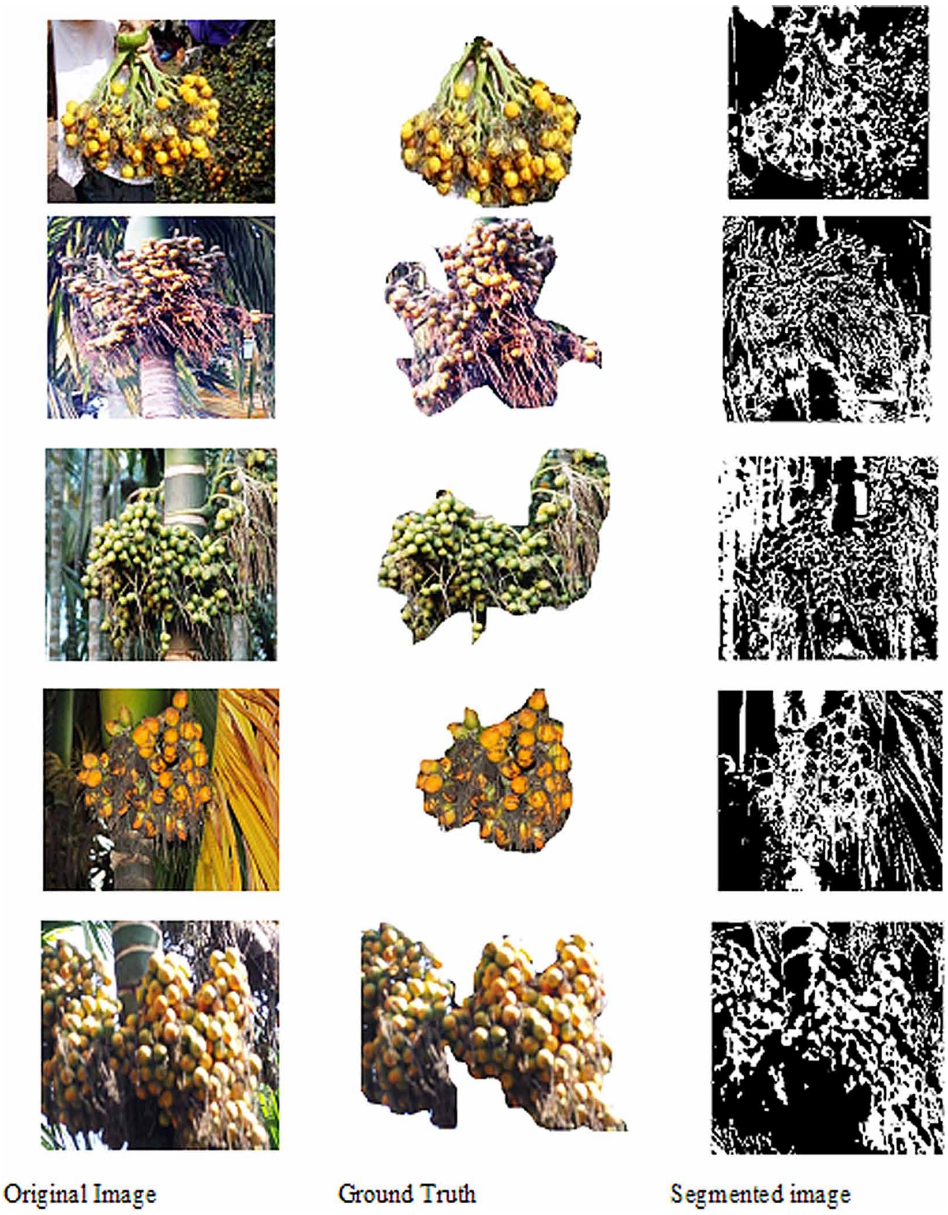
Figure 3. Results of Arecanut crop bunch segmentation using Fuzzy C Means (FCM) clustering method



feature vectors. Hence, the FCM algorithm is well suited to data that is pretty much uniformly distributed around the cluster centers. The FCM algorithm divides the two clusters with characteristic shapes but close boundaries into a large cluster.

In this case, the result obtained is quite better compare to the previous two methods. The unclassified pixels are grouped together based on the fuzzy c means. While grouping the foreground pixels there is an overlapping with background pixels.

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Fast Fuzzy C-Means (FFCM) Method

Fuzzy C Means clustering algorithm is widely used for image segmentation purpose. This concentrates those points which belong to two or more classes with respective membership. This algorithm gives good segmentation results, only when the input image should be noiseless. This fails to properly segment the images which are corrupted by noise.

To avoid these issues, a modified Fuzzy C Means segmentation method based on spatial constraints can be used (Capitaine and Frelicot 2011). The modified FCM segmentation algorithm will be compensating the intensity non homogeneities by modifying the objective function (Chen and Lu 2002; Pratt 2008).

The FFCM algorithm has following steps;

1. Computing the agglomerated histogram of the color image: Let *n* be the number of colors in the agglomerated histogram and *c* is the number of major segments with $(c < n)$, H_k is the number of pixels having color X_k represents the cluster *k.* The modified FCM with histogram data is given by,

$$Y_i = \frac{\sum_{j=1}^{n} u_{ji}^{m} \cdot p_j \cdot H_k}{\sum_{j=1}^{n} u_{ji}^{m} \cdot H_k} \tag{6}$$

where $j = 1,2,....c$.

2. Generation of Fuzzy functions using the following equation by replacing *N* by *n*

$$m_{ij} = \left[\sum_{j=1}^{c} \left(\frac{d_{ik}}{d_{jk}} \right)^{\frac{2}{m-1}} \right]^{-1}, \; i = 1,2,...c \text{ and } k = 1,2,...N \tag{7}$$

3. Construct the partition matrix for FCM of size $cx(n+1)$ using the following equation

$$m = \frac{1}{1 + \alpha d^2} \tag{8}$$

where *m* is the membership value for every pixel of the image, *d* is the Euclidean distance between the color coefficients and the cluster seed, the color coefficients and the cluster seeds are scaled to the interval [0,1] and α is an arbitrary constant to control the memberships on the distances i.e., the fuzziness, such that $0 \le \alpha \le 1$.

4. Determine the cluster centers using equation (6), store the cluster centers.
5. New partition or the membership values can be computed using the cluster centers from Step 4 and equation (7).

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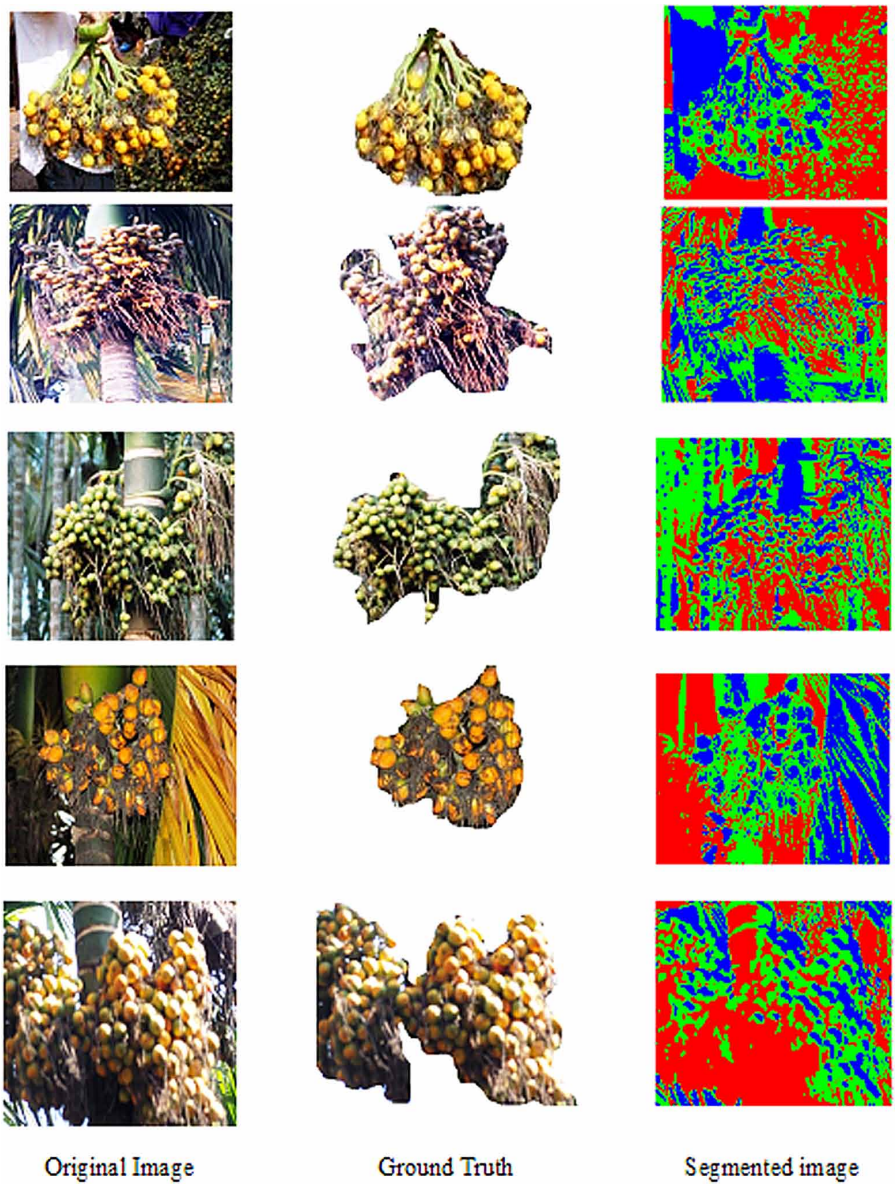
6. Steps 4 and 5 are repeated till the error of the respective cluster centers should become below the threshold.
7. Hardening the converged partition will yield the segmented image.

In this technique the results are better compared to Fuzzy C Means but not sufficient. This is once again based on generation of histogram for color image, which again sets a complexity in selection of proper threshold values between back ground and fore ground.

The corresponding arecanut crop bunch segmentation results are shown in Figure 4 and the performance of this technique is shown in Table 1.

Figure 4. Results of Arecanut crop bunch segmentation using Fast Fuzzy C Means (FFCM) method



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Watershed Algorithm

Due to the problem of selecting a proper threshold values in case of histogram generation, the region based algorithms are used. Region based segmentation algorithms operates based on grouping the pixels iteratively with its neighbors which are having similar values and splitting the group whose pixels are having dissimilar values (Kim and Kim 2003; Schettini 1993).

Watershed transformation is one of the region based segmentation approaches. The idea is coined from the field of geography which includes landscape or topographic relief flooded by water. Watersheds divide the lines of regions of attraction where rain is falling. This can be imagined when the landscape immersed in a lake, with holes in local minima. The catchment basins starts filling up with water from local minima and at some parts water emerges from different basins would meet and builds the dam. This process will be stopped when the water level reaches the highest peak of the landscape. Based on this, the landscape splits into different regions separated by dams known as watershed (Gonzalez and Woods 2009).

Let $f(x,y)$ with $(x,y) \in R^2$, be a real scalar function describing an image *I*. The morphological gradient of I is defined in (Belaid and Mourou 2009) by,

$$\delta_D f = \left(f \oplus D\right) - \left(f \ominus D\right) \tag{9}$$

where $\left(f \oplus D\right)$ and $(f \ominus D)$ are the elementary dilation and erosion of *f* by the structuring element *D*. The morphological Laplacian is given by

$$\Delta_D f = \left(f \oplus D\right) - 2f + \left(f \ominus D\right) \tag{10}$$

This morphological Laplacian influence zones of minima and suprema: regions with $\Delta_D u < 0$ are considered as influence zones of suprema, while regions with $\Delta_D u > 0$ are influence zones of minima. $\Delta_D u = 0$ interprets edge locations, and represent an essential property for the construction of morphological filters. The idea here is to apply either dilation or erosion to the image *I*, depending on whether the pixel is located within the influence zone of a minimum or a maximum.

The Catchment basin *C(M)* associated to a minimum *M* is the set of pixels *p* of Ω an open bounded domain of *R*, such that a water drop falling at *p* flows down along the relief, following a certain descending path, and eventually reaches *M*. The catchment basins of an image *I* correspond then to the influence zones of its minima, and the watershed will be defined by the lines that separate adjacent catchment basins (Belaid and Mourou 2009; Gonzalez and Woods 2009).

Computation of watersheds and the most commonly used is based on an immersion process analogy. This immersion process can be formulated as follows, Let $h_{\min}$ *and* $h_{\max}$ are the smallest and the largest values taken by *f*. Let $T_h = \left\{p \in \Omega, f(p) \le h\right\}$ be the threshold set of *f* at level *h*. A recursion with the gray level h increasing from $h_{\min}$ *and* $h_{\max}$, in which the basins associated with the minimum of *f* are successively expanded. Let X_h is the union of the set of basins computed at level *h*. A connected component of threshold set $T_h + 1$ at level $h + 1$ can be a new minimum, or an extension of a basin in X_h.

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By denoting $\min_h$, the union of all regional minima at level *h*, the following recursion defines the watershed by immersion.

$$\begin{cases} x_{h_{\min}} = T_{h_{\min}} \\ \forall h \in \left[h_{\min,} h_{\max} - 1\right], X_{n+1} = \min_{h+1} UIZ_{Th+1}(X_n) \end{cases}$$

with $IZ_{Th+1} = \bigcup_{i=1}^{k} iZ_{Th+1}\left(X_{n_i}\right), k-$ is the number of minima of *I* and $iZT_{h+1}\left(X_{hi}\right)$

$$iZ_{\Omega}\left(Y_i\right) = \left\{Z \in \Omega, \forall k \neq i, d_{\Omega}\left(Z, Y_i\right) \leq d_{\Omega}\left(Z, Y_k\right)\right\} \tag{11}$$

The set of the catchment basins of a gray level image *I* is equal to the set $X_{h\max}$. At the end of this process, the watershed of the image *I* is the complement of $X_{h\max}$ in Ω (Belaid and Mourou 2009).

The main issue with watershed technique is that it is highly sensitive to local minima. And at each minima a watershed is created. If there is a noise in the image, it creates a watershed which is not desired. So the image with noise will have an impact on the segmentation. In order to rectify this issue the sigma setting of the Gaussian filter is adjusted to smoothen the image, which minimizes the noise and the local minima in turn. This enhances the usefulness of the watershed segmentation. The level of this sigma can be balanced by the user. While setting up the sigma value if the Gaussian filter care has to be taken with the value of sigma, if the value of sigma is too high, the watershed location will be shifted to some other location due to the impact of Gaussian blurring.

This algorithm is based on region, and tried to create different regions present in the given input image. Later based on the similarities, the region can be split or merged. Once again the complexity of background in the input image creates regions which are the combination of foreground and background in certain points due to similarities.

The watershed segmentation results are shown in Figure 5 and the performance watershed technique is shown in Table 1.

Maximal Similarity Based Region Merging (MSRM)

From the analysis and experimentation of the above methods, it is evident that single segmentation techniques will not suited to the requirement. This makes the automatic segmentation very complex and leads to the need of suitable hybrid segmentation techniques. Automatic segmentation of object from background is very hard in case of natural images with color and texture features. Because of this difficulty, semi-automatic segmentation methods with user interactions have been become very popular. The low level image segmentation methods like mean shift (Cheng 1995; Bailer et al. 2005; Zheng et al. 2009), watershed (Belaid and Mourou 2009) etc. will divide the image into small regions. Even these may suffer with over segmentation issues, these methods provide a good reason for the low level operation such as region merging. This is a Hybrid technique which works using the combination of mean shift and region merging technique. The MSRM method is based on the initial segmentation of mean shift. The interaction information is through markers, which is the input provided by the user

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Figure 5. Results of Arecanut crop bunch segmentation using Watershed method

by indicating roughly the object and background. The markers are simple strokes. Once the strokes are marked on the mean shifted input image, this method calculates the similarity of various regions and merges them based on maximal similarity rule. At the end of merging process, the object is extracted from the background (Singh and Singh 2010).

The mean shift algorithm is defined as in (Bailer et al. 2005; Zheng et al. 2009),

Let $S \subset X$ be a finite set or data or sample. Let *K be* a kernel and $w = S \rightarrow (0, \infty)$ a weight function. The sample mean with kernel *K* at $x \in X$ is defined as,

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$$m(x) = \frac{\sum_{s \in S} K(s-x)w(s)s}{\sum_{s \in S} K(s-x)w(s)} \tag{12}$$

Let $T \subset X$ be a finite set or (cluster centers). The evolution of *T* is the form of iterations $T \leftarrow m(t)$ with $m(T) = \left\{m(t); t \in T\right\}$ known as a mean shift algorithm (Bailer et al. 2005). For each $t \in T$, there is a sequence $t, m(t), m(m(t)), \ldots.$ is called as the trajectory of t. The weight $w(s)$ can be either fixed all through the process or re-evaluated after each iteration. It may also be a function of the current 'T'. The algorithm works till it reaches a fixed point $\left(m(T) = T\right)$.

In this work, the EDISON system was used to carry out mean shift segmentation (EDISON v1.1 2002). Once the mean shift segmentation is done, there are small regions available. To guide the region merging process, the regions should be represented by certain descriptors with a rule for merging. A region can be described by some features like color, texture, edge, shape and size. Color histogram is used as an effective feature for representing the object color statistics. The RGB color space is used for color histogram and each color channel i.e., R,G,B are quantize into 16 levels and histogram of each color is computed in the feature space of 16x16x16= 4096 bins.

In the interactive program part, users will mark the some regions as object and some as background. The similarity measure (*R*, *Q*) between two regions *R* and *Q* to accommodate the comparison between various regions is defined as,

$$\rho(R,Q) = \sum_{u=1}^{4096} \sqrt{Hist_R^u \cdot Hist_Q^u} \tag{13}$$

where $Hist_R^u$ and $Hist_Q^u$ are normalized histograms of R and Q, and *u* represents the *uth* element of them. ρ is a divergence measure known as Bhattacharyya coefficient (Fukunaga 1990) having a straight forward geometric interpretation. It is the cosine of the angle between the unit vectors.

$$\left(\sqrt{Hist_R^1}, \ldots., \sqrt{Hist_R^{4096}}\right)^T \; and \; \left(\sqrt{Hist_Q^1}, \ldots., \sqrt{Hist_Q^{4096}}\right)^T.$$

The higher the value of Bhattacharyya coefficient between R and Q, the higher the similarity between them.

In the integrative image segmentation, user has to specify the object and the background. This can be marked by drawing some markers, such as a line, curve or a stroke to highlight the object and the background. One the marking is done, each region is labeled with three regions such as, marked object, marked background and non-marked region. For the total extraction of the object, user needs to assign each non-marker region with a correct label of object region or background region automatically.

After marking process is done, the challenge lies in extraction of object contour from background. To identify all non-marker regions with the guidance of object and background markers, an adaptive maximal similarity based merging is used. Let *Q* be an adjacent of *R* and denote by $S_Q = \left\{S_i^Q\right\}, i = 1,2,\ldots,q$ the set of *Q's* adjacent regions. The similarity between *Q* and all its adjacent regions, i.e.,

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$\rho\left(Q, S_i^Q\right), i = 1,2,...q$ are calculated. Obviously R is a member of $S_{Q.}$ If the similarity between *R* and *Q* is the maximal one among all the similarities $\rho\left(Q, S_i^Q\right)$, we will merge *R* and *Q*. and the merging rule is given by,

$$Merge\ R\ and\ Q\ if\ \rho(R,Q) = \max_{i=1,2,...q} \rho\left(Q, S_i^Q\right) \tag{14}$$

The MSRM process has two stages; first stage is about merging marker background regions with their adjacent regions. After this merging some non-marker background regions will be merged with the respective background markers. The second stage is focused on non-marker regions which are still remaining after first stage. This procedure is iteratively implemented and the iteration stops when the entire non marker region set will not find new regions for merging (Ning et al 2009).

The corresponding results are shown on Figure 6 and the comparison of performance of this hybrid technique with other techniques is shown in Table 1.

This hybrid segmentation technique gives somewhat promising result compared to the previous methods. This drives the need of hybrid segmentation techniques further for the problems related to natural image segmentation.

DISCUSSION AND CONCLUSION

The different segmentation techniques explored in this chapter are having certain limitations (Khan and Ravi 2013). The threshold segmentation method neglects the spatial information of the image, it highly noise sensitive and selection of the threshold value is crucial and based on this it suffers either over segmentation or under segmentation issues. Sometimes this leads to pseudo edges or missing edges. In K-means clustering approach the selection of desired number of clusters based on needs to be set earlier. This creates ambiguity while setting of the number of clusters. Fuzzy C-means method raises the ambiguity among the choice of features for better results for the given image. This is somewhat slow; this can be overcome by using certain histograms as in Fast Fuzzy C Means clustering method (Chaabane et al. 2008). Watershed methods even though give good results, it suffers from over segmentation and it unnecessarily segments into a number of regions (Belaid and Mourou 2009). It provides the connected component at the cost of computation time. This faces difficulty when segmenting the image with noise. Maximal Similarity based Region Merging method is semi automatic and needs human intervention for marking the background and the object; this makes this method computationally slow. It is intolerant to noise and moderately detects multiple objects. After exploring the above mentioned color segmentation techniques since we got better results using MSRM in comparison with other techniques, we have evaluated the MSRM technique using the evaluation parameters such as, Correlation, Jaccard coefficient, mean square error (RMSE) and Dice coefficient.

The correlation used as a measure of the similarity between ground truth image and a segmented image. The value of the correlation coefficient is between -1 and 1, where -1 indicates the similarity measure is away from the desired result. The Jaccard similarity coefficient, also known as the Tanimoto coefficient, measures the cover of two sets. It is characterized as the measure of the intersection

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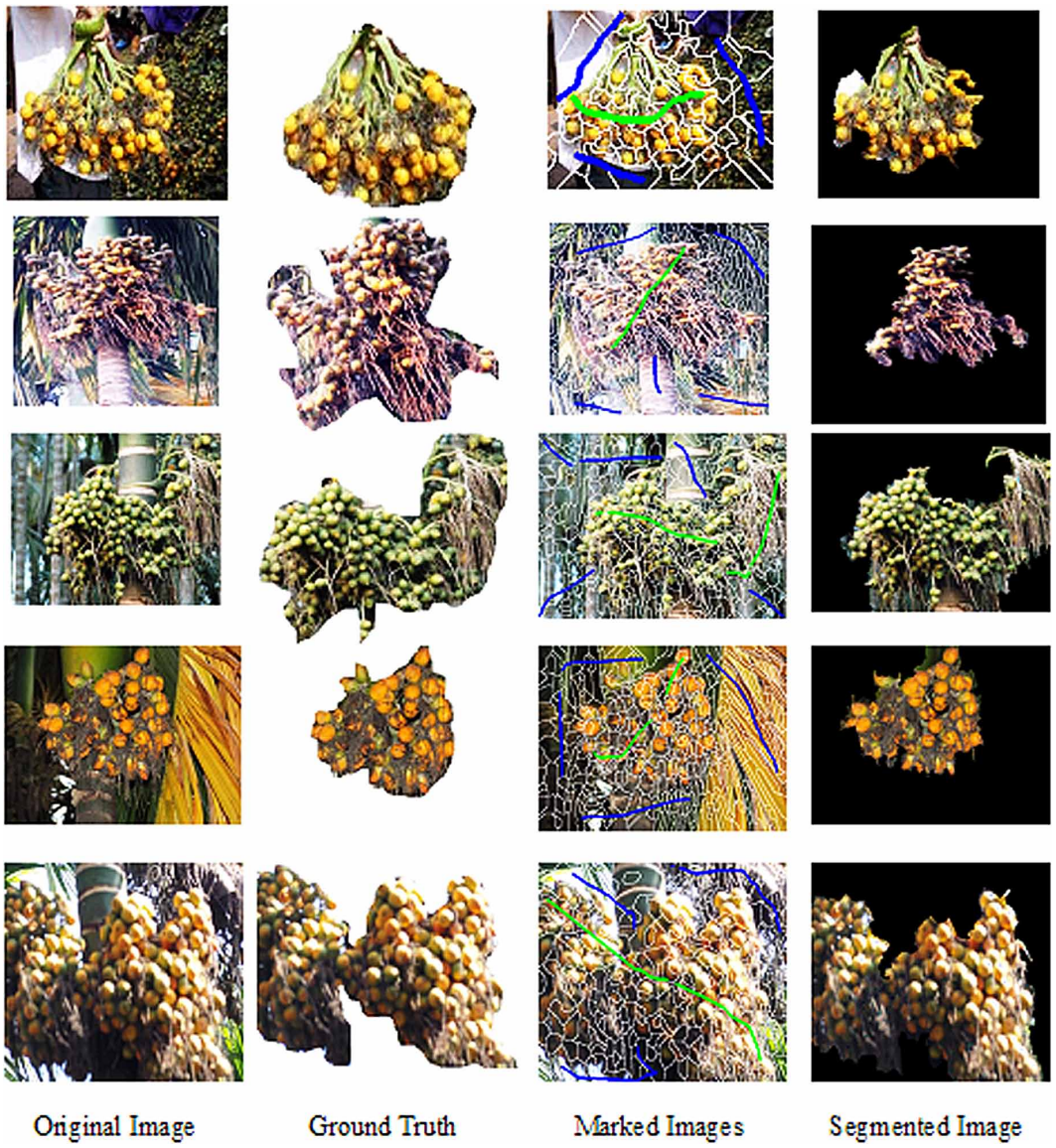
Figure 6. Results of Arecanut crop bunch segmentation using Maximal Similarity based Region Merging (MSRM) method



of the sets partitioned by the span of their union. The Jaccard coefficient is zero if the two sets are disjoint, and is one if they are identical. So when applied this to evaluate the agreement of segmentation results, the goal is to get as close to 1 as possible. The simplest of image quality measurement is Mean square Error (MSE). The large value of MSE means that image is poor quality and The Root MSE (RMSE) is calculated using the formula, $RMSE = \sqrt{MSE}$. The Dice coefficient is similar to Jaccrd coefficient and represents the size of the union of 2 sets divided by the average size of the two sets. Dice coefficient with value of 0 indicates no overlap; and a value of 1 indicates perfect agreement. Higher numbers indicate better agreement.

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The maximal similarity based region merging segmentation (MSRM) method is better compared to other methods and the corresponding evaluation is shown in Table 1 for images shown in Figure 6. From Table 1 it is evident that MSRM provides fair segmentation result and needs some improvement. This further drives for the need for some robust color segmentation algorithm for the purpose of Arecanut crop bunch segmentation.

FUTURE RESEARCH

Based on the experimentation on different color segmentation techniques it is clear that there will be a need of efficient and robust color segmentation techniques is essential for natural images. Also with single algorithm the results are not promising, this makes the essentiality of some hybrid color segmentation techniques which is either the fusion of existing algorithms. In the last technique the approach is semi-automatic which require human intervention in choosing the back ground and the object of interest. So based on these issue the future direction of this work focused at the following:

1. Automation of object and background selection part of MSRM algorithm.
2. Exploring graph based segmentation methods for the better results (Baldevbhai and Anand 2012; Shi and Malik 2000).
3. Exploring more hybrid segmentation methods i.e., fusion of segmentation methods.
4. Formulation of robust color segmentation techniques for images with complex background.
5. Exploration and experimentation of new segmentation techniques on different color spaces and hybridization of the color spaces.

REFERENCES

Agarwal, S., & Xaxa, D. K. (2014). Survey on Image Segmentation Techniques and Color Models. *International Journal of Computer Science and Information Technologies*, *5*(3), 3025–3030.

Bailer, W., Schallauer, P., Haraldsson, H. B., & Rehatschek, H. (2005). Optimized Mean Shift Algorithm for Color Segmentation in Image Sequences. In IS&T/SPIE Electronic Imaging (Vol. 5685, pp. 593–600).

Baldevbhai, P. J., & Anand, R. S. (2012). Review of Graph, Medical and Color Image base Segmentation Techniques. *IOSR Journal of Electrical and Electronics Engineering (IOSRJEEE)*, *1*(1), 1-19.

Baltazar, A., Aranda, J. I., & Gonzalez-Aguilar, G. (2008). Bayesian classification of ripening stages of tomato fruit using acoustic impact and colorimeter sensor data. *Computers and Electronics in Agriculture*, *60*(2), 113–121. doi:10.1016/j.compag.2007.07.005

Belaid, L. J., & Mourou, W. (2009). Image Segmentation: A Watershed Transformation Algorithm. *Journal of Image Analysis and Stereology by International Society for Stereology*, *28*(2), 93–102. doi:10.5566/ias.v28.p93-102

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Benson, E. R., Reid, J. F., & Zhang, Q. (2003). Machine vision–based guidance system for an Agricultural small–grain harvester. *Transactions of the American Society of Agricultural Engineers*, *46*(4), 1255–1264. doi:10.13031/2013.13945

Bhoyar, K., & Kakde, O. (2010). Colour Image Segmentation using Fast Fuzzy C-Means Algorithm. *Electronic Letters on Computer Vision and Image Analysis*, *9*(1), 18–31.

Capitaine, H. L., & Frelicot, C. (2011). A fast fuzzy c-means algorithm for color image segmentation. *Proceedings of International Conference of the European Society for Fuzzy Logic and Technology (EUSFLAT'2011)*, France (pp. 1074-1081). 10.2991/eusflat.2011.9

Celenk, M. (1990). A color clustering technique for image segmentation. *Computer Vision Graphics and Image Processing*, *52*(2), 145–170. doi:10.1016/0734-189X(90)90052-W

Chaabane, B. S., Sayadi, M., Fnaiech, F., & Brassart, E. (2008). *Color Image Segmentation using Automatic Thresholding and the Fuzzy C-Means Techniques. Electro technical conference, 14th IEEE Mediterranean* (pp. 857–861). Ajaccio: ISBN.

Chen, T. Q., & Lu, Y. (2002). Color image segmentation - an innovative approach. *Pattern Recognition*, *35*(2), 395–405. doi:10.1016/S0031-3203(01)00050-4

Cheng, Y. Z. (1995). Mean shift, Mode seeking and clustering. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, *17*(8), 790–799. doi:10.1109/34.400568

Chhabra, M., Gour, R., & Reel, P. S. (2012). Detection of Fully and Partially Riped Mango by Machine vision. *Proceeding of the International Conference on Recent Trends in Information Technology and Computer Science ICRTITCS* (pp. 26-31). 10.1007/978-81-322-0491-6_15

Chuang, K. S., Tzeng, H. L., Chen, S., Wu, J., & Chen, T. J. (2006). Fuzzy c-means clustering with spatial information for image segmentation. *Journal of Computerized Medical Imaging and Graphics*, *30*(1), 9–15. doi:10.1016/j.compmedimag.2005.10.001 PMID:16361080

Cox, S. (2002). Information technology: The global key to precision agriculture and sustainability. *Computers and Electronics in Agriculture Journal*, *36*(2-3), 93–111. doi:10.1016/S0168-1699(02)00095-9

Danti, A., & Suresha, M. (2012a). Arecanut Grading Based on Three Sigma Controls and SVM, Proceedings of the IEEE-International Conference On Advances In Engineering, Science And Management (ICAESM), Nagapattinam, Tamilnadu, India (pp. 372-376).

Danti, A., & Suresha, M. (2012b). Segmentation and classification of raw arecanuts based on three sigma control limits. Journal Procedia Technology. *Sciverse Science Direct*, *4*, 215–219.

Danti, A., & Suresha, M. (2012c).Texture Based Decision Tree Classification for Arecanut, *Proceedings of the CUBE International Information Technology Conference* (pp. 113-117). ACM Publications.

Elbalaoui, A., Fakir, M., Idrissi, N., & Marboha, A. (2013). Review of Color Image Segmentation. *International Journal of Advanced Computer Science and Applications* (Special Issue on Selected Papers from Third international symposium on Automatic Amazigh processing), 15-21. 10.14569/SpecialIssue.2013.030204

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Farnoosh, R., & Zarpak, B. (2008). Image Segmentation using Gaussian mixture model. *International Journal of Engineering Science*, *19*(1-2), 29–32.

Fu, K. S., & Mui, J. K. (1981). A Survey on image segmentation. *Pattern Recognition Journal*, *13*(1), 3–16. doi:10.1016/0031-3203(81)90028-5

Fukunaga, K. (1990). *Introduction to statistical Pattern recognition* (2nd ed.). Academic press.

Furfaro, R., Ganapol, B. D., Johnson, L. F., & Herwitz, S. R. (2007). Neural Network Algorithm for Coffee Ripeness Evaluation Using Airborne Images. *Applied Engineering in Agriculture*, *23*(3), 379–387. doi:10.13031/2013.22676

Gao, H., Siu, W. C., & Hou, C. H. (2001). Improved Techniques for Automatic Image Segmentation. *IEEE Transactions on Circuits and Systems for Video Technology*, *11*(12), 1273–1280. doi:10.1109/76.974681

Godwin, R. J., & Miller, P. C. H. (2003). A Review of the Technologies for Mapping Within-field Variability. *Biosystems Engineering Journal*, *84*(4), 393–407. doi:10.1016/S1537-5110(02)00283-0

Goense, D., Hofstee, J. W., & Bergeijk, J. V. (1996). An information model to describe systems for spatially variable field operations. *Computers and Electronics in Agriculture Journal*, *14*(2-3), 197–214. doi:10.1016/0168-1699(95)00048-8

Gonzalez, R. C., & Woods, R. E. (2009). *Digital Image Processing* (3rd ed.). Pearson Prentice Hall.

Goovaerts, P. (2000). Estimation or simulation of soil properties- An optimization problem with conflicting criteria. *Geoderma*, *3*(3-4), 165–186. doi:10.1016/S0016-7061(00)00037-9

Gracy, C. P., Nagashree, N., Nayak, A., & Girisha, K. (2010). Recent Posts on Indian Scenario of arecanut. Retrieved from http://krishisewa.com/cms/articles/production-technology/61-arecanut.html

Guru, D. S., Mallikarjuna, P. B., Manjunath, S., & Shenoi, M. M. (2012). Machine vision based classification of tobacco leaves for automatic harvesting. *Intelligent Automation and Soft Computing Journal*, *18*(5), 581–590. doi:10.1080/10798587.2012.10643267

Haralick, R. M., & Shapiro, L. G. (1985). Image segmentation techniques. *Computer Vision Graphics and Image Processing*, *29*(1), 100–132. doi:10.1016/S0734-189X(85)90153-7

Hassankhani, R., & Navid, H. (2012). Potato Sorting Based on Size and Color in Machine Vision System. *The Journal of Agricultural Science*, *4*(5), 235–244.

Huang, K. Y. (2012). Detection and classification of areca nuts with machine vision. *Journal Computers and Mathematics with Applications*, *64*(5), 739–746. doi:10.1016/j.camwa.2011.11.041

Johnson, L. F., Herwitz, S. R., Lobitz, B. M., & Dunagan, S. E. (2004). Feasibility of Monitoring Coffee Field Ripeness with Airborne Multispectral imagery. *Applied Engineering in Agriculture*, *20*(6), 845–849. doi:10.13031/2013.17718

Khan, A. M., & Ravi, S. (2013). Image Segmentation Methods: A Comparative Study. *International Journal of Soft Computing and Engineering*, 3(4), 84-92.

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Kim, J. B., & Kim, H. J. (2003). Multiresolution-based watersheds for efficient image segmentation. *Pattern Recognition Letters*, *24*(1–3), 473–488. doi:10.1016/S0167-8655(02)00270-2

Koch, B., and Khosla, R.(2003). The Role of Precision Agriculture in Cropping Systems. *Journal of Crop Production*, 9(1/2), 361-381.

Lee, D., Archibald, J. K., Chang, Y., & Greco, C. R. (2008b). Robust color space conversion and color distribution analysis techniques for date maturity evaluation. *Journal of Food Engineering*, *88*(3), 364–372. doi:10.1016/j.jfoodeng.2008.02.023

Lee, D., Archibald, J. K., & Xiong, G. (2011). Rapid Color Grading for Fruit Quality Evaluation Using Direct Color Mapping. *IEEE Transactions on Automation Science and Engineering*, *8*(2), 292–302. doi:10.1109/TASE.2010.2087325

Lee, D. J., Chang, Y., Archibald, J. K., & Greco, C. G. (2008a). Color quantization and image analysis for automated fruit quality evaluation. Proceedings of the *IEEE International Conference on Automation Science and Engineering* (pp. 194-199). 10.1109/COASE.2008.4626418

Liu, T., Xie, J., He, Y., Xu, M., & Qin, C. (2009). An Automatic Classification Method for Betel Nut Based on Computer Vision, *Proceedings of the IEEE International Conference on Robotics and Biomimetics*, Guilin, China (pp. 19-23). 10.1109/ROBIO.2009.5420823

Lucchese, L., & Mitra, S. K. (2001). Color image segmentation: a state-of-the-art survey. In Proceedings of the Indian National Science Academy (INSA-A), New Delhi, India (Vol. 67, pp. 207–221).

Matthews, J. (1983). Some challenges for engineers in agriculture. *Journal of the Royal Agricultural Society of England*, *144*, 146–158.

Mondal, P., & Tiwari, V. K. (2007). Present status of Precision Farming: A Review. *International Journal of Agricultural Research*, *2*(1), 1–10. doi:10.3923/ijar.2007.1.10

Muthukannan, K., & Latha, P. (2012). Clustering Techniques based Crops Image Segmentation. *International Journal of Computer Applications (IJCA)*, 2, 33-37.

Ning, J., Zhang, L., Zhang, D., & Wu, C. (2009). Interactive image segmentation by maximal similarity based region merging. *Pattern Recognition*, *43*(2), 445–456. doi:10.1016/j.patcog.2009.03.004

Pantofaru, C., & Herbert, M. (2005). A Comparison of image segmentation algorithms [Tech. Report] (CMU-RI-TR-05-40).

Pratt, W. K. (2008). *Image segmentation - Text book of Digital image Processing* (4th ed., pp. 579–622). Wiley.

Scarlet, A. J. (2001). Integrated control of agricultural tractors and implements: A review of potential opportunities relating to cultivation and crop establishment machinery. *Computers and Electronics in Agriculture Journal*, *30*(1-3), 167–191. doi:10.1016/S0168-1699(00)00163-0

Schettini, R. (1993). A segmentation algorithm for color images. *Pattern Recognition Letters*, *14*(6), 499–506. doi:10.1016/0167-8655(93)90030-H

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Schillaci, G., Pennisi, A., Franco, F., & Longo, D. (2012). Detecting tomato crops in greenhouses using a vision based method. *Proc. International Conference on Safety Health and Welfare in Agriculture and in Agro-food Systems*, Ragusa – Italy (pp. 252-258).

Shi, J., & Malik, J. (2000). Normalized Cuts and Image Segmentation. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, *22*(8), 888–905. doi:10.1109/34.868688

Singh, G., & Kamal, N. (2013). Machine Vision System for Tea Quality Determination – Tea Quality Index (TQI). IOSR Journal of Engineering, 3(7), 46-50.

Singh, K. K., & Singh, A. (2010). A Study of Image Segmentation Algorithms for Different Types of Images. *International Journal of Computer Science Issues*, *7*(5), 414–417.

Sridevi, M., & Mala, C. (2012). A Survey on Monochrome Image Segmentation Techniques. *Procedia Technology* (Vol. 6, pp. 548-555).

Stafford, J. V. (2000). Implementing Precision Agriculture in the 21st Century [Keynote address]. Proceedings of AgEng (Vol. 76, 267-275).

Stafford, J. V., & Ambler, B. (1994). In-Field location using GPS for spatially variable field operations. *Computers and Electronics in Agriculture Journal*, *11*(1), 23–36. doi:10.1016/0168-1699(94)90050-7

Stafford, J. V., Ambler, B., Lark, R. M., & Catt, J. (1996). Mapping and interpreting the yield variation in Cereal Crops. *Computers and Electronics in Agriculture Journal*, *14*(2-3), 101–119. doi:10.1016/0168-1699(95)00042-9

Vijay, J., Sohani, M., Shrivas A. (2014). Color Image Segmentation Using K-Means Clustering and Otsu's Adaptive Thresholding. *International Journal of Innovative Technology and Exploring Engineering*, 3(9), 72-76.

Xi, Y., Feng, D. D., Wang, T., Zhao, R., & Zhang, Y. (2007). Image segmentation by clustering of spatial patterns. *Pattern Recognition Letters*, *28*(12), 1548–1555. doi:10.1016/j.patrec.2007.03.012

Xu, L. (2009). Strawberry Maturity Neural Network Detecting System Based on Genetic Algorithm. *Computer and Computing Technologies in Agriculture II*, *2*, 1201–1208.

Yang, Y., Zheng, Ch., & Lin, P. (2005). Fuzzy C-means clustering algorithm with novel penalty term for image segmentation. *Opto-Electronics Review*, *13*(4), 309–315.

Yin H., Chai, Y., Yang, S. X., and Mitta, G. S. (2009). Ripe tomato extraction for a harvesting robotic system. In *Systems, Man and Cybernetics* (pp. 2984-2989). IEEE.

Zhang, N., Wang, M., & Wang, N. (2002). Precision agriculture worldwide - an overview. *Journal of Computers and Electronics in Agriculture*, *36*(2-3), 113–132. doi:10.1016/S0168-1699(02)00096-0

Zheng, L., Zhang, J., Wang, Q. (2009). Mean-shift-based color segmentation of images containing green vegetation. *Journal of computers and electronics in agriculture*, 65(1), 93-98.

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Chapter 49
Applying Indigenous Knowledge in Agricultural Extension in Zimbabwe

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ABSTRACT

Indigenous knowledge (IK) has been viewed as local knowledge that has been developed and accumulated, over time, by a community and has been passed down over generations. Such knowledge is represented in most spheres of human activity, such as in agriculture, traditional and alternative medicine, human and animal health, forestry and botany, among others. The purpose of this chapter is to discuss how IK is accessed and used by agricultural extension workers in Zimbabwe. The study reviews the relevant literature and focuses largely on Indigenous Agricultural Knowledge (IAK). The study utilises both quantitative and qualitative methods; a questionnaire was distributed and extension workers drawn from eight provinces of Zimbabwe. Mashonaland Central Province produced the highest number of respondents because the population for the province included ward and village extension workers in addition to the district and provincial extension officers and supervisors targeted in each province. From the projected sixty (60), forty four (44) districts participated. The study observed that indigenous knowledge is relevant in modern day agriculture and should be given sufficient attention in extension work. The study recommends that IK be documented and integrated into research, education and training for posterity.

INTRODUCTION

Woytek (1998, p. 1) opines that the literature on indigenous knowledge (IK) does not provide a single definition of the concept, partly due to the differences in background and perspectives of the authors, ranging from social anthropology to agricultural engineering. The United Nations Environmental Programme (2008, p. 21) and Masalu, Shalli and Kitula (2010, p. 4) observe that a variety of terms have been used to describe this form of unique knowledge. These have included such terms as "local knowledge," "traditional knowledge," "indigenous traditional knowledge," "indigenous technical knowledge", "tradi-

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tional environmental knowledge", "rural knowledge", "traditional ecological knowledge" and so forth. Warren (1991), Woytek (1998), and Njiraine, Ocholla and Le Roux (2008) view indigenous knowledge as the local knowledge – knowledge that is unique to a given culture or society, which contrasts with the international knowledge system generated by universities, research institutions and private firms. It is the basis for local-level communication and decision making in agriculture, health care, food preparation, education, natural-resource management, and a host of other activities in rural communities. Rajasekaran, Martin and Warren (1994), Ghorbani, Khodamoradi, Bozorgmanesh and Emami (2012), Dixon (2001), Tikai and Kama (2004), Karthikeyan, Veeraragavathatham, Karpagam and Firdouse (2009) view indigenous knowledge as a systematic body of knowledge and skills acquired by local people through the accumulation of experiences, informal experiments, an intimate understanding of the environment. Woytek (1998, p. 2) observes the characteristics of IK, which distinguishes it from other knowledge as:

- **Local:** It is rooted in a particular community and situated within broader cultural traditions; it is a set of experiences generated by people living in those communities. When transferred to other places, there is a potential risk of dislocating IK.
- **Tacit Knowledge:** Not easily codifiable.
- **Transmitted Orally:** Or through imitation and demonstration. Codifying it may lead to the loss of some of its properties.
- **Experiential Rather than Theoretical Knowledge:** Experience and trial and error, tested in the rigorous laboratory of survival of local communities constantly reinforce IK.
- **Learned through Repetition:** this is a defining characteristic of tradition even when new knowledge is added. Repetition aids in the retention and reinforcement of IK.
- **Constantly Changing:** being produced as well as reproduced, discovered as well as lost; though it is often perceived by external observers as being somewhat static.

According to Reij, Scoones and Toulmin (1996), Woytek (1998), and Warren (1991), the indigenous information systems are dynamic, and are continually influenced by internal creativity and experimentation as well as by contact with external systems and influences such as from immigrants, return migrants, extension workers, and visiting businessmen and so on. Woytek (1998, p. i) and Masalu *et al*. (2010, p. 5) perceive that indigenous knowledge is important as it contributes to communities in many ways.

It provides the basis for problem-solving strategies for local communities, especially the poor. It represents an important component of global knowledge on development issues. Learning from IK, by investigating first what local communities know and have, can improve understanding of local conditions and provide a productive context for activities designed to help the communities. Understanding IK can increase responsiveness to clients. Adapting international practices to the local setting can help improve the impact and sustainability of development assistance. Sharing IK within and across communities can help enhance cross-cultural understanding and promote the cultural dimension of development. Help in identify innovative pathways to sustainable human development that enhance local communities and their environment.

The United Nations Environmental Programme (2008) concur, adding that indigenous knowledge systems have enabled the various communities in those countries to live in harmony with their environ-

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ments for generations, and the systems are important tools in environmental conservation and natural disaster management.

Some forms of IK are expressed through stories, songs, myths, proverbs, cultural values, beliefs, rituals, community laws and local language. IK is mainly of a practical nature, particularly in such fields as fisheries, agriculture, health, horticulture, forestry and environmental management in general (Masalu *et al.*, 2010, p. 4). In traditional medical practice, certain herbs are known to treat a variety of ailments in both humans and animals. For example, according to the United Nations Environmental Programme (2008, p. 96) the Swazis use lihala (Aloe saponaria) to make preparations for treating high blood pressure, bile for nausea, fever and lethargy, snake bite, colon irritation, stomach ache. Ash from the leaves of the lihala can be used as cooking soda and as an ingredient for snuff, used by adults only.

BACKGROUND

Agricultural extension, "involves the transfer of agricultural information and technology to the farmers and similarly transferring information from farmers to researchers" (Pazvakavambwa & Hakutangwi, 2006, p. 217). Umali-Deininger and Schwartz (1994, p. 1) argue that: "The backbone of all agricultural extension endeavours is the transfer of agricultural information to enhance the productive capacity of farmers." Umali-Deininger and Schwartz (1994) further observe that embracing new technologies and production approaches in farming systems is essential in meeting the challenges of growing populations and the decreasing availability of productive land for agriculture. These efforts can be realised through the utilisation of various extension systems and approaches.

Agricultural extension in Zimbabwe has mostly been public sector driven through the Ministry of Agriculture. Private extension services are largely undertaken and supported by farmers' unions, private research organisations, and agricultural input suppliers such as seed and fertiliser companies as part of their business marketing. NGOs also provide their own extension services. Agricultural extension was introduced in Zimbabwe in 1927 by Emory D. Alvord with the help of nine field demonstrators (FAO, 2003). The Department of Agricultural Technical and Extension Services (AGRITEX) was established in 1981 following the merger of the Department of Conservation and Extension (CONEX) and the Department of Agricultural Development (DEVAG). CONEX had previously provided extension to large scale commercial farms while DEVAG catered for communal/ rural farmers (Rukuni, 2006). AGRITEX is headed by a Principal Director and seconded by two directors who are responsible for the Technical Division and Field Division respectively. The Field Division is headed by a director who is directly responsible for (8) eight provincial extension officers. Below the provinces are sixty (60) district extension officers, and below them are ward level extension personnel. Each province has six subject matter specialists (SMS). At district level (all sixty districts), there are three subject matter specialists and three hundred and eighty (380) zonal agricultural extension supervisors. The flow of information in the communication process follows both the top-down model and the bottom-up approach. Through AGRITEX officers based at the district offices, information is passed on to the AGRITEX extension supervisors and extension workers and then to the farmers. The officers and agricultural extension workers are also responsible for transmitting indigenous knowledge technologies, practices and problems from farmers to specialists and researchers. This creates a research extension network that is critical for appropriate research and extension messages/ communication (MoAMID, Department of AGRITEX, 2010).

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MAIN FOCUS OF THE CHAPTER

The aim of this chapter was to investigate the use of indigenous knowledge in agricultural extension by addressing the following research objectives:

1. To establish whether IK is used by agricultural extension workers.
2. To ascertain the frequency of use of IK by agricultural extension workers.
3. To investigate how agricultural extension workers acquire IK.
4. To establish the types of IK obtained from various sources by agricultural extension workers.

ISSUES, CONTROVERSIES, PROBLEMS

Various studies have been conducted on the application of IK across disciplines and across the geographical divide. The section below provides literature on how IK has been applied in agriculture.

Indigenous Knowledge Types and Agriculture

Abioye, Zaid and Egberongbe (2011, p. 3) perceive that farmers adopt a wide range of indigenous agricultural practices based on generations of experience, informal experiments and intimate understanding of their environments. They further observe that the application of indigenous agricultural farming has been reflected in the following:

- Indigenous methods of maintaining soil fertility.
- Indigenous methods of controlling pests and diseases.
- Indigenous soil preparation and planting materials.
- Indigenous methods of controlling weeds.
- Indigenous methods of harvesting and storage.

Indigenous Methods of Maintaining Soil Fertility and Water Conservation

Shetto (1999, p. 67) opines that **t**raditional agriculture in the past was compatible with the level of population and ecological environment; long bush fallow periods were effective in restoring soil fertility for the prevailing level of crop yields and intensity of cropping. He further asserts that conventional flat cultivation, which is associated with modern (mechanised) agriculture tillage, encourages splash and sheet erosion as it leaves the soil surface bare, under sporadic tropical downpours. There are several IK methods of maintaining soil fertility and these include; shifting cultivation, mixed cropping, intercropping, mulching, compost (dead leaves), animal manure, (cow dung and goat droppings), chicken waste, planting local legumes (green manure), and charcoal ashes (Tikai & Karma 2004, p. 73; Lakra, Singh, Sinha, & Kudada 2010; Singh & Sureja, 2008, p. 645; Fowler & Rockstrom, 2001; Kolawole, 2005; Mowo, Janssen, Oenema, German, Mrema and Shemdoe, 2006; Notsi 2012, and Mishra & Rai 2013). Non-tillage farming techniques, which involve clearing land by hand or burning, help maintain fertility and have minimum disturbance to the soil as only holes to accommodate the plant are dug using sticks (Tikai & Karma, 2004).

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Singh and Sureja (2008, p. 643) observe that farmers are able to classify soils, broadly as agricultural and non-agricultural soils used for farming and domestic purposes. Based on their experience, farmers are also able to classify soils according to topography, texture and colour, stickiness, depth and crop comparability (Singh & Sureja, 2008, p. 643). Similarly, Mowo *et al*. (2006, p. 52), Buthelezi (2010), and Osbahra and Allanb (2003) note that the local qualities of good soils include colour (black), cracks during the dry season, presents vigorous growth of certain plants, good yield, and low watering frequency, and an abundance of earth worms. Notsi (2012, p. 13) indicates that one method among both Batswana and Basotho of evaluating soil moisture is the hand – feel and soil appearance method, determining soil moisture by hand only gives relative soil moisture and is more accurate than other methods. According to Singh and Sureja (2008, p. 647), Tekwa, Belel and Alhassan (2010), and Shetto (1999) other methods of soil and water conservation include making entire fields into smaller plots, planting shrubs and perennial grass on the edges to prevent runoffs, mulching of seeds to avoid wind erosion, in sloppy lands, hill terraces, earth contour ridges, construction and maintenance of waterways, ploughing and sowing across slopes reduces erosion and stone bunds/lines.

Fenta (2009, p. 4) posits that farmers perceive soil fertility in terms of the capacity of soils for long-term productivity, their permeability, and water holding capacity, drainage, tillage, manure requirement and cultivability. To ascertain the accuracy of IK, Mowo *et al.* (2006, p. 47) compared soil fertility evaluation based on experience and knowledge of smallholder farmer communities with the evaluation by scientists based on soil analysis and model calculations. Farmers' experience and knowledge of local indicators of soil quality were used in identifying soil fertility constraints and in generating resource flow maps. The study established that farmers' indigenous knowledge in soil fertility evaluation mostly agreed with laboratory analysis and model calculations. Buthelezi (2010, p. 44) concurs observing that despite many differences between the scientific and indigenous approaches, farmers' soil suitability evaluation and fertility perception corresponds with the scientific evaluation. Tekwa *et al.* (2010), and Mishra and Rai (2013) concluded that IK technologies appeared viable and relevant in conserving soil and water required for sustainable crop production.

Indigenous Methods of Controlling Pests

Abate, Van Huis and Ampofo (2000, p. 642) assert that traditional control practices are still the major means of pest management to small-scale farmers in Africa and these control practices are based on built-in features in cropping systems, such as farm plot location, crop rotation, and intercropping, or on specific responsive actions to reduce pest attack, such as timing of weeding, use of plants with repellent or insecticide action, traps, scarecrows, smoke, and digging up grasshopper egg masses. Mugisha-Kamatenesi, Deng, Ogendo, Omolo, Mihale, Otim, Buyungo and Bett (2008) identify the major field pests reported by farmers which included banana weevil, bean fly, cereal stem borers, pod feeders, grain moth, rodents, moths, termites, birds, aphids and cutworms. They observe that the use of synthetic pesticides has raised a number of both ecological and medicinal problems while botanical pesticides are hailed for having a broad spectrum of activity, being easy to process and use, with a short residual activity (Mugisha-Kamatenesi *et al.,* 2008, p. 343). According to Tikai and Karma (2004, p. 71), and Mugisha-Kamatenesi *et al.* (2008, p. 343) some of the methods of controlling pests and diseases among crops include sanitation, burning and smoking, dusted plant materials (ashes and sand), and hand picking, fallowing and shifting cultivation, hand picking and squashing of beetles, slashing and burning, to use of physical barriers. Singh and Sureja (2008, p. 651) add that indigenous methods applied against

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insects attack include that adult insects/caterpillars of different vegetables and pulse crops are physically picked from the plants of the infected fields and destroyed by burning and the resultant ashes are broadcasted to control the pests.

Natural plant materials, using ash on crops, hot pepper mixed with ash, and spraying animal urine are found to provide effective substitutes for agrochemicals (Gana, 2003; Akullo *et al.,* 2007, p. 7; Kiplang'at & Rotich, 2008, p. 725; Fenta, 2009, p. 3). Most of the indigenous insect pest control methods included measures to disrupt pests' life cycle by periodically denying them food and to achieve maximum control where the manipulation of ordinary agricultural practices would follow. Odeyemi, Masika and Afolayan (2006, p. 169) observe that in the Eastern Cape, the stem borer (for example, *Chilo partellus* [Swinhoe]), grasshoppers, cut worms, millipedes, moles, birds and the maize storage weevil (*Sitophilus zeamais*) are some of the pests which pose a major threat to maize growers. Besides using synthetic pesticides, the authors note that intercropping was one way used to overcome this problem in which crops such as onion and garlic are known to have characteristic pungent smells that repel insects. They also observed that aqueous extract from plants such as wild marigold (*unukanuke*) and cape aloe (*umhlaba*) is prepared and sprayed on crops. Mugisha-Kamatenesi *et al.* (2008, p. 343) concluded that traditional pest control methods, particularly the use of indigenous pesticide plants if improved, offer a safer, eco-friendly, low cost and more dependable method of field crops protection.

Indigenous Methods of Controlling Weeds

Weeding is generally conducted to eliminate plants which grow where they are not wanted as they may cause harm to legitimate crops. Tikai and Karma (2004, p. 74), and Notsi (2012) observe that methods of controlling weeds include hand weeding, shifting cultivation and fallowing, slashing and burning, intercropping and shallow cultivation. Singh and Sureja (2008, p. 646) also note that to enhance soil and water management, ploughing is a popular practice as it enables farmers to control pests, weeds and diseases by exposing the egg masses of insects and dormant spores of pathogenic organisms to the hot sun, killing embryos of weed seeds, while enhancing the water holding capacity of soil through reduced runoff losses. Rathore, Krose, Naro, Shekhawat and Bhatt (2012, p. 356) observed that the use of common salt for weed control under acidic conditions of a *jhum* paddy was not only effective in minimizing weed competition with planted crop, but also resulted in high productivity without negative impact on the fields. The method was also found to be cost effective compared to traditional methods such as hand weeding.

Indigenous Methods of Post Harvesting and Storage

Studies have shown that communities preserve and store food for consumption after harvest as most crops are seasonal. The United Nations Environmental Programme (2008) for example, observes that in western Kenya beanstalks were burnt and the ashes used as a preservative for grain and cereals. Cowpea, apart from providing food during the rainy season, is harvested, boiled, dried and stored in granaries to be consumed during the dry season. Grain is harvested and dried in the sun after which it is sprinkled with ashes as long term preservation against pests and impending attacks. Ali, Yadav, Stobdan, and Singh (2012) identify three methods of storing vegetables, being *sadong* (underground pit), *tsothbang*

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(vegetable cellar), and *charches* (hanging) and these could keep fresh root crops, carrots, cabbage, onion and turnip fresh for periods ranging from two to eight months and in sub-zero temperature winter months. They observe that these methods can be helpful in developing low cost innovative methods of preservations, minimize the post-harvest losses and increase the availability of vegetables during winter months. Smit (1997), and Tikai and Karma (2004, p. 75) concur and add that storing crops in cool places such as sheds, pit storage and timely harvesting of crops to reduce high moisture content are some of the practiced IK methods. Also, Akullo *et al.* (2007, p. 6) observe that when farmers harvest cassava, for example, the tubers are buried in moist soil measuring one foot deep, while another method involves peeling, slicing, drying and storing in baskets. The harvested crops are dried and stored in various ways, including granaries for crops such as maize and other cereals. The granaries need to be well ventilated as moisture may cause the grain to rot (Kiplang'at & Rotich 2008, p. 726). Sinha (2010, p. 537) also notes that various trappings, rice mixed with toxic seeds, and leaves or branches of *A.vulgaris* are put in and around granaries for repelling insects as well as rats.

Karthikeyan *et al*. (2009) looked at traditional storage practices in India observing that in the past, insect infestation was often a less serious problem because farmers cultivated traditional varieties, which although low yielding, were general less susceptible to insects attack. Karthikeyan *et al*. (2009), Sinha (2010), and Bett and Nguyo (2007) observe that the introduction of high yield varieties has resulted in high storage losses since the varieties are prone to insect attack, hence the need for remedies of which IK methods are considered low cost, avoid chemicals and use resources which are readily available.

Seed Preservation

For some communities, seed for planting, during the following season, is usually selected from the current harvest. As Moreno *et al*. (2006, p. 1778) observe the most common characteristics that Yaxcaba farmers take into account when selecting for seed are ear size and health uniformity of grain colour, and grain size, which are considered to be indicators of germination reliability. Kiplang'at and Rotich (2008, p. 725), and Sinha (2010) observe that farmers select seed which is healthy and a good size. These are then placed in baskets and hung on kitchen ceilings so that the smoke and heat can dry and preserve them. Ash and other concoctions are sprinkled over the seed to prevent the grain from being attacked by rodents, insects and other potentially harmful pests (Karthikeyan *et al*. 2009). Similarly, Moreno *et al*. (2006, p. 1782) note that in addition to granaries, some farmers make use of various containers to store their seed, placing them in different locations and maize seed ears are stored in the rafters of a household kitchen.

Notsi (2012, p. 11) notes that among the Batswana and Basotho the seeds of indigenous vegetables such as *Rothwe, theepe, tenane* and *morogo wa dinawa* are collected when they are dry. Women dispatch the seeds by shaking or threshing dried indigenous vegetables; this will usually suffice for extracting the seeds, and the seeds are protected from over-drying by covering them with leaves or other specially prepared mixtures bags, or clay pots are also used to minimize the risk of over drying. Most seed or seedlings, if cleaned and stored properly, will remain viable for many years. Likewise, Karthikeyan *et al*. (2009) note that vegetable growers store seed indigenously, for use during the next seasons through methods like pressing the seed with the thumb, biting or smelling the seeds, to storing them in cow dung. Other methods include dusting seed with lime, mixing seed with ash or salt which was considered to have abrasive action on the insect skin preventing it from moving inside storage containers such as mud pots.

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Animal Health and Diseases

Indigenous knowledge practices in animal husbandry involve both reproductive health and the treatment of diseases. Various disease control mechanisms for chickens are observed in Akullo *et al*. (2007, p. 9) and these include *enkubebe* (small ants), *muziri* (tiny fish) and cannabis leaves pounded and added to water, to treat the Newcastle disease, while diarrhoea is treated using a mixture of cowpea leaves and salt. Begna leaf sap, sap of Ada (*Ginger*) and crushed black pepper is mixed and fed to the cattle for coughs and colds; seven pieces of chicken egg per day, to be fed for seven days, for the treatment of anoestrus; while to treat wounds, powder is made by grinding the seeds of Ata (custard apple, *Annona squamosa*), which is applied topically on a worm-infested wound (De Amitendu, Tudu &Goswami 2004).

Akullo *et al*. (2007, p. 9), The United Nations Environmental Programme (2008) observe that being mainly livestock keepers, the Maasai in Tanzania have a rich heritage of herbal cures for livestock. For example, they use osendu (Combretum mucronatum) to treat olchotai (guinea worm that attack throats of cows which they catch while drinking water), armme (Euphonobia cuneata) to treat abortion (brucellosis) in cattle and olorien (Olea africana) to sterilize milk gourds and treat East Coast fever in cattle. The leaves of the umsilinga (Melia azedarach) are used by the Swazis to prepare medicine for vomiting, running stomach, ulcers, high blood pressure, de-worming dogs and treating wounds in livestock. Adekunle, Oladele and Olukaiyeja (2002) observe that the frequently practiced indigenous control methods of pests and diseases by herdsmen are hygiene, self-diagnosis, use of herbs, movement from place to place, bush burning and spiritual incantation, magic and religious healing, mostly done by reading the Koran. Practical treatment including herbalism, ie treatment with parts of plants or other natural products, for example feeding animals with plants containing a high level of salt, that results in ticks falling off. Adekunle *et al.* (2002) also note that herdsmen's ages, marital status, contact with extension agents and years of experience influence their decision in practicing indigenous control methods.

Indigenous Knowledge and Weather Focus

Nyong, Adesina and Elasha (2007), and Elia, Mutula and Stilwell (2014) observe that there is a wealth of local knowledge based on predicting weather and climate and farmers have developed intricate systems for gathering, predicting, interpreting and decision making in relation to weather. According to United Nations Environmental Programme (2008) the Nganyi clan of Bunyore in western Kenya is known for their powers in predicting rain for more than 100 years and people believe that the Nganyi clan can make or stop rains, lightning and hailstorms, hence they take their weather advisories seriously and pay some fees to the family at the end of each season in the form of a share of their harvest. The clan perfected their rain-prediction art through observation of vegetation, trees, reptiles, birds and insects in the shrines.

The United Nations Environmental Programme (2008, p. 61) opine that the art of traditional rainfall prediction is, however, shrouded in mystery and is considered as a gift for a few. The potential person to inherit the art is identified in good time and is taken through the process of learning the art. Mutasa (2011) establishes that farmers rely on indigenous knowledge to determine weather patterns as a result of the absence of conventional weather reports from the Agritex Department while the United Nations Environmental Programme (2008, p. 26) cites a case of peasant farmers who listen to weather forecasts on the radio by the meteorological department but still prefer to rely on their own traditional knowledge of when to start planting. The more the "scientific" forecasting deviates from traditional knowledge the

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less it is used for planning purposes by the indigenous communities (United Nations Environmental Programme, 2008, p. 26).

Egeru (2012, p. 223) observes that the traditional rain prediction practices of using events, moon characteristics, tree phenology, diviners and particular animal behaviour patterns were still being utilized. Some of the prediction indicators used include a high density of spider webs in the locality is a sign of a very wet season. The indigenous methods used to predict drought and famine included the abundance of butterflies (Danaus plexippus) during the farming season, presence of army worms (Spodoptera exempta), animal and plant behavior, the availability of wild fruits and wind direction prior to the rainy season also gives indications of the season ahead (Mutasa, 2011; United Nations Environmental Programme, 2008). Maasai elders frequently use the behavior of animals and their health to foretell weather. For example, goat guts would be examined by a specialized Maasai elder, and if they were found to be having watery cysts on them during the month of August this would be taken to predict that the forthcoming season would have a lot of rains, but if the small intestine was found to be empty, drought, famine, hostility and war were to be expected in the chiefdom (United Nations Environmental Programme, 2008). Indigenous people living close to natural resources often observe activities around them and are the first to notice, identify and adapt to any changes. These changes may include the appearance of certain birds (seasonal migration), the mating of certain animals and the flowering of certain plants (Aluma 2001, p. 2; Gyampoh, Amisah, Idinoba and Nkem 2009, p. 70; Akullo *et al.* 2007). The indigenous knowledge on disaster prediction and early warning is based on keen observation of the behavior of animals, birds, insects, vegetation, trees, winds, air and water temperatures, clouds, earth movements and celestial bodies (United Nations Environmental Programme, 2008, p. 64).

Sources and Methods Used in Disseminating Indigenous Agricultural Knowledge

Singh and Sureja (2008, p. 651) observe that people learn about local practices of managing indigenous agriculture and natural resources through various localized sources where parents, nature, rural schools and social institutions, friends, neighbours and village wise men act as sources of knowledge providers. Egeru (2012, p. 217) asserts that the transfer of this knowledge and associated practices has been embedded in the culture through various rites of passage such as birth, initiation into adulthood, marriage, death, twin dancing and social gatherings which include beer parties. These views are shared by Shetto (1999, p. 69), and Mishra and Rai (2013) who note that traditional or indigenous technologies evolved as a result of a gradual learning process and emerge from a knowledge base accumulated by rural people by observation, experimentation and a process of handing down across generations, peoples' experiences and wisdom. Osbahra and Allanb (2003) expound that knowledge is acquired through personal experiences and overlapping communication pathways, both of which are influenced by social factors, including age, gender and family ties. Mundy and Compton (1991) observe that indigenous communication can take many different forms, which include the following:

- **Folk Media:** Used mostly for entertainment, but also educative (for example dance, song, plays, and storytelling among others).
- **Indigenous Organisations and Social Gatherings:** For example religious groups, village meetings, and women's groups, among others.

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- **Deliberate Instruction:** Most cultures have traditional schools where cultural practices are imparted and subject coverage ranges from general to specific areas, including medicinal and agricultural practices (for example initiation ceremonies).
- **Records:** Many societies keep formal records, and these may be written, curved, or painted; African storytellers narrate memorised historical epics and genealogies at length.
- **Unstructured Channels:** Indigenous communication occurs in many settings in Africa (Sturges & Neil, 1998): on the road, in the fields, at the market, and wherever people meet and talk, and such communication is spontaneous and informal.
- **Direct Observation:** Communication does not necessarily involve a second person; by observing a neighbour's bumper crop, a farmer may conclude that the technique or variety used is good.

A study by Protz (1998) establishes how drama is developed to better understand how the nature of gender relationships within the farm family affects agricultural decision making, particularly with respect to fertiliser use and soil fertility issues.

METHODOLOGY

Qualitative and quantitative techniques were applied in this study and data was collected through a questionnaire distributed to extension workers, and through interviews with key informants at the Ministry of Agriculture's national offices. Zimbabwe has ten provinces of which two, Harare and Bulawayo, are urban and did not participate in the study. Extension workers were drawn from eight (8) provinces, which yielded eight provincial extension officers and sixty (60) district extension officers. Ninety-one (91) Subject Matter Specialists in the eight provinces and those stationed at the Head Office were also included in the study. The categories of Agricultural Extension Officers, Agricultural Extension Supervisors and Agritex workers were drawn from Mashonaland Central Province to constitute a representative sample of agro-regions II to V. Foti, Nyakudya, Moyo and Chikuvire (2007:30) explain that Mashonaland Central Province is made up of areas of varied agricultural potential ranging from agro-ecological region II to region V. Zimbabwe's agro-ecological zones range from region I to V, hence owing to the large number of extension workers involved at ward level in the country's eight provinces, the study of this category was restricted to Mashonaland Central Province, which was considered representative in terms of agricultural practices. From the 551 village/ward extension workers in the province, a sample of 10% (55) was selected. Purposive sampling was applied so that each of the seven districts in the province was represented. Random sampling was then applied to select village/ward extension workers in each district. Additional village/ward extension workers from fourteen districts (14) (agro-ecological zone I-V) were randomly selected to provide field experiences, although this category was extensively investigated in Mashonaland Central Province.

Key informants (policy makers) were interviewed and these were the Director – Field Services division and Acting Director – Technical Services division.

The questionnaires were distributed by the researcher and research assistants, and through the assistance of the provincial extension offices, for both Mashonaland and Manicaland regions. In order to validate the research instruments, a pilot study was conducted with the Ministry of Agriculture's Department of Veterinary Services, which was not part of the main study. Data was analysed using SPSS and through content analysis.

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RESULTS AND DISCUSSION

The following sections present the results and discussion of the study.

Characteristics of the Respondents

As indicated in Table 1, of the respondents who completed the questionnaire, one (0.6%) was a Director and another one (0.6%) was a Chief Agricultural Specialist. Twenty-one (12.2%) were in the category of Agricultural Specialist/Snr/Principal. Six out of eight Provincial Agricultural Extension Officers completed the questionnaire, being 3.5% of the total responses. Likewise, 38 (22%) district agricultural extension officers completed the questionnaires although 44 districts participated in the study.

The other categories of respondents were: Agricultural Extension Officer/Snr Principal 30 (17.4%); 24 (14%) Agricultural Extension Supervisors and these were from Mashonaland Central districts and those randomly selected from other districts. In the lower category, 51 (29.7%) were Village/ward Agricultural Extension Workers, being extension personnel at grassroots level, i.e. village/ward level, and these were selected from Mashonaland Central for reasons already indicated in the methodology.

With regards to qualifications of respondents, 66 (38.4%) were holders of a certificate in agriculture, and these were mostly extension workers at ward/village level. Twenty-four (14%) had a diploma; 67 (39%) had a bachelor's degree; 3 (1.7%) had a post-graduate diploma; while 12(7%) were holders of a master's degree. None of the respondents had a doctoral qualification.

Indigenous Knowledge Systems in Agricultural Extension

The use and application of indigenous knowledge in agriculture has been demonstrated in literature. The study sought to ascertain the importance of indigenous knowledge in agricultural extension by looking at its utilisation, frequency of use and type of sources used. Indigenous knowledge was found to be highly utilised in the generation of agricultural innovations, 153 (89%). Extension workers who indicated in the negative were 19 (11%).

Table 1. Designation of respondents

Designation	Frequency	
	N=172	%
Director	1	0.6
Deputy Director	-	-
Chief Agricultural Specialist	1	0.6
Agricultural Specialist/Snr/Principal	21	12.2
Provincial Agricultural Extension Officer	6	3.5
District Agricultural Extension Officer	38	22
Agricultural Extension Officer/Snr Principal	30	17.4
Agricultural Extension Supervisor	24	14
Village/Ward Agricultural Extension worker	51	29.7
Total	**172**	**100**

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Frequency of Indigenous Knowledge Utilisation

This section was an extension of 5.2 above and sought to find out how frequently indigenous knowledge was utilised by the respondents. The results indicated that a minority 19 (11%) of extension workers never used IK for extension while the remainder varied in their use of IK. Results also indicate that a significant number, 35 (20.3%), of extension workers very often utilised IK, while 59 (34.3%) indicated that they "often" and "sometimes" utilise IK for extension, respectively. Table 2 summarises the findings.

Indigenous knowledge can be used to facilitate communication in rural development programmes, for example communication between project personnel and farmers is often very poor, particularly in projects with a structure that favours literacy, and this often results in a serious comprehension gap (Warren & Cashman, 1988, p. 4). It was thus significant to note that there was a high utilisation of indigenous knowledge among the respondents, although there were variations in the frequencies of utilisation among them. This is despite the fact that Bagnall-Oakeley *et al*. (2004, p. 119) observe that "although farmers utilise an indigenous knowledge system, the coverage of their indigenous knowledge system is frequently restricted and does not mesh well with the more formal research and extension networks". Van den Ban and Hawkins (1996, p. 20) also observe that "it is generally recognised that indigenous farmers' knowledge is crucially important for developing sustainable agriculture because this way of farming should be adjusted to local situations which the farmer usually knows better than the researcher or the extension agents".

Sources of Indigenous Agricultural Knowledge

Indigenous knowledge is acquired or derived from various sources, both formal and informal. This section sought to establish the sources of indigenous agriculture among the respondents. The results indicated that books were the chief source mentioned at 88 (51.2%), followed by 85 (49.4%) for conferences and workshops, and colleagues with 71 (41.3%). On the lower end of the scale, the sources which were considered the least by extension workers were village leaders/elders, and social gatherings, both mentioned by 34 (19.8%), and farmers' groups, mentioned by 28 (16.3%). The farmer groups are based on voluntary membership although the membership tends to be high due to benefits derived. Table 3 provides a summary of the findings.

The formal and non-formal nature of IKS was also reflected by the sources mentioned by the respondents. The study revealed that indigenous agricultural knowledge acquisition was derived from a variety

Table 2. Frequency of indigenous knowledge utilisation

Use of Indigenous Knowledge	Frequency	
	N=172	%
Very often	35	20.3
Often	59	34.3
Sometimes	59	34.3
Never	19	11
Total	**172**	**100**

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Table 3. Sources of indigenous agricultural knowledge

Sources of Indigenous Agricultural Knowledge	Frequency	
	N=172	%
Personal experience	51	29.7
Books	88	51.2
Social gatherings	34	19.8
Conferences/workshops	85	49.4
Village leaders/elders	34	19.8
Agricultural shows	37	21.5
Village meetings	42	24.4
Farmer's groups	28	16.3
Demonstration and observation	51	29.7
Colleagues	71	41.3

*Table indicates multiple responses.

of sources, both formal and informal. The responses show that formal sources, ie books and conferences/ workshops, were mentioned by the majority – 51.2% and 49.4% respectively – while colleagues were mentioned by 41.3% of the respondents. Whereas studies have shown that the transfer of IK and associated customs has been embedded in the culture and communicated mostly through informal sources (Mundy & Compton 1991, Akullo *et al.* 2007, p. 2, Kiplang'at & Rotich 2008, Gyampoh *et al.* 2009, Egeru 2012, p. 217) and others, it is interesting to note that books, conferences and workshops were ranked highly as chief sources by the respondents. What the study did not request were these sources for clarity. Studies have also shown that IK is at risk of becoming extinct if it is not documented (Singh & Sureja (2008), Lwoga, Ngulube & Stilwell (2010), Ghorbani *et al*. (2012), and Egeru (2012).

Demonstrations/observations and personal experiences were also ranked high by the respondents, with the least mentioned being farmers' groups. This observation is in concurrence with views from Shetto (1999), Osbahra and Allanb (2003), Mishra and Rai (2013) cited above. In contrast, for example, Lwoga, Ngulube and Stilwell (2010, p. 178) observed that in Tanzania IK was acquired through local sources such as parents/guardian/family, neighbours and friends, and personal experience. Sources such as books and other publications are not highly rated. Studies by Akullo *et al.* (2007), Kiplang'at and Rotich (2008), and Gyampoh *et al.* (2009) demonstrated that the elderly people in traditional societies provide the main source of IK based on experience accumulated over generations. Contrary to these observations from literature, it was also important to note that the elderly was not considered highly as sources of IK. The study has also shown that social gatherings and agricultural shows were among the numerous sources of indigenous knowledge by extension workers.

Interviews were conducted with the two key informants (policy makers) drawn from Field Services division Technical Services division. The respondents acknowledged the importance of indigenous in extension services, indicating that IK was embedded in the Department of Research and Specialist Services' (DR&SS) programmes and as AREX, when the two departments were previously merged. These observations dovetail with the responses in Table 3 in which village elders, village meetings and personal experiences were found to be among the key sources of information by extension personnel.

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Types of Indigenous Agricultural Knowledge Obtained From Sources

The respondents were asked to indicate the types of IAK they obtained from the sources they had mentioned in the preceding question and based on agricultural topics and subtopics. Plant diseases and pests were mentioned by the majority of extension workers, 152 (88.4%), followed by plant breeding, 139 (80.8%), with dairy farming being third, mentioned by 135 (78.5%) respondents. The least mentioned was crop harvest and storage by 31 (18%) respondents. The responses are summarised in Table 4.

Crop harvesting and storage was the least mentioned by 31 (18%) respondents. However, this is despite the observation that crop protection is closely linked to plant diseases and pests, which was mentioned by a high of 88.4% of the total respondents. Singh and Sureja (2008), Akullo *et al.* (2007, p. 2), Egeru (2012), argue that Indigenous Knowledge (IK) has for many years steered farmers in planning agricultural production and conservation of natural resources. In view of this, different types of Indigenous Agricultural Knowledge can be obtained from different sources. Pests and other diseases have been viewed as a major threat to farmers' yields (Odeyemi, Masika and Afolayan, 2006, p. 169, Bett & Nguyo, 2007, Karthikeyan *et al.* 2009, Sinha, 2010). The study concurs as shown among the respondents, the higher categories of information obtained were plant diseases and pests (88.4%), plant breeding (80.8%), and dairy farming (78.5%), while information on plant pathology, animal breeding and soil classification were also reportedly obtained by more than 70% of extension workers. Information on crop harvesting and storage was the least mentioned by extension workers.

The effectiveness of IK in agriculture is demonstrated in the studies by Dakora (1996), Tikai and Kama (2004), Abu (2005), Odeyemi, Masika and Afolayan (2006), Kiplang'at and Rotich (2008), Fenta

Table 4. Types of indigenous agricultural knowledge obtained from sources

Type of Indigenous Agricultural Knowledge Obtained	Frequency	
	N	%
Soil fertility	75	43.6
Horticulture	81	47.1
Soil classification	123	71.5
Plant breeding	139	80.8
Poultry	102	59.3
Plant pathology	133	77.3
Dairy farming	135	78.5
Plant diseases and pests	152	88.4
Crop protection	36	20.9
Animal health	90	52.3
Tobacco culture	105	61
Animal breeding	127	73.8
Weather patterns	55	32
Crop harvesting and storage	31	18
Crop varieties	62	36

*Table denotes multiple responses.

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(2009), Handayani and Prowito (2010), Lakra, Singh, Sinha, and Kudada (2010), Mutasa (2011), and Mugisha-Kamatenesi *et al*. (2008). These studies look at the different types of IK, which include soil fertility, diseases and pests as sources of Indigenous knowledge as well as methods of disseminating IK. The study thus reveals that different types of Indigenous Agricultural Knowledge are obtained from a variety of sources by extension workers, with varying emphasis among the types.

FUTURE RESEARCH DIRECTIONS

The utilisation of indigenous knowledge provides relevant and timely interventions in agricultural activities. As Abioye, Zaid and Egberongbe (2011, p. 9) noted "The urgency of indigenous knowledge documentation in Africa can be appreciated from the fact that when an old man dies in Africa, a whole library/archive perishes with him due to the oral nature of African indigenous knowledge". Hence, Lwoga, Ngulube and Stilwell (2010, p. 175), point out that there is an urgent need to acquire, document and preserve IK for agriculture before much of it is completely lost. In order to continuously harness such knowledge, further research could be conducted on the perspectives from the indigenous farming communities. For example, the impact of climate changes on traditional practices, and on the availability of traditional plants which are used in most remedies.

CONCLUSION

Indigenous Agricultural Knowledge was utilised as indicated by the majority of extension workers, although the frequency of utilisation varied among the respondents. The study also showed that Indigenous knowledge was used and highly appreciated by extension workers and was acquired from a variety of sources, both formal and informal. The top three sources of IK for extension workers were books, conferences/workshops and colleagues, with farmers' groups being the least mentioned source for the two groups. The study revealed that Indigenous knowledge derivation transcended across the different agriculture disciplines (crop science, soil science, animal science, and post-harvest storage).

Indigenous knowledge is used by farmers and extension workers as is evident from literature and the findings presented. It is applied in the crop production processes, which include planting, and protection against pests and other diseases, as well as in post-harvest. IK is also applied in animal husbandry in treating wounds and other diseases. Literature has, however, shown that there are challenges related to IK use in agriculture, which include the incapacity of traditional remedies to cure some ailments and how modern medicinal approaches become substitutes. As Ghorbani *et al*. (2012, p. 89) indicate indigenous knowledge is deteriorating quickly: by every death of old indigenous people, great knowledge resources would be lost also, so every action toward gathering indigenous knowledge is necessary. Singh and Sureja (2008, p. 653) challenge the need to educate policy makers and planners on the value of local and indigenous systems and the importance of integrating them in the development processes in South Africa, the government recognises and appreciates the importance of Indigenous knowledge and this has resulted in the establishment of a national IKS policy and dedicated secretariat (Njiraine, Ocholla & Onyancha, 2010, p. 195). Efforts have already been made for such integration in Uganda (Gorjestani, 2001) and Kenya (Kiplang'at & Rotich, 2008).

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The study recommends that IK methods should be documented and integrated into the curricula, especially extension training. The validity of IK against scientific measures is evident and supported by Mowo et al. (2006, p. 52), Buthelezi (2010), Osbahra and Allanb (2003). As noted by Rajasekaran, Martin and Warren (1994, p. 29), incorporating IK into agricultural extension education will among other things help to understand perspectives of local people, recognize the accomplishments of local farmers as well as increasing the participation of farmers and their organisations in integrating, utilizing and dissemination of what already exist.

REFERENCES

Abate, T., Van Huis, A., & Ampofo, J. K. O. (2000). Pest management strategies in traditional agriculture: An African perspective. *Annual Review of Entomology*, *45*(1), 631–659. Retrieved from http://www.annualreviews.org/doi/pdf/10.1146/annurev.ento.45.1.631 doi:10.1146/annurev.ento.45.1.631 PMID:10761592

Abioye, A., Zaid, Y., & Egberongbe, H. A. (2011, August 13-16). Documenting and disseminating agricultural indigenous knowledge for sustainable food security: The efforts of agricultural research libraries in Nigeria. *Paper presented at the 78th IFLA Conference*, San Juan, Puerto Rico. Retrieved from http://conference.ifla.org/past-wlic/2011/78-abioye-en.pdf

Abu, G. A. (2005). The use of indigenous knowledge in animal and crop pest management in Benue State, Nigeria. *Indilinga African Journal of Indigenous Knowledge Systems*, *4*(1), 243–248.

Adekunle, O. A., Oladele, O. I., & Olukaiyeja, T. D. (2002). Indigenous control methods for pests and diseases of cattle in northern Nigeria. *Livestock Research for Rural Development 14(*2). Retrieved from http://www.lrrd.org/lrrd14/2/adek142.htm

Akullo, D. (2007, August 19-23). Indigenous knowledge in agriculture: A case study of the challenges in sharing knowledge of past generations in a globalised context in Uganda. *Proceedings of the World Library and Information Congress: 73rd IFLA General Conference and Council*, Durban, South Africa. Retrieved from http://www.ifla.org/iv/ifla73/index.htm

Ali, Z., Yadav, A., Stobdan, T., & Singh, S. B. (2012). Traditional methods for storage of vegetables in cold arid region of Ladakh. *Indian Journal of Traditional Knowledge*, *11*(2), 351–353.

Aluma, J. R. W. (2001). Integrating of indigenous knowledge (IK) in agriculture and health development process in Uganda. Retrieved from http://www.underutilizedspecies.org/Documents/PUBLICATIONS/j_aluma_ik_uganda.pdf

Bagnall-Oakeley, H., Ocilaje, M., Oumo, F. I., Nangoti, N., Oruko, O. L., & Rees, D. (2004). Mapping and understanding farmers' indigenous agricultural knowledge and information systems and the implications for contracted research and extension systems. *Ugandan Journal of Agricultural Sciences*, *9*, 119–125. Retrieved from http://www.naro.go.ug/Events/NARO%20Conference/Documents/Papers/Theme%202/UJAS%209(1)%200119-0125%20Bagnall-Oakeley.pdf

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Bebbington, A. (1991). Indigenous agricultural knowledge systems, human interests, and critical analysis: Reflections on farmer organization in Ecuador. *Agriculture and Human Values*, *8*(1-2), 14–24. doi:10.1007/BF01579652

Bett, C., & Nguyo, R. (2007). Post-harvest storage practices and techniques used by farmers in semi-arid and eastern and central Kenya. African Crop Science Conference proceedings, 8, 1023-1027. Retrieved from http://www.acss.ws/Upload/XML/Research/387.pdf

Buthelezi, N. N. (2010). *The use of scientific and indigenous knowledge in agricultural land evaluation and soil fertility studies of Ezigeni and Ogagwini villages in KwaZulu-Natal, South Africa* [Unpublished MSc Thesis]. University of KwaZulu-Natal, Pietermaritzburg.

Dakora, F. D. (1996). Using indigenous to increase agricultural productivity in Africa. In H. Normann, I. Snyman & M. Cohen (Eds.), Indigenous knowledge and its uses in Southern Africa (pp. 109-136). Pretoria: HSRC Publishers.

De Amitendu, A. H. P. S., Tudu, B. and Goswami A. (2004). Indigenous technical knowledge in animal husbandry. *Livestock Research for Rural Development,* 16(8). Retrieved from http://www.lrrd.org/lrrd16/8/arun16059.htm

Dixon, A. B. (2001, January 23). Indigenous knowledge: Its significance for wetland management in Illubabor region. In A. B. Dixon, A. Hailu and A. P. Wood (Eds.), *Proceedings of the Wetland Awareness Creation and Activity Identification workshop in Amhara National Regional State,* Bahar Dar, Ethiopia (pp. 53-60). Retrieved from http://wetlands.hud.ac.uk/ewnra/bahardar.pdf

Egeru, A. (2012). Role of indigenous knowledge in climate change adaptation: A case study of the Teso sub-region, Eastern Uganda. *Indian Journal of Traditional Knowledge*, *11*(2), 217–224.

Elia, E. F., Mutula, S., & Stilwell, C. (2014). Indigenous knowledge use in seasonal weather forecasting in Tanzania: The case of semi-arid central Tanzania. *SA Jnl Libs & Info Sci*, *80*(1), 18–27.

FAO. (2003). *The agricultural extension system in Zimbabwe.* Retrieved from http://www.fao.org/DOCREP/005/AC913E/ac913e05.htm

Fenta, G. (2009). Farmers' indigenous knowledge, the missing link in the development of Ethiopian agriculture: A case study of Dejen district, Amhara region. *Social Science Research Report series, 34*, 3-5. Retrieved from http://publications.ossrea.net/index.php?option=com_content&view=article&id=40&limitstart=1

Foti, R., Nyakudya, I., Moyo, M., & Chikuvire, J. (2007). Determinants of farmer demand for fee-for-service extension in Zimbabwe. *IAALD Quarterly Bulletin*, *LII*(1/2), 28–34.

Fowler, R., & Rockstrom, J. (2001). Conservation tillage for sustainable agriculture: An agrarian revolution gathers momentum in Africa. *Soil & Tillage Research, 61*, 93-107. Retrieved from http://www.sciencedirect.com/science/article/pii/S0167198701001817#

Gana, F. S. (2003). The use of indigenous plant materials among small-scale farmers in Niger State Agricultural Development project. *Indilinga African Journal of Indigenous Knowledge Systems*, *2*(1), 53–60.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Ghorbani, E., Khodamoradi, M., Bozorgmanesh, M., & Emami, A. (2012). Indigenous knowledge in agriculture. *World Rural Observations, 4*(4), 88-92. Retrieved from http://www.sciencepub.net/rural

Gorjestani, N. (2001). Indigenous knowledge for development: Challenges and opportunities. Retrieved from http://www.worldbank.org/afr/ik/ikpaper_0102.pdf

Gyampoh, B. A., Amisah, S., Idinoba, M., & Nkem, J. (2009). Using traditional knowledge to cope with climate change in rural Ghana. *Unasylva, 60*, (231/232), 70-74. Retrieved from http://www.fao.org/3/a-i0670e/i0670e14.pdf

Handayani, I. P., & Prowito, P. (2010). Indigenous soil knowledge for sustainable agriculture. In E. Lichtfouse (Ed.), *Sociology, organic farming, climate change* (pp. 303–318). London: Springer Science. doi:10.1007/978-90-481-3333-8_11

Harwood, R. R. (1990). A history of sustainable agriculture. In C. A. Edwards, R. Lal, P. Madden, R. H. Miller, & G. House (Eds.), *Sustainable agricultural systems* (pp. 3–19). Ankeny, Iowa: Soil and Water Conservation Society.

Karthikeyan, C., Veeraragavathatham, D., Karpagam, D., & Firdouse, S. A. (2009). Traditional storage practices. *Indian Journal of Traditional knowledge, 8*(4), 564-568.

Kiplang'at, J. N., & Rotich, D. C. (2008, August 24-27). Mapping and auditing of agricultural indigenous knowledge in Uasin Gishu and Keiyo districts in Rift Valley Province, Kenya. *Proceedings of the World Conference on Agricultural Information and IT, IAALD, AFITA, WCCA '08*, Tokyo University of Agriculture, Tokyo, Japan (pp. 719-730). Retrieved from http://www.cabi.org/gara/FullTextPDF/2008/20083298153.pdf

Kolawole, O. D. (2005). Local farmers' approach to soil conservation: Lessons from Nigeria. *Indilinga – African Journal of Indigenous Knowledge Systems, 5*(1), 75-86.

Lakra, V., Singh, M. K., Sinha, R., & Kudada, N. (2010). Indigenous technology of tribal farmers in Jharkhand. *Indian Journal of Traditional Knowledge*, *9*(2), 261–263.

Lwoga, E. T., Ngulube, P., & Stilwell, C. (2010). Managing indigenous knowledge for sustainable agricultural development in developing countries: Knowledge management approaches in the social context. *The International Information & Library Review*, *42*(3), 174–185. doi:10.1080/10572317.2010.10762862

Masalu, D. C. P., Shalli, M. S., & Kitula, R. A. (2010). *Customs and taboos: The role of indigenous knowledge in the management of fish stocks and coral reefs in Tanzania*. Dar es Salaam: University of Dar es Salaam in association with World Bank. Retrieved from http://siteresources.worldbank.org/EXTCMM/Resources/CRTR_Customs_Taboos.pdf

Ministry of Agriculture, Mechanisation and Irrigation Development. (2010). *Department of Agricultural Technical and Extension Services.*

Mishra, P. K., & Rai, S. C. (2013). Use of indigenous soil and water conservation practices among farmers in Sikkim Himalaya. *Indian Journal of Traditional Knowledge*, *12*(3), 554–564.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Moreno, L. L., Tuxill, J., Moo, E. Y., Reyes, L. A., Alejo, J. C., & Jarvis, D. I. (2006). Traditional maize storage methods of Mayan farmers in Yucatan, Mexico: Implications for seed selection and crop diversity. *Biodiversity and Conservation, 15*, 1771–1795. Retrieved from http://download.springer.com/static/pdf/107/art%253A10.1007%252Fs10531-004-6679 0.pdf?auth66=1405084103_834980f0e7eca039cc1da3b54e89deba&ext=.pdf

Mowo, J. G., Janssen, B. H., Oenema, O., German, L. A., Mrema, J. P., & Shemdoe, R. S. (2006). Soil fertility evaluation and management by smallholder farmer communities in northern Tanzania. *Agriculture, Ecosystems & Environment*, *116*, 47–59. Retrieved from http://www.sciencedirect.com/science/article/pii/S0167880906001125#

Mugisha-Kamatenesi, M., Deng, A. L., Ogendo, J. O., Omolo, E. O., Mihale, M. J., Otim, M., ... Bett, P. K. (2008). Indigenous knowledge of field insect pests and their management around Lake Victoria basin in Uganda. *African Journal of Environmental Science and Technology*, *2*(8), 342–348. Retrieved from http://www.academicjournals.org/AJes

Mundy, P., & Compton, J. L. (1991). Indigenous communication and indigenous knowledge. *Development Communication Report*, *74*, 3. Retrieved from http://www.mamud.com/Docs/ic_and_ik_dcr.pdf

Mutasa, M. (2011). *Marrying indigenous knowledge and modern science sustains agriculture*. Retrieved from http://mukundi.wordpress.com/2011/01/06/marrying-indigenous-knowledge-and-modern-science-sustains-agriculture/

Njiraine, D., Ocholla, D., & Le Roux, J. (2008). Auditing the indigenous knowledge systems in South Africa (IKS): Challenges and opportunities. *ESARBICA*, *27*, 203–222.

Notsi, L. (2012, September 3-7). African indigenous farming methods used in the cultivation of African indigenous vegetables: a comparative study of Tsitas Nek (Lesotho) and Mabeskraal village (South Africa). *Paper presented at the conference: Strategies to Overcome Poverty & Inequality, "Towards Carnegie III"*, University of Cape Town. Retrieved from http://www.carnegie3.org.za/docs/papers/206_Notsi_African%20Indigenous%20farming%20methods%20used%20in%20the%20cultivation%20of%20African%20indigenous%20vegetables.pdf

Nyong, A., Adesina, F., & Elasha, B. O. (2007). The value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel. *Mitig Adapt Strat Glob Change, 12*, 787-797. Retrieved from http://ies.lbl.gov/iespubs/8nyong.pdf

Odeyemi, O. O., Masika, P., & Afolayan, A. J. (2006). Farmers' knowledge and experience of indigenous insect pest control in the Eastern Cape province of South Africa. *Indilinga – African Journal of Indigenous Knowledge Systems, 5*(2), 167-174.

Osbahra, H., & Allanb, C. (2003). Indigenous knowledge of soil fertility management in southwest Niger. *Geoderma*, *111*, 457–479. Retrieved from http://www.sciencedirect.com/science/article/pii/S001670610200277X#

Pazvakavambwa, S. C., & Hakutangwi, M. B. K. (2006). Agriculture extension. In M. Rukuni, P. Tawonezvi, C. Eicher, M. Munyuki-Hungwe, & P. Matondi (Eds.), *Zimbabwe's agricultural revolution revisited* (pp. 217–234). Harare: University of Zimbabwe Publications.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Protz, M. (1998). Developing sustainable agricultural technologies with rural women in Jamaica: A participatory media approach. Retrieved from http://www.fao.org/sd/CDdirect/CDan0020.htm

Rajasekaran, B., Martin, R. A., & Warren, D. M. (1994). A framework for incorporating indigenous knowledge systems into agricultural extension organisation for sustainable agricultural development in India. *Journal of International Agricultural and Extension Education*, *1*(2), 25–31. Retrieved from http://www.ciesin.org/docs/004-201/004-201.html

Rathore, S. S., Krose, N., Naro, M., Shekhawat, K., & Bhatt, B. P. (2012). Weed management through salt application: An indigenous method from shifting cultivation areas, Eastern Himalaya, India. *Indian Journal of Traditional Knowledge*, *11*(2), 354–357.

Reij, C., Scoones, I., & Toulmin, C. (1996). *Sustaining the soil: Indigenous soil and water conservation in Africa*. London: Earthscan Publications.

Rukuni, M. (2006). The evolution of agricultural policy: 1890-1990. In M. Rukuni, P. Tawonezvi, C. Eicher, M. Munyuki-Hungwe, & P. Matondi (Eds.), *Zimbabwe's agricultural revolution revisited* (pp. 29–61). Harare: University of Zimbabwe Publications.

Shetto, R. M. (1999). Indigenous soil conservation tillage systems and risks of animal traction on land degradation in Eastern and Southern Africa. In P.G. Kaumbutho, & T.E. Simalenga (Eds.), *Conservation tillage with animal traction* (pp. 67-73). Harare. Zimbabwe. Retrieved from http://www.atnesa.org/contil/contil-shetto-indigenous.pdf

Singh, R. K., & Sureja, A. K. (2008). Indigenous knowledge and sustainable agricultural resources management under rainfed agro-ecosystem. *Indian Journal of Traditional Knowledge*, *7*(4), 642–654.

Sinha, B. (2010). An appraisal of the traditional post-harvest management methods in Northeast Indian uplands. *Indian Journal of Traditional Knowledge*, *9*(3), 536–543.

Smit, N. E. J. M. (1997). The effect of the indigenous cultural practices of in-ground storage and piecemeal harvesting of sweet potato on yield and quality losses caused by sweet potato weevil in Uganda. *Agriculture, Ecosystems & Environment*, *64*(3), 191–200. doi:10.1016/S0167-8809(97)00022-4

Stigter, C. J., Dawei, Z., Onyewotu, L. O. Z., & Xurong, M. (2005). Using traditional methods and indigenous technologies for coping with climate variability. *Climatic Change*, *70*(1-2), 255–271. doi:10.100710584-005-5949-5

Sturges, P., & Neil, R. (1998). *The quite struggle: Information and libraries for the people of Africa* (2nd ed.). Loughborough: Cassell Academic.

Tekwa, I. J., Belel, M. D., & Alhassan, A. B. (2010). The effectiveness of indigenous soil conservation techniques on sustainable crop production. *Australian Journal of Agricultural Engineering*, *1*(3), 74–79.

Tikai, P., & Kama, A. (2004). *A study of indigenous knowledge and its role to sustainable agriculture in Samoa.* Retrieved from http://www.mnre.gov.ws/documents/forum/2004/11%20Kama.pdf

Umali-Deininger, D., & Schwartz, L. A. (1994). *Public and private agricultural extension: Beyond traditional frontiers*. Washington, D.C.: World Bank Publications. doi:10.1596/0-8213-2803-4

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United Nations Environmental Programme. (2008). *Indigenous knowledge in disaster management in Africa*. Nairobi: UNEP. Retrieved from http://www.icsu.org/icsu-africa/newscentre/news/Appendix9IndigenousBookletUNEP.pdf

Van den Ban, A. W., & Hawkins, H. S. (1996). *Agricultural extension* (2nd ed.). Oxford: Blackwell.

Warren, D. M. (1991). *Using indigenous knowledge in agricultural development*. World Bank Discussion Paper No. 127. Washington, D.C.: The World Bank.

Warren, D. M., & Cashman, K. (1988). *Indigenous knowledge for sustainable agriculture and rural development.* London: International Institute for Environment and Development, Sustainable Agriculture Programme. Retrieved from http://pubs.iied.org/pdfs/X101IIED.pdf

Woytek, R. (1998). *Indigenous knowledge for development: A framework for action.* Washington, D.C.: The World Bank. Retrieved from http://www.worldbank.org/afr/ik/ikrept.pdf

KEY TERMS AND DEFINITIONS

Agriculture Extension: The transfer of agricultural information and technology to the farmers and similarly transferring information from farmers to researchers.

Indigenous Agricultural Knowledge: The agricultural knowledge that peasant farmers have at any one time. It is constituted both by the empirical contents of that knowledge and by the principles that underlie its production, organization and meaning (Bebbington, 1990, p. 15).

Indigenous Knowledge: The sum of experience and knowledge of a given ethnic group that forms the basis for decision-making in the face of familiar and unfamiliar problems and challenges (Warren & Cashman, 1988, p. 3).

Sustainable Agriculture: An agriculture that can evolve indefinitely toward greater human utility, greater efficiency of resource use, and a balance with the environment that is favourable both to humans and to most other species (Harwood, 1990, p. 4).

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Chapter 50
Multiple Exploration of Entrepreneurs' Suggestions for Agricultural Development of Local Regional Units in Greece

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ABSTRACT

The purpose of the present article is to evaluate the factors which are considered to be important for the agribusiness development of a local economy, with data derived from the entrepreneurs' perspective. For this purpose, an appropriate methodology was designed, in order to include the most of the aforementioned factors. Emphasis was given to questions which can illustrate the level of technological innovation with actions and initiatives like digital marketing, innovative ability and others. Therefore, a questionnaire was created and was then applied to many regions in northern Greece. In respect of data analysis, the contribution of Correspondence Analysis (CA), a method from the multidimensional statistics field, was crucial because it easily revealed the characteristics that intensively differentiated themselves. The above methodologies and their special characteristics facilitated also the implementation of SWOT analysis. In the case of the Regional Units examined in the current research, the positive and negative factors-points were easily revealed and presented.

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INTRODUCTION

The agribusiness sector is facing many challenges worldwide, as the globalization affects its structure and access to markets. Having already many additional problems due to the complexities and uncertainties linked to the sector, it is nowadays even more essential to try to cope with and implement new methods and technologies. One major example of these complexities is the global production networks (Hampton et al., 2007).

The present chapter is the beginning of a new research with a principle goal to help the administrations of the local authorities or/and central government evaluate their performance in aiming to pursue rural economic development. In their effort to contribute to this field, one of the most important actions is to implement initiatives that can assist the agricultural enterprises to develop and stabilize strong entrepreneurship values. Another important activity in the same direction, is to evaluate and record the current situation in their local regional unit. This can be succeeded with the utilization of suitable instruments that collect information from the entrepreneurs themselves.

The above suggestion to collect information, can be realized with an effort to measure the factors that enhance agricultural development from the entrepreneurs' perspective. In order to collect the relevant information, the research presented here, is based on data obtained by a questionnaire survey. The questionnaire that created by the authors, contained a section about demographics and another one concerning the entrepreneurs' perception of the existed local agricultural development's actions-factors. The main goal is to provide an important tool that administrators of the local authorities could use to make decisions, with an aim to improve the economic climate, and furthermore to pursue development.

For the analysis of the data, Correspondence Analysis, a multidimensional statistical methodology, is mainly used, as the most suitable for discovering correspondences (Benzecri, 1992) between the variables. It is an exploratory methodology of data analysis that does not assume any distribution of the data and puts forward possible trends that exist in the data graphically (Greenacre, 2007), as well. The results are presented on graphs that represent the configuration of points in projection planes formed by the first principal axes (Lebart et al., 1984, p. 44). This approach enables the researcher not only to analyze the phenomenon in a more holistic way, but also to highlight potential issues and questions that have not been previously identified. Two proposed tables, which enable the evaluation of ordinal data in a different aspect, will also be utilized (Moschidis, 2006; 2009).

The methodology utilized for the determination of the relationships of the different characteristics, is S.W.O.T analysis. The specific technique is used to evaluate the Strengths, Weaknesses/Limitations, Opportunities, and Threats involved in any business project (Piercy & Giles, 1989). It involves specifying the objective of the business venture or project and identifying the internal and external factors that are favorable and unfavorable to achieve that objective (Helms & Nixon, 2010). In the present case it can be used as a measure for evaluating and presenting the factors that can contribute to the economic development of a local regional unit.

The research had started from regional units from Northern Greece, with a view to be generalized in national level. The study concluded in some interesting results; firstly, in some distinguished factors for the agricultural growth that should be taken into consideration by the authorities, and secondly in the realization that there appeared to be no differences in the opinions of entrepreneurs with different demographic backgrounds. The methodology used, seemed to be perfectly suitable to extract the elements that distinguished as from the present chapter.

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BACKGROUND

Agricultural Economic Development and Innovation

Agriculture is a business sector of the economy, but it seems to be a strategic one as it handles food safety and quality, it produces interdependencies with other sectors of the economy and deals with most of the natural resources of a country's economy (Ariza et al., 2013). The global demand for food will increase by 70% until 2050, but the productivity of the agricultural sector has decelerated the last years (GSRT, 2013;Moschidis & Arabatzis, 2013). For all the above factors, governments are obliged to pay a close attention to this part of the economy. For example, in the unified Europe, there are some common targets and policies for the agricultural policy.

As referred to the ''European Commission rural development program for 2014-2020'' (European Commission, 2014), some of the priorities to be followed are:

- Fostering knowledge transfer
- Enhancing competitiveness
- Promoting food chain organization and risk management
- Restoring, preserving and enhancing ecosystems
- Promoting resource efficiency and supporting the shift toward a low-carbon and climate-resilient economy
- Promoting social inclusion, poverty reduction and economic development in rural areas.

From all the above priorities it can be concluded that the agricultural sector inside the European Union should expand to fields like innovation or/and technology, that they may be seem peculiar (especially to Greek farmers) and perhaps a new addition for this sector, but they are implemented to all other business sectors and activities for many years and they seem to be essential to enhance competitiveness and to survive the demanding global environment. In addition, many researches have highlighted that topics as innovation, entrepreneurship and the learning organization have a linkage with market orientation (Johnson et al., 2009). Market orientation is also a key factor for the appropriate connection with the markets and the customer and this aspect has already been examined in the agribusiness field (van Duren et al., 2003).

Development of agricultural entrepreneurship has been an important policy in order to increase the value of agricultural production and open up the sector for businesses which is a clear departure from what obtained in the past, when oil prices were at their peak (Olawa & Olawa, 2015). Agribusinesses should compete not only on domestic markets, but on global as well (Esterhuizen, 2006) as competition and customer orientation have further increased (Dlamini & Kirsten, 2014). Developing entrepreneurial skills of the farmers seem to be essential to expand the competitive ness of their enterprises, many times needed just to survive or to find chances to expand more. A contribution to this effort can always be an effective regional policy (Polyzos & Arabatzis, 2005), which involves the increase of economic productivity. The productivity of the agricultural sector can be further associated with factors like good rural infrastructure (Llanto, 2012) and access to appropriate technology (Pinstrup-Andersen & Shimokawa, 2007). Investment in infrastructure contributes to the reduction in transport and marketing costs and therefore producers are better linked to markets (Ashok & Balasubramanian, 2006). Surely,

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governments through public investment can further contribute to the establishment of the above factors (Nadeem et al., 2011).

Innovation seems to be another key factor for economic growth and development, both for enterprises and countries. Innovation can be implemented in the fields of product, processes, organization and market (Śledzik, 2013) and can include and can be facilitated by technological aspects and actions (Papaioannou et al, 2015). Many of these actions are examined in the present questionnaire.

Greece's Status in Agricultural Entrepreneurship, Innovation, and Technology

Agriculture is the fourth most important economic activity (see economic sectors in ''Key terms and Definitions'' section) within the structure of Greek GDP(Gross Domestic Product) and represents 3.7% of the total (ELSTAT, 2016), which makes it essential for the Greek economy, although there was a decline in this percentage from 6.08% in 2000 to 3.7% in 2013. Certainly, the economic turmoil existed since 2008 has a serious negative impact to the Greek food sector (Chatzipetrou & Moshidis, 2016). In terms of employment, agriculture accounts for 13.2% of the total in the country (European Commission, 2016). The Northern Greece regions, which are examined in the present study, include those of Central, Eastern and Western Macedonia, Hepirus and Thrace. All together they assemble the 29.4% of the total number of Greek agricultural enterprises and the 26.7% of the added values of agricultural production (ELSTAT, 2009).

It seems that globalization has affected seriously the Greek agricultural sector, as it comes up afainst faces a situation with intense competitiveness with many other economies/countries that are in a position to offer much better prices and very often products of better quality. On the other hand, this globalization is always a big opportunity to enter into new markets and countries. Nevertheless, the Greek agricultural sector is confronts many negative issues, as the great number of small farms (European Commission, 2014) and the high rate of economically active people employed by the sector (Polyzos & Arabatzis, 2005).

Concerning the innovation implemented in this sector, there is a lag in innovation measurement for agricultural firms (Ariza et al., 2013) all over the world and therefore data from two big surveys, the Global Competitiveness and the Global Innovation were also utilized. These surveys present specific indices to express many aspects of economic activities, but surely the most important ones, like competitiveness and innovation (Cornell University, INSEAD & WIPO, 2015; World Economic Forum, 2013). Greece seems to have achieved notable results in the last years (Cornell University, INSEAD & WIPO, 2015; World Economic Forum, 2015), concerning the Competitiveness and Innovation indices and certain pillars (Graduates in science, Quality research institutes, Ease of protecting investions) have distinguished. However, these results refer to the overall Greek economy and entrepreneurship and there is no specific data for the agricultural sector.

METHODOLOGY

Questionnaire

The fifty-five (55) questions of the current questionnaire (Table 11, Appendix), were taken from the relevant bibliography and included topics concerning competitiveness, innovation and other aspects of entrepreneurship.

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More specifically the fifty-five questions (E1-E55), could be grouped in the following categories (in the parentheses some of them are referred):

- Economic factors (ease of getting credit, economic climate, strength of investors protection, effects of taxation, funding from ESPA program, supports new workplaces, agritourism's expansion).
- Marketing factors (effective advertising, consumer satisfaction (examination of trends), possibility of exports, local demand, intensity of local competition)
- Quality of products and processes (quality of local suppliers, possession of quality standards as ISO 9001, 22000 or Agrocert)
- Human capital-Training-Skills (education, extent of staff training, skills possession)
- Infrastructure Logistics-Transports: (quality of roads, connection with big urban centers)
- Internet access and usage: (ICT Access, ICT Use)
- Information and knowledge diffusion-technology: (knowledge diffusion)
- Environment and Energy (ecological sustainability, photovoltaic parks, natural resource protection, protection of biodiversity)
- Innovation in production and marketing: capacity for innovation, use of digital marketing, number of new products, patents.

There were also four questions about demographics: age, level of education, profession and sex. This study covers the results from a research started in the beginning of 2015 and completed in the April of the same year in all the Regional Units of Northern Greece. The questionnaire was distributed to a broad sample of entrepreneurs in the local economy over eighteen years old, covered all professions and education levels. The question for the entrepreneurs was: "To what degree do you think the following characteristics exist in your business sector or local economy?", and the possible answers were, 1:"not at all", 2:"little", 3:"somewhat", 4:"much", 5:"a great deal". Consequently, higher scores on this scale indicate the strong existence of the characteristic. Moreover, there was a definite distinction to which factors referred to the local economy and which to the local business sector.

The main subject to be answered was to seek the most and least featured factors that existed in the local economy or business sector. Afterwards, merely the questions from the agricultural entrepreneurs where distinguished and are presented from now on.

SWOT

The S.W.O.T. analysis is a methodology from the field of management science, which is used to evaluate the Strengths, Weaknesses/Limitations, Opportunities, and Threats existed in any business project. It involves specifying the objective of the business venture or project and identifying the internal and external factors that are favorable and unfavorable to achieve that objective. The final step of the method is a presentation of a table, which includes all the factors for the Strengths, Weaknesses/Limitations, Opportunities, and Threats that exist in the current project.

In the case of the regional public administration, SWOT analysis is a means of reviewing and evaluating on the performance and potentials of the local economy. With the execution of this process, to identify the local, regional unit economic performance, SWOT analysis can be a valuable evaluation tool for the management of the regional administration.

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Correspondence Analysis and Special Tables of Coincidences

C.A. is an exploratory technique of the data analysis field, which does not assume any distribution of the data and is putting forward intensively differentiated trends that exist in the data, graphically as well. (Moschidis et al., 2009).

In this project C.A. is applied to two proposed tables of coincidences:

1. The table of evaluation: this table displays the distribution of the n_1 individuals of group A in 3 grades of the three-grade scale (we assume for convenience that the p questions E1, E2,…, Ep are formulated in a three-grade scale (not at all(1)-moderate(2)- very much(3)), therefore the table of evaluation has the following form (Table 1):

For the meaning of the numbers $K_{ij,}$ we note that number, e.g. K_{23} equals the number of the individuals of group A that chose for the question E2 the grade 3.

2. The table of comparative evaluation (Moschidis, 2006, 2009, 2015), which is defined in the comparative evaluation of the questions E1, E2,…, Ep from the two (or more generally) groups A and B. This table derives from the horizontal union of the tables of evaluations of groups A and B, therefore the table of comparative evaluation has the following form (Table 2):

Subsequently, implementing the correspondence analysis to the table of comparative evaluation and the points-columns e.g. A2, B3 are close to the point-line E2 in the first factorial space, it transpires

Table 1. The table of evaluation of the group A

	A			**Sum**
	A1	**A2**	**A3**	
E1	K_{11}	K_{12}	K_{13}	n_1
E2	K_{21}	K_{22}	$\mathbf{K_{23}}$	n_1
Ep	K_{p1}	K_{p2}	K_{p3}	n_1
Sum	K_1	K_2	K_3	pn_1

Table 2. The table of comparative evaluation of groups A, B

	A			**B**			**Sum**
	A1	**A2**	**A3**	**B1**	**B2**	**B3**	
E1	K_{11}	K_{12}	K_{13}	K'_{11}	K'_{12}	K'_{13}	$n_1+n_2=n$
E2	K_{21}	K_{22}	K_{23}	K'_{21}	K'_{22}	K'_{23}	n
Ep	K_{p1}	K_{p2}	K_{p3}	K'_{p1}	K'_{p2}	K'_{p3}	n
Sum	$K_{.1}$	$K_{.2}$	$K_{.3}$	$K'_{.1}$	$K'_{.2}$	$K'_{.3}$	pn

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that group A evaluated the criterion E2 with the grade "moderate"(2), while the group B with the grade "very much" (3). With this aspect, the comparison of the views of the different groups A and B, for the criteria E1, E2,…, Ep is realized (Moschidis, 2006).

ANALYSIS

Descriptive Statistics

A brief presentation of some descriptive statistics of the sample analysed, are presented below:

The average grade of the responses in the fifty-five questions, of all the agricultural entrepreneurs in the 5-point scale was 2.65, which means that the economic characteristics examined in this research, are not very well implemented in the regions. For example the percentage of the entrepreneurs that replied "somewhat" was 32.72% (Table 4).

Application of the Proposed Methodology

Multivariate Analysis

Firstly, for the implementation of the Correspondence analysis, the table of evaluation for the fifty-five questions was created (see Table 5). This table, is the realized application of the first one of the proposed tables, which were referred above in the methodology section.

Table 3. Demographics of the respondents (agricultural entrepreneurs)

Gender	%	Age	%	Education Level	%
Male	65.2	18-30	36.1	Not attended	1.0
Female	34.8	30-44	28.1	Primary	33.5
		>45	35.8	Secondary	44.6
				Univ.graduate	19.2
				Post graduate	1.7

Table 4. Percentages of the responses in the 5-grade scale

Response-Grade	Percentage-%
1:not at all	18.00
2: little	27.00
3:somewhat	32.72
4:much	16.93
5:a great deal	5.35

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Table 5. Table of evaluation of the fifty-five questions

Questions	Grades						Questions	Grades						Questions	Grades				
	1	2	3	4	5			1	2	3	4	5			1	2	3	4	5
E1	20	51	78	29	2		**E19**	34	60	60	23	3		**E38**	76	50	40	9	5
E2	28	66	55	28	3		**E20**	20	45	71	37	7		**E39**	37	58	50	24	11
E3	20	50	76	28	6		**E21**	19	40	50	57	14		**E40**	24	62	67	22	5
E4	18	49	75	33	5		**E22**	23	50	79	27	1		**E41**	12	36	48	65	19
E5	19	58	71	29	3		**E23**	61	55	51	13	0		**E42**	12	27	46	63	32
E6	57	53	51	19	0		**E24**	28	52	75	22	3		**E43**	37	47	63	27	6
E7	44	**50**	69	16	1		**E25**	24	45	69	37	5		**E44**	50	64	53	11	2
⋮	⋮	⋮	⋮	⋮	⋮		⋮	⋮	⋮	⋮	⋮	⋮		⋮	⋮	⋮	⋮	⋮	⋮
E15	72	62	37	7	2		**E33**	16	12	34	51	67		**E52**	25	56	71	25	3
E16	35	22	57	44	22		**E34**	23	45	85	20	7		**E53**	29	53	71	25	2
E17	30	28	49	43	30		**E35**	11	48	66	45	10		**E54**	16	46	54	48	16
E18	71	52	42	14	1		**E36**	45	62	50	21	2		**E55**	22	56	76	26	0

For the better understanding of the numbers in the above cells, an example is given. Number 50 in question E7, corresponds to the grade 2 of the scale, which means that fifty respondents have answered "little" in this question.

The results after the implementation of the correspondence analysis, to the table of evaluation are following.

Firstly, the table of eigenvalues is presented, where the total inertia is 0.25167 (Table 6).

- The first factorial axis (first main trend) interprets with a percentage of 72.66 the researched issue.
- The second factorial axis (second main trend) has a 19.79 interpretation percentage.

The first factorial space interprets data with a percentage of 92.45, which is a very good and adequate percentage for further analysis.

From the results of correspondence analysis, which are presented in Table 7, we will use the most important interpretation indicator of point (characteristic) towards axis, which is Contribution (CTR), as it expresses its contribution's percentage, in axis construction. The points with large CTR towards the axis, construct and many times highlight its physical importance.

Table 6. Eigenvalues-Inertia for the table of evaluation

TOTAL INERTIA		0.25167		
AXIS	**INERTIA**	**%EXPLAN**	**SUM**	**SCREE PLOT**
1	0.1828533	72.66	72.66	**********
2	0.0498098	19.79	92.45	**********
3	0.0120358	4.78	97.23	***
4	0.0069669	2.77	100.00	**

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Table 7. Interpretation indicators: Co-ordinates (#F1), Projections-correlations (COR), Contributions (CTR) of the first two axes

	#F11	COR	CTR	#F22	COR	CTR			#F1	COR	CTRR	#F22	COR	CTR
E1	-92	87	1	-281	825	**28**		**E28**	-86	192	1	171	763	10
E2	-166	415	3	-103	159	4		**E29**	1342	953	**179**	281	41	**28**
E3	-24	8	1	-219	758	17		**E30**	212	322	5	-272	529	26
E4	3	0	1	-264	942	25		**E31**	77	72	1	-246	719	22
E5	-90	100	1	-251	780	22		**E32**	647	843	**41**	-105	21	4
E6	-382	768	14	175	162	11		**E33**	1350	816	**181**	604	163	**133**
E7	-309	835	10	9	0	1		**E34**	-57	30	1	-185	323	12
E8	-409	849	16	157	125	10		**E35**	207	353	5	-273	607	27
E9	-167	453	3	-44	30	1		**E36**	-301	857	9	86	70	3
E10	190	263	4	-270	528	**26**		**E37**	907	854	**81**	253	66	23
E11	-319	912	10	-57	29	2		**E38**	-442	426	19	493	532	**88**
E12	-381	775	14	106	60	5		**E39**	-69	155	1	116	454	5
E13	-305	709	10	35	9	1		**E40**	-136	286	2	-139	300	8
E14	-481	765	**22**	240	191	21		**E41**	527	754	**27**	-149	59	9
E15	-525	585	**27**	435	405	**69**		**E42**	774	965	**59**	32	1	1
E16	375	690	13	142	99	8		**E43**	-106	722	2	-8	3	1
E17	518	824	**26**	232	165	19		**E44**	-396	838	15	156	130	9
E18	-463	567	**21**	370	364	**50**		**E45**	-427	807	18	172	131	10
E19	-209	856	5	-49	45	1		**E46**	-96	318	1	-76	201	3
E20	67	84	1	-218	888	17		**E47**	-566	629	**31**	422	350	**65**
E21	339	621	11	-128	87	6		**E48**	-118	421	2	-86	223	3
E22	-135	182	2	-263	697	25		**E49**	-369	709	13	165	144	10
E23	-446	763	19	233	209	19		**E50**	117	417	2	-134	539	7
E24	-162	384	3	-158	368	10		**E51**	-198	394	4	-220	491	17
E25	11	2	1	-199	909	14		**E52**	-140	321	2	-181	542	11
E26	594	913	**35**	-119	36	6		**E53**	-168	494	3	-157	428	9
E27	311	812	10	131	143	7		**E54**	315	772	9	-114	100	5
								E55	-172	268	2	-270	663	**26**

Using F indicator (coordinate) we define the side of the axis in which the point (characteristic) is represented. Therefore, the points with positive coordinate are situated on the right side and on the other side are those with negative. We note that the average CTR is 1000:55= 18.18, where 55 is the number of the points-questions. Therefore, we can consider points of high contribution in axis construction, those with CTR values above average (CTR values over 20 are in bold for the first axis and over 25 for the second). Having in mind the above estimations and the help of the visualization of the axes (see Fig. 1, 2, 3), we conclude in the following results (Greenacre, 2007).

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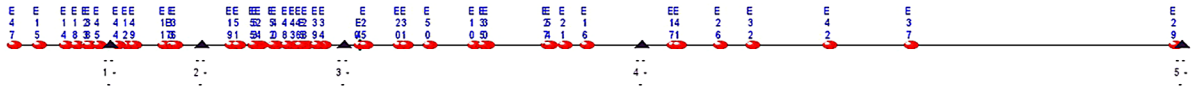
Figure 1. First factorial axis



The first axis (Figure 1), opposes characteristics, that have proved to exist in a great extent in the local economy or agricultural sector, the following: "Productivity of the sector" (E29), ''Connection with big urban centers (E32), "Unemployment" (E33), "Sectorial unemployment" (E37), "Tourist sector's development perspectives" (E41) "Secondary production perspectives" (E42), "Green development" (E17), '' Connection with other sectors'' (E26), to characteristics that their existence have been realized to be negligible, like: "Investments from outsiders" (E15) and "Innovative companies in the sector" (E47), ''Digital marketing in the sector'' (E14) and ''Photovoltaic parks (E18) .

The second axis (Figure 2) opposes factors that were ranked with 1 or 5, as: the "Investments from outsiders" (E15), "Photovoltaic parks" (E18), "Productivity in the sector" (E29), "Unemployment" (E33), "Knowledge diffusion in the sector" (E38), "Innovative companies in the sector" (E47) with factors that got the mediate values (3,4) like, "Care for biodiversity" (E1), "Access to internet" (E10), "Possession of quality certificates" (E55).

From the preceding analysis and Figure 3, we can conclude (Greenacre, 2007), that there are many factors that seem to strongly differentiate themselves. Firstly, the positive ones (that contribute positively to the economic environment and entrepreneurship) are: "Productivity of the sector" (E29), ''Connection with big urban centers (E32), "Tourist sector development perspectives" (E41) "Secondary production perspectives" (E42), "Green development" (E17), "Connection with other sectors" (E26). From the opposing point of view, the negative ones are presented: "Investments from outsiders" (E15), ''Innovative companies" (E47), ''Digital marketing" (E14), ''Knowledge diffusion" (E38), ''Connection with other sectors" (E26), ''Unemployment in the sector" (E37), "Unemployment" (E33), ''General state of the economy" (E5). From the above results, important conclusions can be drawn from the SWOT analysis, which can be seen in Tables 8,9 for the local economy and the agricultural sector, respectively.

Consequently, it is obvious that unemployment (inside the sector or not) from the perspective of the entrepreneurs, is a serious threat in the regions examined. On the other hand, there is an opportunity for the secondary production as well the tourist sector to further expand. Both previous factors are considered very important for the economic prosperity of any region. The agricultural sector of the regions examined, seems to experience some other problems too, like the lack of: innovation, knowledge diffusion and digital marketing, all of which are entrepreneurship friendly. On the other hand, the local

Figure 2. Second factorial axis

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Figure 3. First factorial space

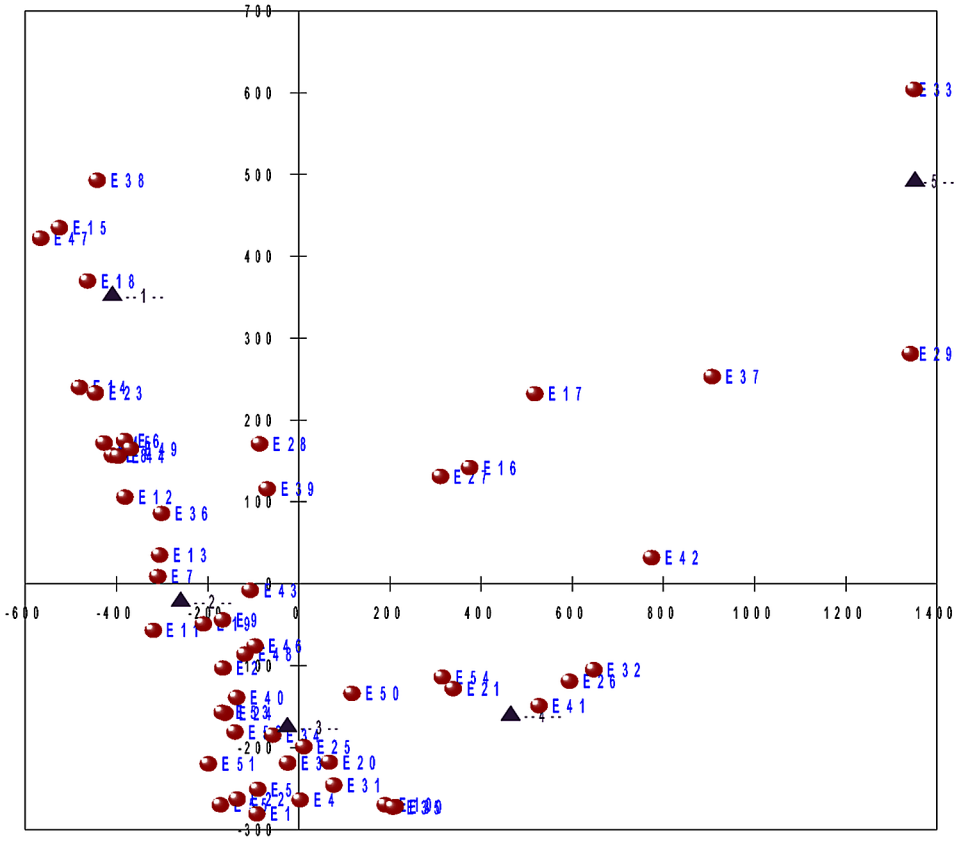

Table 8. SWOT analysis of the local economy

Strengths	Weaknesses	Opportunities	Threats
Green development	Investments from outsiders	Secondary production perspectives	Unemployment
	Photovoltaic parks	Tourism development perspectives	General state of economy
		Connection with big urban centers	

Table 9. SWOT analysis for the agricultural sector of the local economy

Strengths	Weaknesses	Opportunities	Threats
Productivity	Digital marketing	Connection with other sectors	Unemployment in the sector
	Innovative companies		
	Knowledge diffusion		

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agricultural sector seems to have an adequate connection with other sectors, and its productivity is well established. The general state of the economy is not well and there existed few investions from outside the local area. However, some other factors like green development, connecting with big urban centers, seem to be sufficiently featured in the regions examined.

Comparative Evaluation

Except from the above analysis, the effect of all the demographic variables on the factors was also examined. Here, the table of comparative evaluation, which gives the possibility to compare the performance of different groups is applied. The findings showed that the opinions of the citizens do not change when they have different demographic characteristics, a result that means the evaluation from an entrepreneur's perspective, is not affected by other factors.

As an example, the comparative table of the fifty-five questions and the level of education, was also analyzed, after the implementation of Correspondence Analysis in the table of comparative evaluation (Table 10). The symbolization "Sec" belongs to entrepreneurs having completed education below bachelor (secondary or primary or no) and "Univ" to entrepreneurs with bachelor or even higher education. Certainly, Sec1 is the first grade of the category "Sec", Sec2 is the second grade of the category and so on.

The results derived, concluded that there is no difference in the opinions between entrepreneurs with a different level of education. This is also obvious in the visualization of the results, which are displayed in the first factorial space (Figure 4). The entrepreneurs with different level of education 1:Sec, and 2:Univ, have given similar responses, which can be resulted by the closeness of the points. For example, it can be seen from the points 15 and 25 (in the circle), where 15 is the fifth grade of education level 1 and 25 is the fifth grade of education level 2.

FUTURE RESEARCH DIRECTION

The methodology presented in this research could be generalized in all Greek regions and therefore this offers a possibility to compare the economic situation in the different regions.

More questions could be included in the questionnaire, in order to explore the possible reasons for the delay of the economic development and moreover the implementation of technology innovations in the agribusiness sector in Greece.

Local and central governments can adopt measures to improve the situation regarding the economic climate and the same research could be repeated after some years in the same regions, in order to make longitudinal comparisons.

CONCLUSION

The questionnaire designed for the purpose of the present study and which was pilot tested in regions of Northern Greece, has achieved with great ease to extract the most important factors of the economic environment and economic performance, assisted in this effort by a method of the multidimensional statistics field. Regarding the final results, about the local entrepreneurship's opinions of the factors appropriate for economic development in all the regions, differences were detected in some factors.

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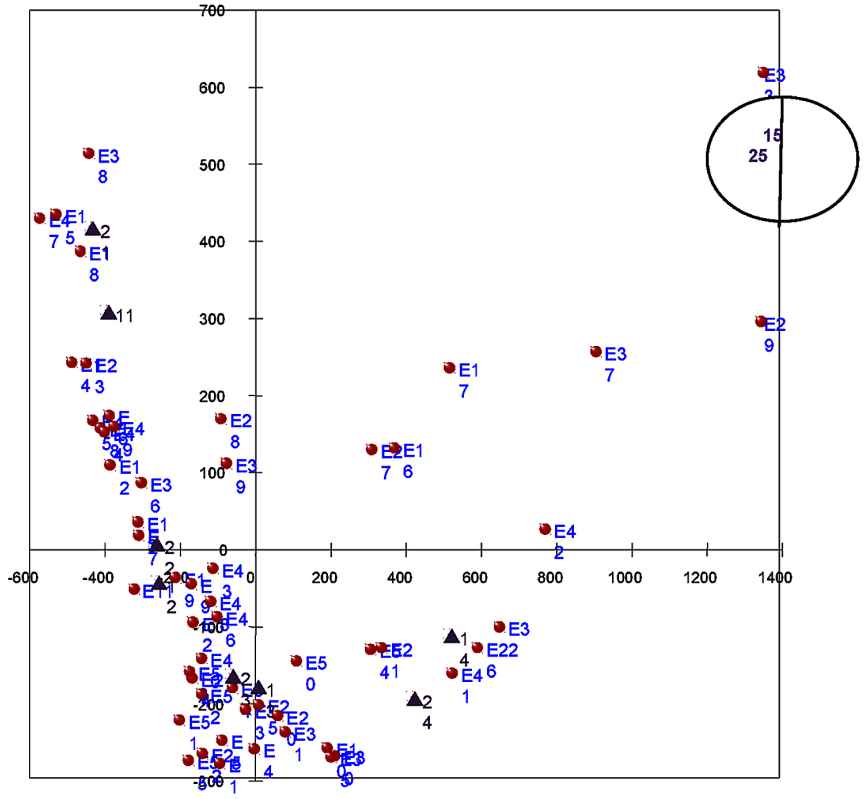
Table 10. Table of comparative evaluation of questions and level of education

Ind	Sec1	Sec2	Sec3	Sec4	Sec5	Univ1	Univ2	Univ3	Univ4	Univ5
E1	10	25	44	10	2	10	26	34	19	0
E2	15	30	33	12	1	13	36	22	16	2
E3	9	26	40	13	3	11	24	36	15	3
E4	8	30	36	14	3	10	19	39	19	2
E5	15	23	38	14	1	4	35	33	15	2
E6	32	28	24	7	0	25	25	27	12	0
E7	23	21	40	6	1	21	29	29	10	0
E8	30	30	25	5	1	21	35	25	8	0
E9	21	24	37	8	1	15	22	37	11	4
E10	9	18	37	25	2	9	19	30	26	5
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
E50	13	28	32	13	5	9	19	30	26	5
E51	14	27	43	7	0	13	25	34	17	0
E52	18	27	36	10	0	7	29	35	15	3
E53	17	31	32	11	0	12	22	39	14	2
E54	11	30	25	18	7	5	16	29	30	9
E55	15	31	34	11	0	7	25	42	15	0

Figure 4. First factorial space of the table of comparative evaluation



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This result makes it possible for the researcher to discover the strengths and weaknesses of municipality's economic performance and the possible potentials, for further improvement. In addition, it can be concluded that the general perception of the current situation in the regions examined is not influenced by the social characteristics of the entrepreneurs like level of education, age and sex. Concerning the innovation and technological aspects that companies could use, it can be deducted that the agricultural sector in the regions examined in this study, did not manage to implement most of them.

Moreover, the present questionnaire can be an important tool to evaluate factors that contribute to the local economic development and can be used to extract the crucial factors that SWOT analysis requires. The correspondence analysis method seems to be perfectly suited for the extraction of the elements needed to perform the SWOT analysis. Particularly, with the contribution of the two proposed tables of evaluation, the final choice of the crucial factors was precise and immediate. This proposed method, can also be used as an instrument to measure and compare different regions' performance, with the help of the indicators (questions) presented in the current study. This project can provide a measurement tool for Central Administration-Government, in order to compare and evaluate the economic performance and environment to different regions. It is a way to implement benchmarking, with the creation of a network of public administrations' organizations which have common practices, and to develop a peer evaluation among them (Cappelli et al., 2011). This performance can be a criterion for another evaluation; the appropriate exploitation of the resources, that municipalities have at hand, in order to achieve their goals.

REFERENCES

Ariza, C., Rugeles, L., Saavedra, D., & Guaitero, B. (2013). Measuring Innovation in Agricultural Firms: A Methodological Approach. *Electronic Journal of Knowledge Management*, *11*(3), 185–198.

Ashok, K. R., & Balasubramanian, R. (2006). *Role of Infrastructure in Productivity and Diversification of Agriculture, A Research Report*. Islamabad, Pakistan: SANEI.

Benzecri, J. P. (1992). *Correspondence Analysis Handbook*. New York: Taylor & Francis.

Cappelli, L., Guglielmetti, R., Mattia, G., Merli, R., & Renzi, M. F. (2011). Peer evaluation to develop benchmarking in the public sector. *Benchmarking an International Journal*, *4*(4), 490–509. doi:10.1108/14635771111147605

Chatzipetrou, E., & Moschidis, O. (2016). Quality costing: A survey in Greek supermarkets using multiple correspondence analysis. *International Journal of Quality & Reliability Management*, *33*(5), 615–632. doi:10.1108/IJQRM-01-2014-0004

Cornell University, INSEAD, & WIPO. (2015). *The Global Innovation Index 2015: Effective Innovation Policies for Development*. Authors.

Dlamini, B., Kirsten, J., & Masuku, M. (2014). Factors Affecting the Competitiveness of the Agribusiness Sector in Swaziland. *Journal of Agricultural Studies, 2*(1).

Esterhuizen, D. (2006). *An Evaluation of the Competitiveness of the South African Agribusiness Sector*. University of Pretoria. Available from UPeTD: Retrieved June 12, 2016, from http://upetd.up.ac.za/thesis/ available/ etd-12082006144349/ unrestricted/ 00front.pdf,9/3/2010

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

European Commission. (2014). *Rural development programme*. Retrieved June 10, 2016, from http://ec.europa.eu/agriculture/rural-development-2014-2020/

European Commission. (2016). *Factsheet on 2014-2020 Rural development programme for Greece*. Retrieved July 12, 2016, from http://ec.europa.eu/agriculture/rural-development-2014-2020/country-files/el/factsheet-greece_en.pdf

General Secretariat of Research and Technology-GSRT. (2013). *Research and Innovation in the Agro-bioalimentary cluster for the 2014-2020 period* (in Greek). Retrieved July 12, 2016, from http://www.gsrt.gr/Financing/Files/ProPeFiles48/ΤΟ%20ΑΓΡΟΒΙΟΔΙΑΤΡΟΦΙΚΟ%20ΣΥΜΠΛΕΓΜΑ%202014-2020_ΕΣΠΕΚ_10-7-2013_A_FINAL.pdf

Greenacre, M. (2007). *Correspondence Analysis in Practice*. Boca Raton, FL: Chapman and Hall/CRC. doi:10.1201/9781420011234

Hampton, R., Fromm, I., & Nyhodo, B. (2007). *International Trade, Consumer Behaviour and Trust: Factors Affecting Agribusinesses in Developing Countries*. Marketing Department Faculty Publications. Retrieved June 20, 2016), from http://digitalcommons.unl.edu/marketingfacpub/6

Hellenic Statistical Authority (ELSTAT). (2009). *Results of Agricultural-Livestock Census 2009*. Retrieved from http://www.statistics.gr/el/statistics/-/publication/SPG31/-

Johnson, A., Dibrell, C., & Hansen, E. (2009, Spring/Fall). Market Orientation, Innovativeness, and Performance of Food Companies. *Journal of Agribusiness*, *27*(1/2), 85–106.

Hellenic Statistical Authority (ELSTAT). (2016). *Gross value added by industry (A10) - NACE REV.2, the sector of Agriculture, Forestry*. Retrieved June 10, 2016, from http://www.statistics.gr/el/statistics/-/publication/SEL45/-

Helms, M. M., & Nixon, J. (2010). Exploring SWOT analysis - where are we now? A review of academic researchfrom the last decade. *Journal of Strategy and Management*, *3*(3), 215–251.

Llanto, G. (2012). *The impact of infrastructure on agricultural productivity*. Philippine Institute for Development Studies, Series: Discussion paper series (Philippine Institute for Development Studies), no. 2012-12.

Moschidis, O. (2006). A proposal of comparative evaluation with the correspondence analysis [in Greek]. *Journal SPOUDAI*, *56*(3), 95–113.

Moschidis, O. (2015). Unified coding of qualitative and quantitative variables and their analysis with ascendant hierarchical classification. *International Journal of Data Analysis Techniques and Strategies*, *7*(2), 114–128. doi:10.1504/IJDATS.2015.068745

Moschidis, O., & Arabatzis, G. (2013). SHP stations and integrated rural development: A multivariate statistical approach. *International Journal of Green Economics*, *7*(4), 333–347. doi:10.1504/IJGE.2013.058561

Moschidis, O., Spathis, C., & Floropoulos, I. (2009). Methodological approach to Multidimensional exploratory evaluation of Taxis (Taxation information system) usefulness:Greek economy in Perspective. *Journal of Financial Management and Analysis:International Review of Finance*, *22*(2), 1–12.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Moschidis, O. E. (2009). A different approach to multiple correspondence analysis (MCA) than that of specific MCA. *Mathématiques et sciences humaines. Mathematical Social Sciences*, (186), 77–88.

Nadeem, N., Mushtaq, K., & Javed, M. I. (2011). Impact of social and physical infrastructure on agricultural productivity in Punjab, Pakistan - A production function approach. *Pakistan Journal of Life and Social Sciences*, *9*(2).

Olowa O.W., & Olowa, O.A. (2015). Factors Affecting Entrepreneurship Development in Agribusiness Enterprises in Lagos State. *Global Journal of Management and Business, 15*(7).

Papaioannou, E., Georgiadis, C. K., Moschidis, O., & Manitsaris, A. (2015). Factors Affecting Customers Perceptions and Firms Decisions Concerning Online Fast Food Ordering. *International Journal of Agricultural and Environmental Information Systems*, *6*(1), 48–78. doi:10.4018/ijaeis.2015010104

Piercy, N., & Giles, W. (1989). Making SWOT Analysis Work. *Marketing Intelligence & Planning*, *7*(5/6), 5–7. doi:10.1108/EUM0000000001042

Pinstrup-Andersen, P., & Shimokawa, S. (2007). Rural Infrastructure and Agricultural Development. In F. Bourguignon & B. Pleskovic (Eds.), *Annual World Bank Conference on Development Economics – Global 2007: Rethinking Infrastructure for Development* (pp. 175-203). Washington, DC: The World Bank.

Polyzos, S., & Arabatzis, G. (2005). *Labour Productivity of the Agricultural Sector in Greece: Determinant Factors and Interregional Differences Analysis*. Department of Planning and Regional Development, School of Engineering, University of Thessaly, Discussion Paper Series.

Śledzik, K. (2013). Schumpeter's view on innovation and entrepreneurship. In Management Trends in Theory and Practice. University of Zilina. doi:10.2139srn.2257783

van Duren, E., Sparling, D., Turvey, C., & Lake, L. (2003). An assessment of the strategies and strengths of medium-sized food processors. *Agribusiness: An International Journal*, *19*(1), 115–132.

World Economic Forum. (2013). *The Global Competitiveness Report 2013–2014*. Geneva: World Economic Forum.

World Economic Forum. (2015). Retrieved from http://www.weforum.org/reports/global-competitiveness-report-2014-2015

KEY TERMS AND DEFINITIONS

Central Administration-Government: The government of a nation-state and this is a characteristic of a unitary state.

Digital Marketing: The advancement of items or brands through one or more types of electronic media. For instance, publicizing mediums that may be utilized as a major aspect of the advanced advertising system of a business could incorporate limited time endeavors made by means of the Internet, online networking, cellular telephones and electronic boards, and in addition through computerized and TV and radio stations.

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Green Development: It is an area use arranging idea that incorporates thought of group wide or local natural ramifications of improvement, and site-particular green building ideas. This incorporates city arranging, natural arranging, engineering, scene design and group building.

Infrastructure: Relatively lasting and foundational capital venture of a nation, firm, or venture that underlies and makes conceivable all its monetary movement. It incorporates authoritative, information transfers, transportation, utilities, and waste expulsion and preparing offices. A few definitions additionally incorporate instruction, human services and innovative work.

Innovation: The way toward deciphering a thought or development into a decent or administration that makes esteem or for which clients will pay. In business, advancement frequently comes about when thoughts are connected by the organization with a specific end goal to facilitate fulfill the necessities and desires of the clients.

Knowledge Diffusion: The way toward imparting exploration, developments as well as information to people, gatherings or associations.

Learning Organization: An association that gains learning and enhances sufficiently quick to survive and flourish in a quickly evolving environment. Learning associations (1) make a society that empowers and backings nonstop representative learning, basic considering, and hazard bringing with new thoughts, (2) permit mix-ups, and esteem worker commitments, (3) gain for a fact and test, and (4) disperse the new information all through the association for fuse into everyday exercises.

Market Orientation: A business methodology or logic that spotlights on distinguishing and meeting the expressed or shrouded needs or needs of clients.

Productivity: A measure of the productivity of a man, machine, processing plant, framework, and so on., in changing over inputs into valuable yields. Productivity is processed by partitioning normal yield per period by the aggregate costs caused or assets (capital, vitality, material, faculty) devoured in that period.

Sector (Economy/Business): The economic-business sector or corporate sector is a part of the economy made up by companies with the same characteristics. The three-sector theory in the economics, subdivides them into: The Primary Sector (Raw Materials): Agriculture, Fishery, Forestry. The Secondary Sector (Manufacturing): Manufacturing, Construction. The Tertiary Sector (Sales and Services): Services, Trade.

Technology: The intentional use of data in the configuration, generation, and usage of products and administrations, and in the association of human exercises.

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APPENDIX

Table 11 presents the number of entrepreneurs per question and grade, the averages of the responses per question and the analytical description of the questions.

Table 11. Grades and averages of the 55 questions

Number	Gr1	Gr2	Gr3	Gr4	Gr5	Aver.	Question	Gen/Sec*
E1	20	51	78	29	2	2.7	Care for the protection of biodiversity	General
E2	28	66	55	28	3	2.5	Care for the protection of natural resources	General
E3	20	50	76	28	6	2.7	Diffusion of knowledge and information	Sectorial
E4	**18**	**49**	**75**	**33**	**5**	**2.8**	Satisfaction from income	General
E5	**19**	**58**	**71**	**29**	**3**	**2.7**	Effective advertising	Sectorial
E6	57	53	51	19	0	2.2	Expectations of the agricultural policy implemented	Sectorial
E7	44	50	69	16	1	2.3	Intense business activity in your sector	Sectorial
E8	51	65	50	13	1	2.2	Encouragement of private initiative from local or central government	General
E9	36	46	74	19	5	2.5	Cooperation of local authority and entrepreneurs	General
E10	18	37	67	51	7	3.0	Access to internet and WWW	Sectorial
E11	37	61	65	17	0	2.3	Exploitation of European funding programs (ESPA)	General
E12	45	72	46	16	1	2.2	New technology and informatics usage	Sectorial
E13	40	70	46	23	1	2.3	Innovative agricultural companies	Sectorial
E14	56	70	45	8	1	2.0	Usage of digital marketing	Sectorial
E15	72	62	37	7	2	**1.9**	**Investments from outsiders**	General
E16	35	22	57	44	22	3.0	Environment awareness	Sectorial
E17	**30**	**28**	**49**	**43**	**30**	**3.1**	**Green development**	Sectorial
E18	**71**	**52**	**42**	**14**	**1**	**2.0**	**Creation of Photovoltaic parks**	General
E19	34	60	60	23	3	2.5	Support from government	General
E20	20	45	71	37	7	2.8	Contribution of tourism to the local economy	General
E21	19	40	50	57	14	**3.0**	Contribution of agricultural sector to the local economy	Sectorial
E22	23	50	79	27	1	2.6	Market knowledge	Sectorial
E23	**61**	**55**	**51**	**13**	**0**	**2.1**	**General state of economy**	General
E24	28	52	75	22	3	2.6	*Cost of using infrastructure*	General
E25	24	45	69	37	5	2.7	Access to internet and WWW	Sectorial
E26	12	27	58	60	23	**3.3**	**Connection with other sectors**	Sectorial
E27	27	43	52	35	23	2.9	Quality products	Sectorial

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Table 11. Continued

Number	Gr1	Gr2	Gr3	Gr4	Gr5	Aver.	Question	Gen/Sec*
E28	45	49	50	26	10	2.5	Education and training of your sector	Sectorial
E29	3	10	45	64	58	**3.9**	**Productivity of your sector**	Sectorial
E30	16	39	66	51	8	3.0	Impact of Taxation	General
E31	22	39	71	43	5	2.8	Connection with the rest Greece	General
E32	14	23	52	68	23	**3.4**	**Connection with big near urban centres**	General
E33	16	12	34	51	67	**3.8**	**Unemployment**	General
E34	23	45	85	20	7	2.7	Number of Associations, Partnerships, Consortiums	Sectorial
E35	11	48	66	45	10	3.0	Number of Tourists	General
E36	45	62	50	21	2	2.3	Number of new patents, products	General
E37	11	25	57	40	47	**3.5**	Seasonal unemployment	General
E38	76	50	40	9	5	2.0	Knowledge diffusion in your sector	Sectorial
E39	37	58	50	24	11	2.5	The interest of the young people to become businessmen in the region	General
E40	24	62	67	22	5	2.6	Connection of primary sector with secondary	General
E41	**12**	**36**	**48**	**65**	**19**	**3.2**	**Developmental perspectives of the tourist sector**	General
E42	12	27	46	63	32	3.4	**Secondary sector perspectives**	General
E43	37	47	63	27	6	2.5	Existence of companies with export activity	General
E44	50	64	53	11	2	2.2	Agrotourism expansion	General
E45	51	69	47	12	1	2.1	Investors' protection	General
E46	28	56	66	23	7	2.6	Reduction of local products	Sectorial
E47	75	57	42	6	0	1.9	**Innovative companies**	**Sectorial**
E48	30	59	56	31	4	2.6	Special skills of the staff	Sectorial
E49	58	47	56	19	0	2.2	Support new workplaces	General
E50	22	47	62	39	10	2.8	Well-trained staff	Sectorial
E51	27	52	77	24	0	2.5	Quality of roads	General
E52	25	56	71	25	3	2.6	**Satisfied with the state of economy**	General
E53	29	53	71	25	2	2.5	Companies are close to the consumer	Sectorial
E54	16	46	54	48	16	3.0	Intensity of local competition	Sectorial
E55	22	56	76	26	0	2.6	Possession of ISO or other quality certificates	Sectorial

* Gen=General(for the local economy), Sec=Sectorial(for the specific sector)

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Chapter 51
Agricultural Productivity in Indonesian Provinces

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ABSTRACT

Indonesia has been recognized as a country with significant potential in agriculture, not only to be self-sufficient in terms of food, but also to be the "food basket" for the world. However, given limited and competing use of resources, raising agricultural productivity is of paramount importance. To date, most of the existing work on Indonesia's agricultural sector is at the national level. Considering the extent of Indonesia's regional diversity, a provincial-level analysis of the country's agricultural sector would be more useful from a policy perspective. In this light, this paper examines agricultural productivity growth in Indonesian provinces during 2000-2011 and draws policy implications from such empirical analysis. The paper uses two methodologies, namely growth accounting and Malmquist index data envelopment analysis. Results suggest that technological change has been improving for most provinces, though there is wide variation in technical efficiency change which in turn is driving differences in total factor productivity growth across provinces.

1. INTRODUCTION

Indonesia is a vast archipelagic country with tremendous potential in its agricultural output. Although agriculture's contribution to the country's gross domestic product (GDP) has steadily decreased from 35.3 percent in 1960 to 11.5 percent in 2012, the sector still employed about 35 percent of Indonesia's labour force as of 2012. Within the agricultural sector, in terms of the contribution of each sub-sector, farm food crops and horticulture together contributed to nearly half of the agriculture's share of GDP

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in 2012. While estate crops[1] and livestock represented about 22.8 and 12.6 percent, respectively, the remaining 17.6 percent came from fisheries and forestry (Biro Pusat Statistik, 2012).

Indonesia's trade surplus in agriculture is mainly a result of its exports of estate crops while its major imports include wheat, cotton, sugar, soybeans, and maize. In fact, Indonesia is one of the world's major producers and exporters of estate crops such as palm oil, rubber, palm kernel, coffee, coconut (copra), cocoa, tea, and spices. Within Asia, Indonesia contributed to more than one third of total agricultural output of the Association of Southeast Asian Nations (ASEAN) (Food and Agriculture Organization, 2012).

Agricultural development policy in Indonesia has evolved in four significant phases (Fuglie, 2010). During 1961-1967, Indonesia had poor macroeconomic performance characterized by slow output growth with very few modern inputs and small improvements in productivity. From 1968-1992, a green revolution took place and agriculture was the top priority in the economic development agenda which gave rise to the invention and wide dissemination of a number of high-yielding varieties, as well as implementation of pro-agricultural policies. During 1993-2001, the agricultural sector faced stagnation, coupled with the Asian Financial Crisis (AFC) in 1997, with fewer sources for public spending in agriculture. Post AFC, the period of 2002-2006 marked the liberalization era of Indonesia's agricultural sector, where import restrictions on food crops were removed. This was a period of significant diversification of agricultural output with land expansion mostly for estate crops. The agricultural value-added in Indonesia expanded by more than one-third from 1993 to 2006 (World Bank, 2012b).

The trend for agricultural output remained positive as strong macroeconomic performance translated into more resources to pursue pro-agricultural policies. This was intertwined with the government's pro-poor policy as agricultural growth and productivity were often cited as the means to reduce rural poverty. According to the OECD (2012), incidence of poverty in rural areas was twice as high as in urban areas and almost three-fifth of the poor depended on agriculture as the main source of income. Hence, continued progress in agricultural productivity and incomes from agriculture plays an important role in diminishing rural poverty. Indonesia has been recognized as a country with significant potential in agriculture, not only to be self-sufficient in terms of food, but also to be the "food basket" for ASEAN and the world. However, given limited and competing use of resources, raising agricultural productivity is of paramount importance.

Indonesia has a considerably diverse agricultural sector and it is most evident when one compares the relative resource endowments and commodities across islands. Rice as a staple crop is widely cultivated in Java Island, with Sumatra being well known for its vast palm oil plantations and Sulawesi for cocoa. Beyond that, diversity persists in other aspects as well, such as in terms of the size of agricultural sector in their own economy and also their contribution to the national agricultural output. For instance, in terms of agricultural sector as a share of GDP in 2011, it was 46 percent in West Sulawesi GDP but a negligible 0.1 percent for DKI Jakarta. The Java Island -- consisting of East Java, West Java, Central Java, Banten, DI Yogyakarta, and DKI Jakarta -- contributed to just over two-fifth percent of national agricultural output in 2011 even though agriculture itself was no longer a prominent economic driver to the island, contributing to only 9.7 percent of Java's GDP. On the contrary, agriculture is still the main economic driver for easternmost provinces such as North Maluku, Maluku, West Papua, and Papua. In fact, agriculture contributed to 20.5 percent of their GDP as a whole. However, their agricultural output only made up 2.5 percent of national agricultural output in 2011.

Despite variations in agricultural contribution to GDP for each province, what persists is a sizeable share of employment in agricultural sector across provinces. In West Sulawesi for example, 59 percent of its labour force worked in agricultural sector and contributed to about 46 percent of its GDP in 2011.

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Sizeable agricultural employment was also found in East Java and Central Java, at about 40 percent and 34 percent in 2011, respectively, even though the share of agriculture in their GDP was relatively small at 14 percent and 18 percent, respectively.

While most of the existing work on Indonesia's agriculture is at the national level, considering the extent of Indonesia's regional diversity as outlined above, a provincial-level analysis of the country's agricultural sector would prove to be more useful from a policy perspective. In this light, this paper examines agricultural productivity growth in Indonesian provinces during 2000-2011 and draws policy implications from such an empirical analysis.

The remainder of the paper is structured as follows. Section 2 provides a literature review on the studies on Indonesia's agricultural productivity to date. Section 3 details the methodology and data to be used in this paper. Section 4 discusses the findings. Section 5 concludes the paper with some policy implications.

2. LITERATURE REVIEW

Various papers have examined agricultural total factor productivity (TFP) in Indonesia with largely varied findings owing to the use of different methodologies, time periods, specification of variables, and data sources, as summarized in Table 1. Relying on more than four decades of time series data, Avila & Evenson (2010) and Fuglie (2010) reported a relatively high TFP growth of 2 percent and 1.8 percent, respectively. They further decomposed the TFP growth into different periods of analysis. The authors found that TFP growth was higher in 1961-1980 at around 4.4 percent than during 1981-2001 with a negative productivity growth of -0.39 percent.

Similar trends could be found in Fuglie (2010) who reported decadal TFP growth rates and found it to be around 3 percent during 1961-1970; followed by about 2 percent growth in the next decade; a little more than 1 percent during 1981-1990; a little less than 1 percent in 1991-2000; and finally about 2.4 percent between 2001 and 2006. A follow-up study by Fuglie (2012) covered close to five decades of data. The paper found that the most recent period 2001-2009 charted the highest TFP growth at around 3.7 percent. The steep decline in TFP growth from the 1980s till 2000 compared the period between 1960 and 1980 was triggered by period of economic stagnation, while the turnaround since 2001 could be attributed to more resources devoted to agriculture, as well as diversification towards estate crops.

The papers listed in Table 1 employed either growth accounting, the Tornqvist-Thiel Index or the Malmquist Index to estimate TFP growth. They also used different sets of output and inputs. For instance, Mundlak et al. (2002) and Warr (2009) used broad agricultural GDP as their output that typically also included forestry and fishery from Indonesia's Statistical Bureau, *Biro Pusat Statistik* (BPS). Meanwhile, Fuglie (2010) limited the output to only include crops, livestock, and aquaculture. Avila & Evenson (2010), Coelli & Rao (2005), and Suhariyanto & Thirtle (2001) used only production of crops and livestock to measure output. For inputs, these papers generally included land, labour, fertilizer, and machinery. National-level data were often sourced from FAO database, BPS, and/or estimated by the authors using available proxies.

The literature listed in Table 1 revealed that most of the existing literature measuring agricultural TFP growth had been done at national-level. However, given the significant regional differences in Indonesia, as explained earlier, this paper will contribute to the growing literature by shedding light on the dynamics of agricultural TFP growth across provinces in Indonesia.

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Table 1. Summary of literature

Author	Methodology	Time Period	Specification of Variables	Data Source	TFP Growth
Suhariyanto & Thirtle (2001)	Malmquist Index	1965-1996	Output: Total value of agricultural production in crops and livestock; Input: land, labour, livestock, fertilizer, and machinery;	USDA World Agricultural Trends and Indicators; FAO Agrostat Database	0.17
Mundlak et al. (2002)	Aggregate production function similar to Cobb-Douglas with a major difference from constant coefficients function in that the coefficients in equation are functions of the state variables and possibly of the inputs.	1971-1998	Output: log of agricultural GDP; Input: irrigated land, rainfed land, fertilizers, capital, and labour; The state variables included: roads, measures of education, health, and incentives;	BPS; FAO	1.49
Coelli & Rao (2005)	Malmquist Index	1980-2000	Output: crops and livestock output; Input: land, tractors, labour, fertilizer, livestock, and irrigation.	FAO Agrostat Database	0.98
Warr (2009)	Growth accounting	1980-2006	Output: agricultural GDP; Input: land, labour, human capital, and physical capital.	BPS; SAKERNAS; Ministry of agriculture	0.90
Avila & Evenson (2010)	Growth accounting	1961-2001	Output: Output growth from FAO Laspeyres indexes using FAO dollar price; Input: for crops – cropland, labour, fertilizer, animal power, and machine services (tractors plus harvesters); for livestock: pastureland, labour, fertilizer, animal capital, and feed;	FAO	2.02
Fuglie (2010)	Tornqvist-Thiel TFP Index	1961-2006	Output: crops, livestock, and aquaculture output; Input: land in crops and ponds, agricultural labour, education, and wages, fertilizer and chemicals, machinery, livestock, and poultry, and feed and seed;	Van der Eng (1996); FAO; BPS; SAKERNAS	1.82
Fuglie (2012)	Growth accounting	1961-2009	Output: crop and livestock commodity production; Input: land, labour, livestock capital, fertilizer, and machinery resources;	FAO	1961-1970 (1.75); 1971-1980 (1.40); 1981-1990 (0.59); 1991-2000 (0.99); 2001-2009 (3.68)

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3. METHODOLOGY AND DATA

TFP growth can be measured using two major approaches - parametric and non-parametric. While more widely used, the accuracy of the parametric approach such as Cobb-Douglas heavily depends on the specification of the production function form. An inaccurate specification of the production function could likely result in a misinterpretation of TFP. Parametric approaches also make strict assumptions on the functional form, such as constant returns to scale and technological efficiency, which are difficult to justify in practice. In contrast, non-parametric approaches such as the Malmquist index methodology are sensitive to outliers and data quality (Tong et al., 2008) but not dependent on model specification per se. This paper applies both methodologies to gain a comprehensive understanding of the agricultural TFP growth in Indonesia. Given the lack of observations to conduct a panel analysis at the provincial-level, we applied the growth accounting method only at the national and regional level. The regional grouping is island-based and aligned with the Master Plan for Acceleration and Expansion of Indonesia's Economic Development (MP3EI) initiated by Indonesia's Coordinating Ministry for Economic Affairs (2011). In order to have a deeper understanding of the driving factors of TFP growth, we adopted the Malmquist index method at the provincial level, which allowed us to decompose TFP change into technological change and efficiency change.

3.1. Growth Accounting Methodology

In this paper, the production function for Indonesia's agricultural sector is defined using a Cobb-Douglas specification, given by:

$$Y_{it} = A_{it} X_{1it}^{\beta_1} \tag{1}$$

where *i* and *t* indicate economy and time respectively. Y_{it} represents the agricultural value added per labour for economy *i* at time *t*. X_{1it} indicates land per labour for economy *i* at time *t* respectively. A_{it} is defined as the measure for TFP, which includes technology factors, and efficiency factors. By taking natural logarithms on both sides of Equation (1) one can obtain Equation (2), which determines the contribution of input to output and is used in calculating TFP growth.

$$\ln Y_{it} = \beta_0 + \beta_1 \ln X_{1it} + \varepsilon_{it} \tag{2}$$

TFP growth is the difference between real agricultural output growth and the weighted sum of input. Hence, TFP growth is calculated as the residual change in output. Therefore, TFP growth can be measured by Equation (3).[2]

$$TFP\,growth_{it} = y_{it} - \hat{\beta}_1 x_{1it} \tag{3}$$

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3.2. Malmquist Index Data Envelopment Analysis

Considering the various limitations of parametric approaches to estimating TFP and given the limited time series data available, this paper also applies non-parametric approaches to measure agricultural TFP growth in Indonesia in the form of the Malmquist index.[3]

The Malmquist index is defined in a distance function by Färe et al. (1994). The subscript *y* in Equation (4) shows that it is an output oriented Malmquist index.

$$M_y(x^t, x^{t+1}, y^t, y^{t+1}) = \left[\left(\frac{D_y^t(x^{t+1}, y^{t+1})}{D_y^t(x^t, y^t)} \right) \left(\frac{D_y^{t+1}(x^{t+1}, y^{t+1})}{D_y^{t+1}(x^t, y^t)} \right) \right]^{1/2} \tag{4}$$

By mathematical transformation, Equation (4) can be written in the form of Equation (5), which allows us to decompose the TFP change into technological change (TC) and technical efficiency change (TEC) (Färe et al., 1994).

$$M_y(x^t, x^{t+1}, y^t, y^{t+1}) = \frac{D_y^{t+1}(x^{t+1}, y^{t+1})}{D_y^t(x^t, y^t)} \left[\left(\frac{D_y^t(x^{t+1}, y^{t+1})}{D_y^{t+1}(x^{t+1}, y^{t+1})} \right) \left(\frac{D_y^t(x^t, y^t)}{D_y^{t+1}(x^t, y^t)} \right) \right]^{1/2} \tag{5}$$

TEC refers to activities which can enhance the efficiency of production, including better resource utilization and management. TC refers to a set of developments that can move the productivity frontier forward such as innovation. As specified by Färe et al. (1994), Equation (5) can be written in a more illustrative form as Equation (6).

$$TFPC = TEC \times TC \tag{6}$$

The appendix to the paper describes this approach to TFP measurement in more detail.

3.3. Data

Finding relevant data at provincial-level is challenging as there is no central database that provides all indicators. The data were collected from 2000-2011. For output, the paper used provincial agricultural GDP from World Bank (2012a), as part of Indonesia Database for Policy and Economic Research (INDO-DAPOER) that captures crops, livestock, forestry, and fishery. Labour and land are used as inputs. For labour, the data were also sourced from World Bank INDO-DAPOER that referred to a number of people employed in crops, livestock, fishery, and forestry sector. The land indicator covers wetland, garden, dry land, shifting cultivation, temporary/fallow land, and utilized land for main estate crops, sourced from BPS (2000-2012a; 2000-2012b; 2000-2012c) and Ministry of Agriculture (2012).

Data on machinery are not available on a consistent time series basis. Fuglie (2010) used the number of tractors in use adjusted for size; 12 horsepower (hp) for two-wheel-tractor and 20, 33, and 50hp per small, medium, and large four-wheel tractor, respectively. *Statistical Yearbook of Indonesia* published these indicators only up to 2002. The data became available again in 2011, but did not report the four-

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wheel tractor. The Ministry of Agriculture also reported the number of tractors but only documented those that were part of government assistance. For fertilizers, Ministry of Agriculture only released the statistics on subsidized fertilizer for recent period, from 2009 onwards. The publication on *Farm Cost Structure of Paddy and Secondary Food Crops* gave fertilizer application rates per hectare for rice and secondary food crops, however, such data were only available in 2008 publication for paddy, 2009 for corn, and 2010 for soybean (BPS, 2008-2010). Nevertheless, such information was only available for half of the provinces. Since the goal of the paper was to cover as many provinces as possible and finding proxies to fill in unavailable data across provinces over time could further distort the results, the data used in the paper was limited to two input variables including labour and land, which had comprehensive time series and provincial coverage.

As of 2014, Indonesia has 34 provinces. The newest province is North Kalimantan which was created in 2012 and hence not included in our analysis. During the period of analysis in the study -- 2000-2011 -- there were seven newly created provinces: North Maluku (carved out from Maluku in 1999), West Papua (carved out from Papua in 1999), Banten (carved out from West Java in 2000), Bangka Belitung (carved out from South Sumatra in 2000), Gorontalo (carved out from North Sulawesi in 2000), Riau Islands (carved out from Riau in 2002), and West Sulawesi (carved out from South Sulawesi in 2004). For some indicators that were not adjusted at source reflecting these changes, data points were estimated based on their past growth trend and relative proportion to their parent province. DKI Jakarta was also not included in the analysis due to the negligible share of its agriculture in the Indonesian economy (0.1 percent).

4. FINDINGS

4.1. Labour Productivity

In the case of Indonesia there were significant disparities across provinces in terms of labour productivity in agriculture. Labour productivity was calculated by dividing agricultural GDP by employment in agricultural sector. For average annual growth rate in labour productivity from 2000-2011 in Figure 1, most provinces in Java Island grew faster than the average rate of 4.5 percent, except East Java where more than seven million people were still employed in agricultural sector.

There were wide variations of labour productivity within provinces in each region. When the figures were aggregated at the regional level, labour productivity in Java was actually lower than that of Kalimantan, Sumatra, and Sulawesi where expansions in high value estate crops such as palm oil, rubber, and cocoa took place. In fact, the highest labour productivity growth was found in Gorontalo (9.2 percent). Other provinces in Sulawesi also reported favourable labour productivity growth rates of 6.9 percent for Central Sulawesi, 6 percent for North Sulawesi, and 5.6 percent for Southeast Sulawesi. On the other hand, the highest labour productivity growth rates in Sumatra and Kalimantan were found in Bangka Belitung Islands (7.3 percent) and South Kalimantan (5.1 percent), respectively.

In contrast, labour productivity for Bali–Nusa Tenggara and Maluku–Papua were lower than the national average. From these two regions, Bali was the only province with higher than average labour productivity growth. Among the eastern provinces, North Maluku reported the highest average of labour productivity growth of 4.1 percent while its neighbors recorded much lower rates; Maluku (1.3 percent), West Papua (2.3 percent), and Papua (0.4 percent). International Fund for Agricultural Development

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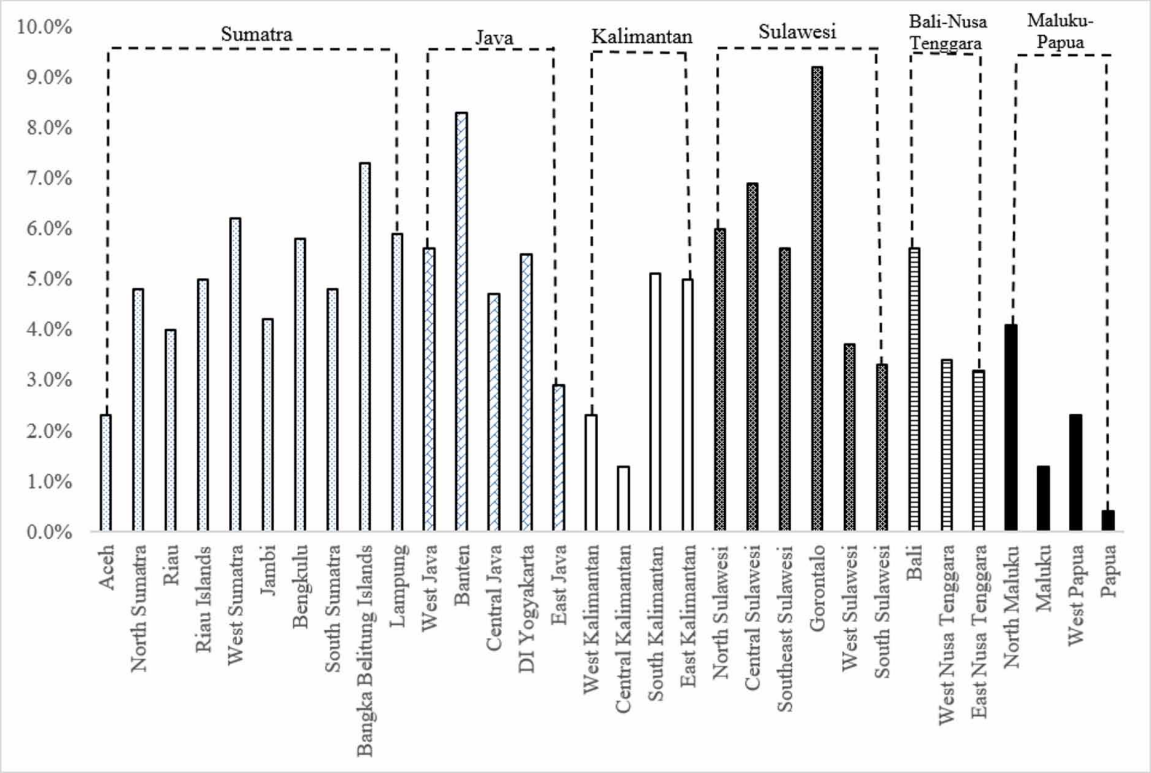
Figure 1. Labour productivity across provinces (average annual growth rates from 2000-2011)



(2011) has cited a number of ingrained issues found in Maluku and North Maluku that led to poor productivity in agricultural sector such as local conflicts, poor marketing and infrastructure, and insufficient natural resource management.[4]

4.2. Total Factor Productivity (TFP)

Based on panel data analysis using growth accounting, as shown in Table 2, TFP growth for 2000-2011 was 3.1 percent for Indonesia as a whole. Further analysis at the regional level revealed that Sulawesi had the highest TFP growth at 3.5 percent. Other regions which reported higher than national TFP growth were Sumatra (3.3 percent), Java (3.3 percent), and Bali–Nusa Tenggara (3.2 percent). Kalimantan and Maluku-Papua were the laggards with 2.0 percent and 1.5 percent of TFP growth, respectively. The recent initiative to push for Merauke Integrated Food and Energy Estate (MIFEE) that will cover over a million hectares of plantations and industrialised agriculture may contribute to higher TFP growth in Maluku-Papua region in the future.[5] Due to limited sample size we did not calculate TFP growth at provincial-level using the growth accounting method.

Based on the Malmquist–DEA results, TFP grew at an annual average rate of 3.2 percent from 2000-2011, which was somewhat aligned with the estimation using growth accounting method. The TC's contribution was 2.9 percent while TEC's contribution was 0.3 percent. While this likely overstated the importance of TFP (since we have excluded other inputs for which data are not available), the TFP estimate was slightly below the 3.7 percent found by Fuglie (2012) during 2001-2009.[6]

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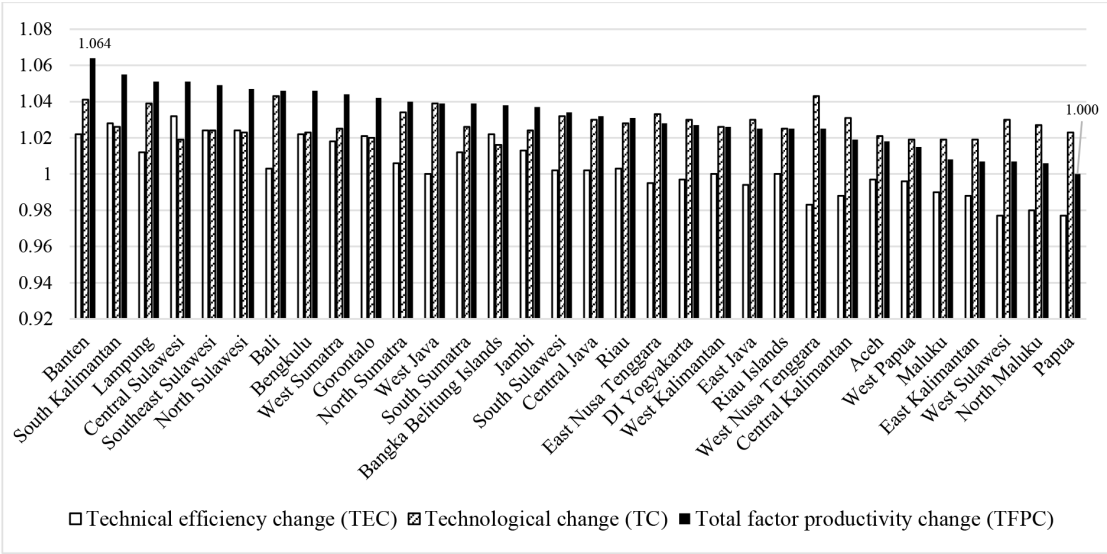
Table 2. TFP growth using growth accounting method (2000-2011)

	β_0	β_1	TFP growth
National	0.030***	0.602***	3.06%
Sulawesi	0.033***	0.579**	3.47%
Sumatra	0.032***	0.674***	3.34%
Java	0.032***	0.921***	3.26%
Bali – Nusa Tenggara	0.030***	0.453	3.24%
Kalimantan	0.024***	0.568***	1.98%
Maluku - Papua	0.015***	0.564*	1.48%

Note: ***, **, and * indicate statistics significance at the 1, 5 and 10 percent levels respectively.

There remained significant variations in TFP growth across provinces as can be seen from Figure 2 which is sorted from the highest to lowest TFP. Banten recorded the highest TFP – a 6.4 percent increase -- and Papua the lowest – attaining a status quo or zero change. Banten performed equally well both in TEC (2.2 percent) and TC (4.1 percent). On the other hand, Papua's low TEC, a decrease of 2.3 percent, drove down its TFP while its TC grew at about 2.3 percent.

Figure 2. Average TFPC and its decomposition from 2000-2011 for 32 provinces



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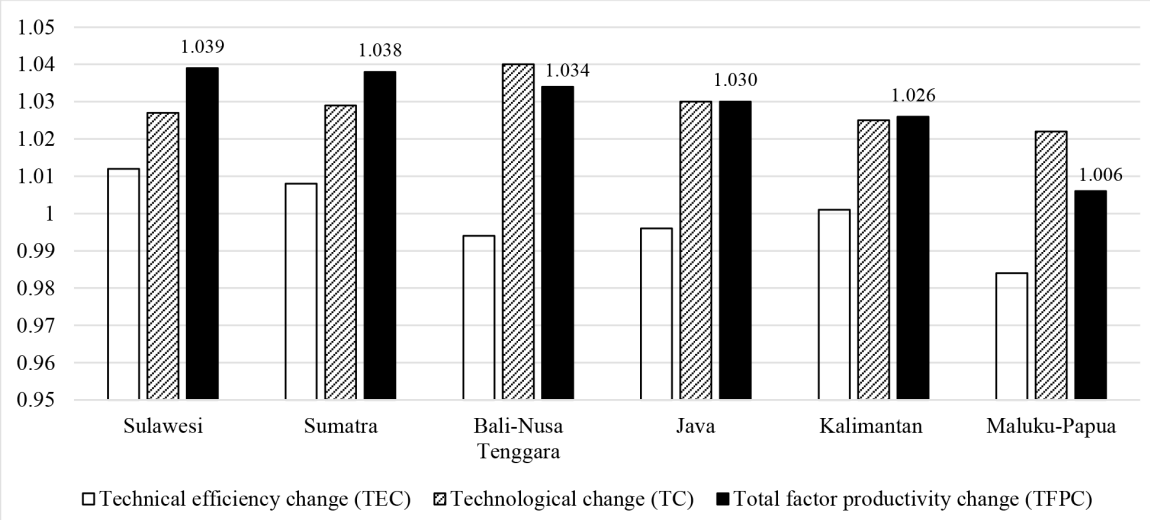
The majority of provinces with high labour productivity growth also reported high TFP growth. For instance, the ten-highest TFP growth provinces recorded labour productivity growth of above 5.1 percent. In fact, the range is between 5.1 percent and 9.2 percent. For the top 10 TFP growth, four provinces were from Sulawesi, three provinces from Sumatra, one from each of Java, Kalimantan, and Bali–Nusa Tenggara.

Across the provinces, results suggest that TFP growth could be predominantly attributed to TC with the growth in TEC being marginal and even negative in most provinces (such as Papua and West Sulawesi with a decrease of 2.3 percent). The fact that TC was relatively similar across provinces might be mainly due to the fact that R&D and innovation was still driven by the central government. The funding would typically be allocated to Ministry of Agriculture, Indonesian Agency for Agricultural Research and Development (IAARD) in particular, and then distributed to its local offices in each province. For estate crops, Indonesian Research Institute for Estate Crops (IRIEC) has mainly been funded by the plantation sector itself, through Indonesian Planters Association for Research and Development (IPARD). IRIEC was relatively better funded as research expenditures per scientist were about four times higher than that of IAARD (Fuglie & Piggott, 2006). TEC largely lagged in provinces with profound infrastructure bottlenecks, such as East Nusa Tenggara, West Nusa Tenggara, West Sulawesi, West Papua, Maluku, and North Maluku, all of which reported negative growth.

The regional TFPC, TEC, and TC were calculated based on the weighted average of provincial contribution to the region's agricultural output. Based on Figure 3, Sulawesi outperformed the rest with TFP growth of 3.9 percent, with 1.2 percent coming from improvements in TEC and 2.7 percent from TC. The results corroborated the findings using growth accounting method. Four out of six provinces in Sulawesi were also part of those that registered the ten-highest TFP growth rates. This supports the region's designated role as a center for production and processing of national agriculture, plantation, and fishery, as stipulated in MP3EI (Coordinating Ministry of Economic Affairs, 2011).

Figure 3. Average TFPC and its decomposition from 2000-2011 for six regions



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Similar to the estimation by the growth accounting method, Maluku-Papua became the laggard with the lowest TFP growth of 0.6 percent. Based on further decompositions we found out that the TC grew at 2.2 percent, however, its TEC decreased by 1.6 percent. As the easternmost region, Maluku-Papua faces perennial challenges of rudimentary hard and soft infrastructure that hampers its agricultural productivity growth.

5. CONCLUSION AND POLICY IMPLICATIONS

The new leadership under President Joko Widodo has emphasized the importance of achieving food sovereignty in Indonesia. The MP3EI also stressed agriculture as one of the eight main programs, with the production of palm oil, rubber, cocoa, animal husbandry, timber, fishery, and food crops as part of 22 main economic activities. Such policies signal the importance of agricultural productivity to the country, especially given the significant regional variations in terms of productivity. In this light, this paper has provided the most recent analysis on estimating agricultural productivity in Indonesia, focusing on the dynamics at the provincial-level.

From 2000-2011, TFP grew on average by 3.1 to 3.2 percent using both the growth accounting methods and the Malmquist index. TFP growth at the regional-level is also broadly consistent, indicating the robustness in the estimates. According to the Malmquist index, TFP growth was predominantly due to improvements in TC which was broadly uniform across provinces. This uniformity is not very surprising as TC is driven primarily by R&D, new innovations, and technology under the provision of the central government. It is important to recognize the role of the IAARD in this context, especially for food crops and livestock research, as IRIEC has been driving the research in estate crops. Going forward, IAARD should continue building its technological capacity to gradually strengthen its focus on non-staple foods with higher value-added and its interaction with the private sector.

For estate crops that are still dominated by small farms, the challenge is to address the low productivity of smallholders with limited access to high quality inputs. Developing effective systems for small farms is key to improving productivity in estate crops such as in the case of nucleus-plasma program based on partnerships between large estates and smallholders.[7]

According to World Bank (2010), the intensity with which Indonesia invests in agricultural research, even after adding the R&D spending from private sector, is relatively low (0.22 percent) which is on par with that of Lao PDR (0.24 percent), and much lower than Malaysia (1.92 percent) and the Philippines (0.44 percent). The budget allocation for agricultural R&D in Indonesia tends to be volatile, especially when time gets tough, as in the case of AFC when the budget was cut by more than 60 percent (Fuglie & Piggott, 2006).

In addition to increasing R&D funding, it is important to forge greater collaboration with the private sector, involvement of universities, and linkages with those of international R&D providers. Various incentives can be set by the government to encourage private investments in agriculture, such as intellectual property protection and provision of tax concessions to make private investment in agricultural R&D and knowledge creation in better farming techniques more appealing. The role of extension services is crucial to ensuring effective adoption and adaptation of new technology at the local level. There is

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room for improvement in enhancing extension service delivery such as using performance-based budgeting, training and ICT utilization to stay abreast with the latest developments as well as reforming the institutional and management of agricultural extension system to improve efficiency and clarity of direction and roles.

As the empirical results point out, the main differences of TFP growth across provinces arise from TEC which can be improved in lagging provinces through better resource utilization. With provincial-level analysis there is an opportunity for inter-province learning to enhance more efficient resource deployment and management techniques. For many lagging provinces, if they are able to learn from high-performing provinces and enhance TEC, overall agricultural sector can be expanded with minimal increase in resources.

Lastly, it is essential to improve the provision of reliable and timely statistics across provinces and over time. With better quality and availability of appropriate data, more evidence-based policy decisions can be made and eventually enhance policy performance.

REFERENCES

Avila, A. F., & Evenson, R. E. (2010). Total Factor Productivity Growth in Agriculture: The Role of Technological Capital. In P. L. Pingali & R. E. Evenson (Eds.), *Handbook of Agricultural Economics* (Vol. 4, pp. 3769–3822). Amsterdam: Elsevier. doi:10.1016/S1574-0072(09)04072-9

Biro Pusat Statistik. (2012). *Regional GDP according to Industrial Origin*. Jakarta: Biro Pusat Statistik.

Biro Pusat Statistik. (2008-2010). *Farm Cost Structure of Paddy and Secondary Food Crops.* Jakarta: Biro Pusat Statistik.

Biro Pusat Statistik. (2000-2012a). *Land size according to its utilisation.* Jakarta: Biro Pusat Statistik.

Biro Pusat Statistik. (2000-2012b). *SAKERNAS (National Labour Force Survey)*. Jakarta: Biro Pusat Statistik.

Biro Pusat Statistik. (2000-2012c). *Statistical Yearbook of Indonesia*. Jakarta: Biro Pusat Statistik.

Coelli, T. J., & Rao, D. P. (2005). Total factor productivity growth in agriculture: A Malmquist Index analysis of 93 countries, 1980–2000. *Agricultural Economics*, *32*(Suppl. 1), 115–134. doi:10.1111/j.0169-5150.2004.00018.x

Coordinating Ministry for Economic Affairs. (2011). *Masterplan for Acceleration and Expansion of Indonesia's Economic Development*. Jakarta: Coordinating Ministry for Economic Affairs.

Färe, R., Grosskopf, S., Norris, M., & Zhang, Z. (1994). Productivity Growth, Technical Progress, and Efficiency Change in Industrialized Countries. *The American Economic Review*, *84*(1), 66–83.

Food and Agriculture Organization. (2012). *FAOSTAT Database*. Rome: Food and Agriculture Organization of the United Nations Statistics Division.

Fuglie, K. O. (2010). Sources of growth in Indonesian agriculture. *Journal of Productivity Analysis*, *33*(3), 225–240. doi:10.100711123-009-0150-x

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Fuglie, K. O. (2012). Productivity Growth and Technology Capital in the Global Agricultural Economy. In K. O. Fuglie, V. E. Ball, & S. L. Wang (Eds.), *Productivity Growth in Agriculture: An International Perspective* (pp. 335–368). Oxfordshire: C.A.B. International. doi:10.1079/9781845939212.0335

Fuglie, K. O., & Piggott, R. (2006). Indonesia: coping with economic and political instability. In P. G. Pardey, J. M. Alston, & R. R. Piggott (Eds.), *Agricultural R&D in the developing world: too little, too late?* (pp. 65–104). Washington: International Food Policy Research Institute.

International Fund for Agricultural Development. (2011). *Smallholder Livelihood Development Project in Maluku and North Maluku*. Asia and the Pacific Division Programme Management Department.

Ministry of Agriculture. (2012). *Agriculture Statistics Database*. Jakarta: Ministry of Agriculture. Jakarta. Retrieved from http://aplikasi.deptan.go.id/bdsp/index.asp

Mundlak, Y., Larson, D., & Butzer, R. (2004). Agricultural dynamics in Thailand, Indonesia and the Philippines. *The Australian Journal of Agricultural and Resource Economics*, *48*(1), 95–126. doi:10.1111/j.1467-8489.2004.00231.x

OECD. (2012). *OECD Review of Agricultural Policies: Indonesia 2012*. Paris: OECD Publishing.

Suhariyanto, K., & Thirtle, C. (2001, September). Asian Agricultural Productivity and Convergence. *Journal of Agricultural Economics*, *52*(3), 96–110. doi:10.1111/j.1477-9552.2001.tb00941.x

Tong, H., Fulginiti, L. E., & Sesmero, J. P. (2009). *Chinese Regional Agricultural Productivity: 1994-2005* (Working Paper No. 89). University of Nebraska-Lincoln, Nebraska, Agricultural Economics Department.

Warr, P. (2009). *Aggregate and Sectoral Productivity Growth in Thailand and Indonesia* (Working Papers in Trade and Development No. 2009/10). Canberra: Australian National University, The Arndt-Corden Division of Economics, ANU College of Asia and the Pacific.

World Bank. (2010). *Indonesia Agriculture Public Expenditure Review 2010*. Jakarta: World Bank.

World Bank. (2012a). *INDO-DAPOER (Indonesia Database for Policy and Economic Research)*. Jakarta: World Bank. Retrieved from http://databank.worldbank.org/data/reports.aspx?source=1266

World Bank. (2012b). *World Development Indicators*. Washington, DC: World Bank. Retrieved December 1, 2014, from http://data.worldbank.org/data-catalog/world-development-indicators

ENDNOTES

1 Estate crops, called *perkebunan* in local term, refer to rubber, coconut, palm oil, coffee, tea, pepper, clove, cocoa, cashew nut, sugar cane, tobacco, and cotton.

2 $y_{it} = ln Y_{it} - ln Y_{i,t-1}$

3 The other commonly used nonparametric measure is the Törnqvist Index. However, this methodology has rather strict data requirements, including prices and quantitative data of both inputs and output. In addition, it also has some assumptions such as a perfectly competitive market and profit maximisation, which are not suitable for agricultural studies.

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[4] On top of that, other issues included limited knowledge of modern agricultural practices and lack of effective extension services, research outreach, supply of production input, and financing. As a result, most agricultural output was of poor quality with low market value as there was no local value addition through processing and marketing. Hence, it was not surprising that most food crop production solely aimed for meeting subsistence needs.

[5] MIFEE is part of the MP3EI projects which designate Merauke as the center of food and energy reserves in eastern part of Indonesia. It was reported that the program has attracted a dozens of domestic and foreign investors who were interested in growing rice, corn, soybean, sugar cane, and palm oil.

[6] Another study by Fuglie (2010) found 2.4 percent TFP growth from 2001-2006.

[7] Under this program, large estates (nucleus) will be provided subsidized capital and long-term leases to state land for crop production with the conditions that they provide inputs, credit, and other services such as technical and marketing services to smallholders (plasma) surrounding their plantations.

[8] TEC can be further decomposed into two parts which are Pure Technical Efficiency Change (PTEC) and Scale Efficiency Change (SEC) as illustrated by Equation (A10).

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APPENDIX

The Malmquist Index Data Envelopment Analysis (DEA) Methodology

According to Färe et al. (1994), the change of TFP can be decomposed into TC and TEC through the Malmquist index. Every time point has its specific technology level. Therefore, if a selected time point is represented by *t*, its corresponding technology level can be labelled as S^t. In this context, x^t can be used to represent all inputs of the production activity, and y^t can be used to represent all outputs of the production activity. Under these circumstances, S^t can be defined in the form of equation (A1) which captures all possible combinations of inputs x^t and outputs y^t under the available technology at time *t*.

$$\mathrm{S}^t = \{(\mathrm{x}^t, \mathrm{y}^t), \mathrm{x}^t \ \text{ produce } \ \mathrm{y}^t\} \tag{A1}$$

Since the agricultural production activity in the real world can hardly fully achieve and implement all cutting edge technologies in a specific time point *t*, a differentiation between the actual output and the ideal output could be spotted. According to Färe et al. (1994), the differentiation can be defined as Equation (A2).

$$D_y^t = \inf\{\theta : (\mathrm{x}^t, \mathrm{y}^t / \theta) \in \mathrm{S}^t\} = \{\sup[\theta : (\mathrm{x}^t, \theta\, \mathrm{y}^t) \in \mathrm{S}^t]\}^{-1} \tag{A2}$$

Equation (A2) is an output-oriented distance function, in which D_y^t represents the reciprocal of the maximum change in output *y* through fully exploiting the input *x*. Given the input level x^t at time *t*, Equation (A2) can be used to measure the maximum expansion θ of the output y^t. Meanwhile, D_y^t can also be interpreted as the reciprocal of the maximum efficiency change of the output y^t by fully exploiting input x^t.

Similarly, as shown in Equation (A3), the input-oriented distance function can measure the change of inputs given the output level.

$$D_x^t = \sup\{\lambda : (x^t / \lambda, y^t) \in S^t\} \tag{A3}$$

$$D_y^t = \inf\{\theta : (x^{t+1}, y^{t+1} / \theta) \in S^t\} = \{\sup[\theta : (x^{t+1}, \theta y^{t+1}) \in S^t\}^{-1} \tag{A4}$$

Equation (A4) represents the reciprocal of maximum change of output, given input x^{t+1}, to make y^{t+1} feasible at time *t*. Hence, the Malmquist index can be written in the form of Equation (A5) and Equation (A6).

$$M_y^t = \frac{D_y^t(x^{t+1}, y^{t+1})}{D_y^t(x^t, y^t)} \tag{A5}$$

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$$M_{y}^{t+1} = \frac{D_{y}^{t+1}(x^{t+1}, y^{t+1})}{D_{y}^{t+1}(x^{t}, y^{t})} \tag{A6}$$

If a specific time *t* is selected, the corresponding technology level will become the reference technology level. Under these circumstances, Equation (A5) can be used to measure the necessary change to generate the output y^{t+1} through utilizing the input x^{t+1} with the feasible technology S^{t}. In order to avoid choosing an arbitrage benchmark, the geometric mean of the two Malmquist indices can be calculated to form a benchmark (Färe et al. 1994).

$$\begin{aligned} M_{y}(x^{t}, x^{t+1}, y^{t}, y^{t+1}) &= \sqrt{M_{y}^{t} * M_{y}^{t+1}} \\ &= \left[\left(\frac{D_{y}^{t}(x^{t+1}, y^{t+1})}{D_{y}^{t}(x^{t}, y^{t})}\right)\left(\frac{D_{y}^{t+1}(x^{t+1}, y^{t+1})}{D_{y}^{t+1}(x^{t}, y^{t})}\right)\right]^{1/2} \end{aligned} \tag{A7}$$

Equation (A7) can be decomposed into two parts through mathematical transformation as illustrated by Equation (A8).

$$M_{y}(x^{t}, x^{t+1}, y^{t}, y^{t+1}) = \frac{D_{y}^{t+1}(x^{t+1}, y^{t+1})}{D_{y}^{t}(x^{t}, y^{t})}\left[\left(\frac{D_{y}^{t}(x^{t+1}, y^{t+1})}{D_{y}^{t+1}(x^{t+1}, y^{t+1})}\right)\left(\frac{D_{y}^{t}(x^{t}, y^{t})}{D_{y}^{t+1}(x^{t}, y^{t})}\right)\right]^{1/2} \tag{A8}$$

Equation (A8) can be perceived as two components. The first component represents the technical efficiency change between time *t* and time *t+1*, and the second component represents the technological change between time *t* and time *t+1*. The practical meaning of this transformation is that, the Total Factor Productivity Change (TFPC) can be decomposed into Technical Efficiency Change (TEC) and Technological Change (TC), as shown in Equation (A9) (Färe et al. 1994).

$$TFPC = TEC \times TC \tag{A9}$$

TEC is broadly related to better resource utilization or deployment as well as more efficient management. TC broadly refers to the technology innovation or progress, which can shift the production frontier. For example, an invention of new technology could shift the agricultural production frontier. Thereafter, the true driving factor could be identified through the decomposition of TFPC, which may potentially draw valuable lessons for future development of the agriculture sector.[8]

Linear Programming approach is used to calculate the Malmquist index in this paper. In short, the Malmquist index methodology not only allows us to decompose TFPC into TEC and TC, but also provides relative rankings of economies based on their distance to the efficiency frontier.

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$$M_y\left(x^t, x^{t+1}, y^t, y^{t+1}\right)$$
$$= \frac{D^{v,t+1}_y(x^{t+1}, y^{t+1})}{D^{v,t}_y(x^t, y^t)} \left[\left(\frac{D^{v,t}_y(x^t, y^t)}{D^{v,t+1}_y\left(x^{t+1}, y^{t+1}\right)}\right)\left(\frac{D^{c,t+1}_y(x^{t+1}, y^{t+1})}{D^{c,t}_y(x^t, y^t)}\right)\right]\left[\left(\frac{D^{c,t}_y(x^{t+1}, y^{t+1})}{D^{c,t+1}_y(x^{t+1}, y^{t+1})}\right)\left(\frac{D^{c,t}_y(x^t, y^t)}{D^{c,t+1}_y(x^t, y^t)}\right)\right]^{1/2} \quad \text{(A10)}$$

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Chapter 52
Importance of Sustainable Rural Development Through Agrarian Reforms:
An Indian Scenario

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ABSTRACT

The chapter tries to find out the relationship between public expenditures on infrastructure related to agriculture and allied factors and agricultural sustainability in Indian context. India has been suffering from appalling chronic poverty and to reduce the same, we need to focus on rural development, particularly in agriculture as it is unavoidable relation with economic development. Gini index of India is 33.9 (2011) i.e. asymmetrical wealth distribution exists. India is being burdened with a population of 1.2 billion as in 2015. The reciprocal relationship between agrarian reform and democratic development is pronounced. Agrarian reform was one of the focal points around which social mobilization occurred. Sustainable rural development could be achieved by a new balance as we find from some econometric model, which is being sought between agriculture and public expenditure and also export of agricultural produce. Adopting bottom-up agricultural development approaches which emphasize the involvement of the rural people in the implementations of different development programmes may escalate agrarian reforms.

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INTRODUCTION

Development is a concept construing changes in the conditions of well being of the people irrespective of income level. It is generally evaluated in terms of changes in aesthetic qualities of the community, i.e. demographics, housing, employment, income, market effects, public services etc. Of late India shows as one of the fastest growing economies in the world. This chapter brushes one more stroke the emerging relationship of infrastructure availability and productivity growth. This analysis relies on both qualitative and quantitative measures of impacts.

Infrastructure, no doubt, is the backbone of any society. Infrastructure development is a *sine qua non* for accelerating progress of the quality of human life. Though infrastructure projects, involve huge initial capital investments, high incremental capital output ratio, high risk with long gestation periods, and low rate of returns on investments but infrastructure development particularly, rural infrastructure encompass economic development of the country. Rural infrastructure has a direct and strong relationship with farmers. Rural infrastructure development is supposed to be a benchmark to transform the existing traditional agriculture or subsistence farming into a most modern, commercial and dynamic farming system so that India could oust the surplus labourers to any other productive jobs. We can group infrastructure under some categories as given in Table 1.

Role of Agriculture in Infrastructure Development

Agriculture ensures supply of food to industrial sector (Lewis, 1954) and hence it is a driving force of overall economic development (Mellor, 1966; Schultz, 1964). Technology spillovers also increase in productivity of Land and labour and as a result income of farmers increase which enhance their purchasing powers. A number of empirical studies (Hazell & Roel, 1983; Hammer & Hazel, 1991; Delgado, 1998; Zhang, 2002) ensured that multiplier effects of agricultural growth are greater than two.

Table 1. Categorization of infrastructure

Based	Resources	Rural Sector	Urban Sector
Input Based	-	Agricultural input like Seed, Fertilizer, Pesticides, Farm equipment and machinery etc.	-
Resource Based:	Water	Irrigation and Drinking	Drinking
	Electricity	Pump and Household	Household and Industrial Purpose
Physical Infrastructure:	Telecommunication, Road connectivity, Transport, storage (including Cold storage), processing, preservation, and Sanitation etc.	Required all Resources	Required all Resources
Institutional Infrastructure:	Education, research, information & communication services, financial services, market, etc.	Required all Resources	Required all Resources

Source: Authors' Own Observation

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Several studies explain the elasticity of poverty reduction with respect to agricultural productivity is significant ((Thirtle, Lin & Piesse, 2003). Some econometric studies (Binswanger & Rosenzweig, 1993; Butzer, 2002; Zhang, 2004) estimated that there is a positive significant relationship between agricultural output and infrastructure investment.

Agricultural sector has also played an important role as foreign exchange earner too. Agricultural exports accounted for 44 percent of India's total merchandise export during 1960-61and in 2013-14 it is more than 17 percent of export earnings of India.

There is a positive correlation between GDP and Public Expenditure on Agriculture (0.98) and similarly, GDP to export of Agricultural and allied product (0.96). So, agricultural infrastructural growth plays a significant role to the economic development in the context of India in particular.

A Brief Discussion on Indian Agriculture

Agriculture is consistently losing its importance in India's economic growth. According to CIA Factbook-2014, agriculture sector contributes 17.9 percent of India's Gross Domestic Product (GDP), and in 2015, in the Budget it is reported that more than 50 percent of the population is still dependent on it. The farm sector, including forestry and fishing, grew by 3.2 percent in the quarter ending September, as compared o 3.8 percent in previous quarter and 4.7 percent in 2013-14. For the entire financial year, it was 1.4 percent. Backed by continued technological innovations in the sector, India's food grain production has more than doubled over the decades to a record 264 million tons in 2014, but the same is not being

Figure 1. Role of Infrastructure in Agricultural Development

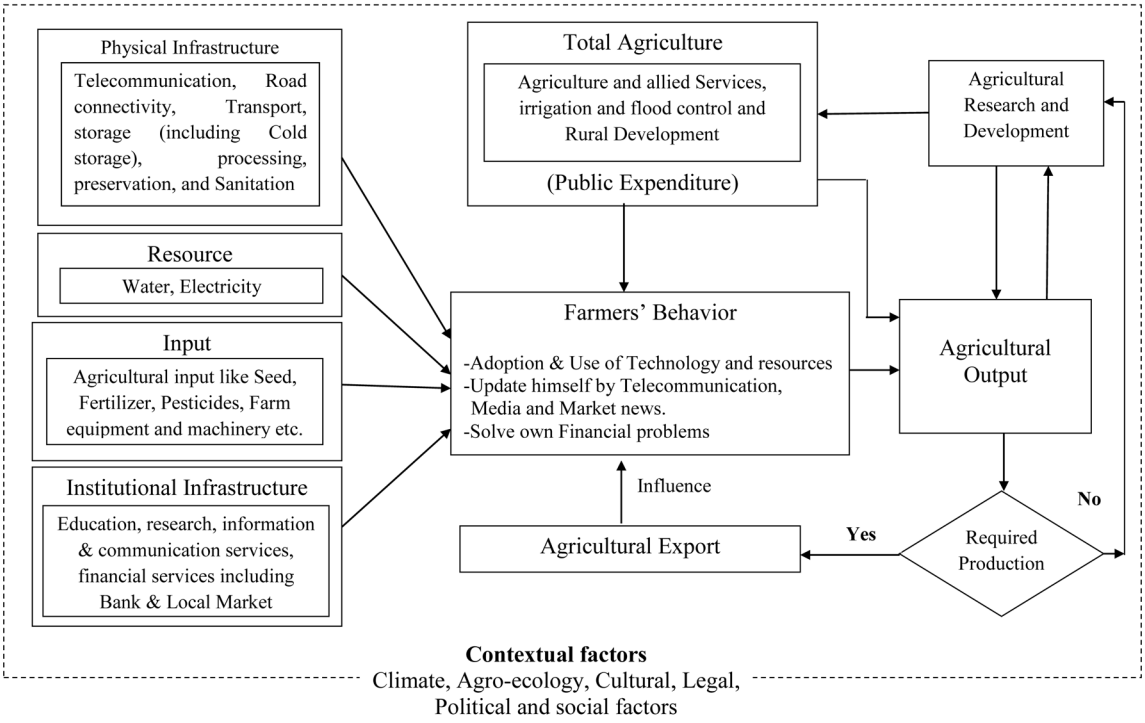

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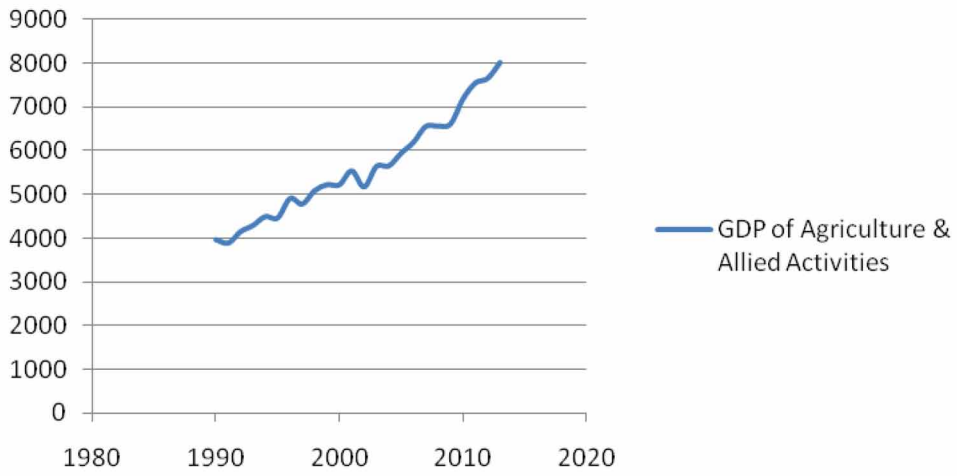
Figure 2. GDP of Agriculture and Allied Services
Source: CSO, Government of India, Annual Data from 1990-2015



capitalized to increase the profit margins and revenue of farmers. There is still a large dependency on rainfall and other climatic conditions for good yield, and post-harvest logistics remains an area of concern.

In the post-1990s period, there has been a continuous decline in government support in the form of declining investments in agriculture. The withdrawal of the State has led to a much greater dependence of farmers on private sources. Very unfortunate to say that there has also been an upward trend in the cases of farmer suicides over the years and the victims have largely been marginal and small farmers. Increasing costs of cultivation leading to higher indebtedness, crop failures, inability to face price rise with greater liberalization of the agricultural sector and profile of gobbling up of lion's share of profit margin by the marketing middleman have forced farmers to take this extreme step a death trap to speak of.

A report was published by zee news exclusive of union budget-2015 that it's a fact in India; farmers are receiving only around 25 to 30 percent of the price paid by the consumers. The loss appears not due to their inefficiencies but also for unwanted role of middlemen. Farmers in developed economies of Europe and the United States, in contrast, receive around 75 percent of the price that consumers pay. The wide gap between ultimate sellers of agricultural goods and the ultimate purchasers of the same makes the system vulnerable in view of sustainability when market is treated as an institution in the age of globalization. The entire system is likely to be changed without any more delay. The growth performance of the agriculture sector has been fluctuating across the time periods 1990 to 2015.

Inflationary trend of food items has got a close link with the supply crunch, triggered by the international market. To deal with this type of vulnerability, there is also a need to make long-term plan. India is still dependent on the other Countries for some commodities such as edible oil (mostly palm oil) and pulses, despite the prevailing agriculture-intensity profile of India. India imports more than 50 percent of its cooking oil. Long-term approach in trade policy and lack of consistency make us dependable for these commodities on overseas market. Government of India generally reduces the import duty of a particular commodity to tame price rise but in the long run escalates the inflow of that commodity in the domestic market and increase our dependability. While taking a decision on duty, the government should take into account the concerns of all stakeholders related to that commodity, mainly producers,

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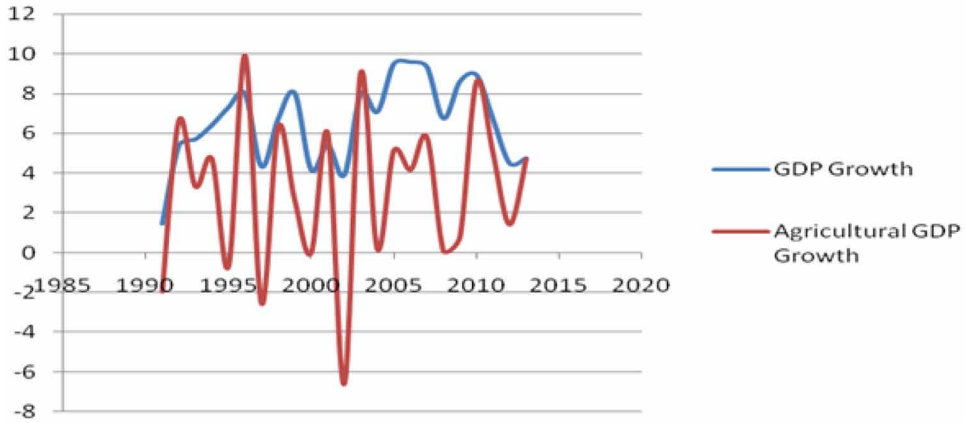
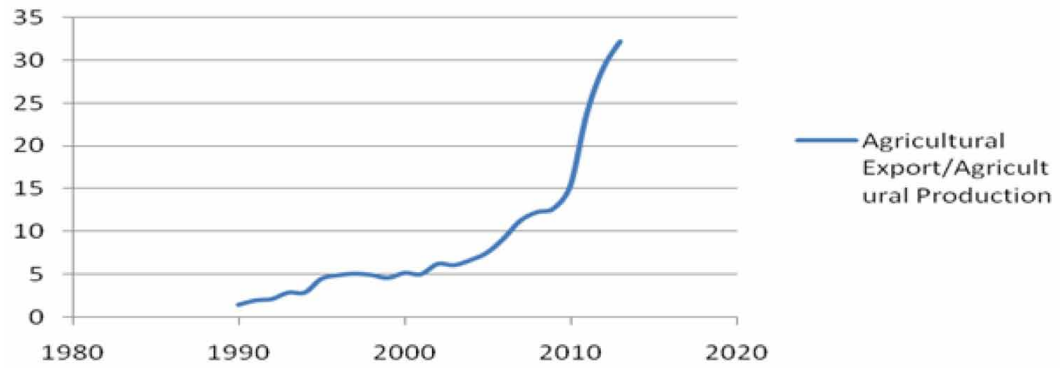
Figure 3. Pattern of growth of GDP and GDP of agriculture
Source: CSO, Government of India, Annual Data from 1990-2015



exporters and consumers too. When the government reduces import duty, it impacts all stakeholders simultaneously. Cutting of import duty makes the same domestic commodity uncompetitive. But consumers get that international commodity at a lower price. When government decides to increase import duty, the same impact appears. In that situation, at the best competitive price, the produce for which import duty is increased minimizes the only option for consumers to get same international commodity.

As export is one of components of GDP the growth by export led hypothesis postulates that export expansion is one of the main determinants of growth. India's export performance is fluctuating in nature from 1990-2015. In 1997, for the first time after liberalization, India's exports registered with negative growth of 2.33 because of the East Asian Crisis. Since the ASEAN countries and Japan were most acutely affected by the crisis, their respective currencies lost value, which also meant that the Indian rupee appreciated against these currencies (due to interest rate differentials). Agricultural export of India faces the impact of negative growth in the year 1999-2000 than previous year. The next major setback for India's exports was the global crisis of 2008. India's trade deficit dampened in 2009-10 with a negative import growth (-0.78 percent) were also impacted with a negative growth rate of 2.9 percent in 2008-09 than

Figure 4. Agricultural export as a share of agricultural GDP
Source: DGCIS and CSO, Government of India, Annual Data from 1990-2015



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previous years. India has been following overall an increasing path in agricultural exports throughout the period from1990 to 2015 except the years 1999-2000 and 2009-2010.

Some commodities such as wheat, sugar, cotton, edible oil, rubber etc are directly related to the government's trade decisions and control. It is observed that in the past few years, the government's approach to deal with the trade of the commodities has been widely exposed. Indian Government has to adopt bottom-up agricultural approaches which emphasize the involvement of the rural people and first prioritize the concerns of our own farmers. Composition of exports means goods that we are selling to other countries. At the time of Independence, exports of India were consisted of agricultural products like tea, spices, tobacco and other raw materials etc. We were also exporting cotton textiles and jute products in large quantities. We are now exporting large quantities of items such as machinery and transport equipment, chemicals allied products, marine products, and handicrafts, however export of items such as fish, cotton, fabric, tea, Jute, manufactures spices etc.

Rural Infrastructure

Rural infrastructure is a major bottleneck in achieving the potential growth-path under globalization. In a Study, (Oshikoya & Hussain, 2002) it is revealed that better rural infrastructure improves price-competitiveness and attracting Foreign Direct Investment (FDI).

In their studies (Wheeler & Ashoka, 1992; Asiedu & Donald, 2004) they found that status of domestic infrastructure is an important determinant of the magnitude of private capital inflow such as FDI. Efficient transportation system with modern telecommunication facilities, reliable energy supply and access to safe water are the essential conditions for attracting investments from outside the country.

Market

Market integration over space and time requires sound infrastructure with all other facilities. Market integration is assumed to be poor in India resulting in drastic drops in local prices and restricted access to commercial finance. We are suffering from poor transport, storage capacity and weak form of communication infrastructure. Rule of law hardly works due low quality of governance; effective competition among the markets is absent. Hence market transaction is highly non-transparent in India. So, development of transparent rules and regulations is essential for infrastructure development as everything is hanging together. As the economic environment becomes adverse, then global financial crisis arises (J.N. Verma, W.P. No. 2009-02-06).

Despite the bottleneck of agrarian crisis, India's food grain production has more than doubled over the decades to a record 264 million tonnes in 2014 because of technological spillover and other factors too, whereas the wellbeing of the growth of output is not transmitted to the farmers with a same rate, a gross inequality. There is still a large dependency on rainfall and other climatic conditions for better yield and post-harvest logistics remains an area of concern. Over the years, marginal and small farmers' suicidal upward trend is observed due to increasing costs of cultivation, higher indebtedness, crop failures and inability to get adequate price.

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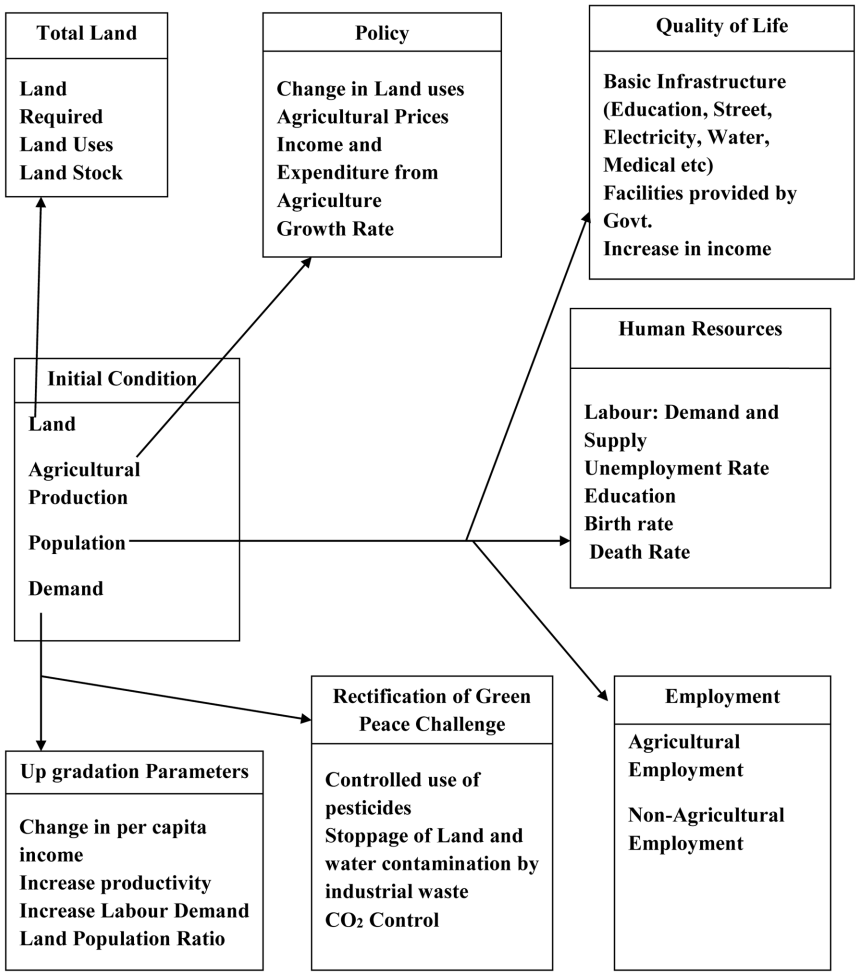
Figure 5. Infrastructure as a base of overall development including agricultural development
Source: Authors' Own Observation



Problem Background

Does investment in "Infrastructure" is beneficial? Govt. of India invests Rs. 12810.22 billion in 2013-14 Union Budget and Rs. 4845.33 Billion in 2014-15 Union Budget for total Infrastructure Development. Only a few researches are available in investment in infrastructure. Bennathan and Canning (2000) indicate that investments in electricity generating and paved roads are more profitable than other public investments. But the question is why the investment is low?

In the view of agrarian crisis, India's food grain production has more than doubled over the decades to a record 264 million tonnes in 2014 backed by Technological spillover, but the same is not being capitalized to increase the revenue and profit margins of farmers. There is still a large dependency on rainfall and other climatic conditions for good yield and post-harvest logistics remains an area of concern. Farmers are greater dependence on private sources led by withdrawal of state. Over the years, marginal and small farmers' suicidal upward trend is observed due to increasing costs of cultivation, higher indebtedness, crop failures and inability to get adequate price.

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REVIEW OF LITERATURE

Tripathi (2008) examined the performance of agricultural productivity in India during the last 37 years, and found stagnation of TFP growth in Indian agriculture. Using the time series data for the period from 1970 to 2005, Shombe (2005) investigated causal relationships among agriculture, manufacturing and exports in Tanzania. The empirical results show that the evidence of Granger causality but agriculture causes both exports and manufacturing. It is really an interesting study where scenario of exports and manufacturing sector become better off with the progress of agricultural activities in developing nation. Khalafalla and Webb (2000) empirically tested the growth hypothesis of export leading for Malaysian economy undergoing major structural changes. Khalafalla and Webb also investigated the relationship between the exports and economic growth in Malaysia using the quarterly data from 1965-1996. Bashir (2003) studied the Pakistan's impacts of economic reforms and trade liberalization on agricultural export performance. He suggested that economic reforms affected the agricultural export performance which is more sensitive to the domestic factors. Shirazi and Manap (2004) re-investigate the exports-economic growth nexus, using the data from 1960 to 2003 period and the results strongly support a long-run relationship among the three variables (imports, export and output). As far as the causality between the exports and output growth is concerned, exports cause output growth, but converse is not true. Khan *et. al.* (1995) investigated the export- growth and economic growth using the granger causality test and co-integration methods and found stable long-run two way relationship between total exports and output while one way relationship between output and primary exports. In their findings, there is a bi-directional causality between total exports growth and economic growth exclude. Huges and Penson (1985) have shown a marked increase in volume of agricultural exports over the years. The authors measured the effects of GDP movements on agriculture. In his research, Chandra (2000) found the bi-directional causal relationship between the growth of exports and GDP growth; short run causal relation is pronounced, because co-integration between GDP growth and growth of exports was not found. Sharma and Panagiotidis (2005) test the export-led growth hypothesis in the Indian context, and the results strengthen the arguments against the export-led growth hypothesis in the context of India. Raju and Kurien (2005) analyzed the relationship between exports and economic growth in India over the period of pre-liberalization (1960-1992), and found strong support for unidirectional causality from exports to economic growth. They have use Granger causality regressions based on stationary variables, with and without an error-correction term. The causal relationship between growth of exports and economic growth in India for the post-liberalization period 1992-2007, analyzed by Dash (2009) ; the results indicate that there exists a long-run relationship between output and exports, and it is unidirectional from growth of exports to output growth.

RESEARCH OBJECTIVE

We are estimating the relationship between public expenditures on infrastructure related to agriculture and allied factors and agricultural sustainability measured in terms of production and export for a given period.

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It is an attempt to provide the emerging relationship of infrastructure availability and productivity growth. By measuring the impact of availability of different type of infrastructural facilities on growth of total factor productivity in state economies in India we may conclude whether the trend is sustainable or not.

HYPOTHESES

On the basis of introductory background, following two null hypotheses are to be tested for achieving the above mentioned objective of the study. They are categorized as following:

H1: Public expenditure on agriculture does not cause output of agriculture in terms of market value.
H2: Public expenditure on agriculture does not have any impact on agricultural export.

DATA SOURCES

The study relies on secondary data compiled from various published sources such as RBI Handbook, World Bank Data etc. The other major sources for the collection of the information are found to be available literature as, journals, books, and news of Government of India and states Governments related to the agriculture, energy, transport, education etc. For trend analysis, we are collecting data from the year 1970-71 to 2014-15. GDP data and export of agriculture and allied product data of same time span are collected for comparing the trend also.

RESEARCH METHODOLOGY

A large number of methods or econometric tools are used in the literature to study the relationship, including infrastructural growth, agricultural-export and GDP. The independent variables used, as a proxy for infrastructure is either some measure of investment or a physical indicator (Straub, 2008).

We know that time series data on any quantitative character or variable may contain either deterministic trend or stochastic trend or both. But implications are obviously different in nature. The time series with deterministic trend follows trend stationary process (TSP), while a non-stationary time series showing stochastic trend is a difference stationary process (DSP). The issue whether a macroeconomic time series is of DSP or TSP is extremely important because the dynamic properties of the two processes are different (Nelson & Plosser, 1982). While the former is predictable, the latter is completely unpredictable. In a series following TSP, cyclical fluctuations are temporary around a stable trend, while for DSP any random shock to the series has a permanent effect. The cyclical components of a TSP originate from the residuals of a regression of the series on the variable time, and a DSP involves regression of a series on its own lagged values and time. A TSP has a trend in the mean but no trend in the variance, but a DSP has a trend in the variance with or without trend in the mean and here it should be mentioned that a random walk without drift has no trend in the mean values of the variable.

The most widely used model to take over stochastic trend is autoregressive of order p [AR(p)]:

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$$X_t = \alpha + \beta_1 X_{t-1} + \beta_2 X_{t-2} + \beta_3 X_{t-3} + \ldots\ldots\ldots\ldots + \beta_p X_{t-p} + \varepsilon_t \quad (1)$$

X_t gives values in log form in time t and ε_t is a stationary series with mean zero and variance σ^2.

This model can generate the trend behaviour of macroeconomic time series and the randomly fluctuating behaviour of their growth rates. If, for example, X_t is generated by the model:

$$X_t = \alpha + X_{t-1} + \varepsilon_t \quad (2)$$

Equation (2) is AR (1) with β_1=1, accumulating X_t starting with an initial value X_0 we get,

$$X_t = X_0 + \alpha t + \sum_{j=1}^{t} \varepsilon_j \quad (3)$$

The Equation (3) has the same form as the conventional log-linear trend equation, excepting for the fact that the disturbance is not stationary.

One important property of time series data, not usually present in cross-sectional data, is the existence of correlation across observations. Income today, for example, is highly correlated with income of the last year. Thus X_t tends to exhibit trend behaviour and to be highly correlated over time. The non-stationary time series containing a unit root will give a stochastic trend. If $\beta_1 = 1$ for the AR(1) model, then X_t has a unit root and exhibit trend behaviour, especially when $\alpha \neq 0$. Unit root series contain a so called stochastic trend.

The Augmented Dickey-Fuller (ADF) test is performed for unit root hypothesis. The more appropriate model for testing a unit root is the AR(p) with deterministic trend:

$$\Delta X_t = \alpha + \rho X_{t-1} + \eta_1 \Delta X_{t-1} + \eta_2 \Delta X_{t-2} + \ldots\ldots\ldots\ldots + \eta_{p-1} \Delta X_{t-p+1} + \delta t + \varepsilon_t, \quad (4)$$

A series belongs to the class DSP exhibiting stochastic trend if ρ =0, δ=0, and the TSP class if $\rho <$ 0. If $\rho = 0$, then X_t contains a unit root. In this case we cannot perform hypothesis testing by utilising the usual distributions appropriate for least square. Thus we have to follow ADF test. If the t-statistics on ρ are less negative than the Dickey-Fuller critical value, we conclude that the series X_t has a unit root.

To test whether the series has a unit root, we have to choose lag length (p). Many sophisticated statistical criteria and testing methods are available to determine the appropriate lag length in an AR(p) model. But we have performed a simple route by choosing a maximum lag length and then sequentially drop lag lengths if the relevant coefficients are insignificant. The maximum lag length is chosen by following Schwert (1989) rule:

$$P_{max} = \text{integer part of } [12(T/100)^{.25}]. \quad (5)$$

AIC is also used for selecting the appropriate lag length. By following such criteria, the maximum lag length is found to be 1. Thus our model would be:

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$$\Delta X_t = \alpha + \rho X_{t-1} + \eta_1 \Delta X_{t-1} + \delta t + \varepsilon_t, \tag{6}$$

The stochastic properties of the time series data in this study have been examined by carrying out Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) unit root tests. Both the intercept and trend components have been incorporated in the ADF estimated relation as following:

$$\Delta X_t = \varphi_0 + \beta t + \rho X_{t-1} + \sum_{i=1}^{P} \gamma_i \Delta X_{t-1} + \varepsilon_t \tag{7}$$

The ADF statistic is the *t*-value associated with the estimated coefficient of ρ, the probability distribution of which is a functional of the Weiner process, the process used in explaining Brownian motion of a particle with large number of molecular shocks (Maddala & Kim, 1998). The PP test is the non-parametric extension of the DF unit root test by adding a correction factor to the DF t statistic. The tests have been performed for all the logarithmic series and their first differences. The choice of lag length is very much crucial at this stage and the number of lags used in the ADF regressions is selected by the Akaike (1969) Information Criterion (AIC).

We have applied cointegration theory developed in Engle and Granger (1987) by utilizing the methodology developed by Johansen and Juselius (1990). The concept of cointegration, first developed in Granger (1981), is relevant to the problem of the determination of long-run equilibrium relationships in economics in a sense that the variables move together over time so that short-term disturbances from the long-term trend will be corrected (Manning & Andrianacos, 1993).

Engle and Granger (1987) have shown that if two time series are cointegrated there will be a causal relation in at least one direction. Furthermore, the Granger Representation Theorem demonstrates how to model cointegrated I(1) series in the form of vector autoregression (VAR). In particular, the VAR can be constructed either in terms of the levels (logarithmic values) of the data, the I(1) variables; or in terms of their first differences, the I(0) variables, with the addition of an error correction mechanism (ECM, which is first used by Sargan (1984) and later popularized by Engle and Granger (1987)) to capture the short-run dynamics. If the data are I(1) but not cointegrated, causality tests cannot accurately be performed unless the data series are transformed into stationary series.

For two variables Y and X, the model can be presented either of the following form:

$$\ln X_t = \theta + \sum_{i=1}^{p} \pi_i \ln X_{t-i} + \sum_{j=1}^{r} \varphi_j \ln Y_{t-j} + v_t \tag{8}$$

$$\ln Y_t = \alpha + \sum_{i=1}^{m} \beta_i \ln X_{t-i} + \sum_{j=1}^{n} \gamma_j \ln Y_{t-j} + u_t \tag{9}$$

or,

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$$\Delta \ln X_t = \theta + \sum_{i=1}^{p} \pi_i \Delta \ln X_{t-i} + \sum_{j=1}^{r} \varphi_j \Delta \ln Y_{t-j} + \lambda ECM_{t-1} + v_t \quad (8.a)$$

$$\Delta \ln Y_t = \alpha + \sum_{i=1}^{m} \beta_i \Delta \ln X_{t-i} + \sum_{j=1}^{n} \gamma_j \Delta \ln Y_{t-j} + \delta ECM_{t-1} + u_t \quad (9.a)$$

Where u_t and v_t are zero-mean, serially uncorrelated, random disturbances, error-correction mechanism is denoted by *ECM*. If the data are I(1) but not cointegrated, valid tests may be done by using the first differences without the error correction term:

$$\Delta \ln X_t = \theta + \sum_{i=1}^{p} \pi_i \Delta \ln X_{t-i} + \sum_{j=1}^{r} \varphi_j \Delta \ln Y_{t-j} + v_t \quad (10)$$

$$\Delta \ln Y_t = \alpha + \sum_{i=1}^{m} \beta_i \Delta \ln X_{t-i} + \sum_{j=1}^{n} \gamma_j \Delta \ln Y_{t-j} + u_t \quad (11)$$

RESULTS AND DISCUSSION

We present our results of unit root test on the basis of methodology taken in our study as mentioned in earlier.

Unit Root Test

Table 2 represents the ADF and PP test statistics for testing unit roots of all the series. Unlike most of the time series analysis, here the null hypothesis of the presence of unit roots is rejected in the original series indicating that all the series are stationary at level in case of both ADF and PP test.

Table 2. Estimated Statistics of Unit Root Tests

Series	Augmented Dickey-Fuller Test Statistics		Phillips Perron Test Statistics	
	Level	First Difference	Level	First Difference
GDPAGR	0.05	-2.04***	-0.33	-4.78***
PEAGRT	0.31	-5.15***	0.29	-5.15***
EXAGR	-0.07	-4.14***	-0.11	-4.15***
Note: ***, ** and * denote the level of significance at 1%, 5%, and 10%, respectively				

Source: Authors' own estimation by using data from HBSIE, RBI database, in E-views 7

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To find the dynamic relationships between agricultural export and different measures of India's public expenditure on agriculture as mentioned above we have used cointegration theory developed in Engle and Granger (1987). The ADF and PP unit root tests suggest that the all the series of the variables are integrated of order one I(1). All the stationary variables at same order of integration may have a common trend and it is reasonable to search for a possible cointegrating relationship among them. In this context we plan for co-integration test. We can also argue that agricultural exports from India continuously follow a time trend.

Cointegration Test

The estimated results of Johansen's cointegration tests have been shown by Table 3. Both the trace or LR test statistic and the eigenvalues are used for testing the hypothesis of presence of cointegrating relation, against the alternative hypothesis of full rank. Findings suggest that are three cointegrating equations as trace statistic reports at 5 percent level. But maximum eigenvalue test indicates no cointegration at the 5 percent level, also denotes the rejection of the hypothesis in case of at most two hypothesized number of cointegrating equations. So we think there may have a long run relationship between India's agricultural export and India's public expenditure on agriculture.

Now we have to test the long run dynamic relationship among the variables by utilizing the structure of vector error correction mechanism (VECM) by incorporating two period lag as suggested by the minimum AIC rule

If a set of variables have one or more cointegrating vectors then a suitable estimation technique is a VECM (Vector Error Correction Model). VECM adjusts to both short run changes in variables and deviations from equilibrium. The vector error correction model (VECM) is a special case of the VAR for variables that are stationary in their differences (i.e., I(1)). The VEC can also take into account any co-integrating relationships among the variables.

Table 3. Estimated statistics of Johansen Cointegration Test

Unrestricted Cointegration Rank Test					
Tests	**Hypothesized No. of CE(s)**	**Eigenvalue**	**Statistic**	**5% Critical Value**	**Prob.****
Trace	None *	0.588955	31.39727	29.79707	0.0324
	At most 1 *	0.299622	9.170966	15.49471	0.3498
	At most 2 *	0.010646	0.267572	3.841466	0.605
Maximum Eigenvalue	None*	0.588955	22.22631	21.13162	0.035
	At most 1*	0.299622	8.903394	14.2646	0.2943
	At most 2 *	0.010646	0.267572	3.841466	0.605
Trace test indicates 3 cointegrating eqn(s) at the 0.05 level					
Max-eigenvalue test indicates 3 cointegrating eqn(s) at the 0.05 level					
* denotes rejection of the hypothesis at the 0.05 level					
**MacKinnon-Haug-Michelis (1999) p-values					

Source: Authors' own estimation by using data from HBSIE, RBI database in E-views 7

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Table 4. Results of Vector Error Correction Model

Error Correction:	D(GDPAGR)	D(PEAGRT)	D(EXAGR)
CointEq1	-0.71822	-1.17944	2.661093
	[-2.76333]	[-1.61121]	[2.62920]
D(GDPAGR(-1))	0.52214	0.928719	-1.00734
	[2.46658]	[1.25972]	[-0.98822]
D(GDPAGR(-2))	-0.06179	0.085089	0.342979
	[-0.35720]	[0.17465]	[0.50915]
D(PEAGRT(-1))	-0.16023	-0.92865	0.314009
	[-1.92889]	[-3.96931]	[0.97071]
D(PEAGRT(-2))	0.866918	-0.61785	0.225633
	[3.77236]	[-2.53196]	[0.66876]
D(EXAGR(-1))	-0.25396	-0.53041	0.411644
	[-2.34835]	[-1.74146]	[0.97748]
D(EXAGR(-2))	-0.26477	-0.45654	0.288386
	[-3.36582]	[-2.06067]	[0.94144]
C	0.001782	0.006193	-0.005
	[0.22709]	[0.28027]	[-0.16366]
R-squared	0.814224	0.584802	0.517655
Adj. R-squared	0.727529	0.391043	0.29256
Sum sq. resids	0.020508	0.162677	0.310994
S.E. equation	0.036976	0.10414	0.143989
F-statistic	9.391802	3.018194	2.299723
Log likelihood	48.12225	24.3065	16.85439

Source: Authors' own estimation by using data from HBSIE, RBI database in E-views 7

Table 4 shows the estimation of coefficients with corresponding t statistics in [] from the mechanism of vector error correction. Results indicate that only the GDP growth of India is significantly determined by the India's Agricultural export with one period lag.

CONCLUSION AND POLICY SUGGESTION

The chapter tried to contribute a new dimension to the study of sustainable rural development through agrarian reforms by investigating the impact of public expenditure on agriculture in terms of production and export empirically in India for a long period from 1970-71 to 2014-15. Our findings, by applying Johansen cointegration tests on the basis of unit root test results, imply that there is at least one co-integrating equation as suggested by both trace and maximum eigen value statistics. So there may have a long run equilibrium relationship among variables. The results of vector error correction mechanism model to find the long run dynamics show that growth of agricultural output is significantly influenced by public expenditures on agricultural and allied sectors with one period lag.

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Low productivity with high cost of production and absenteeism of labour are the important barriers to the Indian agriculture. To develop agricultural market, value addition in the current infrastructure, such as more number of cold storage, roads, green mandi are urgently required. Currently India is facing some problems in productivity gain and in lowering cost of production. FAO suggested that the unit cost must be reduced through productivity gain.

It is most challenging time for introduction of energy and cost effective technology and equipment so that long-term strategy with a good infrastructure only pays the agricultural sustainability. There is also a huge scope to carry forward this research study further by looking at the aspects of long run relationship with direction of causality between agricultural performance and private investment in Indian agriculture in India. This would ensure more robust results and much more meaningful analysis which could be helpful for the policymakers as well as researchers in India to frame an Infrastructure led growth policies in the years to come.

REFERENCES

Ahmad, S. (1966). On the theory of induced innovation. *The Economic Journal*, *76*(302), 344–357. doi:10.2307/2229720

Alston, J. M., George, W. N., & Philip, G. P. (1995). *Science under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting*. Ithaca, NY: Cornell University Press.

Antle, J. M., & Capalbo, S. M. (1988). An Introduction to Recent Developments in Production Theory and Productivity Measurement. Agricultural Productivity: Measurement and Explanation. Washington, DC: Resources for the Future.

Arnade, C. (1998). Using a Programming Approach to Measure International Agricultural Efficiency and Productivity. *Journal of Agricultural Economics*, *49*(1), 67–84. doi:10.1111/j.1477-9552.1998.tb01252.x

Bashir, Z. (2003). The Impacts of Economic Reforms and Trade Liberalisation on Agricultural Export Performance in Pakistan. *Pakistan Development Review*, *42*(4), 941–959.

Bhaumik, S. K. (2015). *Principles of Econometrics: A Modern Approach using E-views*. Oxford University Press.

Bhushan, S. (2005). Total Factor Productivity Growth of Wheat in India: A Malmquist Approach. *Indian Journal of Agricultural Economics*, *60*(1).

Binswanger, H. P., & Ruttan, V. W. (1978). *Induced Innovation: Technology, Institutions and Development, Baltomore and London*. The John Hopkins University Press.

Bradshaw, G., & Orden, D. (1990). Granger Causality from the Exchange Rate to Agricultural Prices and Export Sales. *Western Journal of Agricultural Economics*, *15*(1), 100–110.

Chambers, R. G., & Just, R. E. (1991). Effects of Exchange Rate Changes on U.S. Agriculture. *American Journal of Agricultural Economics*, *73*, 33–43.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Chandra, R. (2000). *The Impact of Trade Policy on Growth in India* (Unpublished PhD Thesis). Department of Economics, University of Strathclyde, Glasgow, UK.

Chandra, R. (2002). Export Growth and Economic Growth: An Investigation of Causality in India. *The Indian Economic Journal*, *49*, 64–73.

Dickey, D. A., & Fuller, W. A. (1979). Distribution of the Estimators for Autoregressive Time Series with a Unit Root. *Journal of the American Statistical Association*, *74*, 427–431.

Engle, R. F., & Granger, C. W. J. (1987). Co-integration and Error Correction Representation: Estimation and Testing. *Econometrica*, *55*(2), 251–276. doi:10.2307/1913236

Fan, S., Hazell, P., & Thorat, S. (1999). *Linkages Between Government Spending, Growth, and Poverty in Rural India. Research Report 110*. Washington, DC: International Food Policy Research Institute.

Fischer, A., Petersen, L., Feldkötter, C., & Huppert, W. (2007). Sustainable Governance of Natural Resources and Institutional Change: An Analytical Framework. *Public Administration and Development*, *27*(2), 123–137. doi:10.1002/pad.442

Government of India. (2015). *Agricultural Statistics at a Glance, Directorate of Economics and Statistics*. New Delhi: Ministry of Agriculture.

Gujrati, D. N. (2003). Basic Econometrics. *McGraw Hill Education*, *4*, 696–702.

Hughes, D. W., & Penson, J. B. (1985). Effects of Selected Macroeconomic Policies on Agriculture: 1984-1990. *Agricultural Financial Review*, *45*, 81–91.

Johnson, P. R., Grennes, T., & Thursby, M. (1977). Devaluation, Foreign Trade Control, and Domestic Wheat Prices. *American Journal of Agricultural Economics*, *59*(4), 619–627. doi:10.2307/1239389

Khalafalla, K. Y., & Webb, A. J. (2001). Export-led Growth and Structural Change: Evidence from Malaysia. *Applied Economics*, *33*(13), 1703–1715. doi:10.1080/00036840010015066

Mellor, J. W. (1966). *The Economics of Agricultural Development*. New York: Cornell University Press.

Oshikoya, W. T., & Hussain, M. N. (2002). Infrastructure for Economic Development in Africa. In J. B. de Macedo & O. Kabbaj (Eds.), *Regional Integration in Africa*. OECD.

Pindyck, R. S. (1998). Irreversible Investment, Capacity Choice, and the Value of the Firm. *The American Economic Review*, *78*, 969–985.

Pinstrup-Andersen, P. (2002). Food and Agricultural Policy for a Globalizing World: Preparing for the Future. *American Journal of Agricultural Economics*, *84*(5), 1201–1214. doi:10.1111/1467-8276.00381

Pinstrup-Andersen, P., & Shimokawa, S. (2002). *Rural Infrastructure and Agricultural development* (pp. 185–203). Rethinking Infrastructure for Development.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Rao, K. S. C., & Dhar, B. (2011). *India's FDI Inflows- Trend and Concepts*. Working Paper No. 01. Institute for Studies in Industrial Development.

Razin, O., & Collins, S. M. (1997). Real Exchange Rate Misalignments and Growth. In *The Economics of Globalization: Policy Perspectives from Public Economics*. Cambridge, UK: Cambridge University Press.

RBI handbook data for GDP growth, export and total public expenditure on agriculture. (n.d.). Retrieved from https://rbi.org.in/Scripts/AnnualPublications.aspx?head=Handbook%20of%20Statistics%20on%20Indian%20Economy

Schultz, T. W. (1964). *Transforming Traditional Agriculture*. New Haven, CT: Yale University Press.

Sinha, M., & Sengupta, P. P. (2016). *Post Reform Trends in India's Foreign Exchange Rate: Testing the Role of Agricultural Exports*. Presented at National Symposium on Statistics for Sustainable Agricultural Development, Kolkata, India.

Tripathi, A., & Prasad, A. R. (2008). *An Overview of Agrarian Economy in India: Then Performance and Determinant.* Retrieved from http://blogs.wsj.com/indiarealtime/2013/08/26/where-are-the-onions/

Zee News. (2015). *Exclusive Union Budget*. Available at: http://zeenews.india.com/exclusive/budget-2015-the-need-for-an-overhaul-in-indian-agriculture-sector_1541831.html

KEY TERMS AND DEFINITIONS

Agrarian Reform: Agrarian reform is government-initiated or government-backed redistribution of agricultural land.

Agricultural Development: Agricultural development includes providing assistance, employing latest techniques, controlling pests and facilitating diversity to the crop producers with the help of various agricultural resources.

Agriculture: Agriculture is the cultivation of plants and animals for food, fiber, bio fuel, medicine and other products which are used to sustain and enhance human life.

Econometric Model: Econometric models are based on statistical models used in econometrics which specifies the statistical relationship to hold among the various economic quantities pertaining to a particular economic phenomenon under study.

Economic Development: Economic development is the efforts that seek to improve the economic well-being and improve quality of life for a community by creating jobs and supporting or growing incomes and the tax base.

Implementation: The process of execution of a decision or plan into effect.

Infrastructure Development: For economic development and prosperity of a country, infrastructure development is essential. Infrastructure includes the basic physical systems of a nation communication, transportation, sewage, water and electric systems etc.

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Policy: A course or principle of action adopted or proposed by an individual or organization.

Public Expenditure: When spending is made by the government of a country based on collective needs and wants such as pension, provision, infrastructure, etc.

Rural Development: Rural development is the process of improving the quality of life and economic well-being of people living in sparsely populated areas.

Social Mobilization: Social mobilization is the primary step of community development for awareness and to organize and initiate action for their recovery with their own initiative and creativity to protect from disasters etc.

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Chapter 53
Mitigation of Climate Change Impacts Through Treatment and Management of Low Quality Water for Irrigation in Pakistan

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ABSTRACT

The Indus Plains of Pakistan are situated in arid to semi-arid climate where monsoon rains are erratic and mostly fall in the months of July and August. These rains are not only insufficient to grow even a single crop without artificial irrigation but also cause flood havoc very frequently that is associated with the climate change. The Indus river transports water for agriculture, industry and domestic usage within the basin and downstream. The Indus Basin is among the few basins severely affected by global warming and resulting climate change. The alteration in temporal and spatial patterns of rainfall has resulted in unexpected drought and floods. About 70 to 80% of total river flows occur in summer season due to snow melt and monsoonal rainfalls. Lack of storage reservoirs has decreased the ability to regulate flood water as well as its potential use during the drought season along with cheap hydro-electricity generation. The sedimentation in the system has limited the storage capacity of the existing three reservoirs by 28%. Consequently carry over capacity of these storage structures is only 30 days compared to 120 to 220 days in India and 900 days in Colorado Basin. Pakistan is facing shortage of good quality water

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due to competition among agricultural and non-agricultural sectors, this scenario will continue rather will further aggravate in future. According to the climate change scenario, the warming is reflected in the river-flow data of Pakistan, especially during the past 2-3 decades. To bridge the gap between fresh water availability and demand, ground water is being pumped to meet the irrigation requirements of crops. The pumped ground water (70-80%) is brackish and could become a sustainability issue in the long run. The prolonged agricultural uses of such water will deteriorate soils, crops and human living environments. Water quality parameters usually considered include electrical conductivity (EC) for total soluble salts, and sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) reflect the sodicity hazards. In order to limit or even to eliminate adverse effects of such waters, certain treatment and/or management options are considered as important pre-requisites. For bringing down high concentration of total soluble salts, dilution with good quality water is the doable practice. To decrease high SAR of irrigation water, a source of calcium is needed, dilution (with good quality water) will decrease SAR by the square root times of the dilution factor, while use of acids will be cost-intensive rather may adversely impact the soil health. For high RSC, dilution with low $CO_3^{2-}+HCO_3^-$ water will serve the purpose, addition of Ca-salts will raise $Ca^{2+}+Mg^{2+}$ to bring a decrease in water RSC, while acids will neutralize $CO_3^{2-}+HCO_3^-$ to lower water RSC. Gypsum is the most economical and safe amendment while acids could also decrease RSC but at higher relative cost. City wastewater and seed priming in aerated gypsum solution is also presented. Such practices at small and/or large scale surely will help a lot to sustain the food security and the environment in the days to come where climate change has to be experienced round the world. Therefore, a well-coordinated program is necessary to create awareness among different sections of the society including the policy makers, general public, organizations, industrialists and farmers.

INTRODUCTION

The Indus Plains of Pakistan are situated in arid to semi-arid climate zones where rains during monsoon are erratic and mostly fall during the months of July to September. These rains cause flood havoc very frequently that is associated with the climate change; floods during the years of 2010, 2011 and 2014 are very good examples to such climate change impacts those resulted in hundreds of human and animal deaths as well as caused billion dollar loss to infrastructures, soil quality and crops. The Indus river transports water for agriculture, industry and domestic usage within the basin and downstream. About 70 to 80% of total river flows occur in summer due to snow melt and monsoonal rains.

The effect of climate change is not limited to water availability only but it also affects crop yields and thus the food security and worsens the human living environments. The increasing soil salinity might cause additional harm in future, if less annual rainfall and higher temperatures prevailed at the current rate in future due to climate change. Due to reduction in annual rainfall, sufficient leaching of salts will not be achieved and higher temperatures will further aggravate the salt stress in regions already threatened by soil salinity (Sommer et al., 2013). The availability of water in Pakistan has decreased from 5300 m^3/year/person in 1950's to 1066 m^3/person/year in 2010 and it is estimated to be < 850 m^3 per capita by the year 2025 (WAPDA, 2011). The World Bank has included Pakistan in the list of 17 countries predicted to encounter severe water shortages by 2025. There is immense need and scope to develop additional surface water storage for drought periods since a plenty of river water is discharging into the Arabian Sea, ≈ about 34 to 37 million acre foot (MAF) water is discharged into the sea. Such policy issues have

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to be decided by overlooking the political interests and giving priority to national interests by all the sections of society including politicians, policy makers and techno-crates.

An additional option is ground water (unfortunately poor quality) that may supplement growing irrigation needs because of increased cropping intensity and competition for fresh water by non–agricultural sectors. At present, $> 1.07 \times 10^6$ tube wells are pumping 9.05×10^6 ha–m ground water in Pakistan (Federal Bureau of Statistics, 2011-12), of which≈ 70-80% is unfit for agriculture because of high EC, SAR and/or RSC (Ghafoor et al., 2004). The irrigation with poor quality water may cause soil salinity/sodicity, poor infiltration, hard setting of soils, specific ion toxicity in plants; all combined to adversely affect the growth and economic yields of crops along with human living environments. Further to this, sub-soil drying due to draw-down of water table could be an important future concern (Wichelns and Qadir, 2015).

The ground water, storm water during floods and raw city sewage (from industry-mix) may pose serious hazards because of high EC ($\geq$1.0 dS m^{-1}), SAR ($\geq$10.0), RSC ($\geq$2.5 $mmol_c$ L^{-1}), heavy metals, high Mg to Ca ratio, diseases, pathogens, detergents, azo-dyes and pesticide residues (Murtaza et al., 2010; Qadir et al., 2010). However, management or treatment depends upon many factors like crop type, plant growth stage, physical/chemical properties of soils, and reactions between water and soil solids, climatic factors, farmers' skills, drainage water quality, requirements of consumers and socio-economic conditions and acceptable decrease in produce yield as well as quality. Recently United Nations Climate Change Conference (COP21, 2015) was held in Paris ended up with the conclusions to decrease global greenhouse gases (GHGs) emission to zero level and to limit the average rise in global temperature to 2 degrees Celsius. To follow the goals and accomplish them saline water can be used for irrigation to bring more lands under cultivation. Bio saline agriculture can help in improving salt-affected soils such as cultivation of salt tolerant crops and growing of forest trees in barren lands instead of leaving them fallow. This would help in sequestering environmental CO_2 and alleviates global temperature rise. Deserts can also be made productive by installing solar energy panels. Recently, Morocco has floated a tender for 400 MW solar power project (COP21, 2015). In Pakistan a solar power project has also been installed in Bahawalpur with a capacity of 100 MW.

This chapter describes efforts related to brackish water treatment and/or management that must be critically examined to learn lessons and shape the future for safe and sustainable use of brackish water. This chapter also highlights the economic feasibility of using gypsum, acids and/or acid formers and like amendments for brackish water treatment with least disturbing the biosphere equilibrium.

Brackish Water

Brackish water is a general term for water having high EC, SAR and/or RSC. Canal water supply has become short to cope with the crop requirements because of prolonged and un-expected droughts mostly in response to climate change, silting of water reservoirs, competition between agricultural and non-agricultural demands and increased cropping intensity. As a result, pumping of ground water has increased tremendously over the years. Due to canal water shortage, number of tube wells is increasing at an alarming rate, i.e. 3000 in 1950 to > a million in 2014. Unfortunately, the pumped ground water is unsuitable for irrigation, since ≈ 70-75% tube wells were and are pumping brackish water (high EC, SAR and/or RSC) during the period of 1995 to 2014 (personal communication from Directorate of Soil Fertility Res. Inst., Lahore). Continued use of such waters for irrigation is one of the major reasons to induce soil salination/sodication along with hard setting, deterioration in produce quality/shelf life, and

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creating environment problems (Ghafoor et al., 2001a). In addition, sub-soil drying due to draw-down of water table is another future concern and must be addressed immediately and wisely. Indiscriminate pumping of ground water is also deteriorating the ground water quality, particularly under the decreased of ground water recharge due to lining of water courses, canals and increasing water use efficiency leading less leaching fraction; a minimum leaching fraction is the key to arrest the salt accumulation in the root zone under arid and semi-arid climates even with canal water irrigation. It is the rule of thumb that as one goes deeper into subsoil and away from rivers, ground water quality becomes poorer and poorer.

The shortage of quality irrigation water in Pakistan has attracted the international interest. Some private organizations are trying to market their products for the treatment of brackish water without proper testing to prove validity/usefulness under local agro-climatic conditions as explained in a later section.

Water Quality Criteria for Irrigation

Numerous water quality guidelines have been proposed by various scientists in Pakistan (Hussain, 1978; Sheikh, 1989; Yunus, 1977) and India (Gupta, 1990) but lack support of experimental data. The guidelines developed by the US Salinity Lab. Staff (1954) and Ayers and Westcot (1985) have been most commonly followed which more accurately predict the effect of water quality on soils and crops. Extensive experimentation is required to develop water quality guidelines keeping in view the physical and chemical properties of soils and agro-climatic conditions of Pakistan. Depending upon the degree of restriction, the three poor quality water classes (saline, saline-sodic and sodic) could be further grouped each into three homogenous subgroups (Table 1), since each subgroup needs specific management practice(s). This classification also helps to serve the purpose at regional levels.

Table 1. Grouping ground water for quality parameters

Water Quality	EC_{iw} (dS m^{-1})	SAR_{iw}	RSC ($mmol_c$ L^{-})
E. Good	< 1. 5	< 1 0	< 2. 5
F. Saline			
Marginally saline	1.5-3.0	< 10	< 2.5
Saline	≥ 3.0	< 10	< 2.5
High-SAR saline	≥3.0	≥ 10	< 2.5
G. Saline-sodic			
Marginally saline-sodic	1.5-3.0	10-15	2.5-4.0
Moderately saline-sodic	1.5-4.0	10-15	≥ 4.0
Highly saline-sodic	≥ 4.0	≥ 15	≥ 4.0
H. Sodic			
Marginally sodic	0.5-3.0	10-15	2.5-4.0
Moderately sodic	1.5-3.0	≥ 15	≥ 4.0
Highly sodic	< 3.0	≥15	≥ 4.0

Source: Ghafoor et al. (2004)

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GROUND WATER RESERVES

Previously, the quality of ground water was assessed on the basis of total soluble salts (TSS). The extent of areas possessing groundwater of different salinities within 350 feet is 40.73 MA (Ahmad & Chaudhry, 1997). It may also be noted that groundwater of the reported quality does not exist within the full depth of 350 feet. Generally, quality of water in the upper depth is relatively better owing to recharge through seepage from canal water irrigation structures and useable except at certain sites. But, in general, groundwater quality deteriorates as we move deeper and away from the rivers and canals. However, highly hazardous properties of water, RSC and SAR have been neglected in the past surveys which even need scientifically more emphasis. Furthermore, EC: SAR, Ca^{2+}: Mg^{2+}, Na^{+}: K^{+} and Ca^{2+}: total cation ratios in water have seldom been considered.

TREATMENT OF BRACKISH WATER

Salinity

The EC_{iw} is an index of total soluble salts. The only treatment option to bring a decrease in total soluble salts is dilution with low salt water. Use of any chemical like gypsum, acid or acid formers will increase salt contents making the use of treated water even more hazardous. However, high EC_{iw} for initial reclamation of saline-sodic/sodic soils have proved better because of favorable effects of electrolytes on soil hydraulic properties (Ghafoor et al., 2004; Murtaza et al., 2009). Addition of organic matter to soil could help counter partially or extend the time to appear ill effects of high EC_{iw} on soils and crops (Ghafoor et al., 2002). Dilution required for high EC_{iw} can be calculated by the formula:

$$EC_{BW} = [(EC_a)F_a)] + [EC_b)(F_b)] \text{ if } a + b = 1, \text{ then } a = 1 - b \text{ or } b = 1 - a \quad (1)$$

where EC_{BW} = EC of blended water, EC_a = EC of water a, F_a = Fraction of water a, EC_b = EC of water b, F_b = Fraction of water b.

Dilution

The SAR will decrease by the square root times of the dilution factor (DF) or will increase square root times of the concentration factor (CF), i.e. Blended water SAR = Original SAR/$(DF)^{1/2}$ or Original $SAR_{iw} \times (CF)^{1/2}$

Desalination

Desalination is a process to remove excess salts and other minerals from water to make it suitable for irrigation. Sometimes table salt is obtained as a by-product. In order to sustain irrigated agriculture, construction of water desalting plants provides another option. The traditional process used in these operations is like to distillation. In this technique, systems require large amounts of energy to produce desalted water. This is possible only where low cost energy is available. Another technique (reverse osmosis) is used to remove all the types of soluble salts from brackish water. The brackish water is passed

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through semi-permeable membranes under pressure and concentrated brine is collected separately down the stream for safe disposal. Because of decreased volume, the concentrated brine can be used to extract some commercial-grade salts. In reverse osmosis, a pressure greater than the osmotic pressure of water is applied to saline water which causes desalted water to flow through membranes while retaining back salts. The higher the applied pressure above the osmotic pressure, the higher the rate of desalted water transports across membranes. This technology is well established and systems have been fabricated at economical costs. Such systems are in operation in USA, Saudi Arabia, China, USSR and Morocco at under government management (Ghafoor et al., 2004). This technology seems very difficult and expensive for the time being to practice in Pakistan due to energy crises and high prices.

SODICITY

Sodium Adsorption Ratio (SAR)

It is calculated using soluble ions in water or soil solution (US Salinity Lab. Staff, 1954) as:

$$SAR = Na^{+}/ (Ca^{2+} + Mg^{2+}/2)^{1/2} \quad (2)$$

ions concentration in $mmol_c\ L^{-1}$ OR

$$SAR = Na^{+}/ (Ca^{2+} + Mg^{2+})^{1/2} \quad (2)$$

ions concentration in $mmol\ L^{-1}$

Dilution

Like $EC_{iw,}$ mixing with low SAR or high $Ca^{2+} + Mg^{2+}$ water will decrease it by square root times of the dilution factor.

Addition of Ca-Source

Concentration of Na^{+} in irrigation water could not be decreased economically because of large volumes required for agriculture except dilution with low Na^{+} water. Concentration of Ca^{2+} can be increased through lining of water courses with gypsum stones as baffled structures/ geometry to enhance the flow velocity of water as well as to maximize the water-stone contact. This strategy is safe and economical although some problems of rodents, weeding of water courses or decreasing gypsum stone dissolution with time due to lime coating ($CaCO_3$) on gypsum stone surfaces if water has high RSC and thus may prove cost-intensive (Oster, 1994) because frequent acid flushing of stones will be essential to sustain the dissolution rate of gypsum stones in order to have effective treatment of water. The calculated amount of gypsum powder required to decrease the SAR hazards (or to counter the adverse water SAR effects) could also be soil-applied before planting the designed crop. The soil-application of gypsum considering volume of water can be calculated as:

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Water has EC 3.25 dS m^{-1}, $Ca^{2+} + Mg^{2+}$ 6 $mmol_c\ L^{-1}$, Na^+ 24 and SAR 13.87. How much 90% pure gypsum is required to lower SAR to 10 of a 10 cm-ha irrigation.

$$SAR = \frac{Na\ 24}{(Ca + Mg/2)^{1/2}} = \frac{}{(6/2)^{1/2}} = 13.87$$

Additional $Ca^{2+} + Mg^{2+}$ required = 13.87 – 6.00 = 7.87 $mmol_c\ L^{-1}$

100% pure gypsum required for 10 cm-ha irrigation = $10^6 \times 7.87\ mmol_c\ L^{-1} \times 86 \times 10^{-6}$

= 676.82 kg of 100% pure

752.20 kg required of 90% pure gypsum

Residual Sodium Carbonate (RSC)

The RSC calculations are based on the assumption of quantitative precipitation of CO_3^{2-}, HCO_3^- and Ca^{2+} ions in soils (Eaton, 1950) which could not be always true. Quantity and rate of salt precipitation is governed by the least amount of any one of these ions. Upon irrigation (dilution), the recently formed $CaCO_3$ precipitates are dissolved while reverse (re-precipitation) may be true upon concentration of soil solution through evapo-transpiration. The formula for RSC calculation is:

$$RSC = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+}) \quad (3)$$

where ions concentration in $mmol_c\ L^{-1}$.

Addition of Ca Source

This treatment could be achieved by the water course lining with gypsum stone as baffled structures/ geometry to enhance the flow velocity of water as well as to maximize the water-stone contact. The calculated amount of gypsum powder required to decrease the RSC hazards (or to counter the adverse water RSC effects) could also be soil-applied before planting the designed crop.

Neutralization of CO_3^{2-} and HCO_3^-

This could be accomplished with mineral acids (H_2SO_4, HCl, HNO_3) or acid former (S, CaS_5, FeS) but the option is and has to be highly site-specific because this treatment will simultaneously increase EC. General chemical reactions of carbonates with acids (say Na_2CO_3 and H_2SO_4) will be:

$$2Na_2CO_3 + H_2SO_4 = 2NaHCO_3 + Na_2SO_4 \quad (4)$$

$$2NaHCO_3 + H_2SO_4 = Na_2SO_4 + 2H_2O + 2CO_2 \quad (5)$$

Without changing its SAR, these reactions will tend to lower pH of water and the soil irrigated with such treated water for reasonably longer periods.

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Dilution

Like $EC_{iw,}$ mixing with low RSC or high $Ca^{2+} + Mg^{2+}$ water will decrease it in direct proportion of the dilution factor.

Among amendments for lowering RSC, gypsum is the most economical and safe, while acids could serve the purpose but at 5-8 times higher cost than gypsum (Ghafoor et al., 2004). The best economical solution for high SAR and/or RSC waters is soil-applied gypsum with or without farm manure or green manure before each crop considering the delta of water of crops and intensity of SAR and/or RSC problem. The blended/mixed use of canal and brackish waters is not possible in our conditions as the canal water supplies are not in the control of farmers.

High Concentration of Mg^{2+}

In some areas, irrigation water may contain high concentration of Mg^{2+} with Mg^{2+} to Ca^{2+} ratio > 1. The use of such water for irrigation and reclamation may increase exchangeable Mg^{2+} in soils (Karajeh et al., 2004). Exchangeable Mg^{2+} at excessively high levels may result in soil degradation because of its adverse effects on physical properties of soils. According to McNeal et al. (1968) soils having mixed Na^{+}–Mg^{2+} will have lower hydraulic conductivity than did soils with Na^{+}–Ca^{2+} under similar conditions. This could be due to the fact that t the hydration energy as well as hydration radius of Mg^{2+} are greater than that of Ca^{2+} (Strawn et al., 2015). Thus soil surface retains more water than where exchangeable Ca^{2+} is present, causing weakening of forces that stabilize soil structure. This, in turn, decreases the amount of energy needed to break down soil aggregates (Oster & Jayawardane, 1998). Further to this, at low levels of exchangeable sodium percentage (ESP), Mg^{2+} also exaggerates the effects of Na^{+} on clay dispersion and hydraulic conductivity (Qadir & Schubert, 2002). Oster (2001) reported that when Mg^{2+} proportion compared to Ca^{2+} increases than exchangeable Mg^{2+} resulted in greater dispersion thus causing a larger decline in hydraulic conductivity. Similarly, at a given ESP, replacing the exchangeable Ca^{2+} with Mg^{2+} decreased the infiltration rate of soils (Rengasamy et al., 1986). A recent review (dating back to the 1930s) by Smith et al. (2015) supports the general conclusion that the relative order of deleterious effects on soil hydraulic properties of the four common cations in soils was in the order of $Na^{+} > K^{+} > Mg^{2+} > Ca^{2+}$. It was concluded that Mg^{2+} was significantly less effective than Ca^{2+} in improving soil structure and water permeability.

The achieved results from the above stated brackish water quality improvements, several other untested technologies by some vested interest people are claiming. These technologies include Sulphurous Acid Generator (SAG) by Sweet Water Solution of USA, EM/BM technology from Japan, RISTECH Technology from UK, and Electro-Magnetic Membrane technology from Germany. Novel claims of these technologies are to desalinate the brackish water, convert sodium into nitrogen, change in soil texture over a period of 2-3 years, and bacteria in these recipes eat salts as well as sodium present in water or soils. Unfortunately, none of these have been demonstrated at any university or research farm. In spite of this fact, they are be-fooling the farmers at a very large scale to make money. Government should give attention immediately to stop their business and save hard earnings of farmers since farmers are drowning and try to catch a straw to save themselves.

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EC_{iw} to SAR_{iw} Ratio

Low EC_{iw} or EC_e at a given SAR_{iw} or SAR_{ss} tends to decrease soil infiltration through decreasing the thickness of Diffused Double Layer (DDL) (Ayers & Westcott, 1985; Ghafoor et al., 2004). Water having low SAR_{iw} and high EC_{iw} was found better for normal and salt-affected soils because of favorable effects of electrolytes on soil infiltration and hydraulic conductivity, while reverse was true for high SAR_{iw} with low EC_{iw}. Therefore at start of reclamation of saline-sodic or sodic soils, waters having high EC: SAR ratios were found equally useful (Ghafoor et al., 2001b) but has to switch to better quality water (low EC_{iw}, low SAR_{iw}) with the advancement of soil reclamation (Murtaza et al., 2009). It is important to consider this quality parameter for sustainable management of brackish water in order to maintain a leaching fraction as well as if used for reclaiming salt-affected soils. Some studies were conducted by authors in the Fourth Drainage Project Area (FDPA), Faisalabad using brackish water, wherein it was concluded that such waters can be used safely at the early stages of reclamation (Ghafoor et al., 2008, 2011, 2012; Murtaza et al., 2009). However, presently this parameter is not given very much importance and must be considered for future irrigation water quality guidelines.

PERMEABILITY PROBLEMS

Permeability refers to the percolation of infiltrated water through soils. Doneen (1975) suggested a formula to predict the infiltration rate which was designated as Permeability Index (PI).

$$PI = [100\ \{Na^+ + (HCO_3^-)^{1/2}\}/\{Na^+ + Ca^{2+} + Mg^{2+}\}] \quad (6)$$

where ionic concentrations in water are in $mmol_c\ L^{-1}$.

This relationship is quite useful in predicting the effect of water on permeability of soil and also this does not need extra determination in routine water analysis.

INFILTRATION PROBLEM

The rate at which water enters into soils is referred to as the rate of infiltration. An infiltration rate (IR) as low as 3 mm h^{-1} is considered low while a rate > 12 mm h^{-1} is high (US Salinity Lab. Staff, 1954). This parameter is affected by many factors other than water quality, like soil physical characteristics (soil texture, type of clay minerals) and chemical characteristics (exchangeable cations). The IR generally increases with increasing salinity (EC) and decreases with either decreasing EC or increasing Na^+ concentration relative to Ca^{2+} and Mg^{2+}, i.e. SAR (Murtaza et al., 2006). Therefore, EC and SAR must be considered for a proper evaluation of the ultimate effect of water on its infiltration rate.

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SPECIFIC ION EFFECTS

It is the concentration of an ion relative to total concentration which when exceeds beyond a certain limit cause specific ion effect. If Na^+ concentration is > 60% of the total cations, water becomes hazardous for irrigation because it induces K^+ and/or Ca^{2+} deficiency and scorching of leaf tips in addition to deteriorating physical and chemical properties of soils. It is worth mentioning that deterioration in physical properties of soils starts much earlier than specific ion effects of Na^+ on plant growth. The concentrations of Cl^- and SO_4^{2-} strongly correlate with EC of irrigation water (EC_{iw}). About 5-10 $mmol_c\ L^{-1}$ Cl^- becomes harmful to sensitive plants. However, relatively wide range of sensitivity to Na^+ and Cl^- effects among different plants exists which is more pronounced under sprinkler irrigation. Woody plants are more sensitive to Cl^- than annual crops. If Cl^-: SO_4^{2-} ratio becomes greater than 1: 3, the water is considered more hazardous than that where this ratio is 3: 1. The SO_4^{2-} ions are considered more harmful for roots and disturb internal metabolism of plants. These ions induce precipitation of Ca^{2+} as $CaSO_4$ which causes a rise in soil pH and SAR, and thus make the soil environment unfavorable for nutrient availability to plants. Generally waters having high EC under arid to semi-arid conditions may contain $Mg^{2+} > Ca^{2+}$. Magnesium >50% among $Ca^{2+} + Mg^{2+}$ adversely affects soils and plants. Increasing Mg^{2+} over Ca^{2+} in irrigation water increased the sodicity in soils at a given SAR_{iw} and EC_{iw} and its effects were more pronounced at higher than that at lower SAR_{iw}. Release of Ca^{2+} from the in-situ soil weathering and native lime increased with increasing Mg^{2+}: Ca^{2+} ratio in irrigation water. With an increase in Mg^{2+}: Ca^{2+} ratio and SAR of soil and/or irrigation water, the degree of dispersion increased significantly. The Ca^{2+}: Mg^{2+} ratio $\geq$ 1.0 is considered safe for most of the crops and soils. Generally, grasses are more sensitive to Mg^{2+} than other plants since former crops acquire high Mg^{2+} in living tissues. From previous studies, it was also noted that high Mg^{2+} water is relatively more harmful to affect rice yield as compared to wheat and cotton crops (Ghafoor et al., 1997). This aspect needs further research since a lot of ground waters contain Mg^{2+} higher than Ca^{2+} under arid regions of the world. However, the productivity of Mg^{2+} dominated soils can be improved by increasing levels of Ca^{2+} on the cation exchange complex to counter the adverse impacts of Mg^{2+}. This could be accomplished by applying sufficient amount of Ca^{2+} to soils (Vyshpolsky et al., 2008).

SEED PRIMING

Seed priming is a process where seed is hydrated for specified time periods under controlled conditions followed by re-drying that allows all the pre-germination metabolic activities but prevents radicle protrusion (Khan et al., 1992). Poor stand establishment is a widespread constraint for crop production in salt-affected soils (Harris et al., 1999; Saifullah et al., 2002). Presence of excessive soluble salts and/or exchangeable Na^+ may adversely impact the physical, chemical and nutritional properties of soil that in turn may lead to lower plant population (Qadir et al., 2014). Moreover, such plants after emergence often grow slowly and are highly susceptible to stresses such as drought, salinity, pests and diseases (Francois et al., 1986). Under such conditions farmers may choose to re-sow, although this entails severe yield penalties, increased labor and financial losses. Pre-sowing seed treatments with salts, nutrients or hormones have been advocated to enhance seed germination in saline medium (Afzal et al., 2013; Ashraf & Foolad, 2005). However, it fails in saline-sodic or sodic soils due to poor physical condition. In these soils, seeds fail to emerge out of soil due to surface crust. Gypsum helps to improve soil physical and

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chemical properties. In this backdrop, a three years project was initiated on salt-affected soil to monitor the effect of combined application of seed priming and soil-applied gypsum on growth and yield of wheat and rice crops using brackish water for irrigation. The results indicated that combined application of gypsum and seed treatment with saturated solution of gypsum was the best treatment in terms of soil health improvement, yield enhancement and economic output. Priming enhanced the seed germination through protein synthesis, repair of nucleic acid and membranes (Hameed et al., 2010; Fujikura & Karssen, 1995). In a recent study (Saifullah, 2012), it was concluded that sowing of wheat seed soaked for 24 hours in aerated gypsum saturated solution + gypsum at 50% of soil gypsum requirement helped better crop stand and ultimately the economic yields.

WASTEWATER

In developing countries including Pakistan, it is a common practice to discharge domestic and industrial effluent (premixed due to common water carrying channels) directly to a sewer system, a natural drain or water body, a nearby field or an internal septic tank. Unfortunately, this wastewater is not properly treated because of non-functioning and/or availability treatment plants. The sewage in drains is mostly have high EC, SAR, RSC and elevated levels of several metals, organics and associated pathogens that warrant site-specific management strategies. The wastewater used for irrigation is becoming an attractive commodity for farmers mainly because of its nutrient contents and reliability of supply (Ensink et al., 2004; Murtaza et al., 2010). It can have positive impacts on agriculture and monthly income despite producing adverse effects on soil physical and chemical properties in addition to contamination of human food chain and related health risks (Hanjra et al., 2012; Qadir et al., 2010; Vincent, 2014). Recent estimates depict (Table 2) that total volume of wastewater generated in Pakistan is about 962,335 million gallons (4.369×10^9 m^3/yr) out of which 674,009 million gallons (3.060×10^9 m^3/yr; and 5.54×10^9 m^3/yr for the year 2011) are shared by municipalities and 288,326 million gallons (1.309×10^9 m^3/yr) from industries. As with other developing countries, in Pakistan, wastewater is not subjected to any treatment and none of the cities have any biological treatment process except Islamabad and Karachi, and even these cities treat only a small proportion before disposal (Table 3). Estimates suggest that the amount of treated wastewater is not > 1% (Murtaza & Zia, 2012). The treated wastewater generally flows into open drains, and there are no provisions for its reuse for agriculture.

Table 2. Sector-wise wastewater production in Pakistan in the year

Sr. No.	Source	Volume	
		10^6 m^3 y^{-1}	Percent (%)
1	Industry	395	6
2	Commercial	266	5
3	Urban residential	1,628	25
4	Rural residential	3,059	48
5	Agriculture	1,036	16
	Total	6,414	100

Source: Murtaza & Zia (2012)

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Table 3. Wastewater produced annually from major cities of Pakistan

City	Urban Population (1998 Census)	Total Wastewater Produced (10^6 m^3/y)	% of Total	% of Treated	Receiving Water Body
Lahore	5,143,495	287	12.5	0.01	River Ravi, irrigation canals,
					vegetable farms
Faisalabad	2,008,861	129	5.6	25.6	River Ravi, River Chenab and
					vegetable farms
Gujranwala	1,132,509	71	3.1	-	SCARP drains, vegetable farms
Rawalpindi	1,409768	40	1.8	-	River Soan and vegetable
					farms
Sheikhupura	870,110	15	0.7	-	SCARP drains
Multan	1,197,384	66	2.9	-	River Chenab, irrigation canals
					and farms
Sialkot	713,552	19	0.8	-	River Ravi, irrigation canals
					and farms
Karachi	9,339,023	604	26.3	15.9	Arabian Sea
Hyderabad	1,166,894	51	2.2	34.0	River Indus, irrigation canals and SCARP drains
Peshawar	982,816	52	2.3	36.2	Kabul River
Other	19,475,588	967	41.8	0.7	-

Source: Master Plan for Urban Wastewater (Municipal and Industrial) Treatment Facilities in Pakistan. Final Report, Lahore: Engineering, Planning and Management Consultants, 2002.

It is highly recommended that the wastewater should be treated at source. Different chemical and plant based technologies are available for the remediation of wastewater (Murtaza et al., 2014). One opportunity to address these concerns is the use of low cost agrowaste adsorbents for the treatment of urban wastewater for irrigation of crops, trees, forests and greenbelts (Abdolali et al., 2013). There seems week national policy and implementation on sustainable use of wastewater in developing countries including Pakistan. The problems of wastewater disposal emerge from distortions due to economy-wide policies, failure of targeted environmental policies and institutional failures. Therefore, a well-coordinated program is necessary to create awareness among different sections of the society including the policy makers, general public, organizations, industrialists and farmers to save future of nations.

CONCLUSION AND RECOMMENDATIONS

It is important to consider and adopt preventive measures immediately to avoid the disaster of soil salination and sodication in response to poor quality tube well water irrigation. The deterioration of soils adversely affects the ambient environments for all the living organisms including human beings. Thus, it seems essential and wise to reclaim the saline and/or sodic soils and adopt measures to limit the adverse

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effects of hazards associated with low quality irrigation waters in favor of crops/plants growth in order to keep the environment clean.

The best economical solution to high SAR and/or RSC waters is to soil-apply gypsum along with farm manure or green manure before each crop, considering the delta of water of a crop and gravity of SAR and/or RSC problem. Blended/mixed use of canal and brackish waters is not possible under our conditions since canal water supplies are not at the disposal of farmers. The cyclic (alternate irrigation, or one crop with canal and next with brackish water) are already in practice (Oster & Grattan, 2002; Rhoades et al., 1992). The farmers should try to avoid irrigation with brackish water at critical crop growth stages. They should also try to use good water on good soils and poor quality water on poor soils.

There is an immense need to initiate the tube well water analyses for appropriate and site-specific advice by soil and water experts, and simultaneously it must be made mandatory and legal for tube well owners to get the water analyzed and act upon the advice. Assuming 70% pumped ground water hazardous which require addition of gypsum at 4 $mmol_c\ L^{-1}$ of irrigation water, 400 kg for each acre-foot and 15.6 million tons gypsum for 39 MAF tube well water annually will be required, i.e. 234 million tons quality gypsum will be essential to soil-apply in order to mitigate the adverse effects of high SAR/RSC tube well water. For a door-step supply of this much gypsum has to be ensured on credit for sustainability of irrigated agriculture and safe environment since the salt-stress land and tube well owners might not be in a position to purchase gypsum on cash payment.

The potential of virtual use of water could be exploited at regional/provincial/national levels. The idea of virtual use of water compares the amount of water embodied in a crop that can be purchased at regional/provincial/international levels with the amount of water that should be required to produce that crop natively. For example, transferring every kilogram of wheat into water stress area means to transfer about 1000 L of virtual water at a much less price than the price of the same quantity of water from the native water resources in the area itself (Qadir et al., 2003).

There is significant loss in storage capacity of water reservoirs which is increasing gradually and this loss will become about 33% of the designed capacity by the year 2020. It is strongly recommended that additional storage facility is developed, and the silt load of in-coming water into existing dams is decreased through controlling/ promoting vegetation with or without the help of engineering structures in the catchment areas. Seed priming in saturated gypsum solution for 4-8 hours did help early and enhanced germination of cereal crops which latter improved crop stand for better yield since as plants grow older, their performance in salt-stress environment (saline and/or sodic soils or irrigation waters) become promising.

The city wastewater poses threats of heavy metals. Under such situations, metals could be made less available with the soil-applied gypsum, mono-ammonium phosphate, DAP or some other economical Ca-salts. The metals could also be removed by enhancing their availability through soil-application of acids, acid formers and EDTA salts with crops not directly consumed by human beings. However, growing leafy vegetables with sewage water must be banned.

Another feasible practice for brackish water irrigation is to cultivate salt-tolerant crops requiring less irrigation, particularly to decrease the input of chemicals into soils and ground water contamination. This practice will also help decrease the problem of waterlogging. The breeders should come forward and conduct research in the fields of genomics, proteomics, biotechnology, and nanotechnology to breed salt-resistant and drought-tolerant crops (Roy et al., 2014; Seabra et al., 2014).

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The allocation of irrigation water is not uniform in various provinces of Pakistan. The water allocation is more in Sindh compared to Punjab. Moreover, water allocation is higher in Southern Punjab as compared to central and upper Punjab. Improvement in water allocation is required to achieve sustainable irrigation and to avoid salinity and waterlogging.

POLICIES

To tackle the water quality problems some policies are suggested 1) give priority to increasing irrigation efficiencies, essentially with allowance for salinity/ sodicity control through effective leaching of in-coming salts, 2) move towards a demand based irrigation water supply, 3) promote water use associations (WUA) and thereafter Federation of WUA, 4) maintain the existing drainage infrastructure with site-specific emphasis on new projects, 5) strengthen the advisory service to farmers and training to extension staff.

MEASURES

Some specific measures for the safe use of brackish water on sustainable basis are 1) take incremental but specific measures towards volumetric consumption as the ultimate basis for water charges, 2) undertake studies in community management of a few distributaries on a pilot scale, 3) address problems of water table draw-down by holistic approaches, encompassing both the demand management and methods to increase water recharge, 4) promote farmer education and extension activities as well as in-service training of staff, 5) review funding, goal should be 60:40 ratio for research: administration, 6) in kind credit facility for gypsum in time and space, particularly to small and resource poor farmers, 7) make it legal for farmers to get their tube well water analyzed, mobile teams of experts be organized to collect, analyze and advice solutions for tube well water quality.

REFERENCES

Abdolali, A., Ngo, H. H., Guo, W. S., Lee, D. J., Tung, K. L., & Wang, X. C. (2014). Development and evaluation of a new multi-metal binding biosorbent. *Bioresource Technology*, *160*, 98–106. doi:10.1016/j.biortech.2013.12.038 PMID:24405652

Afzal, I., Basra, S. M. A., Cheema, M. A., Farooq, M., Jafar, M. Z., Shahid, M., & Yasmeen, A. (2013). Seed priming: A shotgun approach for alleviation of salt stress in wheat. *International Journal of Agriculture & Biology*, *15*, 1199–1203.

Ahmad, N. C., & Chaudhry, M. R. (1997). *Review of research on reclamation of salt-affected soils in Pakistan (Publication No. 175)*. Lahore, Pakistan: International Waterlogging And Salinity Research Institute, Water And Power Development Authority.

Ashraf, M., & Foolad, M. R. (2005). Pre-sowing seed treatment-a shotgun approach to improve germination growth and crop yield under saline and none-saline conditions. *Advances in Agronomy*, *88*, 223–271. doi:10.1016/S0065-2113(05)88006-X

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Ayers, R. S., & Westcott, D. W. (1985). *Water quality for agriculture. Irrigation and Drainage Paper 29*. Rome, Italy: Food and Agriculture Organization of the United Nations.

COP21 (Conference of Parties 21). (2015). *United Nations Climate Change Conference*. Retrieved from http://www.scoop.it/t/cop21news

Doneen, L. D. (1975). Water quality for irrigated agriculture. In A. Poljakoff-Mayber & J. Gale (Eds.), *Plants in saline environments* (pp. 56–79). Springer-Verlag. doi:10.1007/978-3-642-80929-3_5

Eaton, F. M. (1950). Significance of carbonate in irrigation waters. *Soil Science*, *69*(2), 123–133. doi:10.1097/00010694-195002000-00004

Ensink, J. H. J., Simmons, R. W., & van der Hoek, W. (2004). Wastewater use in Pakistan: The cases of Haroonabad and Faisalabad. In C. A. Scott, N. I. Faruqui, & L. Raschid-sally (Eds.), *Wastewater use in irrigated agriculture* (pp. 91–99). Wallingford, UK: CAB International. doi:10.1079/9780851998237.0091

Federal Bureau of Statistics. (2011–12). *Pakistan statistics year book, Statistics Division*. Islamabad, Pakistan: Planning Commission Government of Pakistan.

Francois, L. E., Maas, E. V., Donovan, T. J., & Youngs, V. L. (1986). Effect of salinity on grain yield and quality, vegetative growth, and germination of semi-dwarf and durum wheat. *Agronomy Journal*, *78*(6), 1053–1058. doi:10.2134/agronj1986.00021962007800060023x

Fujikura, Y., & Karssen, C. M. (1995). Molecular studies on osmoprimed seeds of cauliflower: A partial amino acid sequence of a vigour- related protein and osmopriming-enhanced expression of putative aspartic protease. *Seed Science Research*, *5*(03), 177–181. doi:10.1017/S0960258500002804

Ghafoor, A., Gill, M. A., Hassan, A., Murtaza, G., & Qadir, M. (2001a). Gypsum: An economical amendment for amelioration of saline-sodic waters and soils, and for improving crop yields. *International Journal of Agriculture & Biology*, *3*(3), 266–275.

Ghafoor, A., Murtaza, G., Ahmad, B., & Boers, Th. M. (2008). Evaluation of amelioration treatments and economic aspects of using saline-sodic water for rice and wheat production on salt-affected soils under arid land conditions. *Irrigation and Drainage*, *57*(4), 424–434. doi:10.1002/ird.377

Ghafoor, A., Murtaza, G., Maann, A. A., Qadir, M., & Ahmad, B. (2011). Treatments and economic aspects of growing rice and wheat crops during reclamation of tile drained saline-sodic soils using brackish waters. *Irrigation and Drainage*, *60*(3), 418–426. doi:10.1002/ird.577

Ghafoor, A., Murtaza, G., Rehman, M. Z., Saifullah, & Sabir, M. (2012). Reclamation and salt leaching efficiency of treatments for tile drained saline-sodic soil using marginal quality water for irrigating rice and wheat crops. *Land Degradation & Development*, *23*(1), 1–9. doi:10.1002/ldr.1033

Ghafoor, A., Nadeem, S. M., Hassan, A., & Sadiq, M. (2001b). Reclamation response of two different textured saline-sodic soils to EC_{iw} to SAR_{iw} ratios. *Pakistan Journal of Soil Science*, *19*, 92–99.

Ghafoor, A., Qadir, M., & Murtaza, G. (1997). Potential for reusing low quality drainage water for soil amelioration and crop production. In *Proceedings of the International Symposium on Water for the 21st Century: Demand, Supply, Development and Socio-Environmental Issues* (pp. 411-20). Lahore, Pakistan: Centre of Excellence in Water Resources Engineering, University of Engineering and Technology.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Ghafoor, A., Qadir, M., & Murtaza, G. (2002). Agriculture in the Indus Plains: Sustainability of land and water resources. *International Journal of Agriculture & Biology*, *4*(3), 429–437.

Ghafoor, A., Qadir, M., & Murtaza, G. (2004). *Salt-affected soils: Principles of management*. Lahore, Pakistan: Allied Book Centre.

Gupta, I. C. (1990). *Use of saline water in agriculture. Bombay, India*. Oxford, UK: IBH Publishing House Co, Pvt. Ltd.

Hameed, A., Afzal, I., & Iqbal, N. (2010). Seed priming and salinity induced variations in wheat (*Triticum aestivum* L.) leaf protein profile. *Seed Science & Technology*, *38*(1), 236–241. doi:10.15258st.2010.38.1.25

Hanjra, M. A., Blackwell, J., Carr, G., Zhang, F., & Jackson, T. M. (2012). Wastewater irrigation and environmental health: Implications for water governance and public policy. *International Journal of Hygiene and Environmental Health*, *215*(3), 255–269. doi:10.1016/j.ijheh.2011.10.003 PMID:22093903

Harris, D., Joshi, A., Khan, P. A., Gothkar, P., & Sodhi, P. S. (1999). On-farm seed priming in semi-arid agriculture: Development and evaluation in maize, rice and chickpea in India using participatory methods. *Experimental Agriculture*, *35*(1), 15–29. doi:10.1017/S0014479799001027

Hussain, G. (1978). *Determination of irrigation water quality standards.* (Unpublished doctoral dissertation). Colorado State University.

Karajeh, F., Suleimenov, M., Karimov, A., Vyshpolsky, F., Mukhamedjanov, Kh., Bekbaev, U. (2004). Technology of irrigation, water saving and improving soil fertility in Arys Turkestan canal command zone. *Kazakh Research Institute of Water Management: Taraz, 18.* (in Russian).

Khan, A. A., Maguire, J. D., Abawi, G. S., & Illas, S. (1992). Matriconditioning of vegetable seed to improve stand establishment in early field planting. *Journal of the American Society for Horticultural Science*, *117*, 41–47.

McNeal, B. L., Layfield, D. A., Norvell, W. A., & Rhoades, J. D. (1968). Factors influencing hydraulic conductivity of soils in the presence of mixed-salt solutions. *Soil Science Society of America Proceedings*, *32*(2), 187–190. doi:10.2136ssaj1968.03615995003200020012x

Murtaza, G., Ghafoor, A., Owens, G., Qadir, M., & Kahlon, U. Z. (2009). Environmental and economic benefits of saline-sodic soil reclamation using low-quality water and soil amendments in conjunction with a rice-wheat cropping system. *Journal Agronomy & Crop Science*, *195*(2), 124–136. doi:10.1111/j.1439-037X.2008.00350.x

Murtaza, G., Ghafoor, A., & Qadir, M. (2006). Irrigation and soil management strategies for using saline-sodic water in a cotton-wheat rotation. *Agricultural Water Management*, *81*(1-2), 98–114. doi:10.1016/j.agwat.2005.03.003

Murtaza, G., Ghafoor, A., Qadir, M., Owens, G., Aziz, M. A., Zia, M. H., & Saifullah. (2010). Disposal and use of sewage on agricultural lands in Pakistan: A review. *Pedosphere*, *20*(1), 23–34. doi:10.1016/S1002-0160(09)60279-4

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Murtaza, G., Murtaza, B., Niazi, N. K., & Sabir, M. (2014). Soil contaminants: sources, effects and approaches for remediation. In *Improvement of crops in the era of climatic changes* (pp. 171–196). Springer Science, Business Media. doi:10.1007/978-1-4614-8824-8_7

Murtaza, G., & Zia, M. H. (2012). *FAO Report - UNW-AIS. Individual's capacity development on the safe use of wastewater in agriculture in Pakistan*. Available at http://www.ais.unwater.org/ais/pluginfile.php/232/mod_page/content/124/pakistan_murtaza_finalc ountryreport2012.pdf

Oster, J. D. (1994). Irrigation with poor quality water. *Agricultural Water Management*, *25*(3), 271–297. doi:10.1016/0378-3774(94)90064-7

Oster, J. D. (2001). *Magnesium effects on soil physical properties—Hydraulic conductivity and infiltration rate*. SLPHYCHM. Available online at http://esce.ucr.edu/oster/SLPHYCb.html

Oster, J. D., & Grattan, S. R. (2002). Drainage water reuse. *Irrigation and Drainage Systems*, *16*(4), 297–310. doi:10.1023/A:1024859729505

Oster, J. D., & Jayawardane, N. S. (1998). Agricultural management of sodic soils. In M. E. Sumner & R. Naidu (Eds.), *Sodic soil: Distribution, management and environmental consequences* (pp. 126–147). New York: Oxford University Press.

Qadir, M., Ghafoor, A., Boers, Th. M., & Murtaza, G. (2003). Agricultural water management in water starved countries: Challenges and opportunities. *Agricultural Water Management*, *62*(3), 165–185. doi:10.1016/S0378-3774(03)00146-X

Qadir, M., Quillérou, E., Nangia, V., Murtaza, G., Singh, M., Thomas, R. J., ... Noble, A. D. (2014). Economics of salt-induced land degradation and restoration. *Natural Resources Forum*, *38*(4), 282–295. doi:10.1111/1477-8947.12054

Qadir, M., & Schubert, S. (2002). Degradation processes and nutrient constraints in sodic soils. *Land Degradation & Development*, *13*(4), 275–294. doi:10.1002/ldr.504

Qadir, M., Wichelns, D., Raschid-Sally, L., McCornick, P. G., Drechsel, P., Bahri, A., & Minhas, P. S. (2010). The challenges of wastewater irrigation in developing countries. *Agricultural Water Management*, *97*(4), 561–568. doi:10.1016/j.agwat.2008.11.004

Rengasamy, P., Greene, R. S. B., & Ford, G. W. (1986). Influence of magnesium on aggregate stability in sodic red-brown earths. *Australian Journal of Soil Research*, *24*(2), 229–237. doi:10.1071/SR9860229

Rhoades, J. S., Kandiah, A., & Mashali, A. M. (1992). *The use of saline waters for crop production. Irrigation and Drainage Paper 48*. Rome, Italy: Food and Agriculture Organization of the United Nations.

Roy, S. J., Negrão, S., & Tester, M. (2014). Salt resistant crop plants. *Current Opinion in Biotechnology*, *26*, 115–124. doi:10.1016/j.copbio.2013.12.004 PMID:24679267

Saifullah, G. A., Murtaza, G., & Qadir, M. (2002). Brackish tube well water promotes growth of rice and wheat and reclamation of saline-sodic soils. *Pakistan Journal of Soil Science*, *21*, 83–88.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Saifullah. (2012). *Enhancing crop productivity on salt-affected soils through combined use of soil applied gypsum and pre-sowing seed treatments*. Final Technical Progress Report for Endowment Fund Secretariat (EFS) funded project (July 2008 – June 2011). Institute of Soil & Environmental Sciences, University of Agriculture.

Seabra, A. B., Rai, M., & Durán, N. (2014). Nano carriers for nitric oxide delivery and its potential applications in plant physiological process: A mini review. *Journal of Plant Biochemistry and Biotechnology*, *23*(1), 1–10. doi:10.100713562-013-0204-z

Sheikh, I. A. (1989). Country report on problems of waterlogging and salinity in Pakistan. In *Proceeding Information Seminar on Waterlogging and Salinity Research in Some Major Problem Countries* (pp. 1-10).Lahore, Pakistan: International Waterlogging And Salinity Research Institute.

Smith, C. J., Oster, J. D., & Sposito, G. (2015). Potassium and magnesium in irrigation water quality assessment. *Agricultural Water Management*, *157*, 59–64. doi:10.1016/j.agwat.2014.09.003

Sommer, R., Glazirina, M., Yuldashev, T., Otarov, A., Ibraeva, M., Martynova, L., ... de Pauw, E. (2013). Impact of climate change on wheat pro-ductivity in Central Asia. *Agriculture, Ecosystems & Environment*, *178*, 78–99. doi:10.1016/j.agee.2013.06.011

Strawn, D. G., Bohn, H. L., & O'Connor, G. A. (2015). *Soil chemistry*. New York, NY: Wiley-Blackwell.

US Salinity Lab. Staff. (1954). Diagnosis and improvement of saline and alkali soils (Agriculture Handbook 60). Washington, DC: United States Department of Agriculture.

Vincent, S. (2014). Environmental health monitoring: A pragmatic approach. *International Journal of Waste Resources*, *4*(4), 164. doi:10.4172/2252-5211.1000164

Vyshpolsky, F., Qadir, M., Karimov, A., Mukhamedjanov, K., Bekbaev, U., Paroda, R., ... Karajeh, F. (2008). Enhancing the productivity of high-magnesium soil and water resources in central Asia through the application of phosphogypsum. *Land Degradation & Development*, *19*(1), 45–56. doi:10.1002/ldr.814

WAPDA (Water And Power Development Authority). (2011). *Hydro potential in Pakistan*. Water And Power Development Authority, Pakistan. Retrieved from http://www.wapda.gov.pk/pdf/BroHydpwrPotialApril2011.pdf

Wichelns, D., & Qadir, M. (2015). Achieving sustainable irrigation requires effective management of salts, soil salinity, and shallow groundwater. *Agricultural Water Management*, *157*, 31–38. doi:10.1016/j.agwat.2014.08.016

Yunus, M. (1977). Water quality in The Indus Plains. In *Proceedings of the Seminar on Water Management for Agriculture* (pp. 283-292). Lahore, Pakistan: Exxon Chemicals Pakistan Ltd.

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Chapter 54
Rural Innovations:
Text and Cases

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ABSTRACT

In a country like India innovations are more referred as "jugaad". Though the dictionary does not explain such kind of words, but every person in India understands the importance of jugaad. India has one of the largest systems for agricultural research in the world. However this system has focused predominantly on strengthening of cereal production under irrigated conditions. It would be essential that they participate in all decision making which cater to overall development of rural India. India also needs to increase its efforts to tap into the rapidly growing stock of global knowledge through channels such as FDI, technology licensing, importation of capital merchandise that embody knowledge, as well as advanced products, components, and services. This chapter analyses and focuses on various innovative practices done with the help of Government, Public Private Partnership, private Players, Individuals, NGOS, etc.

BACKGROUND

Innovation is increasingly being seen as the currency of 21st century. The future prosperity of India in the new knowledge economy will increasingly depend on its ability to generate new ideas, processes and solutions, and through the process of innovation convert knowledge into social good and economic wealth. (India Innovation Portal Decade of Innovation 2010-20)

India lives in numerous villages scattered thorough out the country. Rural areas are nearly three-fourth of the country of India and accounted for more than half of economic consumption. In spite of urbanization about 63 percent of population will continue to live in rural areas in year 2025. And the total potential of Indian rural market will reach to about 500 billion by 2020. According to 2011 census there is 640000 villages in India. India has substantial population below poverty line and having literacy level.

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INNOVATION

"The process of translating an idea or invention into a good or service that creates value or for which customers will pay. To be called an innovation, an idea must be replicable at an economical cost and must satisfy a specific need. "Innovation involves deliberate application of information, imagination and initiative in deriving greater or different values from resources, and includes all processes by which new ideas are generated and converted into useful products. In business, innovation often results when ideas are applied by the company in order to further satisfy the needs and expectations of the customers. 'Innovation is defined as a process by which varying degrees of measurable value enhancement is planned and achieved, in any commercial activity. This process may be breakthrough or incremental, and it may occur systematically in a company or sporadically; it may be achieved by introducing new or improved goods or services and/or implementing new or improved operational processes and/or implementing new or improved organizational/ managerial processes in order to improve market share, competitiveness and quality, while reducing costs.' Business Dictionary (2014) Innovation and competitiveness have a dynamic, mutual relationship. Innovation thrives in a competitive environment and in turn, plays a key role in the achievement of such an environment. Innovation generates economic value, new jobs in the economy and cultures of entrepreneurship. By virtue of its relationship with competitiveness, Innovation emerges as a factor in promoting economic growth. Given the fact that the Indian economy is growing at 6-8% per year, while exports are growing at 30% Cumulative Annual Growth Rate (CAGR), India Innovation (2014) and many Indian firms are successfully competing against international firms and brands, it can be concluded that this has been made possible by a combination of factors, including enabling environment, rising capital and labor productivity as well as improved quality of goods and services at lower costs. In a social context, innovation helps create new methods for alliance creation, joint venturing, flexible work hours, and creation of buyer's purchasing power. Innovator need not be a person who comes from a wealth background, with a huge credential and qualification. Innovation can be done and are happening at grass-root levels. The story of Mandar Talukar, a small town boy from Nagpur winning the "best innovator in the world" award at USA for his innovation mobile shoe charger, show that innovators are not born; they are developed in adversity thus proving that "necessity is the mother of invention". Rao et al (2012)

In a country like India innovations are more referred as "jugaad". Though the dictionary does not explain such kind of words, but every person in India understands the importance of jugaad. The classic examples of jugaad are the use of washing machine to make huge amount of "lassi" (sweet butter milk, sold in northern part of India), pressure cooker used for making espresso coffee, etc.

As we can see India is the land of innovation (jugaad) and innovation is here to stay for a long time. Innovations have become a way of life and life without innovations is unimaginable. To its credit, India has been taking bold steps to strengthen its R&D infrastructure, developing technological innovations and altering the mind-set of its people toward better creation, acquisition, and use of technology. It is endowed with a critical mass of scientists, engineers, and technicians in R&D and is home to dynamic hubs of innovation, such as Bangalore and Hyderabad. It also has vast and diversified publicly funded R&D institutions, as well as world class institutions of higher learning, all of which provide critical human capital. India is also emerging as a major global R&D platform; about 100 multinational corporations (MNCs) have already set up R&D centers in the country, leading to the deepening of technological and innovative capabilities among Indian firms.

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AUTOMATED TELLER MACHINES IN RURAL PARTS OF INDIA

Though it has given its remarkable footprints in rural development but still there are some parts were there are lack of facilities in rural parts and remote areas. When studied awareness of ATM facilities in rural part we come to know that, within two decades, ATM technology development is happening at an alarming rate. Qureshi, Kumar, Jhunjhunwala (2002). Gone are the days when customers were limited to only withdrawing cash from ATM's. We have now reached an era, where we can use multi function and biometric ATM, (See Figure 1) equipped with touch sensitive and user friendly options to transfer funds, book air and train tickets, go for mobile recharge, and even deposit cheque with scanning.

The consumers in the rural areas lack awareness about various schemes and e-banking services of bank. The emergence of new technology allows to access the banking service without physical direct re-course to the bank premise by the customer at present atm is city oriented in the country. Agarwal (2012) The growth of rural it industry fosters financial inclusion by providing financial services to people in the farthest reach of the country. Qureshi, Kumar, Jhunjhunwala (2002)

Rural marketing plays an important role in development strategy, particularly in the areas of diversification, modernization, globalization and self-reliance. 70% of Indian population belongs to rural part of the country.

When it specifically comes to contribution of information technology ATM (automated teller machine) had played a very important role in rural development. The emergence of new technology has effect the consumer awareness in rural parts to a remarkable extent. (Srinivasa Rao, 2013) (See FIGURE 2)

It has also give awareness and education to undeveloped part of the region. It has also influenced over the population with financial support. Agarwal, Dadhich (2012)

India lives in numerous villages scattered thorough out the country. Rural areas are nearly three-fourth of the country of India and accounted for more than half of economic consumption. In spite of urbanization about 63 percent of population will continue to live in rural areas in year 2025. And the total potential of Indian rural market will reach to about 500 billion by 2020. According to 2011 census there is 640000 villages in India. India has substantial population below poverty line and having literacy level. Rural banking system with emergence of information technology is influencing the population

Figure 1. An ATM (automated teller machine) in a small village in INDIA

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towards banking services like ATM cards, credit cards and other quick and easy services. Even now, rural development defies any clear definition as it has gone through a number of changes over a period of time. Persuasive communication for rural development has been given highest priority for bringing about desirable social and behavioral change among the most vulnerable rural poor and women. Initially, the approach lacked gender sensitivity and empathy of the communicators and development agents who came from urban elite homes. Agarwal, Dadhich(2012) Added to these constraints is political will that still influences the pace and progress of rural development. We are one of the world's oldest and ancient civilizations that evolved, matured and decayed over several millennia.

After independence we have been experimenting and carving a path of revitalization for development through democracy. The existing sharp divide between the small but economically, politically and socially "rich elite ruling class" and a very big but "economically poor and socially deprived" continue to persist as a legacy of the past.

After independence, the government took upon itself the major responsibility of development. Hence, the central and state governments carried out development projects. The experiment was carried out from February to April 1956 in five districts of Maharashtra state by all India radio (air). Rao (2013)

Rural listener groups were organized, who would listen to radio broadcasts twice a week. The summative impact evaluation indicated positive outcome of radio rural forum. Impressive knowledge gains as a result of radio listening were reported across illiterates and literates, agriculturists and non-agriculturists, village leaders and others. Almost all healthcare projects for rural poor, especially women and children have used demand driven social marketing approach for rural the development.

HDFC Bank 'Project Jharkhand': An IT Enabled Financial Inclusion Program

HDFC Bank, launched 'Project Jharkhand' a financial inclusion program. As part of the program, the Bank launched its world class services at a Common Service Center in Kanke comprising over 1.5 lac households spread across 100 villages in 30 Panchayats. The Bank also adopted Chakala village near Ranchi as part of the Common Service Center program. Under Project Jharkhand HDFC Bank will

Figure 2. A solar operated ATM – innovation for greener tomorrow

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look to cover over 45 lac households in the state through both the Common Service Center and village adoption models, subject to regulatory provision.CSC is an integral component of the Central Government's National e-Governance Plan (NEGP) that seeks to set up over 5000 CSCs in Jharkhand and about 100,000 in the country.

These Common Service Centers will make available to the rural population a slew of services ranging from public information services, e-governance services, educational services to agri related and financial services. Common Service Center will also work like a 'Human ATM' that the rural people can use to withdraw and deposit cash. (HDFC Bank launches 'Project Jharkhand 2008, http://www.hdfcbank.com/htdocs/common/pdf/Project_Jharkhand.pdf)

TRANSFORMING RURAL INDIA THROUGH AGRICULTURAL INNOVATION

"Agricultural jeopardy is related with undesirable outcomes that shoot from badly expectable biological, climatic, and price agents. These variables include natural calamities and climatic factors not within the control of agricultural producers." Shanmugam, Chandrasekaran, Vijayasarathy. (2011)

They also include adverse changes in both input and output prices. To set the stage for the discussion on how to deal with risk in agriculture, we classify the different sources of risk that affect agriculture. Agriculture is often characterized by high variability of production outcomes or, production risk. Unlike most other entrepreneurs, agricultural producers are not able to predict with certainty the amount of output that the production process will yield due to external factors such as weather, pests, and diseases. Agricultural producers can also be hindered by adverse events during harvesting or collecting that may result in production losses. Agriculture community (2014)

Figure 3. Some Agricultural Innovations

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Input and output price volatility is important sources of market risk in agriculture. Prices of agricultural commodities are extremely volatile. Output price variability originates from both endogenous and exogenous market shocks. Segmented agricultural markets will be influenced mainly by local supply and demand conditions, while more globally integrated markets will be significantly affected by international production dynamics. In integrated markets, a reduction in prices is generally not correlated with local supply conditions and therefore price shocks may affect producers in a more significant way. Another kind of market risk arises in the process of delivering production to the marketplace. The inability to deliver perishable products to the right market at the right time can impair the efforts of producers. The lack of infrastructure and well-developed markets make this a significant source of risk in many developing countries. The ways businesses finance their activities is a major concern for many economic enterprises. However, in this respect, agriculture also has its own peculiarities. Many agricultural production cycles stretch over long periods of time, and farmers must anticipate expenses that they will only be able to recuperate once the product is marketed. This leads to potential cash flow problems exacerbated by lack of access to credit and the high cost of borrowing. These problems can be classified as financial risk. Agriculture community (2014)

Another important source of uncertainty for agricultural producers is institutional risk, generated by unexpected changes in regulations that influence producers' activities. Changes in regulations can significantly alter the profitability of farming activities. This is particularly true for import/export regimes and for dedicated support schemes, but it is also important in the case of sanitary regulations that can restrict the activity of producers and impose costs on households.

Like most other entrepreneurs, agricultural producers are responsible for all the consequences of their activities. However, the growing concern for the impact of agriculture on the environment, including the introduction of genetically modified organisms (GMO), may cause an increase in producer liability risk. Finally, agricultural households, along with other economic enterprises, are exposed to personal risks to the wellbeing of people who work on the farm, and asset risks, the possible damage or theft of production equipment and assets. With a majority of its population living in villages, rural poverty is a major problem in India. The disparity between the urban and rural incomes is also on the rise. This leads to migration to urban areas resulting in urban blight as well. Therefore addressing the problem of rural poverty assumes urgency. Agriculture community (2014)

Rural innovations has been involved in a range of interventions—infusion of technology, soil enrichment, efficient farm and water management, improved cattle development, functional literacy, rural sanitation and public health, human resource development, establishment of self-help groups particularly among women, self-employment opportunities and facilitating institutional credit—to address the problem of farm productivity in India. Rural innovations focus on the poor and marginal farmers, women, unemployed youth, and depressed communities. Rural innovations work in about 250 villages in tamil nadu and have reached 30,000 rural families. A large part of rural innovations' effort with farmers is to help break their initial emotional barriers to new technologies. This has provided the platform to launch into other initiatives. The success of these measures has had a demonstrative impact on the farmers' willingness to adopt and internalize new technologies. This may be considered an attitudinal breakthrough (Figure 3).

Another initiative, the center for rural development (CFRD), a training cum village knowledge center, has been established in illedu village of kancheepuram district with classrooms, computer lab with internet facilities, input and product handling center, farm machinery workshop, model experimental farm, residential complex for trainees and an open air theatre to cater to the needs of various sections of

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rural community. Rural innovations also helps in housing a comprehensive soil testing laboratory, food safety and standards laboratory and a plant tissue culture lab to provide agriculture support services.

Agriculture productivity improvements through resource conserving "lean farming": paddy (55%), groundnut (113%), vegetables (116%), sugarcane (40%), and corn (150%). Through successful lead farmers, technology transfer has been effected over an area of 10,000 acres with a "lead farmer—lead village" concept. Addressing the agriculture value chain—soil testing, facilitation of inputs and credit, market linkage, and field advisory services—is part and parcel of agriculture development initiatives. Promotion of climate resilient agriculture, resource conserving technologies and promotion of use of information communication technology (ICT) in agriculture are being attempted too. Watershed and natural resource management initiatives have resulted in increase in water table ranging from 3.5 meters to 5 meters in the project area of over 6,000 hectares. Cropping intensity has been doubled (two crop cultivation in a year instead of one crop) and about 20% additional area which had been left fallow has also been brought under cultivation. Soil erosion, nutrient loss, damage due to flooding during rainy seasons has reduced significantly. Agriculture community (2014)

To sustain the benefits derived, the social development initiatives of rural innovations have helped village communities in establishing community-based institutions like farmers clubs, self help groups and joint liability groups, farmers producer organizations, watershed committees, etc for collective decision and action.

India has many of the key ingredients for making this transition. The time is very appropriate for India to make its evolution to the knowledge economy—an economy that creates, disseminates, and uses knowledge to enhance its growth and development. It has a critical mass of skilled, English-speaking knowledge workers, especially in the sciences. Its local market is one of the world's largest. The knowledge economy is often taken to mean only high-technology industries or information and communication technologies (ICTs). It would be more appropriate, however, to use the concept more broadly to cover how any economy harnesses and uses new and existing knowledge to improve the productivity of agriculture, industry, and services and increase overall welfare. In India, great potential exists for increasing productivity by shifting labor from low productivity and subsistence activities in agriculture, informal industry, and informal service activities to more productive modern sectors, as well as to new knowledge-based activities—and in so doing, to reduce poverty and touch every member of society. India should continue to leverage its strengths to become a leader in knowledge creation and use. To get the greatest benefits from the knowledge revolution, the country needs to press on with the economic reform agenda that it put into motion more than a decade ago and continue to implement the various policy and institutional changes needed to accelerate growth. It has a large and impressive Diaspora, creating valuable knowledge linkages and networks. The list goes on: macroeconomic stability, a dynamic private sector, institutions of a free market economy, a well-developed financial sector, and a broad and diversified science and technology(S&T) infrastructure. In addition, the development of the ICT sector in recent years has been remarkable. India has created profitable niches in information technology (IT) and is been remarkable. India has created profitable niches in information technology (IT). Rapid advances in ICTs are dramatically affecting economic and social activities, as well as the acquisition, creation, dissemination, and use of knowledge. The use of ICTs is reducing transaction costs and lowering the barriers of time and space, allowing the mass production of customized goods and services.

Some of the examples of rural innovations which are changing the lifestyle, business and way of life are as follows

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INFORMATION AND COMMUNICATION TECHNOLOGY (ICT) GYANDOOT

Situated in Dhar district of Madhya Pradesh, Gyandoot is an Intranet based Government to Citizen (G2C) service delivery portal it was launched in January 2000. Gyandoot aims to create a lucrative, replicable, economically independent and financially viable model for the rural population to take the benefits of Information and Communication Technology (ICT). Gyandoot: The Purveyor of Knowledge (2014)

E-CHOUPAL BY ITC

Choupal is a Hindi word which means "village meeting place". Market is a meeting place where vendors and customers come together to do transactions. e-choupal is a virtual market place where farmers can transact directly with a processor and can realize better price for their produce. The main charisma of e-choupal is that it can be used for connecting large producers/small producers and small users/large users, thereby eliminating the need for chain of command of brokers.

Geographical distances do not restrict participation in the e-choupal. E-choupal has the advantages of the market but spans very large varieties of vendors and customers. The main disadvantage of Traditional market is that information asymmetry is inherent in the market where as e-choupal provides for transparent transactions. This enables the participation of smaller as well as larger players. Exclusion of intermediaries allows for larger share of profits to reach the bottom end of value chain.(https://www.echoupal.com/)

UNIQUE IDENTIFICATION PROJECT

In a country like India, absence of social security number or its equivalent has made more than 380 millions of poor suffer in the hands of the existing corrupt system because they are unable to participate in the official financial system of the country. The government of India's Unique Identification (UID) project has created avenues for this people to become a part of the different projects and plans developed for self sufficiency, growth and improvement in living standards. This innovation has revolutionized the way Identification is done. The linking of bank account to the card has helped government send direct subsidy to the poor and the needy, thus removing the middle men and barriers. The gas subsidy is directly transferred to the card holders every time they purchase a cylinder thus creating a barrier for black marketing of gas cylinders. Adhar card (2014)

INNOVATION FOR IMPROVING HEALTH IN RURAL INDIA

Innovation is required to address health needs at the bottom of the pyramid. Delivering affordable and quality health care to India's billion-plus people presents enormous challenges and opportunities. Innovations could be a way out for a large number of people get quality care at a cost that the nation can afford.

Addressing healthcare challenges in rural India is a complex proposition. Healthcare starts with generating awareness of risk factors, disease symptoms and the benefits of healthy living to the rural masses for the betterment of the rural population. Measures are taken to convert these messages into actions

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resulting in the prevention of disease or morbidity. Patients suffering from disease would then require provision of primary, secondary or tertiary care. This is followed by protection of patients from relapse or future risks through management of disease, regular monitoring and health maintenance. Addressing this continuum of care is more complicated owing to the 'double burden of disease' i.e. the co-existence of both communicable and non-communicable diseases. While the country is still dealing with the issue of communicable diseases, the share of non-communicable diseases is also increasing rapidly requiring the health system to come up with a wide range of diverse interventions to address the varying financing, prevention, provision and protection needs of the diseases. Governments schemes (2012)

In addition, a number of other external factors have a bearing on health and health seeking behavior. Recent research increasingly relates health inequalities to social factors such as poverty, nutrition, hygiene, water and sanitation, education, empowerment of women and living space. This would mean that to make any lasting impact on population health outcomes, addressing issues along the complete gamut including these social determinants of health is essential.

TOTAL SANITATION CAMPAIGN

In spite of noteworthy investments over the last 20 years, India faces the most daunting sanitation challenge in any region in the world. The Total Sanitation Campaign in Ahmednagar (Maharashtra) has bought innovation into Sanitation systems. Innovation in the Ahmednagar pilot project is in its use of conditional financial incentives. Most sanitation front individual household subsidies used to assist private toilet construction. Yet stopping open defecation requires collective action, which suggests that the financial incentives would be more effective if used to encourage the attainment of community, rather than individual, goals. In Ahmednagar, every household has to fund its own toilet. Governments schemes (2012)

However, the BPL households do so on the understanding that they will be paid US$ 8.10 if everyone builds a toilet and the community is declared 'open defecation free'.

The remainder of the TSC subsidy (US$ 2.69 per BPL household), paid to the GP on achieving universal access, thus acts as an incentive for the GP to assist in stopping open defecation, including the promotion and facilitation of the construction of toilets by the landless, the very poor, and those unwilling to invest. A similar financial incentive is provided to the NGO working in the village. It is paid US$ 1.07 commission for every household that builds a toilet (from the IEC funds), but does not receive any of this money until the village is declared 'open defecation free'.

For more than 800 million men, women and children across India living on USD 1-3 a day, the idea of accessible and affordable medicines is often as remote as their rural homes.

Arogya Parivar ("Healthy Family" in Hindi): A social initiative developed by Novartis to reach the underserved millions living at the bottom of the pyramid in rural India.

After just five years, Arogya Parivar is proving to be both a force for improving health in rural communities and a sustainable business. Arogya Parivar provides opportunities to expand business in an innovative and responsible way. The program offers education on diseases, treatment options and prevention as well as increases access to affordable medicines. Health educators, usually local women, raise awareness about local diseases and preventive health measures. They also refer sick people to doctors and cooperate with local NGOs to further spread their message. Each educator covers a few villages every day, with an Arogya Parivar branded cap, shirt and banner, making them easily recognizable. Sales supervisors serve as the initiative's local sales force. They interact with local pharmacies and collaborate

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with doctors, hospitals and NGOs to organize health camps where villagers can receive treatment and preventive care. Arogya Parivar focuses on the diseases most prevalent in rural India. Further, products and services are tailored to meet the needs of underserved rural populations with a low disposable income, usually earned on a daily basis. Novartis arogya (2014)

IKURE TECHSOFT

Delivering affordable healthcare to the doorsteps of rural masses, India continues to face enormous challenges. With a population over one billion, rural India comprising of 840 million people are served by only 30 per cent of the country's combined medical force. Out of which, three per cent of India's physicians live in rural areas, and 25 per cent in semi-urban areas. This is disproportionate, and an example of the Pareto Principle – where 20 per cent of the doctors serve 80 per cent of the population.

This is disproportionate, and an example of the Pareto Principle – where 20 per cent of the doctors serve 80 per cent of the population. Moreover, the morbidity rate in people reporting the same, in rural areas increased to 70 per cent in 2011 against 64 per cent in 2004. Rural India is critically flawed with inefficient heath care system. They either remain short of medical personnel or untrained officers. According to NRHM report, out of 22,000 primary healthcare centers, eight per cent do not have a doctor, 39% remain unattended without a lab technician and 17.7% without a pharmacist, and this is when, each primary health center is supposed to have at least one medical practitioner. Based in Kolkata ikure sets up rural health centers across India. with an initial funding of Rs 45 lakh from Intellecap Impact Investment Network and Calcutta Angels; Rs 70 lakh from WEBEL iKure Techsoft has built a network of rural health centers where doctors are available through the week and pharmacists dispense only ac. (http:/www.ikuretechsoft.com)

DRINKING WATER QUALITY IN RURAL INDIA: ISSUES AND APPROACHES

The rural population of India comprises more than 700 million people residing in about 1.42 million habitations spread over 15 diverse ecological regions. It is true that providing drinking water to such a large population is an enormous challenge. Our country is also characterized by non-uniformity in level of awareness, socio-economic development, education, poverty, practices and rituals which add to the complexity of providing water.

The health burden of poor water quality is enormous. It is estimated that around 37.7 million Indians are affected by waterborne diseases annually, 1.5 million children are estimated to die of diarrhoea alone and 73 million working days are lost due to waterborne disease each year. The resulting economic burden is estimated at $600 million a year. The problems of chemical contamination are also prevalent in India with 1,95,813 habitations in the country are affected by poor water quality. The major chemical parameters of concern are fluoride and arsenic. Iron is also emerging as a major problem with many habitations showing excess iron in the water samples. Transforming rural India, (2014)

The provision of clean drinking water has been given priority in the Constitution of India, with Article 47 conferring the duty of providing clean drinking water and improving public health standards to the State. The government has undertaken various programs since independence to provide safe drinking water to the rural masses. Till the 10th plan, an estimated total of Rs.1,105 billion spent on providing

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safe drinking water. One would argue that the expenditure is huge but it is also true that despite such expenditure lack of safe and secure drinking water continues to be a major hurdle and a national economic burden.

COMMUNITY BASED MAINTENANCE OF WATER SOURCES MAINTENANCE OF WATER SOURCES

Ramakrishna Mission Lokasiksha Parishad (RKMLP) is one of the biggest units of the Ramakrishna Mission Ashram, Narendrapur. It has done remarkable work in the field of maintaining water sources and has successfully demonstrated community based maintenance of 800 hand pumps in Medinipur. To carry out this process, a seven-member 'water committee' with four female and three male members from the beneficiary families were formed for each hand pump. These members were trained in operation and maintenance by the RKMLP. A maintenance chest fund was developed for individual pumps, with each family contributing one rupee per month. The money is collected once or twice a year depending on the paying capacity of the family. An innovative strategy developed is to collect the money during religious ceremonies after the harvest season as people have money during this time of the year. In this way, the water committee was able to collect Rs. 300-500 from the beneficiary families. The members of the committee also organized awareness generation activities relating to safe collection, storage and handling of drinking water simultaneously promoting sanitation and personal hygiene practices. Transforming rural India (2014) & Indian rural water supply (2014)

DUAL WATER SUPPLY AND WASTE WATER TREATMENT

To reduce the burden on fresh water sources, the option of dual water system is being worked out in several parts of the country. The success of this system lies in the fact that filtered purified water is used only for drinking purposes while other source of water may be used for purposes other than drinking. This is also is cost saving measure as resources spent on providing clean water is saved by using alternate sources. Waste water treatment can also be another effective means of reducing the burden on freshwater sources. The treated waste water can be used for purposes other than drinking. One example of effective wastewater treatment is in Mehsana district of Gujarat where wastewater from homes in villages is used for agriculture. The wastewater coming out of homes is collected in a pond which is then auctioned to farmers for use in agriculture.

Magod Dungri village in Valsad district in Gujarat has a population of 4,264. An old well served as a water source, but the water was saline and not potable. In 2006, this village was brought under the Bigri Malwan group water supply scheme of the GWSSB and it started getting safe drinking water. But in-village distribution of water continued to pose difficulty. Under the Swajaldhara programme, the village community decided to develop a system of household connections. The entire community made a 10 per cent contribution towards capital costs and the responsibility of collecting the contribution was taken up by one individual in each habitation. In the process, a 5,000 liter water tank in the village school, electricity connections, a 2,208 meter distribution pipeline, a 318 meter gravity pipeline and 15 stand posts were made. Out of a total expenditure of Rs.5, 20,000, the community contributed Rs.80,000. The foremost priority of the village was to get regular and safe water to meet their drinking water require-

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ments. As far as water for other purposes was concerned, this need could easily be met from the village well. For drinking water, the villagers make use of the treated water supplied through the regional water supply scheme. This is accessed from the 15 stand posts constructed in the 15 habitations in the village. Drinking water is received for about 30-45 minutes every day Thus by making use of dual sources of water, the community has ensured that treated water is not wasted and is used only for drinking purposes. Indian rural water supply (2014)

The villagers regularly pay water tariff fixed by the Pani Samiti. The Pani Samiti regularly pays Rs 14 per person as water tariff to the water supply department and if need be the villagers are ready to contribute more. The villagers also contribute Rs.16 per person towards electricity and maintenance charges.

SOLAR HOME SYSTEMS FOR RURAL ELECTRIFICATION

Lack of access to electricity is one of the biggest issues facing the world's poor, with over 1.6 billion left in the dark globally. The vast majorities of these people live in rural areas of developing countries because they are too poor and may be in too remote a location to be reached by the national grid. For their lighting needs they rely on candles, kerosene lanterns, and firewood which results in a daily expense that is expensive in the long run. Furthermore, this type of indoor lighting causes indoor pollution and chronic lung problems. Long-term, solar energy is the most practical and economical way of bringing power to poor and remote communities. Small-scale, distributed solar home systems provide an effective and affordable way to bring light to people without electricity. A basic system consists of a small solar panel, a battery, a charge controller, LED lights, and a universal outlet for charging cell-phones or other small appliances.(See Figure 4) A basic system can be made affordable through microfinance options. Partnering with local banks and/or microfinance organizations to create payment plans can help overcome the large initial investment associated with purchasing a system. Energy savings result from not having to buy candles or kerosene fuel, and can make the monthly payments affordable. When proposing this technology to a new area, it is important to target a community that has expressed a need and desire for solar electricity. Identifying and allying oneself with a respected community leader who is receptive and supportive is a good idea.

THE CLASSIC CASE OF SELCO IN SOLAR ELECTRIFICATION

SELCO's pioneering efforts with microfinance in rural India is a large reason why they have become a world leader in the field. However, their case also brings to light another issue relating to "free riders." Innovative companies willing to be first in the game can be put at a competitive disadvantage when they spend resources on innovation and capacity building. This is due to other companies taking advantage of their earlier efforts, getting a "free-ride." For example, after SELCO spent many years and dollars on developing India's rural financial infrastructure, other companies benefited from it. There were even some banks that, after giving out successful loans for SELCO systems, started selling their own systems for personal social development programs. Broadly speaking this isn't a bad thing, as it results in greater adoption of the technology and increased electrification for the poor. However, it does result in a decreased incentive for individual companies to innovate if their competitors are accruing benefits from their investment. To overcome the free-rider problem, governments and non-profit development

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institutions should provide funding and incentives for enterprises to innovate. This could be in the form of technical and financial support for businesses entering a not served geographical area. Furthermore, a government or non-profit could provide financing for early-stage systems, which would allow local banks in the private sector to see the technology successfully implemented before they decide to take on the risk of loans. (http:/www.selco-india.com)

Sunkalp Energy

A solar power company Sunkalp Electricity is launching a project called Solar Soldiers to involve people in Rural Electrification in Uttar Pradesh through the innovative use of Solar Power. A number of corporate are stepping up the green ante this day. This is what Sunkalp asks, "No TV. No internet. No AC. In fact, no LIGHT!!! Can you imagine a world without electricity? Not for a minute, an hour– but for 25 years. This Indian village in Uttar Pradesh has lived without power for so long that they can't remember what electricity means. We are here to bring them back from the past." Hence the idea is to rescue a forgotten community from the clutches of darkness. With this mission, it is building a solar mini-grid to power the lives of around 200 villagers without access to electricity. About 93% of the villagers in Gulabganj have already signed up for an electricity connection from the mini-grid. Sunkalp Energy has developed a low cost micro grid tailored to the needs of off-grid villages. Sunkalp Energy is constructing and will operate a pilot project initially in a small village of 25 households and will approximately extend to 4 new village-level micro grid lighting facilities to reach 300 new customers and 1,800 new beneficiaries in Hamirpur districts of Uttar Pradesh, India (http:/www.sunkalp.com).

DRAWBACKS OF RURAL INNOVATION

While innovation helps in attaining cost efficiency, reliability and ease of use, the investment in terms of land, labor, machinery and other fixed assets may be huge. As far as Innovations in electrification

Figure 4. Some Solar Instruments for electrification

Solar Pannels and Euipments for Lighting Using Solar Energy

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and water purification is concerned, it requires huge initial investments. Implementation part is also a major concern when it comes to government policies. Challenges are huge when we talk about the implementation part. How much work is actually done on ground will be a million dollar question. Moreover if private investors are encouraged to invest in these rural innovations sector will inculcate in drawing quickly the return on their investment. This may hamper the main concern of helping the rural people for which the process was started altogether. Moreover less private players would like to put their liquidity into these matters as they may not find the area interesting for their bottom line. Minor drawbacks can be catered to in long term but projects like solar electrification, water purification and rural electrification may also lead to environmental hazards which can be cause of great concern.

CONCLUSION

So after going through various context, cases, contention and issues we can conclude that many innovations are coming up for the agricultural sector but they are not widely known nor have they been systematically monitored and evaluated. Many of the innovative models are still relatively new, but through time and the use of appropriate systems to monitor and evaluate their achievements, we will be able to draw more complete lessons that can help in scaling up and replicating them. This will help us better understand what works and what does not, and under what conditions. What seems to be missing at this point is some repository of innovative models, systems to monitor, and methodologies to evaluate them. In addition, we need to think of incentives to strengthen existing innovative models and also promote further innovation

As said early in the chapter 'Innovation is defined as a process by which varying degrees of measurable value enhancement is planned and achieved, in any commercial activity. This process may be breakthrough or incremental, and it may occur systematically in a company; it may be achieved by introducing new or improved goods or services and/or implementing new or improved operational processes and/or implementing new or improved organizational/ managerial processes in order to improve market share, competitiveness and quality, while reducing costs.' India has one of the largest systems for agricultural research in the world. However this system has focused predominantly on intensification of cereal production under irrigated conditions. There has been criticism that this research system enabled an exploitative agriculture without a proper understanding of the various consequences of every one of the changes introduced into traditional agriculture. So it becomes imperative, based on previous experience of change in Indian agriculture to empower the resource poor smallholder and marginal farmers to be able to negotiate with stakeholders to their development their needs for political, social, economic and technological development. It would be essential that they participate in all decision making. The technologies they need will not therefore be limited to those related to agriculture alone but also to politically, socially and economically aggregate and collectively decide. Those who will generate enable adoption and, if need be, adaptation and innovation, will need to understand how development works along with how technology works and adapt each other for success. The has to be focus on innovation and the rebuilding will be based on social research of the needs of small holder farmers and that includes the study of socio-economics of the new technologies of Agriculture, ICT, Irrigation technologies, Solar

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Electrification that are developed to meet the needs of smallholder farmer. But, more important, it will be important to understand how development and technology, with all its facets and components, work side by side. And within this context, this would need entire communities, especially agricultural, to be included in decision making through participation.

In cases where the total sanitation approach had been used, program managers and local government officials were aware that their main objective was to stop open defecation, and that this required community-wide action, universal toilet use, and hygiene behavior change. Opinion was divided as to how these changes should be effected, but there was little argument about the approach. In this respect, the 'total sanitation' concept is a major step forward, as this level of shared understanding and purpose was sadly lacking in many earlier sanitation programs. It would be also important to redirect research for agriculture so that its purpose is to provide the innovations needed by small holder farmers as a direct product and not as a spillover or trickledown effect. The system has to recognize that a large number of technologies influencing each other and working together and in tandem contribute to agricultural development and all these need to be brought about appropriately. It can also be concluded that no single innovation can be considered the miracle or "silver bullet" solution, and this is despite the various calls over time to come up with grand schemes and search for big solutions. Creation of a forum of large agribusinesses that could be encouraged to leverage their networks in emerging markets and create openness that could be encouraged to leverage their networks in emerging markets and create opportunities for attracting financial institutions that could fund parts of their value chain, like local small traders, processors, farmers, etc. Financing could be linked and become the catalyst for technology improvements and promotion of environmental and social standards along specific value chains.

Based on the current state of healthcare system in rural part of Indian States the scope for Innovation is there. Through Government sponsored schemes, private sector interventions and the recent string of PPP Projects are intervening and trying to build up an infrastructure to make possibilities of inroads for betterment of facilities, it is understood that there is still a long way to go in terms of uplifting of the healthcare sector and reaching the desired health goals. It is very much evident that huge investment will be required in developing upgrading of healthcare infrastructure, in order to improve accessibility and quality of care. The private sector must consider this as business opportunity to establish their presence and expand their operations/ market share in the healthcare delivery market in India either by partnering with the different state governments or pursuing a pure private model. The government at the same time needs to understand the issues faced by private sector currently (working independently or in the existing PPP programs) and take measures to improve the investment climate in the respective states. The states will need to put in place clear policies and guidelines in the healthcare sector which will enable to attract large private investments in the health care industry

In the end it can be concluded that Rural Innovation will envision what is there in store for India as a country to develop as the next super power which will dominate the Subcontinent and create inroads and benchmarks for countries to follow. Under developed countries in Africa and other parts of the world are looking forward towards India to create a magnum opus so that the same model can be followed and replicated in their countries.

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REFERENCES

Adhar card. (2014). Retrieved from, http:/www.uidai.gov.in

Agarwal, M. D. (2012). Online banking services: An empirical study of banker's and customer's awareness about obs. *Journal of Exclusive Management Science*, *1*(7), 25–35.

Agriculture community. (2014). Retrieved from http://data.gov.in/community/agriculture-community/blog/national-agricultural-innovation-project

Annual Report of State Bank of India 2011-2012. (n.d.). Retrieved from http://www.sbigroup.co.jp/english/investors/library/filings/pdf/2012_en.pdf

Bhatnagar, S. C. (2004). *E-Government: From Vision to Implementation – A Practical Guide with Case Studies*. New Delhi: SAGE Publications Pvt. Ltd.

EchoupalI. T. C. (n.d.). Retrieved 2 July 2014 from https://www.echoupal.com/)

Governments schemes. (2012). Retrieved from http://yojana.gov.in/CMS/(S(y4dqrc55g1m1qhnd4soqih45))/pdf/Kurukshetra/English/2012/January.pdf

Gyandoot: The Purveyor of Knowledge. (2014). Retrieved from http://gyandoot.nic.in/

HDFC Bank launches 'Project Jharkhand' – an IT enabled Financial Inclusion program. (n.d.). Retrieved from http://www.hdfcbank.com/htdocs/common/pdf/Project_Jharkhand.pdf

iKure. (2014). *Solar Soldiers*. Retrieved from http:/www.ikuretechsoft.com

India Innovation. (2014). Retrieved from http:/www.IndiaInnovationPortalDecadeofInnovation2010-20.com

Indian Rural Water Supply. (2014) Retrieved from, http:/www.worldbank.org/projects/.../india-rural-water-supply-sanitation-project

Innovation. (n.d.). Retrieved from) http:/www. Businessdictionary.com

Kumar, R., & Jhunjhunwala, A. (2002). *Taking Internet to Village: A case study of Project at Madurai Region*. TeNeT Group of IIT Madras.

Novaritis arogya. (2014) Retrieved from www.novartis.com/downloads/corporate.../arogya-factsheet.pdf

Planning Commission. Government of India. (n.d.). Retrieved 2 July 2014 from http:/www.planning-commission.gov.in

Qureshi, T. M. (2008). Customer Acceptance of Online Banking in Developing Economies. *Journal of Internet Banking and Commerce*, *13*(1), 13–20.

Rao, C. S. (2013). Consumer awareness in rural India with special reference to E-Banking services in SBI. *Indian Journal of Research*, *2*(2), 46–48.

Rural Finance Learning Center. (n.d.). Retrieved 2 July 2014 from http:/www.ruralfinance.org

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Satyanarayana, J. (2004). *E-Government. The Science of the Possible*. New Delhi: Prentice Hall of India Pvt. Ltd.

SELCO. (2014). *Rural financial infrastructure*. Retrieved from http:/www.selco-india.com

Shanmugam, T. R., Chandrasekaran, M., & Vijayasarathy, K. (2011). *Economic Analysis of Farm and Market Risk*. Saarbrücken: LAP Lambert Academic Publishing.

Sustainable Access in Rural India. (2014) Retrieved from http://www.tenet.res.in/rural/sari.html

The World Bank. (n.d.). Retrieved 2 July 2014 from http:/www.worldbank.org

Transforming rural India. (2014). Retrieved from http://blogs.hbr.org/2014/02/transforming-rural-india-through-agricultural-innovation/

United Nationals Conference on Trade and Development. (n.d.). Retrieved 2 JULY 2014 from http:/www.unctad.org

White paper. (n.d.). Retrieved from http://edevelopment.media.mit.edu/SARI/papers/uncrd_report.pdf

Rao, R., Menaria, D., Maurya, A., & Parashar, A. (2012). *Video Case on Social Innovation*. Retrieved from https://www.youtube.com/watch?v=CA4Q2sEcsg0

KEY TERMS AND DEFINITIONS

ATM (Automated Teller Machines): Machines with the help of which money can be stored by a bank and retrieved by the customer of a bank without any human intervention.

ICT: Information communication technology helps in connecting people with the help of tools like telephone, mobile phones and Internet.

Innovations: Innovation is defined as a process by which varying degrees of measurable value enhancement is planned and achieved, in any commercial activity.

Rural Innovations: Innovations happening in underdeveloped and rural parts of a country.

Sunkalp Energy: A solar power company Sunkalp Electricity is launching a project called Solar Soldiers to involve people in Rural Electrification in Uttar Pradesh through the innovative use of Solar Power.

UID (Unique Identification Project): The government of India's Unique Identification (UID) project has created avenues for this people to become a part of the different projects and plans developed for self-sufficiency, growth and improvement in living standards.

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Chapter 55
Low Carbon Energy Innovations Systems in Natural Resource Rich Developing Countries: The Case of Brazil

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ABSTRACT

The transition to low carbon economy requires deep changes in the energy systems of the great majority of developing countries. However, only a small group of these countries is engaging significant efforts to develop renewable energies. The success in the diffusion of renewable energy technologies requires dynamic systems of innovation. In this chapter we analyze the recent evolution Brazilian sugarcane innovation system that was pioneering in the development and diffusion of bioethanol. This system is increasingly challenged by the acceleration of the technological regime, which is provoked by the energy crisis and the transition to the low carbon economy. The Brazilian innovation system has different capacities to cope with this challenge. In this chapter we differentiate the agriculture subsystem, which function in a STI (Science, Technology, and Innovation) mode from the industrial subsystem, which operates in a DIU (Doing, Using, and Interacting) mode. The agricultural subsystem has demonstrated a better ability to cope with the technological challenges of the new biotech research methodologies while the capital goods industry has much less propensity to deal with the second generation technologies for bioethanol. We describe also the present ethanol supply crises and its probable causes.

INTRODUCTION

The transition to Low Carbon Economies entails significant challenges for most of the developing countries. Their future seems to be related to fossil fuels by two main reasons. At one side their energy demand is increasing rapidly, in part because important sectors of their population are excluded from modern energy welfare benefits, and at the other side most of their energy supply lend on fossil fuels[1].

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As it is unfair to suppose that energy demand in developing countries could be contained, even if energy efficiency has an important contribution to give[2]. Thus we should expect that fossil fuel consumption will continue to increase if nothing happens at the side of renewable sources of energy. These dynamics makes the non Annex I countries responsible also by most of the increase in the world CO2 emissions since 1990 (IEA, 2012).

In present days most of the renewable used by developing countries are related to biomass. Biomass accounts for 10% of the global primary energy supply, mostly (6%) related to traditional uses of biomass like cooking and heating in the rural areas of developing countries. The share of traditional biomass is expected to decline since urbanization increases and modern energy carriers penetrate in poor households. Otherwise modern renewable energies technologies are projected to increase their share in future energy system. The main new sources are modern biomass, wind, photovoltaic, thermal solar, geothermal, and hydropower. Their share in the world energy supply was 10% in 2012 (REN 21, 2014).

Modern renewable have progressed impressively in developed countries during the recent years due to their environmental policies that determined quantitative targets for renewables, and also because of their innovation and industrial policies related to these technologies. In 2013, European Union and United States had 58.6% of the world renewable electric power generation capacity without hydro. However we notice also that a group of emerging economies is well positioned in the promotion of these new sources of energy. BRICS countries have a 28.9% share that is rapidly increasing mainly due to China. This country alone has the world largest wind power capacity (28.6%) in 2013. For solar thermal heating the Chinese hegemony is impressive with 64% of the world capacity. In hydroelectricity China also is first placed with 26% of the generation capacity, followed by Brazil (8.6%). More than being a world leader in power generation capacity, China also is at the forefront position for equipment supply. In Photovoltaic and Wind energy, Chinese companies are among the world leaders (REN 21, 2014).

Biomass is a very promising primary energy source for many developing countries. It is already an important energy source mainly due to traditional Biomass. In the future, modern biomass will increase its presence in the energy matrix (Goldemberg & Coelho, 2004). The leadership in modern biomass always belonged to developed countries. However, Brazil had been longtime the world leader for liquid biofuels. Nevertheless, more recently the Brazilian sugarcane ethanol lagged behind the USA corn ethanol. In 2013, US and Brazil accounted for 57.6% and 29.4% of the world bioethanol production. In the other kinds of biomass, developed countries still the world leaders like in biomass power generation, biogas and wood pellets, where European Union and United States are the world leaders (Ren 21, 2014).

In this paper, we would like to consider the effective potentials of a resource rich developing country to become a world leader in modern biomass supply and technology. Our argument is that, alongside favorable resources endowment, national innovation system requires continuous learning in order to advance in the absorption and the development of new technologies.

BIOMASS IN THE BRAZILIAN ECONOMY

Brazilian economy has a very dynamic biomass production system. Biomass commercial production, not only connected with energy, and related industries had an impressive evolution in the present century. The production of grains rose from 100 million tons in 2000/2001 harvest to 198 million tons in 2014/2015, most of it soya and corn. Sugarcane expanded impressively from 254 to 642 million tons in the same period (CONAB, 2015). Other biomass activities are also expanding quickly. Cellulosic Pulp

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production has almost doubled in more than a decade from 2000 until 2013 from 7.4 to 15.1 million tons. These figures illustrate the productive dynamism of the Brazilian agro-industrial system. They result from land expansion but also of a deep increase in the land productivity, which is connected to an important process of technological learning. Crop varieties had to be adapted to the Brazilian soil and climate conditions, which varies impressively according to the region, state or even locally. At the other side Brazilian tropical climate conditions like the very high level of sun exposure or the lack of a cold winter season gave the opportunity to develop new agriculture technologies.

The dynamism of the Brazilian agriculture is also fostering renewables technologies in the National Energy Matrix. Renewable energy had, in 2012, 42.3% of the country energy supply (EPE, 2014), which is much higher than world (13.5%) and OECD (9%) averages (IEA, 2014). This involvement is firstly related to biomass (27.5%), but unlike many others developing countries the greatest share (23.4%) belongs to modern biomass, which is deeply integrated in the agro-industrial production system. Brazil is the third in the world ranking of electricity biomass generation after United States and Germany, and almost 7.6% of all its domestic electricity supply is related to biomass conversion[3], where sugarcane has a dominant role.

The vitality of the Brazilian agriculture can be attributed to the junction of several factors. At one side there is a large potential of available land, even without the appropriation of forest and savannas ecosystems. There is close to 100 million hectares of degraded pasture lands that can be used by the agriculture. At the other side, Brazil has an innovation system formed by a set of public and private actors cooperating to develop new technologies or adapt the existing technologies to new ecosystems. The leading actor of the Brazilian agriculture – Embrapa - is a federal organization in charge of the main research efforts in this sector, but there are also several others state and private organization working for the development and adoption of new technologies.

THE BRAZILIAN SUGARCANE INNOVATION SYSTEM

Sugarcane is a very active segment of the modern biomass agro-industry, which dynamism lends on a long-lasting technological learning process. The dynamic trajectory of the sugarcane agro-industry in Brazil started when this culture was progressively transferred from the Northeast region to the state of São Paulo. In the Northeast, sugarcane created a very conservative sociotechnical system based mainly in slavery, which was preserved with small changes after the end of this social regime. This sociotechnical system had a limited ability to introduce technological innovation and to produce local development. Because of its restricted food supply capacity, it became a serious constraint for the development the urbanization and the industrialization of this region (Furtado, 1959).

Things started to change when this culture was introduced in the State of São Paulo, where capitalist social relations were better established. In this region sugarcane agroindustry emerged more dynamically, based in modern production techniques, surrounded by an industrial complex of equipment producers and by significant research institutions as the Agronomic Institute of Campinas (IAC) and the Agronomic School of Piracicaba (ESALQ).

The expansion of the sugarcane production in Brazil was supported by the state of São Paulo. The sectoral innovation system for sugarcane production tended to expand more dynamically in the richest region of the country. And the dynamism of the São Paulo region was based in the conjunction of several factors from which one can emphasize the abundant good quality natural resources, better transport and

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energy infrastructure, nearness to the country's biggest market and, above this all, the insertion into a regional system of innovation which congregate producers, capital goods manufacturers, research institutes and universities. The region experimented gradual increases in its sugarcane productivity based on the varieties developed in the same region.

For this reason, the Brazilian sugarcane innovation system is essentially from São Paulo. This region supports and sustains important institutions that are behind the dynamism of this system. The originality of the sugarcane innovation system in São Paulo is the supremacy of private research over the public one, although it was not always like this, contrary to the rest of the agro industry.

Brazilian agricultural research is predominantly financed by the public sector. A study conducted by Embrapa (Beintema, N. M.; Avila A. F. D.; Pardey, P. G. 2001) estimated that Federal research institutions (mostly Embrapa) as well as the state ones and universities were responsible for 89% of the Brazilian research efforts on agriculture and cattle-raising. This does not seem to be the situation of the sugarcane sector. The most important sugarcane research center, the Centro de Tecnologia Canavieira - CTC, is a private institution. Federal Government has a limited contribution in this area, since the extinction of the IAA (Institute of Sugar and Ethanol), in the beginning of the Collor Government in the 90's.

The leading players of the São Paulo innovation system do research mainly in agriculture developing new sugar cane varieties. The increase of sugar cane yields measured by tons by hectare or the sugar content of the sugarcane were obtained developing new varieties more adapted to Brazilian weather and soil conditions, and also more resistant to plant diseases. This improvement allowed to reduce the ethanol cost, and to increase its production. However, important advances were also obtained in industrial plants by improving sugar juice extraction, vinasse reuse for land fertilization, improvements in the fermentation process and in the energy co-generation of bagasse. Alongside with research centers, the federal and São Paulo research funding organizations are also important to fund innovation and organize sugarcane and bioethanol technological programs.

The innovation activities were mainly directed towards improving and perfecting the large sugar mills productive system, which was already established since mid of the last century. There wasn't any radical innovation that could change drastically the productive process of sugar and ethanol. However, the productivity gains were expressive and placed Brazil at the first level in terms of production costs, while the use of bagasse reduced dramatically the fossil fuels and external electricity needs in the industrial process. Thus mainly based in an incremental technological trajectory, Brazil sugarcane ethanol became competitive in terms of costs, and also in terms of environmental sustainability, because of its low green house gas emissions (Macedo & Nogueira, 2004; EPA, 2010; Wang et al. 2012).

As it was analyzed in a previous article (Furtado et al., 2011) and by several others authors (Dunham et al. 2011; Andersen, 2015) the Brazilian sugarcane innovation system have undergone several important steps and transformations since its constitution. Even though the production of biofuels was already in place almost since the 1930, the system was technologically laggard until the Proalcohol program was launched in 1975. Since that, the sugarcane production started to grow regularly. The program created a new market[4] for sugarcane – biofuels – and at the same time directed credit facilities to fund new mills and land expansion. This favorable environment changed deeply in the middle of the 80's when oil prices dropped and the Brazilian economy went through a deep crisis. Ethanol loosed its attractiveness, while government abandoned progressively its policy to promote biofuels supply and demand. Because of this political dismiss, local market ethanol scarcity happened in the beginning of the 90's and resulted in the collapse of the new ethanol cars demand. However, the deepest change came in 1990 when the main public organization in charge of the sector, the Sugar and Alcohol Institute– IAA, was shut down.

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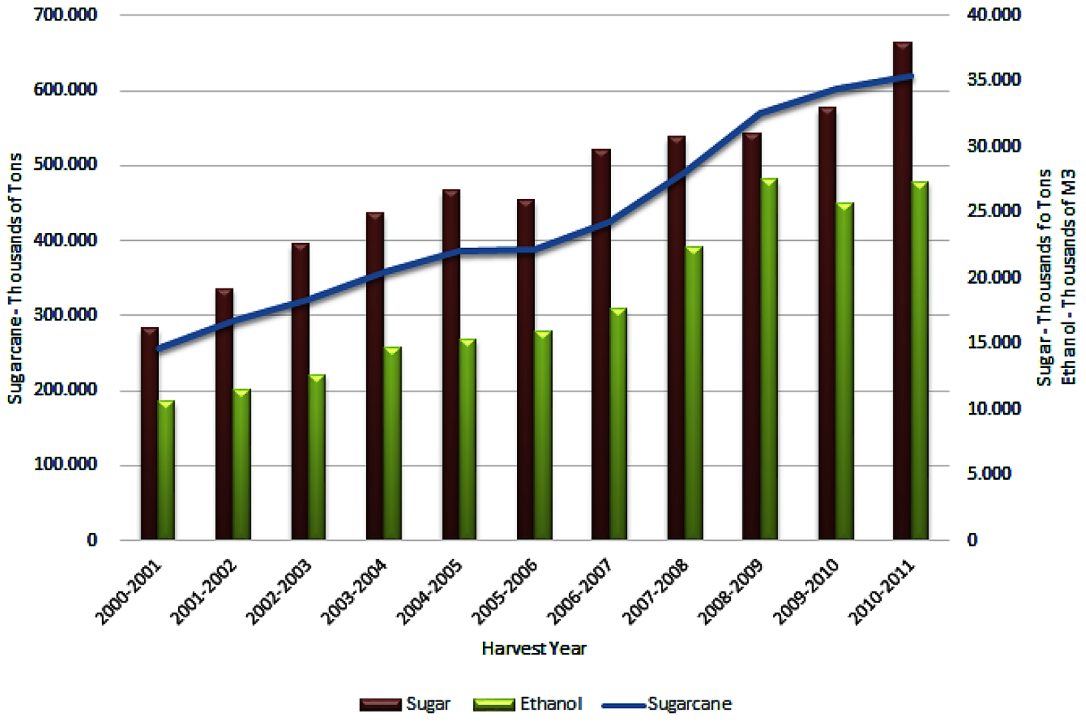
The main public research program – Planalsucar - in charge of the modernization of the industry was also discarded.

The bioethanol did not collapse because the sectoral innovation system was able to create new opportunities. Hydrated ethanol, used by pure ethanol cars, was progressively substituted by anhydrous ethanol consumed melted with gasoline. Sugarcane production was diverted to sugar external market that increased strongly since the 90's. Almost at the same time private and public actors replaced the federal IAA system in its promoting role of the sugarcane agro-industry. The Planalsucar plant breeding program was replaced by Ridesa, a network of Universities that continued the previous public program with private funds from sugar mills. At the other side CTC private breeding program continued its development, and the Campinas Agronomic Institute breeding program recovered after a longstanding stagnation. The engagement of the State of São Paulo Research Agency – FAPESP - funding sugar cane basic research expanded. All this aspects demonstrated the great resilience of the Brazilian sugarcane innovation system that was able to adjust to new circumstances and finance with private funds its own research.

In the years 2000, when the oil prices peaked again, making more attractive ethanol to car owners, the sugarcane innovation system and also the car industry were able to respond quickly to the new reality. The automotive industry introduced the flex fuel cars, solving the problem of the missing demand policy for pure ethanol, since the end of the Proalcohol program. This technology, by reducing the risk of the consumers, allowed the pure ethanol car market to increase again. The sugarcane production was able to expand quickly and the investments in sugar and ethanol mills started to grow again. These favorable conditions created the circumstances for a new cycle of expansion of ethanol and sugarcane (Figure 1).

Figure 1. Brazil Sugarcane, Sugar and Ethanol Production
Source: UNICA



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Thus, the technological trajectory of the Brazilian sugarcane innovation system rests mostly on incremental innovations, which means the improvement and adaptation of existing technologies inside a dominant technological system. Several authors (Dahlman & Westphal, 1982; Lall, 1982; Katz, 1987) studied this kind of technological change in developing countries, which initiates by a cumulative learning process on the implementation and use of imported technologies. Firms and others research institutions of the innovation system have to devote increasing technological efforts to improve the existing technologies and also to create the new ones. However, the possibility to maintain the technological capabilities created in the local learning process is allied to the relative stability of a dominant design or of a certain technological paradigm (Dosi, 1982). If the technological trajectory switches significantly, the capabilities connected with the prior technological system can easily be lost. According to this assertion, the fastening of the technological frontier can impair local capabilities and also make more difficult to follow up the technological frontier.

Some authors in development economics diverge from this view about the real chances of latecomers to catching up advanced countries (Soete, 1985; Perez & Soete, 1988). According to them there is a great advantage to be a latecomer in times of important technological ruptures. They recognize that technological development has a cumulative nature, but asserts that when radical technological changes happens, newcomers are less engaged in large investments in the previous dominant technological paradigm than the leading countries. Because they can commit larger amount of resources in new dynamic technologies, technological ruptures can be windows of opportunity for latecomers. Other factors can contribute to these to these windows of opportunity as demand changes and policy-based regulatory changes (Lee & Malerba, 2013). In our opinion this approach is useful to explain how in XIX Century happened the catching up of Great Britain by Germany and United States, and in XX Century how North America and Europe were catch up by Japan and after by South Korea. China more recently seems to be reproducing this same evolution.

However this kind of evolution poorly concerns much of the technological learning cases that happens in developing countries. It often occurs in mature sectors and are of an incremental and adaptive nature. In this context, as we will see as follows, changes in the selection mechanisms can jeopardize local learning process. In the present context, energy crisis and the challenges of a new low carbon economy are fastening the international technological regime and improving the technological efforts of developed countries and of some emerging countries in renewable energies. In this sense, the actors of the Brazilian sugarcane sectoral innovation system are trying to cope with these new challenges but there seem not always be prepared to it.

TECHNOLOGICAL DISCONTINUITIES IN BIOFUELS

The energy prices upswing in the present century together with changes of the energy policy in several developed and developing countries has hastened technological change in new renewable energies. The very fast evolution in wind power and photovoltaic power generation technologies has impressively dropped the production costs in many countries, and they are becoming more and more competitive with the dominant fossil fuels technologies. Liquids biofuels have a similar challenge. Important technological discontinuities need to be introduced to make biofuel competitive with fossil fuels and to improve its supply at the size required by liquid fuel markets.

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The analysis about energy transition agrees that mature renewables energy technologies, called first generation, will not be enough to face this challenge. The first generation technologies applies fermentation to convert sugarcane juice or cornstarch into ethanol[5]. These technologies are almost mature and can be considered as the main factors of recent expansion of supply. However, these technologies are bounded by raw materials supply, and also by the fact that these cultures also compete for land against food and others industrial crops.

To overcome the limits of first generation technologies, disruptive technologies called second or third generation technologies need to be developed and diffused (Johnstone et al., 2008). In the case of liquid biofuels, the most representative second generation biofuels technologies are enzymatic hydrolysis and biorefineries. In both cases, a greater diversity of raw material like biomass cellulose and agriculture residues are used to produce liquid biofuels.

This promise has increased the technological efforts in second generation biofuels, especially because developed countries are feeling more deeply the constrain of raw material supply in the first generation biofuels. Second generation can process others biomass raw materials than food crops like cellulose rich crops, or treat the part of the biomass food crops that is not directed towards food consumption like straw and bagasse, commonly called agricultural residues.

Cellulose rich biomass requires an additional conversion process into biofuels. Several possible technological routes can allow this conversion. One of the most promising technological process is hydrolysis, which can convert cellulose and hemicellulose into glucose. The acid trajectory is used since more than a century by chemical and food industry, but is not considered economically feasible because of its worse process conditions and a great quantity of residues. Meanwhile the enzymatic hydrolysis is a much more promising route. The developed countries like United States and Europe Union are investing large amounts of resources in this emerging technology (Pereira, Bomtempo & Chaves, 2015).

At the other side, sugarcane plant breeding is also submitted to a similar technological evolution. The conventional methodologies used in sugarcane breeding are long lasting. A new sugarcane variety takes almost 12 years to be developed. New biotechnologies can shorten this period of time and be more precise in the development of more performing new plant varieties. In this sense, the use of gene markers can help to identify specific characters in new plants. New plants can also be genetically engineered. However, this kind of technology requires long legal tests process, which finally can last more time than conventional breeding methodologies.

The transition to second generation technologies is changing the technological regime of liquid biofuels agro-industry. The hastening of the international technological frontier makes more difficult for developing countries, which accumulated local technological capabilities based on incremental innovations, to follow-up new technological developments (Katz, 1987). Thus, this quickening of the technological regime increasingly challenges the Brazilian sugarcane system of innovation, which was very successful in the first generation technologies. The Brazilian innovation system has different capabilities to cope with this challenge.

Innovation system are defined as a set of technologies, actors of different natures as firms, universities, research centers and government, networks and institutions that are engaged in the generation, adoption and diffusion of new technologies (Lundvall et al., 2009). These innovation systems especially in developing countries can have missing links, weak institutions or missing organizations (Chaminade et al., 2009). Our main assumption in this chapter is that shorter the network of actors, greater are difficulties to follow-up the technological frontier.

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To understand the evolution of the Brazilian sugarcane system of innovation we separate the agriculture subsystem from the industrial subsystem. In the agriculture subsystem research efforts are higher and the linkages with basic research done in universities are stronger while in the industry side the R&D efforts and the connection with academic research are weaker. The agriculture subsystem functions in a STI (science, technology and innovation) mode while the industrial subsystem, which operates in a DIU (doing, using and interacting) mode (Jensen et al., 2007; Varrichio, 2012). In this sense, the agricultural subsystem demonstrated a better ability to cope with the technological challenges of the new biotech research methodologies while the capital goods industry has weaker propensity to deal with the second generation industrial technologies for bioethanol.

BRAZILIAN SECTORAL INNOVATION SYSTEM RESPONSE

The years 2000 have brought new dynamics to the Brazilian innovation systems. At one side, there was an increasing concern from Federal and State Governments about the sugarcane and renewable bioethanol relevance for the national economic wealth. Federal Government decided to create the Centre of Bioethanol Technologies (CTBE) at the side of UNICAMP in 2009 and enlarged dramatically the funding channels to finance the productive expansion and the innovation in the sugarcane agro-industry.

BNDES, the Brazilian National Development Bank, financed new mills, requiring more energy efficient co-generation facilities in these projects[6]. At side FINEP (Federal Innovation Agency) launched in 2006 the economic subvention program, a special non reimbursable account to finance innovation in firms. In 2007 and 2008 14 firms received R$ 65 million[7] to develop new technologies, mostly second generation industrial technologies, biotechnologies applied to sugar cane, and new crop technologies.

The federal government funding policy get a step forwards recently in 2011 when the PAISS program was launched. The BNDES in charge of funding new plant facilities, and FINEP financing innovation and R&D had their instruments put together in this program, allowing government to support radical innovations at a deeper level. Before, new technologies were only financed at the federal level until the laboratory stage but faced great difficulties to reach the preindustrial or industrial stage. With the new program, large firms have engaged innovation efforts towards the industrial plants in second generation technologies, making more feasible the whole innovation process. In this sense Federal Government innovation policy has learned from the past failures, and is trying to improve its efficacy.

The change in the direction of the Brazilian biofuels innovation policy is also influenced by the USA and European experience at the same level. The financial amounts, the variety of funding instruments and the mechanism of coordination are larger and much more sophisticated in the similar American and European programs than in Brazilian case (Nyko et al., 2010). Trying to respond to this new technological challenge, the two federal agencies assigned R$ 1,57 billion to the PAISS program. The program is directed to 3 areas: 1) second generation biofuels; 2) new sugar cane products; 3) gasification. In the first call, 25 firms had their business plan approved mostly in the first and second areas (Table 1).

The State of São Paulo is also a central actor of the sugarcane innovation system. Since the 1990, FAPESP (São Paulo Research Agency) has an increasing role funding basic research mostly in biotechnologies related to this cultivation. The Sugarcane Genome Project started in 1998. The advances made by this project were fundamental for the surge of a biotech firm like Alellix. After 2000 the agency engaged in the funding of industrial technologies as the Dedini HDR project of fast acid hydrolysis. FAPESP made several partnerships with important national firms like Braskem, ETH-Oderbrecht, Oxiteno and

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Table 1. PAISS List of Firms with Selected Business Plan in 2011/12/16 by Funding Line

Companies	Line 1	Line 2	Line 3
Abengoa Bioenergia Agroindustrial Ltda.	x		
Agacê Sucroquímica Ltda.		x	
Amyris Pesquisa e Desenvolvimento de Biocombustíveis		x	
Barauna Comércio e Indústria Ltda.		x	
BioFlex Agroindustrial Ltda.	x		
BIOMM S/A	x		
Bunge Açúcar e Bioenergia Ltda.		x	
Butamax Biocombustíveis Avançados		x	
CTC – Centro de Tecnologia Canavieira S.A.	x	x	
Dow Brasil S/A	x	x	
DSM South America Ltda.	x	x	
Du Pont do Brasil S/A		x	
Eli Lilly do Brasil Ltda.	x		
ETH Bioenergia S.A.	x	x	
Ideom Tecnologia Ltda.		x	
Kemira Chemicals Brasil Ltda.		x	
LS9 Brasil Biotecnologia Ltda.		x	
Mascoma Brasil	x		
Methanum Engenharia Ambiental Ltda.		x	
Metso Paper South America Ltda.	x		
Methanum Engenharia Ambiental Ltda.		x	
Metso Paper South America Ltda.	x		
Novozymes Latin America Ltda.	x		
Petróleo Brasileiro S/A	x		x
PHB Industrial S/A		x	
Solazyme Brasil Oleo Renováveis e Bioprodutos		x	
VTT Brasil – Pesquisa e Desenvolvimento Ltda.	x	x	

Line 1: second generation biofuels; Line 2: new sugar cane products; Line 3: gasification.

Source: BNDES (available at http://www.bndes.gov.br/SiteBNDES/bndes/bndes_pt/Institucional/Apoio_Financeiro/Plano_inova_empresa/paiss/resultado_planos_de_negocio.html); access in 2013/08/18.

Dedini for funding academic research. The more recent initiative was the FAPESP and ETH partnership, which approved in 2011, 11 research project amounting R$ 20 million.

There is no doubt that at the side of innovative funding, new instruments were created to face the industry technological challenges. The problems came from the main actors of the industry itself and the lack of a demand policy for biofuels. To better understand this evolution, the sugarcane innovation system can be split in 2 main subsystems: The agriculture and the industrial subsystem. Agriculture subsystem concerns technology and knowledge related to sugarcane plantation and harvesting, while industrial subsystem is associated to sugarcane processing, and to sugar, ethanol and electricity production.

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The agronomic research is much stronger in the agriculture subsystem. There are already four sugarcane plant breeding programs (Ridesa, CTC, IAC, Alellix/Canavialis) that have in a way or another strong contact with academic research. Thus, the sugarcane agriculture subsystem can be labeled as a Science, Technology and Innovation system by the terms of Jensen et al. (2007), in which there is a strong linkage between academic and firm research. The discontinuity introduced by the genetic engineering technologies could be assimilated without great harm, in part due to the Fapesp Genoma project.

The main problem came with the financial crisis of 2008, when Votorantin Group decided to sell Canavialis and Alellix to Monsanto. The acquisition of the two start-ups by the American multinational has broken the links between the academic research and the private sector in an important Brazilian initiative especially for genetic engineering.

The strong tendency of privatization in the technological research has also provoked relational problems between Brazilian private and public research. CTC, which is a private R&D company, roughly restrained the access of its agronomic station for seedlings hybridization at Camamu in the State of Bahia to IAC program. The Agronomic institute of São Paulo had to create its own hybridization station near CTC to maintain its own genetic breeding activities.

The industrial research is facing a similar technological discontinuity. The transition from 1st to 2nd generation means an important rupture with the previous technological base. However, the capital goods industry is the weakest actor of the national system of innovation. Even if Brazil is almost self-sufficient in capital goods for first generation bioethanol technologies, a study in 10 representative firms of these industries oriented to sugarcane industry revealed very limited technological efforts, especially in R&D (Varrichio, 2012). While 7 out 10 of this representative sample were large firms with more than 500 employees, only 2 had R&D activities. There innovation were mostly of an incremental nature and resulted from their close interaction with sugarcane mills. In the terms of Varrichio (2012), the maturity of 1st generation technologies almost of public nature makes the adaptive kind of innovation much more based on tacit knowledge. Thus, the industrial innovation subsystem is based in Doing, Using and Interacting mode of learning (Jensen et al., 2007).

In this sense while having a great mastery of the 1st generation technologies, the local capital goods industry seems not to be prepared to face the 2nd generation challenge. The main reason is that the new knowledge related to second generation comes from biotech and chemical industry, while first generation is a traditional agriculture capital good industry. The only capital goods firm that was making significant technological efforts in this new area was Dedini. However the company for reasons related to the financial crisis interrupted its Acid Hydrolysis HDR semi-industrial project. This project in spite of having technical interest was outdated because of the dominant bet of the industry is in enzymatic hydrolysis technology (Silva, 2013).

The way that the Brazilian industry is facing the scientific and technological challenge is by the entrance of new actors. Few local firms were engaged in the 2011 PAISS public offer (Table 1). In this program only Petrobras and CTC are committed with significant technological efforts of the 2nd generation biofuels and green chemistry. At the other side a great number are foreign owned firms like Abengoa, Amyris, Bunge, Dow, Dupont, Mascoma, Novozymes, Solazyme, had their own project approved in the program. Dedini, the capital goods national leader, couldn't get inside in spite of its association with Novozymes.

The loose of national control over the second generation technologies can be perceived in new biofuels industrial plants. These industrial projects are owned by local companies, but these firms have weak control over the main technologies. There are 2 important second generation industrial projects that have

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already started their activities in Brazil, which are using enzymatic hydrolysis to transform sugarcane bagasse and straw into bioethanol.

The first case is Granbio, which is a private national group without industrial tradition that created a technology driven bioethanol company. This company launched in 2014/09 the first Brazilian enzymatic hydrolysis industrial plant at San Matheus, Alagoas. In spite of important efforts done in the development of new sugarcane cellulose oriented varieties and yeast for the conversion of the pentose into glucose, all the technology concerning the industrial process from pretreatment, hydrolysis until fermentation were transferred from an Italian company named Beta Renewables. The industrial capital goods were purchased from Biochemtex, and Novozymes has an exclusive supply contract of the enzymes. The yeast technology is licenced from DSM (Corrêa, 2014).

Cosan, the Brazilian largest sugar and ethanol Company, has merged with Shell do Brasil establishing a new company called Raizen. Raizen wined the last subvention call of 2010 to build a flexible 2nd generation industrial plant and started producing 40 million litres of ethanol per year 2014/11. Iogen, a Canadian Company, licensed to Raizen all the process technology from pretreatment to fermentation. Novozymes has also an exclusive supplier contract for the enzymes (Corrêa, 2014).

In this two cases, while the companies are totally or partially national owned, the control of the most important process technologies like pretreatment, hydrolysis and fermentation are completely controlled by new biotech foreign companies. The advances of the national companies happens in peripheral or complementary technologies like new sugar cane varieties or yeast.

The only case of a greater control of national technology is CTC, the private research organization located in Piracicaba. CTC has already a patented hydrolysis process and is running a 1,000 liters by day pilot plant. However, in spite of being sponsored by PAISS program the industrial plant has no fixed date to be launched.

Thus, it is clear the increasing difficulty of the Brazilian national industrials firms to cope alone with the technological discontinuity of the 2nd generation biofuels. Even in the case of strategic alliances, the level of technology transfer of core technologies is limited. This evolution is happening in spite of the federal government efforts to create appropriate funding and credit conditions for the Brazilian firms and new research organizations like CTBE (Centre of Bioethanol Technologies).

The presence of foreign firms in the control of sugar and ethanol mills increased dramatically. In 2010, foreign firms controlled 28% of the Ribeirão Preto region in the State of São Paulo and 23% of the Unica mills (Folha de São Paulo, 03/11/2010). Informal estimate calculate that in 2013 this share has increased until 40%.

WHY THE BRAZILIAN SUGAR CANE PRODUCTION IS LAGGING?

The technological evolution does not completely explains why the Brazilian sugarcane and particularly bioethanol production is lagging behind. These elements are connected to the business cycle that happened in sugarcane agroindustry during the last decade. In the beginning of the decade, there was a widespread expectation that Brazilian sugarcane production could increase continuously several times (CTBE, 2009). Effectively, the production more than double in a decade, rising from 254 million tons in 2000/2001 to 624 million tons in 2010/2011. However, thereafter the sugar cane production oscillated stabilizing in 650 millions in the last harvest (Table 2). Brazil lost its first place as a bioethanol producer

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to United States. Only after seven years of crisis Brazilian ethanol production is increasing reaching the score 29 billion liters in 2015/2016 harvest.

Several factors can explain the slower evolution of the sugarcane agro industry since the 2008 crisis. At the first level, the Government has abandoned an effective demand policy since the end of Proalcohol at the beginning of the 90's. During the program, IAA set ethanol prices in an advantageous parity with gasoline and guarantee the purchase of a predefined ethanol volume, like in the Feed-in tariff system, which was used by several countries to promote their renewable energies. However since the 90`s liberal reforms, the sugarcane industry had to face a competitive environment with no guarantee of fixed prices. This lack of demand policy was one of the main reason for the crisis because during a certain period of time, before and after the financial crisis of 2008, ethanol prices dropped dramatically in the internal market. The mills, which largely run into debt for expanding their activities in the previous period, get in red and had to cut their investment in the agriculture treatment. The result was a drop of the sugarcane land productivity.

The second challenge, also related to a lack of an ethanol demand policy, is the Federal Government control of gasoline prices. Because of the widespread of flexfuel cars, ethanol price need to be competitive with gasoline prices. Given that Government determined the gasoline price under the general prices index, especially since 2010, the ethanol prices has gown down in real terms. Meanwhile sugarcane production cost increased substantially eroding the profitability of the industry.

This lack of demand policy confronted bioethanol with a third challenge, which is the competition with sugar market for the use of sugarcane. A large portion of the mills in Brazil produces simultaneously ethanol and sugar. When ethanol prices dropped in the internal market the sugar prices raised at the international level. Thus the share of sugarcane processed for sugar production increased and the sugar production did not declined as much as ethanol (see Table 2).

At the fourth level, the expansion of the sugarcane production motivated deep changes in the geographic distribution of this crop. Until the middle of the last decade, sugarcane was restricted to regions with high soil fertility and good weathers conditions, mainly the central and the Northern regions of the State of São Paulo. Since then sugarcane culture expanded to western areas of this State and to outside in the Middle West States of Brazil (Goiás, Mato Grosso do Sul, Minas Gerais) where the weather and the soils conditions are very different from the previous regions. These new expansion areas are mostly located in the Cerrado region, which is a certain kind of savanna that occupies the central part of Brazil. The adaptation of São Paulo sugarcane varieties to Cerrado's weather and soil conditions do not seem to be an easy task. This requires important efforts of the sugarcane breeding programs. The largest Brazilian programs are attending to this challenge by displacing their agronomic research activities to central part of the country. The results are beginning to emerge. CTC has launched 3 new sugarcane varieties adapted to Cerrado's conditions.

The other challenge came from harvest mechanization. The use of mechanical harvesting in place of the hand cut traditional method is mainly the result of the evolution of São Paulo's environmental legislation that obliged sugarcane growers to avoid sugarcane burning, which is a necessary step before hand cut harvesting. The mechanization became inevitable and disseminated very fast but it brought several problems like soil compression and the lack of qualified personnel to operate the harvest machines. Sugarcane varieties need also to be adapted to mechanical harvesting because machines can more easily cut erected plants. Sugarcane culture is incurring deep changes in its main work methodologies and in the natural environment where it is cultivated. The impact of these changes was translated in reduced productivity yields.

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Another element contributing to the drop of crop yields was the more adverse climate conditions. These changes can be attributed in part to global climate change. The future climate scenarios point out that São Paulo weather conditions will be closer to the today's Cerrado conditions.

FINAL COMMENTS

The transition to a low carbon economy is a great challenge for the great majority of the developing countries. Most of their energy matrix is based in non renewable energy sources and their internal energy demand is increasing very quickly. Only a small group of the leading developing countries is making significant efforts to master and innovate in renewable sources of energy. China and at a lesser length India have great relevance in the wind and photovoltaic energies, but Brazil has a longstanding position in biomass, especially in bioethanol. This leadership is related to the strong technological dynamism of the Brazilian agro-industrial productive system. Renewables sources of energy, and specially biomass, have a strong share of the Brazilian energy matrix.

Based on favorable natural resources endowments alongside with long term innovation policies the Brazilian sugarcane innovation system bring about a longstanding learning process in bioethanol that gave an important leadership to Brazil in the 1st generation bioethanol. However the Brazilian leading position in bioethanol is challenged by the speeding-up of the technological frontier motivated by the transition from 1st generation to 2nd generation biofuels technologies, and also from traditional breeding technologies to modern biotechnologies. The Brazilian sugarcane innovation system is losing its coherence and its leadership.

The difficulty seems higher in the industry subsystem of innovation, which is oriented towards incremental innovation and is based in doing and using kind of learning. In this subsystem the Brazilian capital goods industry are little alike to follow-up fast changes in the technological base. The only local industrial firms that are intending to move behind like Oderbrecht, Braskem, Raizen and Petrobras belongs to chemical and oil industry and are acquiring hydrolysis technology from foreign sources. At the other side foreign companies infiltrated deeply the Brazilian innovation system. This entrance of external influences cannot only be considered negative for Brazil because it's allowing the national system to cope with modern technologies, nevertheless it reveals clearly the increasing difficulties of the traditional Brazilian capital goods firms to become players in this new innovative environment.

In the agriculture subsystem the situation seems more favorable. The connection between industry, agronomic research centers and universities is much more intense. Several public and private initiatives are intending to introduce new biotech technologies in the sugarcane breeding programs. However, the transfer of Alellix and Canavialis to Monsanto control has also weakened the cohesion of this subsystem.

Thus the main assumption that shorter the network of actors, greater are difficulties to follow-up the technological frontier was confirmed in the two different technological subsystems. In the agricultural subsystem the larger network of innovation, including research institution, makes it more adaptable to the technological transition to the biotechnology, while in the industrial subsystem limited capabilities and short network restrained the ability of capital good industry to attend to the challenge of second generation technologies.

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The problems of the Brazilian innovation system are not limited to the loose of national control. The stabilization of the ethanol production in the last years reveals a structural fragility of the energy policy that was unable to create appropriate conditions for a regular expansion of the supply. The increase of the production requires the displacement of the sugarcane culture to new area, which are creating new technological challenges that needs also to be faced.

REFERENCES

Andersen, A. D. (2015). A functions approach to innovation system building in the South: The pre-Proálcool evolution of the sugarcane and biofuel sector in Brazil. *Innovation and Development*, *5*(1), 1–21.

Beintema, N. M., Avila A. F. D., & Pardey, P. G. (2001). P&D Agropecuário no Brasil. Política, Investimentos e Perfil Institucional [Agricultural R&D in Brazil. Policy, Investments and Institutional Profile]. Washington, DC: Instituto Internacional de Pesquisas sobre Políticas Alimentares, Empresa Brasileira de Pesquisa Agropecuária, Fundo Regional de Tecnologia Agropecuária, August.

CGEE (Centre of Management and Strategic Studies). (2009). *Bioetanol combustível: uma oportunidade para o Brasil* [Bioethanol fuel: an opportunity to Brazil]. Brasilia, DF: CGEE.

Corrêa, C. (2014). Parcerias Estratégicas Tecnológicas em Projetos de Etanol Celulósico: Oportunidades e Desafios Para as Firmas Nacionais. [Cellulosic Ethanol Strategic Technological Partnerships Projects: opportunities and challenges for the national firms]. (Unpublished master dissertation), University of Campinas, Campinas, Brazil.

Dahlman, C., & Westphal, L. (1982). Technological effort in industrial development – an interpretative survey of recent research. In F. Stewart & J. James (Eds.), *The Economics of New Technology in Developing Countries* (pp. 105–137). London: Frances Pinter.

Dosi, G. (1982). Technological paradigms and technological trajectories: A suggested interpretation of the determinants and directions of technical change. *Research Policy*, *11*(3), 147–162. doi:10.1016/0048-7333(82)90016-6

Dunham, F. B., Bomtempo, J. V., & Fleck, D. L. (2011). A Estruturação do Sistema de Produção e Inovação Sucroalcooleiro como Base para o Proálcool [The Structuration of Sugar and Alcohol Production and Innovation System as the Base for the Proalcohol]. *Revista Brasileira de Inovação*, *10*(1), 35–72.

EPA (Environmental Protection Agency). (2010). EPA Lifecycle Analysis of Greenhouse Gas Emissions from Renewable Fuels. Regulatory Announcement, Office of Transportation and Air Quality, EPA-420-F-10-006, February 2010.

Furtado, A., Scandiffio, M., & Cortez, L. (2011). The Brazilian sugarcane innovation system. *Energy Policy*, *39*(1), 156–166. doi:10.1016/j.enpol.2010.09.023

Furtado, C. (2001). Formação Econômica do Brasil. [Economic Formation of Brazil]. São Paulo, SP: Companhia Editora Nacional.

Goldemberg, J., & Coelho, S. T. (2004). Renewable energy—traditional biomass vs. modern biomass. *Energy Policy*, *32*(6), 711–714. doi:10.1016/S0301-4215(02)00340-3

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

IEA (International Energy Agency). (2012). CO2 Emissions from fuel Combustion – Highlights. Paris: IEA-OECD.

IEA (International Energy Agency). (2013). World Energy Outlook 2013. Paris: IEA-OECD.

IEA (International Energy Agency). (2014). Key Energy Statistics 2014. Paris: IEA-OECD.

Jensen, M. B., Johnson, B., Lorenz, E., & Lundvall, B. A. (2007). Forms of knowledge and modes of innovation. *Research Policy*, *36*(5), 680–693. doi:10.1016/j.respol.2007.01.006

Katz, J. (1987). Domestic Technology Generation in LDCs: A Review of Research Findings. In *Technology Generation in Latin-American Manufacturing Industries* (pp. 13–55). London: Macmillam. doi:10.1007/978-1-349-07210-1_2

Lall, S. (1982). Technological learning in the Third World: some implications of technological exports. F. Stewart & J. James (Eds.), The Economics of New Technology in Developing Countries (pp. 157-179). London: Frances Pinter.

Lee, K., & Malerba, F. (2013). Changes in Industrial Leadership and Catch-Up by Latecomers: Toward a Theory of Catch-up Cycle from Eight Sectoral Studies. *Proceedings of Globelics*, *13*, 11.

Macedo, I., & Nogueira, L. A. (2004). *Biocombustíveis, Cadernos NAE, nº2, julho*. Brasília: Núcleo de Assuntos Estratégicos da Presidência da República, Secretaria de Comunicação do Governo e Gestão Estratégica.

Milanez, A. Y., & Nyko, D. (2012). O Futuro do Setor Sucroenergético e o Papel do BNDES [The Future of Sugar cane industry]. *BNDES Setorial*. Retrieved May 15, 2015, from: http://www.bndes.gov.br/SiteBNDES/export/sites/default/bndes_pt/Galerias/Arquivos/conhecimento/livro60anos_perspectivas_setoriais/Setorial60anos_VOL2Biocombustiveis.pdf

Nelson, R., & Winter, S. (1977). In search of a useful theory of innovation. *Research Policy*, *6*(1), 36–76. doi:10.1016/0048-7333(77)90029-4

Nyko, D., Garcia, J. L. F., Milanez, A. Y., & Dunham, F. B. (2010). A corrida tecnológica pelos biocombustíveis de segunda geração: uma perspectiva comparada [The second generation biofuels technological race: a comparative perspective]. *BNDES Setorial, 32*, 5-48. Retrieved May 15, 2015, from: http://www.bndes.gov.br/SiteBNDES/export/sites/default/bndes_pt/Galerias/Arquivos/conhecimento/bnset/set32101.pdf

Pereira, F. S., Bomtempo, J. V., & Alves, F. C. (2015). Programas de subvenção às atividades de PDI: uma comparação em biocombustíveis no Brasil, EUA e Europa [RD&I subvention programs: a comparison between Brazil, USA and Europe in biofuels]. *Revista Brasileira de Inovação*, *14*, 61-84.

Perez, C., & Soete, L. (1988). Catching up in technologies: entry barriers and windows of opportunity. In G. Dosi, C. Freeman, R. Nelson, G. Silverberg, & L. Soete (Eds.), *Technical Change and Economic Theory* (pp. 454–479). London: Pinter Publishers.

REN 21. (2013). *Renewables Global Futures Report*. Paris: REN21.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Silva, G. (2013). Aprendizado do etanol celulósico no Brasil: o caso do projeto Dedini Hidrólise Rápida (DHR) [The Cellulosic Ethanol Learning in Brazil: the case of Dedini Fast Hydrolisis Project]. Univerersity of Campinas.

Soete, L. (1985). International Diffusion of Technology, Industrial Development and Technological Leapfrogging. *World Development*, *13*(3), 409–422. doi:10.1016/0305-750X(85)90138-X

Varrichio, P. V. (2012). *Uma análise dos condicionantes e oportunidades em cadeias produtivas baseadas em recursos naturais: o caso do setor sucroalcoleiro no Brasil* [An analysis of the opportunities and conditioning factors in resource based production chain: the case of sugarcane industry]. (Unpublished doctoral dissertation). University of Campinas, Campinas, Brazil.

Wang, M., Han, J., Dunn, J. B., Cai, H., & Elgowainy, A. (2012). Well-to-wheels energy use and greenhouse gas emissions of ethanol from corn, sugarcane and cellulosic biomass for US use. *Environmental Research Letters*, *7*(045905). Retrieved from stacks.iop.org/ERL/7/045905

ENDNOTES

1. In 2012, fossil fuels satisfied 80% of the total energy needs of non OECD countries, while renewables responded for 16.3% (IEA, 2014).
2. Even in its 450 Scenario, IEA estimates that non OECD energy demand will increase 7.4 billons toe in 2011 to 9.6 in 2035 (IE, 2013).
3. The biopower capacity in United States was 15.8 Gw that produced 60 TWh in 2013, Germany had an 8.6 GW capacity with an 48 TWh electricity supply while Brazil had 11.4 GW capacity that generated 46.4 TWh. (Ren 21, 2014).
4. The market wasn't completely new because ethanol was mixed to gasoline in small proportion (E05) since the 1930's. However Proalcohol program established a E20 mixture and afterwards created the pure ethanol market.
5. Cornstarch need previously to be converted into glucose before being fermented.
6. Total BNDES disbursements to sugarcane industry amounted 42.8 billions reals (2011 values) between 2000 and 2011 (Milanez e Miko, 2012).
7. The exchange rate is approximately 2 reals = 1 US$.

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Section 5

Organizational and Social Implications

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Chapter 56
The Collective Aestheticization of Farming as Participatory Civic Engagement

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ABSTRACT

This chapter is a case study that traces the life of a young artist farmer who developed a community-based educational farm. The case study illuminates networked connections between small-scale farming, a revitalized interest in handmade production, and a burgeoning desire for a living ethics rooted in direct engagements. This chapter reveals the breadth of the handmade revolution, tracing a singular example to investigate the desire to become a small-scale farmer; the network of apprenticing makers, farmers, and artists; the necessary participatory aestheticization of the farm as a marketing strategy and mode of cultural consumption; and the ethical complexity of sustaining the life of a young farmer in the current organic and locally-grown marketplace.

I drove up the path to Amanda's new house. Typically, there were volunteers, friends, or the other farm staff there. Today, she was home alone. I went into the kitchen, and she was warming butternut squash soup and cornbread that she made the day before. We took our bowls outside and sat on a park bench in the lawn. We talked about what was happening in our lives, and she explained how different she felt now that she owned her own home.

She told me she needed to move some greenhouses that had been donated from a church nearby, so I offered to help. We drove to a field, where five large greenhouse frames stood. They were composed of rows of steel beam arches fixed into pegs in the ground. I had never been in a greenhouse, much less a constructed one. Amanda needed help dismantling two of them, and her farm apprentice would be out soon. My job was to remove a series of rusted bolts from a bar that ran down the center and connected all of the arched poles. It was relatively dangerous. I had to stand atop a ten-foot ladder and repeatedly use my left hand to hold a nut in place, while unscrewing a rusted bolt from the bar with my right hand.

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Up to that point, I had developed a relationship with Amanda through her role as a research participant in the work that led to this paper. Over the year that we had been working together, I had joined her CSA and my son had attended her Young Farmers classes. Our friendship always felt mediated by her as research participant or me as researcher, customer or client. The research seemed to structure the relationship, but the work on the greenhouses—outside in a field, as a friend—that was different. It was how I had wanted to be involved. I think I wanted her to see that I was not some bullshit academic, buried in books and theory.

Construction and manual labor were common weekend activities for my family when I was growing up. We often came together to help whomever was moving or improving their house. Work was compensated with chicken and beer for the adults, and the kids would help if they were old enough. I had not lived near my family for over a decade and had forgotten about those experiences until I started this research on DIY practices and artists' homes. This day with Amanda reminded me how much I learned through those experiences with my family.

I got all the bolts out, and the next step was dismantling the whole thing. I was there for four hours. It was a big task. I felt strong and proud. I had almost passed on the chance to help her that day because I felt overwhelmed with the stress of work, school, and family. All of that swirling in my mind from the morning had stopped. This felt like doing something that mattered.

INTRODUCTION

Amanda developed a working and educational farm in 2010 called, Cardo's Farm Project (CFP). My work with her was one of a group of case studies that focused on the homes of artists and makers to consider how their current art practice was shaped, in part, by histories of formal and/or informal arts education. Amanda was a young artist, who had recently graduated with a degree in painting and drawing. The site of CFP was a working farm, residence, and educational center. Through the farm, she offered educational programming, which "uses sustainable agriculture to engage the community, empowering youth adults to learn the source of our food, connect with the land, and to take responsibility for positive change" (Cardo's Farm Project, 2014). Amanda was interested in the educational and community-building potential of environmentally conscious agricultural work. As the quote suggests, she is focused on individuals' potential to realize their role in affecting "positive change."

CFP is one example of an increasing interest in localized agricultural work, urban farming, and hands-on production in response to factory farming, increasing globalization of food systems, and genetic modification. Post-Fordism[1] and our globalized economy have exacerbated physical and cognitive disconnects from agricultural and textile production that was born from industrialization (Hardt & Negri, 2004; Jeppesen, 2011; Thrift, 2012) – facilitating the often-overlooked exploitation of many life forms. This chapter explores one example of a renewed and expanding interest from artists in local farming and agriculture as an ecological expression of their art practices. By tracing Amanda's early influences, her choices during art school, internship at a social justice farm, work with contemporary artists in New York, and finally developing her own educational farm, this paper illuminates farming as one offshoot of participatory aesthetics (Bishop, 2012b) in response to neoliberal globalized capitalism.

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Over the last three decades, a movement merging craft and activism has grown in popularity. These material practices stem from a shift in values and are part of broader activist efforts for human and animal rights, environmentalism, and food justice as modes of cultural resistance to corporate globalization (Holtzman, et. al, 2005; McKay, 1998; Spencer, 2005). These modes of resistance are not without contradictions, as many of these practices have been co-opted by corporate entities to develop lifestyle-marketing campaigns based on a craft aesthetic and embedded in neoliberal rhetoric about individuation, choice, freedom, and a knowledge economy (Bishop, 2012a).

Small-scale and local farming have gained broad attention (Inwood, 2010; Meehan, 2012; Spaid, 2012) as part of this broader craft and hands-on revolution, as some call it (Levine, 2008). In Amanda's story, we see networks of apprenticing makers, farmers, and artists that illuminate the local/global relationship of agriculture-cum-art in response to the increasingly biopolitical terrain of food, art, and education. By mapping her process, the complexity of resisting global capitalism through localized, hands-on efforts with an emphasis on embodied learning and collective action is illuminated.

Moreover, her story is an illustration of the contemporary cultural desire for participation and consumption as event (Bishop, 2012b; Dunlap, 2013; Kalin, 2014; Kester, 2011). Amanda frequently incorporates hands-on experiences for visitors, customers, and students as a form of cultural participation; the act of farming, selling, and teaching become communal and aestheticized, and her agricultural output, farm, home, and lifestyle become commodities (Schaefer, 2013). But just as in my narrative, brief evens of direct engagement can produce the shallow satisfaction that we have performed a civic duty, overlooking vast systemic inequality that has become invisible through globalization. The farm illuminates the messy spectrum between resisting neoliberal capitalism and becoming subject to it, considering how the farm owner must negotiate and perform to our globalized economy to stay viable.

The chapter is ordered through education, art, and farming. I focus on themes of collective effort, fundamental skills, participatory civic engagement, and sacrifice to explore contemporary social conditions produced from neoliberal global capitalism through Amanda's story. I start by contextualizing the growing popularity of small scale farming in relation to histories of craft and community engagement as an art of resistance. Then, I trace Amanda's process of coming to and developing the farm through her art practice. Finally, I analyze ways that Amanda's experiences illuminate the complexity of the current relationship between craft activism and neoliberal capitalism, where "so many other aspects of this art practice dovetail even more perfectly with neoliberalism's recent forms (networks, mobility, project work, affective labor)" (Bishop, 2012a, p. 39).

AESTHETIC ACTIVISM IN RESPONSE TO INDUSTRIALIZATION

At each historical moment participatory art takes a different form, because it seeks to negate different artistic and sociopolitical objects. In our own times, its resurgence accompanies the consequences of the collapse of really existing communism in 1989, the apparent absence of a viable left alternative, the emergence of contemporary "post-political" consensus, and the near total marketization of art and education. The paradox of this situation is that participation in the West now has more to do with the populist agendas of neoliberal governments. Even though participatory artists stand against neoliberal capitalism, the values they impute to their work are understood formally (in terms of opposing individualism and the commodity object), without recognizing that so many other aspects of this art practice

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dovetail even more perfectly with neoliberalism's recent forms (networks, mobility, project work, affective labor). (Bishop, 2012a, p. 39)

As early as the Arts and Crafts movement, William Morris used creative and material practices to question capitalism, industrialization, and the increased fragmentation of humans from nature (Efland, 1990; Zabel, 1993). Dewey (1916/2007) later questioned how the spaces of institutional education and pedagogical content of public schooling were intrinsically removed from everyday life and argued for an enlivened way of being in the world as a form of living aesthetics (Efland, 1990). Progressive education of the 1930s was a form of social reconstruction encouraging skills and practices, including arts and craft production as part of everyday life, unifying communities through a pragmatic and problem-based education (Efland, 1990). Similar efforts to merge craft production as way of being in the world can be seen at the Bauhaus, Jane Addams Hull House, the Owatonna Project, and Black Mountain College. Each of these sites used craft as a form of education and civic engagement, where creative participation in the everyday functioned collectively and as a certain amount of political resistance.

A similar form of social reconstructivism emerged in the 1960s and 70s as part of the arts-in-education movement. Again, proponents argued against the fragmenting force of "disciplining" education, where art is set apart as a creative practice (Efland, 1990). They promoted problem-based learning in local environments, through activities that functioned as necessary skills for life, and saw art as integral to all subjects. Unlike the Progressivist efforts of the 1930s, arts-in-education advocates of the 1960s and 70s looked to the work of performance artists and encouraged the direct involvement of practicing artists in educational settings (Efland, 1990).

Since the 1970s, politically active cultural groups driven by a DIY ethic have revealed alternatives to the increasing power of corporate capitalist structures often using participatory approaches to intervene in daily acts of consumption (Duncombe, 1997). These types of interventions in state and civil society are geared at changing or highlighting inequality in the everyday. Artistic interventions in the everyday become increasingly visible primarily during times of broad social upheaval or political transition.

This ethic has reemerged in the last two decades in response to the ubiquitous nature of corporate capitalism in every aspect of life. Unlike previous public efforts to combat unjust labor conditions and social inequality that took the form of labor unions and public protests, the networked nature of our contemporary global economy has produced the necessity for equally networked forms of resistance. These efforts attempt to intervene on individual, grassroots, and systemic levels.

In the late 1990s, Green (1999) identified *new genre public art education* as a combination of traditional and non-traditional art methods merging art and life to make socially-conscious art. She promoted socially-based pedagogy through constructive projects with the use of critical thinking strategies in community-based art education that work with and in the community to develop problem-solving skills that are socially relevant and merge art and life.

Neoliberal capitalism today makes resistance different than it has been in previous generations. An increasing desire for post-politics and anti-intellectualism have created conditions where creative resistance must tactically engage participants and viewers in activities that open new modes of understanding without overtly supporting a political agenda. Many artists and activists start with their local environment, focusing on place as a generative concept. Pedagogies of place (Callejo Perez, Fain, & Slater, 2004; Ellsworth, 2005; Gruenewald, & Smith, 2008) draw attention to the vitality of a physical setting to instruct, oppress, structure, and inspire. In art education, place-based studies often focus on the potential of learning beyond the institutional setting, into domestic spaces (Ballengee Morris, 2000;

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Congdon, 2006), public places (Duncum, 2011; Trafi-Prats, 2006, 2009), in the natural environment (Blandy & Hoffman, 1993; Garoian, 1998, jagodzinski, 1987), and through direct engagements with built environments (Gude, 2004; Powell, 2008, 2010). Others argue the institutional environment's potentially negative impact across ecologies (Graham, 2007; Wallin, 2007). Environmentally-conscious research in art education has questioned the hierarchy of humans over the environment (jagodzinsky, 1987) and "demonstrate the interdependence of all living and non-living things" (Blandy & Hoffman, 1993, pp. 24-25). Scholarship about place is often rooted in environmental awareness and the desire to affect change in local and global communities.

ART AS PARTICIPATORY CULTURAL ENGAGEMENT

First, there is growing interest in collaborative and collective approaches in contemporary art. And second, … there is a movement toward participatory, process-based experience and away from a 'textual' mode of production in which the artist fashions an object or event that is subsequently presented to the viewer. (Kester, 2011, pp. 7-8)

Kester (2011) describes two modes of participatory art, collaborative and participatory, that have emerged in part from the fragmented character of our contemporary society embedded in neoliberal conditions. Kester (1998) claimed, "the current political moment demands an activist aesthetic based on performativity and localism…. An activist art…defined as an intersubjective 'communicative action'" (p. 15). Kester positions activist art as performative act in the local.

This approach also parallels a shift to the relational in contemporary art considered by Bourriard (2002) as, "the realm of human interactions and its social context" (p. 14). Similarly, Bourriard (2002) highlights contemporary possibilities of work that addresses "learning to inhabit the world in a better way, instead of trying to construct it based on a preconceived idea of historical evolution" (p. 13). Such a conception of the centrality of newly generated forms of social relations is essential to the idea of an activist art that engages questions of politics and power relations.

Art based in relational encounters can have a superficial effect, though, of lulling viewers and participants into the notion that they have become politically active, or performed as active members of society. Bishop (2004) argues that the very messiness of contemporary artistic activism is critical to its efficacy, embracing the destabilizing meaning of relational aesthetics, and claiming that congenial encounters are not enough to produce critical affects. Instead, a critical situation must express a *relational antagonism* that troubles customary modes of representation "going to public space to engage with ways that participants perceive 'conflict, division, and instability'" (Bishop, 2004, p. 65) in local communities. The resulting discomfort of defamiliarized experience can trouble subjectivities in ways that illuminate new possibilities.

Artist activists have become interested in Socially Engaged Art, which embodies a pedagogy of ethical encounters that rely on the performative aspects of our lives in the world and an emphasis on affect. Helguera (2011) describes a social interest in contemporary art, where artists are "interested in creating a kind of collective art that affects the public sphere in a deep and meaningful way" (p. 7). A shift to a socially engaged art involves a focus on public participation that is local, performative, and often political. These political and public shifts to a performative action are emerging in response to increased private ownership of all public space, as well as an institutional critique of the state, the school, and the art

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world. Artists, educators, and scholars are coming together publicly as members of larger communities to enact change and attempt to produce a collective intersubjective shift in our global society through direct engagement (Thompson, 2014). Socially engaged art aims to disrupt and transform "through a form of practical or experiential production, the outcome of which is not predetermined" (Kester, 2011, p. 185).

Farming as Socially Engaged Art

Small local and urban farms operate through the same hands-on ethos that is driving craftivism and socially engaged art. Today, common public spaces, such as malls, parks, and shops are typically constituted at least in part by capitalist forces. In response, the handmade revolution described above along with other forms of craft activism have made an effort to intervene in these sites to resist globalized capitalism. Farmer's markets and local or urban farms have become popular spaces of civic engagement through interactions directly with farmers, craft artisans, and their land. Participatory and socially engaged art have infiltrated the public sphere in an effort to activate political discourse in the commons. Practitioners, which are often artists, are interested in bringing people together through collective, first-hand engagements with agricultural work to eliminate the cognitive and corporeal fracture historically constituted through capitalist production.

While the popularity of farming and local agriculture has increased, artists are also responding to and engaging with farming. Farms have been represented in artwork for centuries, from pastoral landscape paintings to the photographs created by the WPA. Paralleling contemporary shifts toward participatory art, farms have taken on a performative role for artists today. Links between art and farming are now being investigated in relation to similarities of process and activities of production, and less for as commodities or modes of representation (Barney, 2009).

Contemporary artists are using processes embedded in farming and the construction of farms in a variety of ways and locations, including urban lots, abandoned fields, and community sites (Meehan, 2012; Spaid, 2012). Sue Spaid curated an exhibition addressing forty years of farming as art in the Contemporary Arts Center in Baltimore in 2012. Art dealer Cynthia Mulcah, and artist Robert Hamilton developed a farm as a community center in the middle of an urban area in South Dallas. These are just two examples among many of ecologically minded artists and cultural workers developing green spaces and/or educational programming around combined efforts between art and farming.

As I introduce Amanda's narrative in the following sections, I view her farming practice and her aesthetic practices as performative craft production. In her story, we see networks of apprenticing makers, farmers, artists, and educators that illuminate the local/global relationship of agriculture-cum-art in response to the increasingly biopolitical terrain of food, art, and education.

Methodology

This research was part of a two-year inquiry that considered how narratives embedded in the objects and material elements of artists' and makers' homes might teach about ways that subjectivity was produced through their social and material practices. To understand the singular and systemic aspects of Amanda's farm project, I approached the research through a methodological bricolage (Kincheloe, 2005) that included traditional ethnographic methods, cultural and historical research, and autoethnography. Over the course of two years I made initial formal visits to the original site of her farm project to administer two formal interviews with tours of the site and many informal visits and interactions during which I learned

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how the ideas shared in the initial visits were lived. During the research, my children took part in the educational programming offered at CFP, and I joined her community farm share program, which is a form of Community Supported Agriculture (CSA). I also volunteered time to help with tasks associated with the farm, such as the experience described in the opening of the chapter. In addition to experiences on the farm, I interacted with Amanda in public spaces, such as the local farmer's market. Data included interview transcripts, photographs, personal reflections, publicly posted and online artifacts produced to advertise her project, and historical and cultural research.

Amanda was the last participant I met, and her home was an anomaly for a number of reasons. Amanda's domestic space, which shifted during the research process, was unusual because the home was on the farm that also served as the site of her small business. In the two years that we worked together, she moved from a trailer located on the original site of CFP to her own home on acreage that would continue to serve as Cardo's Farm Project but as a more independent business venture. As a result of this overlap, I was able to learn about Farm Based Education, the small farmers movement, and challenges of developing a local agricultural operation. All of these factors intersected with her background as an artist and her interest in histories of female farmers.

I use Amanda's narrative to consider how the farm project as business and educational site illuminates the complexity of neoliberal globalization, where participation is both aesthetic and civic engagement and simultaneously a marketing strategy. To analyze the data in response to these questions, I consider how Amanda's choices, sacrifices, opinions, and material practices highlight potential for broader collective efforts and illuminate the systemic conditions that limit them.

ARTIST-CUM-FARMER

In this section, I describe Amanda's influences, education, and experiences that produced the shift from being a practicing artist to a developing CFP. As noted earlier, a renewed interest in craft has emerged in part as a response to global capitalism. Many artists are drawing attention to the importance of fundamental skills, such as gardening and sewing as a way of developing a sense of agency in relation to material necessities and of living with less dependency on globalized capitalist production. The argument exists that there is no way to live outside of capitalism, but many artists and makers feel that highlighting the significance of skills in fundamental material production is one small mode of resistance.

Art and Education but Not Art Education

Women's narratives and an interest in fundamental skills fueled Amanda's concentration on craft and agricultural knowledge, but her institutional education in art in public school and the university have equally influenced her desire to become an educator, artist, and farmer. A nurturing art teacher, Ms. Wilson, helped Amanda develop confidence in her drawing skills. As she thought about going to college, she saw Ms. Wilson as a model for future potential. Amanda decided to pursue art education and studio courses in painting and drawing at the university. She considered art education a subject that was about usable skills that were physical and productive—information that could be applied.

After one art education course, she decided not to continue a traditional certification route. As she explained,

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And then I dropped the art education. Because I, well, I took one class, and I was like, 'these people are going to educate children about art? We're not even making art.' They don't know anything about art. It didn't make any sense to me. (Amanda, personal communication, February 19, 2013)

As I heard Amanda say this, I wondered what would have turned off someone who genuinely cared about making art and had a sincere desire to educate. What is art education training? I will explore possible answers to this question and how this experience is not unusual in the discussion at the end of this chapter. Amanda decided to take her desire to educate to community work instead, focusing on farm-based education and craft in community settings.

Hidden Villa and Social Justice

To learn about farm-based education while finishing her art degree, Amanda took an internship at an educational farm outside of San Jose, California. "Hidden Villa is a nonprofit educational organization that uses its organic farm, wilderness, and community to teach and provide opportunities to learn about the environment and social justice" (Hidden Villa, 2014). Hidden Villa invited school and community groups out to engage in learning experiences through direct contact with animals and agriculture. Its approach is rooted in farm-based education (FBE). FBE is,

...a form of experiential, interdisciplinary education that connects people to the environment, their community, and the role of agriculture in our lives. Farm-based education promotes land stewardship, the value of meaningful work, and supports the local food systems that sustain us. (Farm Based Education Network, 2014)

This focus on direct engagement with the land through experiential and interdisciplinary learning was critical to Amanda. Just as Amanda was drawn to the stories of her grandmother's large family where each sibling played a role in the family's well-being, FBE can instill a sense of purpose in students.

This type of education does not just take place at farms. We can see similar experiences in urban and school-based gardens (Inwood, 2010). Students are able to take ownership over something and nurture its growth.

I think kids are really good at picking up on where they are in the world and in a system whenever they are asked to be the caretaker of the animal or the plant. And then they know that this is my responsibility to care for this and then they are working next to each other and they are trying to figure it out and how to do and how to use the tools – like all of this confidence building. (Amanda, personal communication, April 5, 2013)

In addition to developing sensitivity to all life forms, FBE promotes social justice through the experience of being on the land together and in teaching about what it means to take only what you need and build consideration for the larger global community through a collective responsibility. The founder of Hidden Villa started the first multi-racial summer camp in 1944 with the idea that children playing outside together might be able to forget their socially constructed differences at least temporarily. The Duvenecks, who had purchased Hidden Villa in 1924, had an ongoing mission of using the land to advance social justice.

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In addition to starting the first multiracial summer camp, they "sheltered refugees fleeing from the Nazis, assisted Japanese-American families returning from internment camps, and hosted groups for social and educational reform." Later the family "opened their home to the United Farm Workers movement in the 1960s and provided a safe space for Cesar Chavez to organize California's first farm workers strike" (Hidden Villa, 2014).

Social justice is woven into farm-based education as people come together to care for the environment and for each other through direct engagement and personal responsibility. Amanda highlighted the kind of camaraderie that develops among those who are working together to build a local garden or a large farm. It is a kind of camaraderie that children and adults alike often lack in our globalized and media-driven society.

Performing the Farm Through Collective Responsibility and Fundamental Skills

When Amanda returned for her last year of school, she visited Cardo's Sprout Farm. She had other friends who had volunteered there and thought it might be a good place to continue exploring FBE. During her final year of school, Amanda was growing and delivering sprouts for Cardo while pulling together her final work for her BFA show. Her internship in California the previous summer revealed to her the potential for teaching and learning through work on the farm. There she saw a new domain for teaching.

Amanda's grandmother influenced both the subject matter and ethical drive for her shift to farming and her art practice. Her grandmother was a seamstress who lived on a small farm. Amanda learned to sew from her when she was young. Together they would crochet and make quilts. As a young art student, Amanda took an interest in histories of female farmers. Her work dealt with what it might means "to be a farmer and have a life that was so different and to be a woman who was working physically as hard as the man" (personal communication, February 19, 2013).

Amanda spent a lot of time on her grandmothers' farm growing up, and a map of that farm (Figure 1) was the visual and conceptual inspiration for Amanda's BFA show. Amanda's grandmother drew the map, illustrating the layout of the farm (refer to Figure 1). The details of the drawing provide insight to the life of her farm with a variety of crops, a garden, calves and chickens, and also a number of different physical structures.

Through her time with her grandmother, Amanda learned the importance of individual responsibility and collective effort. Collective engagement by all members of the family was critical to the operation of a farm. As she described,

[My grandma] had a real role – she was a kid and her siblings were kids but they had a real contribution to the existence of their families. And I don't think they were resentful at all. Like she talks about doing the work and being so excited they could go out and swim in the river that afternoon. And before school you milk the cow and then you come home and do whatever chore you have to do. I think that would help me appreciate what it means to be here and to be part of the world. (Personal communication, April 5, 2013)

With a life engaged in the direct production of food and other necessities came purpose as well as the joyful reward of leisure thereafter. For Amanda, collective processes of coming together through essential and direct practices are the root of subsistence and survival.

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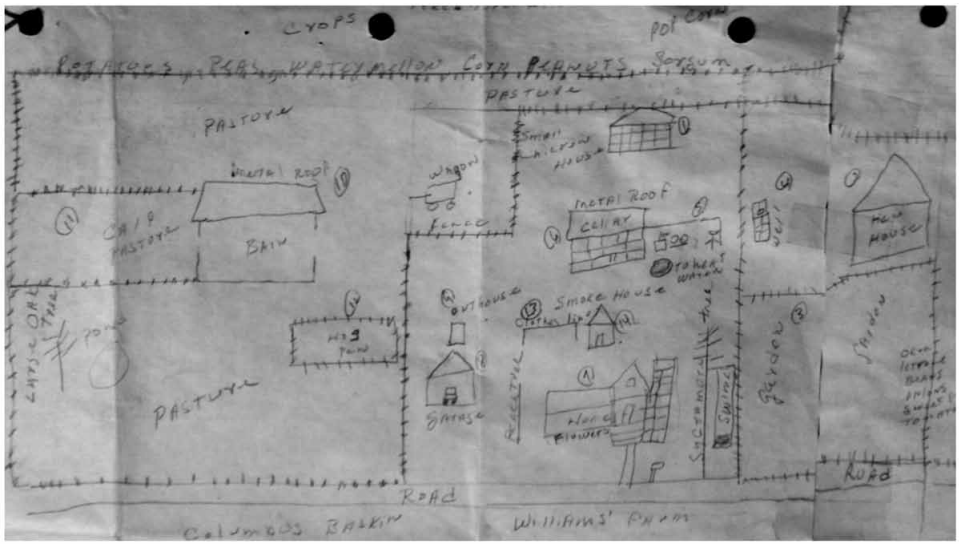
Figure 1. Close-up of map drawing Amanda's Grandmother's house



I just wanted so badly to have the simplified version – I guess it was a kind of romanticism, but these foundational or fundamental skills – all of it – all of the DIY skills, crafting, sewing, weaving, growing food, building, cooking – I just really wanted to know those things – for me it meant some kind of simplification – like a simpler form of living. (personal communication, April 5, 2013)

As we discussed learning fundamental skills in Amanda's trailer, I noticed a spinning wheel (Figure 2), but I was not sure of its purpose. Juxtaposed against the prefabricated walls of the trailer, the wooden apparatus seemed both a living being and a relic simultaneously. I asked her what it was, and the concept of fundamental skills was instantly clear.

Amanda explained that she was constructing pieces for her BFA show that would be an installation work that addressed life on the farm and stories she had heard, she repeatedly asked her grandmother for hand-spun yarn. Finally, her grandmother introduced her to a woman who taught her to spin her own yarn from animal hair. She used it to produce string installations (Figure 3) that would represent the crop rows from her grandmother's drawn map (Figure 1).

The work in Amanda's senior show wove together her interests in women's histories, a lifetime of developing skills in craft and making, memories of experience on her grandma's farm, the visual inspiration of her grandmother's hand-drawn map, and her recent embodied knowledge of farm work. She was becoming the subject of her memories and realized a parallel in her life and the research on female farmers' memoirs she had studied. The desire that fueled her work on the farm was the same passion that drove her artwork—a desire to make, teach, and learn.

So it just kind of evolved out of a practice from where I was drawing fields to where I was working in the fields. And then it was, like I would take vegetables that I was growing here and put them in my artwork. And then eventually it was like – a lot of it was time – I was working from sun-up to sun-down, but I have always thought of this like it was kind of like it was a big performance of the work that I had been making on paper for so long. It felt that way because it was kind of self-centered – like I was making

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Figure 2. Spinning wheel in Amanda's trailer

Figure 3. Small part of Amanda's large crop installations

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these artworks and it was all kind of the same thing for me, and then I started going through the motions of becoming a farmer that I had been making this art about because I felt like I kind of idolized it. (Amanda, personal communication, April 19, 2013)

Common Ground and Contemporary Art

After graduation, Amanda served as an apprentice at Common Ground Farm outside of Beacon, NY for six months. Like Hidden Villa, the farm provided educational programming for all ages and it emphasized food justice as part of its mission. Possibly because of its proximity to New York City and only a few miles from the Dia, Beacon was a large artist presence between volunteers, workers, and CSA members at Hidden Villa.

I asked Amanda why there seems to be such a strong overlap between artists and the young farmers movement. Having attended conferences and coming to know the farmer community, she explained that many young farmers are either the artist or the scientist type. She saw similarities between farming and art making in the way that both elicit a sensitivity to connect and exchange ideas, and require using your hands and mind to problem solve. For a young artist, farming can be much more rewarding than administrative or managerial jobs. Furthermore, Amanda stressed the potential for change that can come from agricultural work—change that might take the form of a week's vegetables, developing a community supported agriculture program, or a summer camp that introduces kids to the roots of much of their food.

During her apprenticeship at Common Ground, Cathy Lebowitz was the artist in residence on the farm. Lebowitz was an editor for *Art in America.* She introduced Amanda to a number of artists who would visit the farm, and they would attend shows in New York City together. Amanda's background as an artist opened doors to expand and become part of the larger community involved with Common Ground.

While interning at Common Ground, Simon Draper, a contemporary artist who was developing an artists collective called *Habitat for Artists* (Lipton, 2014), was also working there. Amanda explained that Draper wanted to take artists from their traditional studios and put them out in the community or in nature because he was interested in how that shift might affect an artist's consciousness. With a team of artists, he built small mobile studios and placed them around the Hudson Valley, allowing artists to use them. This work was collective and environmentally conscious, in the sense that the spaces were not based on profit, but on a shared time and labor to produce a different sense of connection with the world and question how that might affect their artistic production. His work was a response to global capitalism in its resistance to the privatization of time, space, and knowledge production.

After finishing her apprenticeship at Common Ground, Amanda apprenticed with Draper. She took testimonies of the artists who were occupying the spaces he built as part of her work with him, again blurring the lines between art, anthropology, education, design, and science. "I remember whenever I came home from New York, I was like, I'm an artist, and I just didn't know. I am an artist and I am a farmer and I'm a teacher." (Amanda, personal communication, April 5, 2013).

PRODUCING CARDO'S FARM PROJECT

Amanda returned home motivated to expand Cardo's Farm from a sprout farm into a local working and educational farm. She quickly realized that she was running a business and must learn how to manage it as such by teaching herself accounting and inventory software and honing her negotiation skills. Amanda's

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experience building the farm project highlights the complexity of developing ethical business practices that rely on and are responsible to a community and the environment.

The first summer, the temperature rose to over one hundred degrees for sixty days. She worked with another farmer she had met in California to put on a makeshift summer camp with a surprisingly large turnout. The camps were full and the kids were excited. They also held adult workshops on gardening and farming. By the end of the summer, they were committed to seeing the Farm Project grow. Amanda raised $15,000 through a successful Kickstarter campaign. With the capital in place, she renovated the barn to make it a more functional education center (see Figure 4) and community kitchen, expanded the growing space to another plot of land, put in irrigation, and started their first CSA. The capital campaign allowed them to develop a business model that could function as a more self-sustaining system.

Sacrifice, Communal Living, and Collective Responsibility

While the Farm Project has been successful, Amanda was honest about sacrifices she felt she had to make to maintain its integrity. She was forthright about her fatigue with living outside and often without hot water. During their first winter, Amanda moved to the farm and lived in the small (approximately four foot by four foot inside) dome structure that Cardo built years earlier (see Figure 5). Amanda lived in the dome for over a year. There was no indoor restroom facility and no hot water. She would start a fire to use the shower and it was still not in a walled structure. The kitchen in their barn is the only kitchen on the land, so they share it with Cardo and any of his guests as well.

She eventually saved up the money to buy the trailer she was living in during the interview (see Figure 6). She said, "Sometimes I am just like, 'When, when can I have a normal house? Turn on the faucet and have hot water came out" (Amanda, personal communication, April 5, 2013).

Figure 4. Chalkboard inside renovated education center at Cardo's farm in Ponder

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Figure 5. Small dome structure built by Cardo

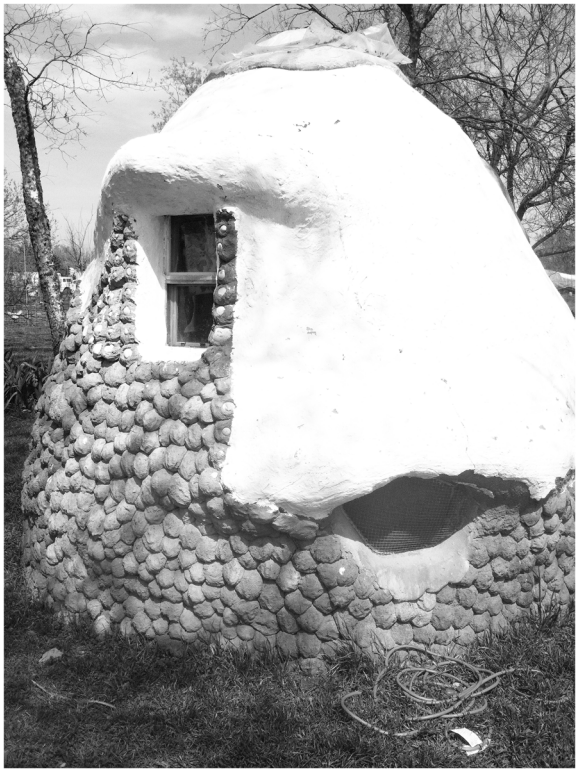

Figure 6. Exterior of trailer Amanda lived in during first visit

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Outside of the broader community in town, life on the farm was its own living system that relied on sharing, moderation, respect, and a collective responsibility. Amanda was only able to keep the farm going because it was based in a material form of communalism. With Cardo's land also came all of his equipment, barns, and fences. That kind of infrastructure would have cost far more than the cost of rent to start up.

Amanda shared the land with two farm managers. They shared an outdoor solar shower. They bought food staples in bulk for the farm based on a strict shared budget, and they ate all meals together because the cost of each member to eat individually would have been too high to manage with the resources they earned from produce. She explained that the cooking also operated on a rotation,

It's like you work your ass off every day and then to cook every night, it just gets really hard, I remember last summer before we had a system like this. Then it was just me and Dan, and Dan didn't cook very much so I was really just cooking for myself, and I pretty much lived off fried egg sandwiches. (Amanda, personal communication, April 5, 2013)

While I am focusing on farm production in this paper, many artist cooperatives are realizing that they must make similar sacrifices to resist neoliberal capitalism and exist in a world dominated by corporations. The micro-community of CFP reflects what needs to happen on a global scale to affect significant change. Amanda's sacrifice on the farm is one example of ways that people can live more ethically through communalism and limiting their use of natural resources. I recognize that few people would make the choice to live in a hut without hot water for a year, but the sacrifices made to conserve food and share responsibilities are examples of everyday changes that could make a broad impact.

Exploiting Rhetoric

Through our conversation, I learned about the realities of organic and locally grown produce sales. As we talked about sustainable practices and organic farming, Amanda spoke with disdain about a local organic grocer. As she described, "he's a peddler in town who hides under fancy words like organic, sustainability, and community" (Amanda, personal communication, April 5, 2013). Essentially, he was using marketing rhetoric for a disingenuous practice. He does not grow anything himself. He drives to a number of local farms and buys the most visually appealing produce wholesale.

It's so hard for us to compete with because he can drive all over and take out the stuff that looks bad, and we've worked our asses off and we're next to his glorious stand with our little bruised vegetables…. I just realized how many people are buying his stuff because of the words – sustainable and organic – we don't have any of those words. I refuse. You can talk about our growing practices, but I'm not interested in being associated with Monsanto and sustainability. It's a load of shit. But he's totally capitalizing on it. (Amanda, personal communication, April 5, 2013)

Amanda explained that wholesale distribution that relies on the middleman kills small farms because they do not get market value for their produce. Without the middleman distributor, farmers get market value for their food. In addition, when you buy directly from farmers, you may also have a better understanding or appreciation of what goes into growing it. Industrialized global agricultural production has exacerbated the struggles of small farms.

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Amanda and I repeatedly talked about food justice and the challenges with providing healthy foods to low-income populations. Thinking about what it means to feed people who cannot afford to buy food introduces much broader issues about education. Eating healthy food often costs more than industrialized food, and it can take more time to cook and a familiarity with the produce being grown. Kale and rhubarb are commonly sold to her CSA members, but donating these to low-income families is not beneficial if they do not know what to do with them. These are some of the challenges that food justice efforts are facing. Solutions are not as simple as giving out free vegetables. Amanda sees ways that after-school programs on a farm, where students are paid with the food they have grown, could be one positive approach that is educational, service-oriented, and purpose-driven.

Participatory Pedagogy and Affective Potential

Since that first summer, Amanda ran summer camps for children ages Kindergarten through 6th grade annually. She served approximately eighty kids in each summer session, and activities include planting, working with animals, drawing, mapping, and tending the chickens, among other programming. They use multi-sensory investigations to learn about plants and other elements of the farm environment. She also teaches adult and children's classes at a community center, and invites local schools to visit the farm.

She explained that her approach to teaching is embedded in the belief that embodied learning and a focus on problem solving builds confidence in kids. By being able to see a direct connection between themselves and food and plants grown in the ground or to work closely with animals teaches kids a sense of responsibility and place. Amanda also frequently incorporates hands-on experiences for visitors, customers, and students as a form of cultural participation. Even for myself, my first real physical work was on a day that I volunteered to help dismantle greenhouses, described in the reflection that opened the chapter. I learned something every time I visited the farm for interviews, to pick up vegetables, or drop off my kids.

DISCUSSION

Amanda's process coming to and developing Cardo's Farm Project as a business and educational site illuminates the complexity of art, education, and community building in a period of increasing neoliberal globalization, where participation can become both civic engagement and simultaneously marketing strategy. Amanda's narrative reveals the potential of aesthetic practices to affect change in individuals and presents the challenges and possibilities of collective efforts in the face of an increasingly globalized economy. To analyze her process, I consider how participation as direct engagement produced a sense of agency and became an index of collective force through each aspect of her development from artist to farmer-educator.

Leaving Institutional Education

I realized that what was different in Amanda's direction with the farm and her misgivings about institutionalized art education were the lack of direct engagement and teacher preparation's increasing focus on corporate time in the form of accountability measures and the commodification of knowledge. Education courses are often based in decontextualized pedagogical methods. Students are disconnected

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from lived experiences, often thinking through detached representations of classroom practices, where humans and experiences are generalized into procedures and data.

Effects of neoliberal policies on education have resulted in exponential increases in assessment measures in an effort to produce data. With more focus on assessment, education has become increasingly fractured and mediated by codes and rules. Through his explanation of the corporatization of universities, Giroux (2003/2006) describes the difference between what he calls corporate time versus public time. In this argument, the corporate university is "wedded to a notion of accelerated time in which the principle of self-interest replaces politics, and consumerism replaces a broader notion of social agency" (Giroux, 2003/2006, p. 260). Public time, on the other hand, "demands and encourages forms of political agency based on a passion for self-governing, actions informed by critical judgment, and a commitment to linking social responsibility and social transformation" (Giroux, 2003/2006, p. 261).

When the possibility of knowing outside of what already exists is foreclosed by codification of methods and the commodification of time, education becomes a product rather than a process. Amanda's frustration with and abandoning of institutionalized teacher preparation was in part recognition of this condition. Her experience in a formalized teacher education program was embedded in training rather than in the development of social agency. On the other hand, Amanda's community-based education at Common Ground and Hidden Villa operated entirely through what Giroux (2003/2006) described as public time: embedded in self-governing, social responsibility, and social transformation.

While Amanda's educational work at her current residence and at Cardo's Farm is not operating in a public space, it is open to the public where kids work both agriculturally and creatively to develop critical thinking skills about processes of production, natural resources, and the roots of material goods. For children, such as my son, her educational programming produced a different kind of subjectivity in relation to the natural environment, where the fruits of their labor are realized as plants grow and eggs hatch over multiple visits.

When kids attend Amanda's young farmers classes, she has to spend time helping students understand the difference in expectations on the farm from those in a traditional classroom because most are embedded in an institutional disconnect from life that is too often produced in public education. She feels that children are given little opportunity to take responsibility in a classroom, particularly with experiences dealing directly with living organisms.

Amanda shifted her focus to farm-based and community-focused education to return to a model closer to that which she experienced with her grandmother. Farm Based Education continues a mode of progressive education that Dewey (1934) encouraged a century ago. Amanda described how artists and scientists are drawn to the hands-on and problem-solving aspects of farming. Local, community-supported farms provide a place to practice ethical behavior through collective efforts with a visible community. In this sense, farms like Common Ground, Hidden Villa, and Cardo's Farm Project can be seen as sights of community based education through socially-engaged pedagogy, and if we view farming as an aesthetic practice, they intersect with and expand the potential of art education.

While artists have been drawn to this kind of embodied learning historically, Amanda's experience of working with Draper and Lebowitz in New York exemplifies ways that links between arts-based thinking and authentic learning exist today. Amanda's experience echoes that of performance artist and art educator, Charles Garoian, who described feeling "like a fish out of water" as a student at Stanford where "much of my studies there were based in academic models of pedagogy and curriculum" (Cempellin, 2013, 83). Garoian described (1999), "From the beginning, I wanted to teach in a way that invited the creative disruptions I found so valuable from my days growing up on my parents' farm and in my art

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education" (p. 201). Garoian realized his interest in the performative process of art was the necessary component for powerful teaching:

The best teaching occurs when you are engaged with your students in exploratory, experimental, and improvisational processes; in the liveness of what art does, its conceptual operations, rather than illustration and representation. Academic representations will always constitute schooling, but what emerges from creative activity in the classroom is the source from which transformation and agency are made possible. (As cited in Cempellin, 2013, p. 83)

Amanda's decision to leave institutional education was a result of the absence of what Garoian calls "liveness of what art does."

Farming as Hands-On Resistance to Globalization

Neoliberal policies and practices have exacerbated modes of injustice through the exploitation of environmental and human resources, often in third world countries. A primary of globalization has been the move of manufacturing operations to countries with less human rights regulations. Moving these industries to less developed locations makes the effects of capitalist exploitation invisible to consumers in large industrialized nations. As one way of reconnecting with skills that have been lost in over two generations of outsourcing manual labor, the growing maker's movement has reinvigorated interest in craft, electronics, gaming, design, music, cooking, and much more. Artistic, DIY, and educational responses to globalization have embraced first-hand experiences focused on process and direct engagement.

Like the Arts and Crafts movement at the end of the 19th century, the farm movement is rooted in resisting the fragmenting nature of capitalism to separate laborers from their products. The ethic that girds many of the efforts of young farmers attempting to develop their own sustainable agricultural operations aligns with the anti-capitalist work and a sincere belief in importance of teaching fundamental skills through direct engagements and experiential learning. Amanda learned this ethic early on from life on her grandmother's farm. Life on the farm allowed Amanda to see the importance of collective effort and communal practices. Moreover, Amanda's grandmother taught her how to work through necessities, such as spinning yarn and knitting rather than purchasing mass-produced products.

Contemporary artists' "growing interest in collaborative and collective approaches in contemporary art…. toward participatory, process-based experience" (Kester, 2011, p. 7-8) were evidenced through Amanda's work at Common Ground. There, she witnessed a growing force of artists turning to agriculture and craft production embedded in a revolutionary spirit that connects art, activism, and education (Campana, 2011).

Participation as Ethical and Aesthetic Encounter

An ethic embedded in living as a form of art is becoming more relevant, where artists are illuminating vital interconnections of material practices or aesthetics as encounters with the world, where participatory engagement become aesthetic event (Thompson, 2014). With this in mind, I am viewing the farm as an aesthetic site, where Amanda's work performs Kester's (1998) claim for "collaborative and collective approaches…toward participatory, process-based experience" (p. 7-8).

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In this way, the aesthetic engagement with the farm is profoundly creative. jagodzinski (2009) describes that the force of the artistic event is its ability to change, rupture, and transform a system of set relations. If a traditional formal aesthetics engages with the ways art allows us to see beauty as a transcendental force, then couldn't this participatory approach to aesthetics grounded in the "dynamics of being" and the "performative affect of becoming" describe engagements with natural spaces through farming as aesthetic experiences? Encounters with the vitality of her farm become art events that can teach us about a more ethical way of living. Eyermen suggests art as 'experiential space':

A form of social activity through which new kinds of identities and practices emerge… as a cognitive praxis, art is a space for individual and collective creation that can provide society with ideas, identities, and ideals… like a social movement, art opens space for experimentation, social and political, as well as aesthetic. (as cited in Campana, 2011, p. 281)

Amanda's individual and collective practices on the farm engage with this kind of experimental, social, and political activity. Moreover, the farm as participatory aesthetic space aligns with Green's (1999) characterization of new genre public art education merging life and material production as a socially-engaged pedagogy.

Through my embodied participation with Amanda and CFP, I was able to recognize effects of industrialized agriculture that I had never seen before, rupturing my habituated understanding of agricultural production. While I experienced a shift in consciousness from even brief encounters with farm work, brief, enjoyable experiences do not engage with the much more complex and challenging issues of inequality embedded in the broader system of factory farming, such as migrant labor, environmental destruction, animal cruelty, and genetic modification. We must be careful to not become blind to broader forms of exploitation

Moreover, the limited time involved in brief, privileged encounters of "playing farmer" (Dunlap, 2011), rather than farming out of necessity, provides a sense of civic engagement while being spared from the messiness, struggle, and sacrifice that go along with actually running a small farm. Amanda's years of sacrifices and significant lifestyle changes were also invisible.

Unfortunately, the reality becomes more equivalent to pseudo-ethnographies (Desai, 2002) or edutainment (Kalin, 2014) because the event being consumed is so far removed from the challenges that go into the process. In her analysis of the ethnographic turn in art, Desai (2002) examines the complex and problematic relationship between experience, interpretation, and representation when the public sphere becomes an arena for active investigation. Desai (2002) especially scrutinizes the weakness of "pseudo-ethnography," wherein an artist enters a community for a day or week to engage in a brief cultural investigation, leaving "the socio-economic and political relations, which underscore the representation . . . hidden" (p. 314).

Bishop (2004) addressed this kind of superficiality with relational encounters in art of the 1990's, concerned that viewers and participants were lulled into thinking that they have become politically active. She argued instead for "relational antagonism" that might produce discomfort among participants to illuminate new possibilities. While I would argue that the exhausting work on Amanda's farm goes some way in affecting new ways of understanding the plight of small farms, participation on a large industrial agricultural operation might go a lot further in understanding the impact of globalization.

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Participatory Engagement as Neoliberal Practice and Collective Resistance

As many young people choose to become farmers in an effort to act as individually responsible agents for a more environmentally sustainable future, they are often unknowingly buying into the system they are resisting. The maker's movement, in large part, privileges local markets, handmade products, efforts for more ethical forms of consumption, and a resistance to corporate production, but as Bishop (2012a) describes, one characteristic of neoliberal capitalism is its ability to co-opt modes of resistance into profitable commodities. One way of co-opting modes of resistance is through Post-Fordist tactic of marketing a lifestyle over individual material objects. This phenomenon highlights the complexity of cultural participation.

For instance, Amanda invites clients to pick their own vegetables and flowers. On the one hand, this is not unlike bagging one's own groceries. In the grocery store, the quick check out can be seen as a form of convenience or freedom from the line. We often fail to think that we are helping the grocery store increase their profits by working for them for free and eliminating a cashier's position.

At CFP, picking one's own flowers or vegetables can be viewed as freedom, choice, or cultural participation. It works as a marketing strategy and as a mode of resistance-as-hands-on engagement to people interested in cultural participation. Her invitation is both a reaction to globalized agricultural production and a need to exist within that market. By making the farm a participatory site, Amanda has "infiltrated the world of market and social relations" (Ranciere, 2010, p. 149) because the customer is, to a certain degree, becoming producer. At the same time, this strategy is now part of the neoliberal nexus. Collective participatory on the farm exists somewhere on a continuum between neoliberal marketing strategy and mode of cultural consumption as collective resistance.

Furthermore, Amanda's Community Supported Agriculture (CSA) program and Farmer's Market stand can be viewed as another performative public intervention in inequitable capitalist practices. There are 80 members of the CSA, but she did not have specific figures for the average weekend sales at the local Farmer's Market. As a CSA member, I would drive to Amanda's house one time per week to pick up a load of vegetables. I paid Amanda directly. I feel that on a micro level, this mode of direct exchange is one way to intervene in the capitalist drive for surplus. The exchange also became personal, local, and embodied. If we view processes of consumption as political acts, then my choice to buy directly from Amanda was a community-building act in opposition to neoliberal privatization that views all objects and relations as potential profit. My act of consumption shifted to a focus on communication, interpersonal relations, and local investment.

Even as I was helping the farmers at the local farmer's market and CSA, the privileged position of buying food direct from farmers often reifies racial and ethnic divides in local populations (Joassart-Marcelli & Bosco, 2014). For instance, the location of farmers markets driven by primarily Caucasian artisans and craft makers are often not the same as those that are driven by minority populations, such as Bazaars in Latino neighborhoods. This is the case of the Farmer's Market where Amanda sells produce. While there are Latino grocery stores nearby that sell local produce, the Saturday Farmer's and Artisans market in the center of town is frequented by primarily middle to upper middle class Caucasian clients. The differences point to a continued class-based and ethnic segregation.

Finally, through Amanda's challenges, I was better able to understand how rhetoric is exploited to appeal to the lifestyle politics of well-intentioned consumers. Amanda's frustration over the local wholesale produce dealer stemmed from the disingenuous use of popular rhetoric misleading well-intentioned consumers into thinking they were buying directly from a small farmer. The conflation of terms like

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sustainable and organic again becomes a tool to attract people who don't know the processes embedded in their production. Many people attracted to those labels have good intentions. I would never have known about these unfair market practices. I thought that the local distributor was good because he was "local." She pointed out how people like me think they are doing the right thing because he uses misleading labels.

Amanda's small operation was compromised by buyers' desire for more ethical modes of consumption while also wanting aesthetically pleasing produce, not realizing that the rhetoric used to sell the products was erroneous. Again, neoliberal policies and Post-Fordist capitalism have produced a complex network of relations between production and consumption, commodifying desire, lifestyle, and rhetoric to make traditional models of resistance feel nearly impossible.

CONCLUSION

People need to be educated for democracy not only by expanding their capacities to think critically, but also for assuming public responsibility through active participation in the very process of governing and engaging important social problems. (Giroux, 2003/2006, p. 276)

To conclude this chapter, I return to the narrative that opened it. Our time spent on the greenhouses that day produced a connection with Amanda and the farm that transcended our intellectual or academic work. Through a pedagogy of participation, I realized how little I knew about the breadth of manual labor required to run a farm. Amanda taught me how the daily physical engagement of agricultural production could be an activist art practice embedded in the community-building force of direct engagements.

When I left that day, I felt a sense of agency and hope for the power that collective efforts might make against the exploitative conditions of globalized corporate capitalism by taking even a small amount of responsibility for the success of the farm through my time and physical effort. Her farm helped me see how a shift in cultural values is performed through the ways we spend our time, money, energy, and knowledge. Amanda's participatory aestheticization of farming through Cardo's Farm Project represented a site of resistance to industrialized farming practices as a way to teach daily methods of making that enact a DIY ethic of liberation from neoliberal capitalism (Holtzman, et. al, 2005; Kester, 2011; Levine 2008).

REFERENCES

Ballengee Morris, C. (2000). A sense of place: The Allegheny Echoes Project. In P. E. Bolin, D. Blandy, & K. G. Congdon (Eds.), *Remembering others: Making invisible histories of art education visible* (pp. 176–187). Reston, VA: NAEA.

Barney, G. (2009). *Art and farming in Britain.* Arts Council England. Retrieved from http://www.face-online.org.uk/art/art-and-farming-in-britain

Beaver, T. D. (2012). By the skaters, for the skaters the DIY ethos of the roller derby revival. *Journal of Sport and Social Issues*, *36*(1), 25–49. doi:10.1177/0193723511433862

Bishop, C. (2004). Antagonism and relational aesthetics. *October, 110*, 51-79.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Bishop, C. (2012a). Participation and spectacle: Where are we now? In N. Thompson (Ed.), *Living as form: Socially engaged art from 1991-2011* (pp. 34–45). New York, NY: Creative Time.

Bishop, C. (2012b). *Artificial hells: Participatory art and the politics of spectatorship*. Brooklyn, NY: Verso.

Blandy, D., & Hoffman, E. (1993). Toward an art education of place. *Studies in Art Education*, *35*(1), 22–33. doi:10.2307/1320835

Bourriard, N. (2002). *Relational aesthetics*. Dijon-Quetigny, France: Les presses du Reel.

Callejo Perez, D., Fain, S. M., & Slater, J. J. (2004). *Pedagogy of place: Seeing spaces as cultural education*. New York, NY: Peter Lang.

Campana, A. (2011). Agents of possibility: Examining the intersections of art, education, and activism in communities. *Studies in Art Education*, *52*(4), 278–291.

Cardo's Farm Project. (2014). *Who We Are*. Retrieved from: http://www.cardosfarmproject.com/

Cempellin, L. (2013). Charles R. Garoian: Exploring the in-between. *Juliet Art Magazine, 165*, 83.

Congdon, K. G. (2006). Folkvine.org: Arts-based research on the web. *Studies in Art Education*, *48*(1), 36–51.

Congdon, K. G., Blandy, D., & Bolin, P. E. (Eds.). (2001). *Histories of community-based art education*. Reston, VA: National Art Education Association.

Cornelius, A., Sherow, E., & Carpenter, S. B. II. (2010). Water: Social issues and contemporary art education. *Art Education*, *63*(6), 25–32.

Desai, D. (2002). The ethnographic move in contemporary art: What does it mean for art education? *Studies in Art Education*, *43*(4), 307–323. doi:10.2307/1320980

Dewey, J. (1934). *Art as experience*. New York, NY: Perigee.

Dewey, J. (2007). *Democracy and education*. Middlesex, UK: Echo Library. (Original work published 1916)

Duncombe, S. (1997). *Notes from underground: Zines and the politics of alternative culture*. London, UK: Verso.

Duncum, P. (2011). Engaging public space: Art education pedagogies for social justice. *Equity & Excellence in Education*, *44*(3), 348–363. doi:10.1080/10665684.2011.590400

Dunlap, R. (2013). Playin farmer: Leisure experiences in a craft-based community of practice. *International Journal of Qualitative Studies in Education*, *26*(1), 118–137. doi:10.1080/09518398.2011.604648

Efland, A. (1990). *A history of art education: Intellectual and social currents in teaching the visual arts*. New York, NY: Teachers College.

Ellsworth, E. (2005). *Places of learning: Media, architecture, pedagogy.* Falmer Routledge.

Farm Based Education Network. (2014). *What is farm-based education?* Retrieved from: http://www.farmbasededucation.org

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Garoian, C. R. (1998). Art education and the aesthetics of land use in the age of ecology. *Studies in Art Education*, *39*(3), 244–261. doi:10.2307/1320367

Garoian, C. R. (1999). *Performing pedagogy: Toward an art of politics*. Albany, NY: State University of New York Press.

Giroux, H. A. (2006). Youth, higher education, and the crisis of public time: Educated hope and the possibility of a democratic future. In C. G. Robbins (Ed.), *The Giroux reader* (pp. 253–281). Boulder, CO: Paradigm. (Original work published 2003)

Graham, M. A. (2007). Art, ecology, and art education: Locating art education in a critical place-based pedagogy. *Studies in Art Education*, *48*(4), 375–391.

Green, G. (1999). New genre public art education. *Art Journal*, *58*(1), 80–83. doi:10.1080/00043249.1999.10791924

Gruenewald, D. A., & Smith, G. A. (Eds.). (2008). *Place-based education in the global age: Local diversity*. New York, NY: Taylor & Francis.

Gude, O. (2004). Psycho-aesthetic geography in art education. *Journal of Cultural Research in Art Education*, *22*, 5–18.

Hall, S. (1991). Brave new world. *Socialist Review*, *91*(1), 57–58.

Hardt, M., & Negri, A. (2004). *Multitude: War and democracy in the age of empire*. New York, NY: Penguin.

Helguera, P. (2011). *Education for socially engaged art: A materials and techniques handbook*. New York, NY: Jorge Pinto Books.

Hidden Villa. (2014). *Hidden Villa*. Retrieved from: http://www.hiddenvilla.org/

Holtzman, B., Hughes, C., & Van Meter, K. (2005). Do it yourself… and the movement beyond capitalism. *Radical Society*, *31*, 719.

Inwood, H. (2010). Shades of green: Growing environmentalism through art education. *Art Education*, *63*(6), 33–38.

jagodzinski, j. (1987). Toward an ecological aesthetic: Notes on a "Green" frame of mind. In D. Blandy, & K. Congdon (Eds.), *Art in a democracy* (pp. 138-164). New York, NY: Teachers College Press.

jagodzinski, j. (2009). Beyond aesthetics: Returning force and truth to art its education. *Studies in Art Education, 50*(4), 338-351.

Jeppesen, S. (2011). The DIY post-punk post-situationist politics of CrimethInc. *Anarchist Studies*, *19*(1), 23–55.

Joassart-Marcelli, P., & Bosco, F. J. (2014). Alternative food projects, localization and neoliberal urban development: Farmers' markets in Southern California. *Metropoles, 15,* 1-23. Retrieved from https://metropoles.revues.org/4970

Kalin, N. (2014). Art's pedagogical paradox. *Studies in Art Education*, *55*(3), 190–202.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Kester, G. (1998). Afterimage and activist art. In G. Kester (Ed.), *Art, activism, and oppostionality: Essays from Afterimage* (pp. 1–19). Durham, NC: Duke University Press.

Kester, G. (2011). *The one and the many: Contemporary collaborative art in a global context*. Durham, NC: Duke University Press. doi:10.1215/9780822394037

Levine, F. (2008). *Handmade nation: The rise of DIY, art, craft, and design*. New York, NY: Princeton Architectural Press.

Lipton, A. (2014). *Simon Draper: Habitat for artists*. Retrieved from: http://www.liptonarts.com/simon-draper-habitat-for-artists-2/

McKay, G. (Ed.). (1998). *DIY culture: Party & protest in nineties Britain*. New York, NY: Verso.

Meehan, M. (2012). Seventeen hundred seeds: Cultivating community as art. *Glasstire*. Retrieved from http://glasstire.com/2012/06/02/seventeen-hundred-seeds-cultivating-art-and-community/

Powell, K. (2010). Viewing places: Students as visual ethnographers. *Art Education*, *63*(6), 44–53.

Powell, K. A. (2008). Remapping the city: Palimpsest, place, and identity in art education research. *Studies in Art Education*, *50*(1), 6–21.

Rancière, J. (2010). *Dissensus: On politics and aesthetics*. New York, NY: Continuum International.

Schaefer, B. (2013). The commodification of the American farmer. *The Society Pages*. Retrieved from http://thesocietypages.org/sociologylens/2013/10/11/the-commodification-of-the-american-farmer/

Spaid, S. (2012). *Green acres: Artists farming fields, greenhouses, and abandoned lots*. Baltimore, MD: Contemporary Arts Center.

Spencer, A. (2005). *DIY: The rise of lo-fi culture*. London, UK: Marion Boyers Publishers.

Thompson, N. (Ed.). (2012). *Living as form: Socially engaged art from 1991-2011*. New York, NY: Creative Time.

Thrift, N. (2005). *Knowing capitalism*. Thousand Oaks, CA: Sage.

Trafi-Prats, L. (2006). *ABC Milwaukee: The visual culture literacies of growing up urban*. Retrieved from: http://www.inter-disciplinary.net/wp-content/uploads/2009/06/trafi_vl3_draft.pdf

Trafi-Prats, L. (2009). Destination Raval Sud: A visual ethnography on pedagogy, aesthetics, and the spatial experience of growing up urban. *Studies in Art Education*, *51*(1), 6–20.

Wallin, J. (2007). Between public and private: Negotiating the location of art education. *International Journal of Education & the Arts*, *8*(3), 1–15.

Zabel, G. (Ed.). (1993). *Art and society: Lectures and essays by William Morris*. Medford, MA: Geoge's Hill Publications.

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KEY TERMS AND DEFINITIONS

Aestheticization: The application of an aesthetic lens to analyze contemporary shifts toward local farming as a political act by farmers and artisans. This term is historically related to the work of Walter Benjamin in an analysis of the political nature of art and a broader analysis of life as being innately aesthetic.

Civic Engagement: Citizen participation for the betterment of a community.

Collective Responsibility: Group effort toward a collectively determined goal that is based in democratic membership and individual responsibility.

Farm-Based Education: Community-focused, interdisciplinary education based in farming and agricultural processes aimed at teaching about connections between living organisms, as well as links between nature and industrialization. Teaching methods are primarily experiential, hands-on, and student centered.

Globalization: Process of integration across global nations. The term often relates to trade markets, but also ideas, cultural artifacts, and worldviews spread through the development of new technologies, increases in international migration, and international trade policies.

Localized Agriculture: Shifts to smaller farms run by one or a few farmers in a region near or within urban areas, primarily in response to industrialized agriculture.

Neoliberalism: An economic philosophy that relates to market policies focused on deregulation and a laissez-faire capitalist approach. Since the 1970's this term relates to broader social shifts that emphasize individualism, free enterprise, accountability, privatization, and a focus on profitability.

Participatory Action: This term relates to collective action in terms of art, activism, research, and everyday community involvement aimed at human agency and social transformation.

ENDNOTES

[1] Stuart Hall (1991) defines Post-Fordism in this way: "'Post-Fordism' is a broader term, suggesting a whole new epoch distinct from the era of mass production…. It covers at least some of the following characteristics: a shift to the new information 'technologies'; more flexible, decentralized forms of labor process and organization; decline of the old manufacturing base and the growth of the 'sunrise,' computer-based industries; the hiving off or contracting out of functions and services; a greater emphasis on choice and product differentiation, on marketing packaging, and design, on the 'targeting' of consumers by lifestyle, taste, and culture rather than by the categories of social class; a decline in the proportion of skilled, male, manual working class, the rise of the service and white-collar classes and the 'feminization' of the work force; an economy dominated by multinationals, with their new international division of labor and their greater autonomy from nation-state control; and the 'globalization' of the new financial markets, linked by the communications revolution.

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Chapter 57
Inter Linkages of Water, Climate, and Agriculture

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ABSTRACT

Climate is the primary determinant of agricultural productivity and evidence shows possibility of shifts in earth's climate. Concern over the potential effects of long-term climatic change on agriculture has been raised over the past decade. Change in the climatic conditions on the globe created threat to the availability water for agriculture production. The present chapter is an attempt to distil what is known about the likely effects of climate change on water availability to agriculture for food security and nutrition in coming decades. Apart from few exceptions, the likely impacts of climate change on agriculture water resources in the future are not understood in any great depth. There are many uncertainties as to how changes in various environmental parameters will interact with the availability of water and further agriculture production. The future consequences of water resources on agriculture are discussed and summarized. Possible mitigation and adaptations to changing water availability for agriculture are also discusses.

INTRODUCTION

The world population, which took more than 50,000 years to reach the first billion, has just surpassed 7 billion. Even if fertility continues to decline at the world level and with it population growth rates, the United Nations projects that the world population could reach 9.3 billion by 2050 and surpass 10 billion by the end of the century (United Nations, 2011). If fertility were to be higher than in that projection, the population may surpass 10 billion by 2050 and may be several billions higher by 2100.

To feed a growing world population, we have no option but to intensify agriculture and crop production. Further, numerous factors shape and drive the agricultural sector and climate is the primary determinant of agricultural productivity. Given its inherent link to natural resources, agricultural production is also at the compassion of uncertainties driven by climate variation, including extreme events such as flooding and drought. The fundamental role of agriculture in human welfare, concern has been expressed

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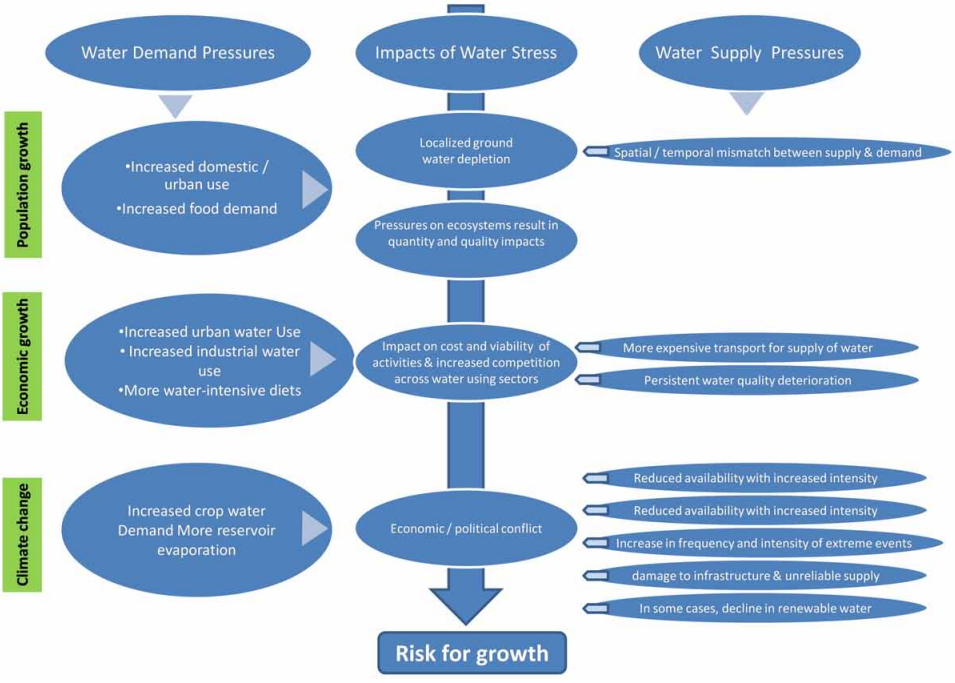
by federal agencies and others regarding the potential effects of climate change on agricultural productivity. Interest in this issue has motivated an extensive of research on climate change and its impact on agriculture production over the past decade.

There may be increasing threat to agriculture production due to climate change which is now largely accepted as a real, pressing and truly global problem. There is also increasingly aware that the risks of climate change are so great, that ignoring or delaying in addressing them would be far more costly than not doing so. Climate change is now global problem for the agriculture production and food security on the globe.

The long-term climatic risk to agricultural assets and agricultural production may be linked to availability of water which is known with great uncertainty. There may be threat to risk of loss of rural livelihoods and income due to insufficient access to drinking water. The risk of alarms for agricultural irrigation and reduced agricultural productivity, particularly for farmers and pastoralists in semi-arid regions. There may be risk of loss of terrestrial and inland water ecosystems, biodiversity, and the ecosystem goods, functions, and services they provide for human being and their livelihoods. In general agriculture production and food security may face serious consequences due to inadequate water resources. Apart from this increasing demand for water from urban, industry, etc. has exaggerated the problem in many folds. From the available literature overall demand and supply relationship with linkage to risk for overall development is compiled and presented in Figure 1.

It is well known fact that agriculture production is dependent on set of climatic conditions. Climatic resources are the deciding factor for successful cultivation of any crop and which cannot be manipulated by the human beings. The availability of water for irrigation and the source of the water both are climate dependent factors. Both shortage and excess of water will interfere the agriculture production

Figure 1. Water demand and supply relationship



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to greater loss. The latest reports (FAO, 2013) of statistics of utilization of world land says that thirty percent of the earth's land is used for crops and pastures and seventy percent of all abstracted freshwater is directed towards irrigation to produce the food that people and livestock need for a stable food supply. This large-scale utilization of land and water resources is increasingly threatening environments. Furthermore, farming is important because it provides the livelihood of hundreds of millions of people. Water resources are important for agriculture production in all the regions of the globe. Agriculture system is vulnerable because of too hot and dry climate, limited and variable water supply, low and degraded soil quality and lack of adaptive capacity.

The chapter "Inter linkages of water, climate, and agriculture" discuss about the probable impacts of climate change on availability of water for agriculture. The document encompasses not only irrigation, but also other forms of water control intended to optimize growing conditions for crops, livestock and pasture. Change in climatic conditions like precipitation, temperature, Carbon dioxide (CO_2), etc. may be having adverse effect on global agriculture production. Hence the core of the document concerns adaptive and mitigation options and activities that can contribute to maintaining global food security and supporting farmers' livelihoods in changing water availability.

Keeping in the view the challenges of availability of quality water for agriculture in changing climate, the chapter focuses on the impact of climate change on agriculture, knowledge on the relationship between climate change, water and food security and how agriculture is able to adapt such climate change. The chapter also explores future availability of water and what will be the impending impact of availability and what mechanisms can be implemented to mitigate the resulting impact?

In order to meet the elevated flow of agricultural production further research and extension activity need to be focused keeping in mind the changing climatic situations. Hence, at the end, the chapter discuss about the latest trends in the water and agriculture research for changing climatic situations. However, the impact on agriculture and its ability for adaption may vary with different parts of world.

The purpose of the chapter is to enrich the current state of knowledge of readers on the relationship between water availability, climate change and food security and nutrition to provide an evidence base discussion. The chapter provides an analysis of empirical evidence results to highlight the relationship between water for agricultural production in climate change situations and food security.

Background

Survival of human and livestock on the globe is highly dependent on the agriculture. Agriculture and allied activities are highly climate dependent and change in the climatic parameters may severely affect food security on the globe. Apart from few exceptions, the likely impacts of climate change on agricultural sector in the future are not understood in any great depth. There are many uncertainties as to how changes in temperature, rainfall and atmospheric carbon dioxide concentrations will interact in relation to agricultural productivity (Londhe, 2016). Lobell & Gourdji (2012) noticed that climate trends over the past few decades have been fairly rapid in many agricultural regions around the world, and increases in atmospheric carbon dioxide (CO_2) and ozone (O_3) levels have also been ubiquitous. The virtual certainty that climate and CO_2 will continue to trend in the future raises many questions related to food security and health. One of the important research question mingling in agriculture research environment across globe is weather agricultural production will affect due to changing climatic conditions. One of the most important input for agriculture is availability of sufficient quantity of quality water. Change in climatic condition may result some regions with scarcity of water where as others with excess water. Both the

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situations are not cozy for agriculture and will having serious impacts on global agricultural production and livelihood of rural poor and marginal farmers in various agro-ecological regions.

In addition to water many factors will shape global food security over the next few decades which includes increasing human population, agricultural productivity, income growth and distribution, dietary preferences and disease incidence. Apart from agriculture, there will be increased demand for land and water resources for nonagricultural uses also. In this situation, maintaining increased flow of agricultural production is important to meet the need of growing population and new food habits. The main question of interest here is: how important will climate change in the contest of quality and timely water availability in shaping future crop yields and other agricultural production at the global scale. This question helps to set the challenge of climate change adaptation in context.

Apart from these important climatic parameters like atmospheric concentrations of carbon dioxide (CO_2) and Ozone (O_3), and changes in temperature and precipitation conditions will be having direct or indirect impact on water availability and agriculture production. It may be expected that due to climate change there is possibility of change in climatic regimes and shift in seasons. This will create need based on the water availability to change in cropping patterns in some of the regions.

The vast majority of the Earth's water resources are salt water, with only 2.5% being fresh water. Approximately 70% of the fresh water available on the planet is frozen in the icecaps of Antarctica and Greenland leaving the remaining 30% (equal to only 0.7% of total water resources worldwide) available for consumption. From this remaining 0.7%, roughly 87% is allocated to agricultural purposes (IPCC, 2007). According to the Comprehensive Assessment of Water Management in Agriculture, one in three people are already facing water shortages (CA, 2007). Further FAO and UN Water (Anonymous, 2007) reported that around 1.2 billion people, or almost one-fifth of the world's population, live in areas of physical scarcity, while another 1.6 billion people, or almost one quarter of the world's population, live in the developing country that lacks the necessary infrastructure to take water from rivers and aquifers which is known as an economic water shortage.

Projections of climate change are inherently uncertain, due to the natural variability in the climate system, imperfect ability to model the atmosphere's response to any given emissions scenario. Taken in to consideration the recommendations of Intergovernmental Panel on Climate Change (Christensen et al., 2013) with identified model agreement on future changes, the global monsoon, aggregated over all monsoon systems, is likely to strengthen in the 21st century with increase in its area and intensity, while the monsoon circulation weakens. Monsoon onset dates are likely to become earlier or not to change much and monsoon retreat dates are likely to delay, resulting in lengthening of the monsoon season in many regions. The Predictions of Intergovernmental Panel on Climate Change may further increase the complexity of food security many folds. Again these uncertainties are compounded by the paucity and unreliability of basic information related to agricultural production.

Water resource availability may be altered by changed rainfall patterns and increased rates of evaporation. Changes in rainfall will also increase variability in groundwater recharge and river flow, thus may affect all water sources. For many of the world's poorest people, rainfall variability may be a major impediment to their livelihoods. The inability to predict and manage rainfall, and consequent runoff, variability is a key contributing factor to their food insecurity and poverty. Frequent periods with too much water are followed by periods with too little and intermittent water scarcity is often a direct consequence of rainfall variability.

National economies, highly dependent on rain-fed agricultural production, are exceedingly vulnerable to fluctuations in rainfall. Although there are opposing views, there is little evidence that water

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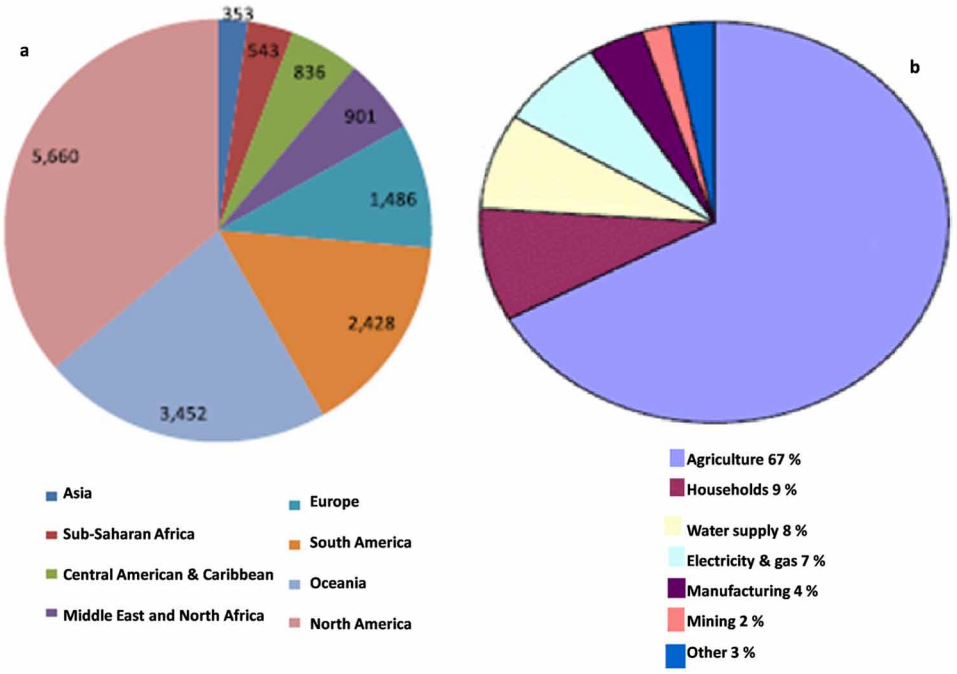
scarcity by itself is a major factor limiting economic growth in most countries (Barbier, 2004). However, in contrast, rainfall variability has been shown to be a significant factor that has an effect on economic growth (Brown & Lall, 2006).

Under these circumstances, water storage can, by safeguarding domestic supplies and supporting crops and/or livestock during dry periods, significantly increase agricultural and economic productivity and enhance people's well-being. Sector-wise utilization and per capita water consumption is given in Figure 2. Water storage can also contribute to electricity generation and providing water supply to commercial and industrial enterprises. Consequently, it has an important role to play in poverty reduction, sustainable development and adaptation to climate change. Yet, despite greater rainfall variability than many other places, per capita water storage is lower in Africa and Asia than elsewhere in the World. Lack of water storage infrastructure is posited by some as a major constraint to economic development in many developing countries (Grey & Sadoff, 2006).

Physical water storage, for the future needs to rethink water storage in a future of rapidly rising population and increasing uncertainty related to climate change, and for better planning and management

large dams are often the first thing that comes to mind when "water storage" is mentioned. Mainly because of their considerable financial requirements, as well as the political opportunities that they represent, large dams (defined as those greater than 15 meters (m) high or with storage capacity exceeding 3 million cubic meters (Mm^3) for heights between 5 and 15 m (ICOLD, 2003) have often been the principal focus of water storage efforts in recent decades. Just under 50% of the 50,000 large dams constructed globally - since the 1950s - have been built to support irrigation.

Figure 2. Per capita water storage in cubic meters (m^3) in human-made reservoirs by continent
Source: White, 2005
**For a more accurate representation of this figure, please see the electronic version.*



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Many others have been built to provide hydropower and domestic and industrial water supply as well as to provide flood protection. In many cases a single dam supports many of these functions (ICOLD, 2003). Numerous large dams have brought significant social and economic benefits. The broad links between infrastructure development (including dams), increased agricultural productivity and economic growth have been documented (Hanjra et al., 2009; Hussain & Hanjra, 2004). However, having a high per capita storage in large reservoirs is no guarantee of national economic development.

In common with all human development, large dams also have costs. Still water storage is important because in changing climatic situations, the water requirement of agriculture may be more and the stored water in the large dams may be having the potential for fulfilling the water scarcity. From the available literature it is not very clear that the large dams will fully satisfy the future need completely in climate change situations.

Agricultural and Water Management

Increasing agriculture production with population growth is the most important issue in almost all over the globe. In order to achieve this objective, the immediate solution to the farmer is enhancing the inputs to the agriculture which may not always proper for environmental health. One of the study (Fuglie, 2012) analyzed that how much of the growth in output is due to increased resources, and how much of it is due to improved productivity? After nearly four decades, of primarily resource-driven growth, a dramatic shift to productivity-driven increases in global agricultural output began around the early 1990s (Figure 3). Between 1961 and 2009, total resources and inputs grew about 60 percent as fast as growth in total agricultural output, implying that improvement in Total Factor Productivity (TFP) accounted for only 40 percent of total output growth. But TFP's contribution to output rose over time, and between 2001 and 2009 it accounted for about 75 percent of the growth in global agricultural production. The contribution of natural resources (including land and water) to output growth has decreased gradually over time while that of input intensification (including the amount of labor, capital, and materials per hectare of land) has fallen sharply.

Water management in agriculture production is one of the important parameter for high and sustainable yields. Water requirement for growth and development of every crop is different. Some crops like paddy requires more water for the growth as compared with others like sorghum and bajara. Crop stress at critical growth stages my severely reduce yield of crops or completely failure of the crop. The water requirement also vary with region as well as season. It depends on the other environmental parameters like temperature, CO_2 etc. along with type of soils they grow. Rain-fed agriculture can be severely affected by long dry spells and uneven distribution of rainfall. Hence water management in agriculture depends on many parameters. Some of the environmental factors which influence crop water requirement are described briefly in below paragraphs.

C3 and C4 Plants

Most agricultural plants are categorized by their photosynthetic mechanisms that control the chemical processes in their glucose manufacture from CO_2 and H_2O (water) as C3 and C4 species because of their photosynthetic pathways. Other plants are called CAM that stands for Crassulacean Acid Metabolism after the plant family in which it was first found (Crassulaceae) and because the CO_2 is stored in the form of an acid before use in photosynthesis. Common C3 species include wheat, cotton, soybean, and

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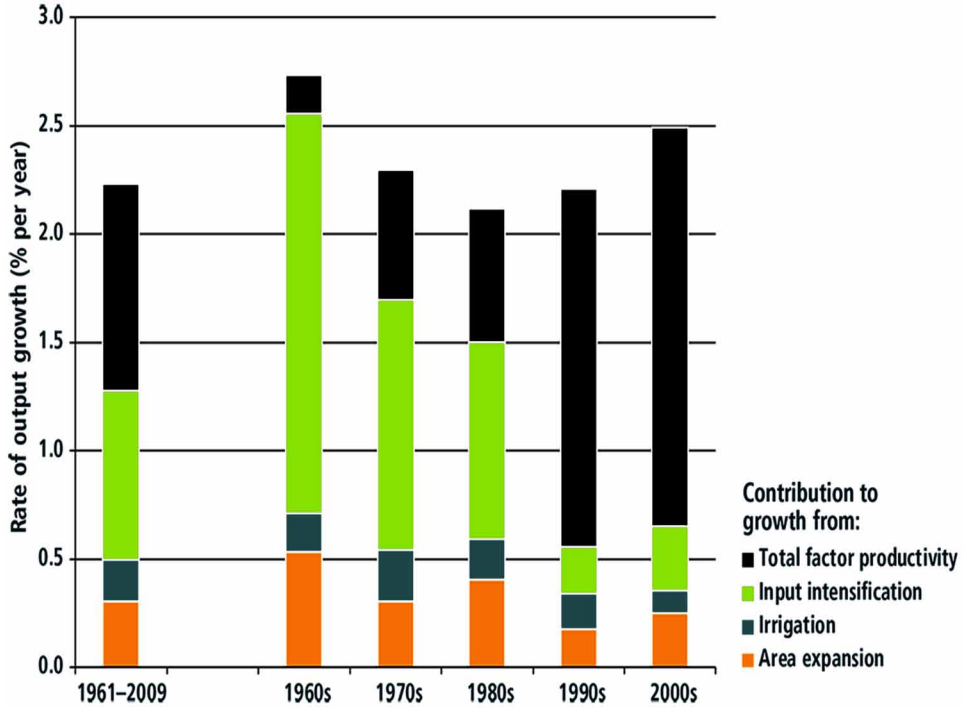
Figure 3. Sources of growth in global agricultural production
Source: Fuglie, 2012



most legumes like alfalfa while common C4 crop species include sorghum, corn, and sugarcane. Some grass species are either C3 or C4 types. C3 plants fix atmospheric CO_2 directly onto 5 carbon sugar RuBP (ribulose bisphosphate) and thus into glucose. C4 plants first fix atmospheric CO_2 into 4-carbon acids in the mesophyll of the leaf and decarboxylate the 4-carbon acids in the bundle sheath cells where the CO_2 is then fixed by RuBP carboxylase (all of this takes place during the day). CAM plants first fix atmospheric CO_2 into malic acid and other 4C-acids at night. During the day, malic acid is decarboxylated and the CO_2 released is then fixed by rubisco (all of this takes place in the same cell). Generally, the C4 photosynthetic pathway is considered more water efficient than C3 species. However, C3 species typically are more sensitive to elevated CO_2 (Rosenberg et al., 1988). The carbon-fixing efficacy of Rubisco depends on the ratio of CO_2:O_2. For C3 plants, this is closely coupled to ambient conditions, and efficacy is approximately 2/3 while for C4 plants, the CO_2:O_2ratio is much greater and carboxylation efficacy is nearly 100% (Ainsworth & Rogers, 2007). Therefore, increased CO_2 in air should directly increase assimilation for plants with C3 physiology. For C4 plants, the elevated CO_2 effects are indirect due to increased stomatal resistance and reduced transpiration.

Climate change (changes in temperature and/or precipitation regimes) would likely lead growers to change crops, cultivars, and management practices, including irrigation, to mitigate any adverse effects or to take advantage of more favorable conditions. Peterson & Keller (1990) suggested that higher temperatures and reduced precipitation could increase crop water demand in some areas and prompt the development of irrigation in regions previously devoted to dry-land or rain-fed cropping.

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CLIMATE CHANGE IMPACTS ON AGRICULTURAL WATER MANAGEMENT

Agriculture encompasses various activities including raising crops, raring livestock, poultry, fisheries etc. Availability of water for successful agriculture production is very important. As discussed above each crop water requirement is specific which is based on soil and various climatic parameters. Cropping pattern of any region is established over period of time based on available soil and climatic situation and farmer's knowledge base. Scientific evidences shows that due to global warming the climatic parameters are changing which may be having direct or indirect impact on global agriculture production.

Plant systems, and hence crop yields, are influenced by many environmental factors, and these factors, such as moisture and temperature, may act either synergistically or antagonistically with other factors in determining yields (Waggoner, 1983). In most land regions the frequency of warm days and warm nights may likely increase in the next decades, while that of cold days and cold nights will decrease. The impact of various climatic parameters on global agriculture from available literature is summarized in table 1.The below discussion is trying to analyze the impact of climate change on water availability to agriculture and its production.

Precipitation

Precipitation that regulates life on Earth and soil moisture is essential to sustain plant growth and biodiversity flourishes where water is abundant. Precipitation also has a bearing on local climate (Priestley, 1966). Variation in the precipitation may be having large impact on agriculture production on the globe. The general pattern of wet-get-wetter (also referred to as 'rich-get-richer', e.g., Held & Soden 2006; Chou et al., 2009; Allan et al., 2010) and dry-get-drier has been confirmed, although with deviations in some dry regions at present that are projected to become wetter by some models.

It has been demonstrated that the wet-get-wetter pattern implies an enhanced seasonal precipitation range between wet and dry seasons in the tropics, and enhanced inter-hemispheric precipitation gradients (Chou et al., 2007).

Intergovernmental Panel on Climate Change in AR5 report (Kirtman et al., 2013) presented results of Coupled Model Intercomparison Project (CMIP5) for projections of near-time changes in precipitation (Figure 4). It is clear from the Figure 4 that the basic pattern of wet regions tending to get wetter and dry regions tending to get dryer is apparent. There may be some regional deviations in the precipitation pattern. There may be possibility of the uncertainty in the substantial spread in the magnitude of projected change based on the simulation models used. The Figure 4 also highlight the large amplitude of the natural internal variability of mean precipitation. On regional scales, mean projected changes are almost everywhere smaller than the estimated standard deviation of natural internal variability. For zonal means and at high latitudes, the projected changes relative to the recent past exceed the estimated standard deviation of internal variability. The Figure 4 also depicts that the overall, zonal mean precipitation will very likely increase in high and some of the mid latitudes, and will more likely than not decrease in the subtropics. In case of the regional scales precipitation changes may be influenced by anthropogenic aerosol emissions and may be strongly influenced by natural internal variability.

Figure 4 Time series of relative change relative to 1986–2005 in precipitation averaged over land grid points over the globe in October to March. Thin lines denote one ensemble member per model, thick lines the CMIP5 multi-model mean. On the right-hand side the 5^{th}, 25^{th}, 50^{th} (median), 75^{th} and 95^{th} percentiles of the distribution of 20-year mean changes are given for 2081–2100 in the four RCP scenarios.

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Table 1. Climate change fact and impact on crop production

Parameter	Fact	Effect
Temperature	Global Mean Surface Temperature	Has increased since the late 19th century.
	Comparison with past	Each of the past three decades has been successively warmer at the earth's surface than all the previous decades in the instrumental record, and the first decade of the 21st century has been the warmest.
	Global Mean Temperatures	Will continue to rise over the 21st century if Greenhouse Gas (GHG) emissions continue unabated.
	Impact on different regions	Temperature change will not be regionally uniform.
	Temperature extremes	In most places, there will be more hot and fewer cold temperature extremes.
	Global temperatures rise.	Mean sea level pressure is projected to decrease in high latitudes and increase in the mid-latitudes.
Water Cycle	Precipitation	In the long term, global precipitation will increase with increased global mean surface temperature.
	Average precipitation in warmer world	Will exhibit substantial spatial variation. Some regions will experience increases, other regions will experience decreases and yet others will not experience significant changes at all.
	Annual surface evaporation	Projected to increase as global temperatures rise over most of the ocean and is projected to increase over land.
	Humidity	Global near surface and tropospheric air specific humidity have increased since the 1970s.
Extreme Events	Day and night temperature	It is very likely that the numbers of cold days and nights have decreased and the numbers of warm days and nights have increased globally since about 1950.
	Warm days and warm nights	In most land regions the frequency will likely increase in the next decades.
	Cold days and cold nights	In most land regions the frequency will likely decrease in the next decades.
	Precipitation	Since about 1950 the number of heavy precipitation events over land has increased in more regions than it has decreased.
Sea Level	The rate of sea level rise	Increased from the early 19th century to the early 20th century, and increased further over the 20th century.
GHG	CO_2	Increased by 40% from 278 ppm about 1750 to 390.5 ppm in 2011.
	CH_4	Increased by 150% from 722 ppb about 1750 to 1803 ppb in 2011.
	N_2O	Increased by 20% from 271 ppb about 1750 to 324.2 ppb in 2011.
Land Use Change	Radiative Forcing (RF)	There is robust evidence that anthropogenic land use change has increased the land surface albedo, which leads to Radiative Forcing (RF) of -0.15 ± 0.10 W m^{-2}.
	Zonal mean precipitation	Will very likely increase in high and some of the mid latitudes, and will more likely than not decrease in the subtropics.
	Specific humidity	Increases in near-surface over land are very likely.
	Evaporation	Increases in over land are likely in many regions.
Earth's Energy Budget	Independent estimates of effective RF of the climate system	The observed heat storage, and surface warming combine to give an energy budget for the Earth that is closed within uncertainties (high confidence), and is consistent with the likely range of climate sensitivity.

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Table 1. Continued

Parameter	Fact	Effect
Monsoon Systems	Future changes	The global monsoon, aggregated over all monsoon systems, is likely to strengthen in the 21st century with increases in its area and intensity.
	Monsoon circulation	The global monsoon circulation weakens.
	Monsoon onset and retreat dates	Onset likely to become earlier or not to change much and monsoon retreat dates are likely to delay, resulting in lengthening of the monsoon season in many regions.
	Annual precipitation change	Follows a 'warmer-get- warmer'pattern, increasing where warming of sea surface temperature exceeds the tropical mean and vice versa.
Cyclones	Projections	It is likely that the global frequency of occurrence of tropical cyclones will either decrease or remain essentially unchanged, concurrent with a likely increase in both global mean tropical cyclone maximum wind speed and precipitation rates.
	Regional projections	The future influence of climate change on tropical cyclones is likely to vary by region.
Crop Yield	Crop yield	In developing countries, climate change will cause yield declines for the most important crops. South Asia will be particularly hard hit.
	Irrigated crop	Will have varying effects on yields across regions, but yields for all crops in South Asia will experience large declines.
	Higher maximum temperatures, more hot days and heat waves over nearly land areas	Increased risk of damage to a number of crops
	Increased summer drying over most mid-latitude continental interiors and associated risk of drought	Decreased water resource quantity and crop yields.
	Intensified droughts and floods associated with El niño events in many different regions	Decreased agricultural and rangeland productivity in drought- and flood-prone regions.
	Increased intensity of mid-latitude storms	Increased damage to coastal ecosystems.
	Food price	Will result in additional price increases for the most important agricultural crops–rice, wheat, maize, and soybeans.
	Fodder price	Higher feed prices will result in higher meat prices. As a result, will reduce the growth in meat consumption slightly.
	Calorie	Calorie availability in 2050 will not only be lower than in the no-climate-change scenario-it will actually decline relative to 2000 levels throughout the developing world.
	Calorie and child nutrition	By 2050, the decline in calorie availability will increase child malnutrition by 20 percent relative to a world with no climate change. Climate change will eliminate much of the improvement in child malnourishment levels that would occur with no climate change.
Livestock	Higher maximum temperatures, more hot days and heat waves over nearly land areas	Increased heat stress in livestock and wildlife

Source: Hartmann et al., 2013, Collins et al. 2013, Rhein et al. 2013, Myhre et al., 2013, Christensen et al., 2013, Nelson et al. 2009 & IPCC, 2001

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In response to GHG forcing, dry land areas tend to show a reduction of evaporation and often precipitation, accompanied by a drying of the soil and an increase of surface temperature, in response to decreases in latent heat fluxes from the surface (e.g., Fischer et al., 2007; Seneviratne et al., 2010).

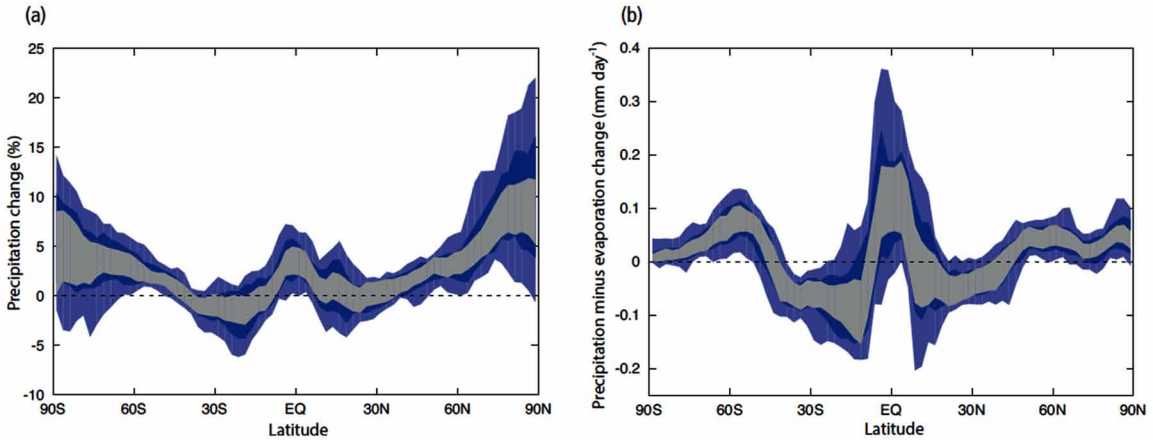
Evapotranspiration

The main source of water for agriculture production is through precipitation and the loss of water in the form of evaporation depends on the climatic conditions of the region. It has long been recognized (Priestley, 1966) that the availability of surface water regulates evaporation and local temperature. Where there is abundant surface water and plant growth, the local evaporation constrains temperature and in hot climates temperatures are very much higher in the absence of surface evaporation. So it is necessary to have proper balance between precipitation and evaporation for agriculture production.

The evaporation of surface water and condensation of atmospheric water vapor to form clouds and precipitation, is an essential component of energy flow through the climate system. This phenomenon may be explained by the Clausius-Clapeyron relationship which is the rate of increase of saturated vapor pressure with temperature and is important in regulating many of the processes of the hydrological cycle. The global atmospheric water content is constrained by the Clausius–Clapeyron equation to increase at around 7% K^{-1}; however, both the global precipitation and evaporation in global warming simulations increase at 1 to 3% K^{-1} (Lambert & Webb, 2008; Lu & Cai, 2009).

Consideration of hydrological drought conditions employs a range of different dryness indicators, such as soil moisture or other drought indices that integrate precipitation and evaporation effects (Seneviratne et al. 2012). In order to provide an indication of future changes of water availability, figure 4 (b) presents zonal mean changes in precipitation minus evaporation (P - E) from Common Management Information Protocol CMIP5 (Kirtman et al., 2013). As in the case of precipitation (Figure 4), the uncertainty is

Figure 4. Multi-model projections of changes in annual and zonal mean (a) precipitation (%) and (b) precipitation minus evaporation (mm day–1) for the period 2016–2035 relative to 1986–2005 under RCP4.5. The light blue denotes the 5 to 95% range, the dark blue the 17 to 83% range of model spread. The grey indicates the 1σrange of natural variability derived from the pre-industrial control runs
Source: Kirtman et al., 2013



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dominated by model differences as opposed to natural variability (compare blue versus grey shading). The results are consistent with above discussion on the wet-get-wetter and dry-get-drier pattern. In the high latitudes and the tropics, most of the models project zonal-mean increases in P – E, which over land would need to be compensated by increases in runoff. In contrast, zonal mean projected changes in the subtropics are negative, indicating decreases in water availability.

Evapotranspiration is the combined effect of evaporation and transpiration, and it is a key part of the hydrologic cycle. Evaporation is simply the phase change from liquid water to water vapor as temperature increases. Transpiration involves the uptake of water in soil by plants, the transport of water through the plant, and its eventual evaporation from plant leaves and other surfaces. Evapotranspiration is a natural cooling process because heat at the earth's surface is captured by water droplets, which, through evaporation, disperse the heat out of the atmosphere and into space.

Change in CO_2 Levels

The prevailing view among researchers is that global climate change may prove beneficial to many farmers at least in the short term. The logic is straightforward: Plants need atmospheric carbon dioxide to produce food, and by emitting more CO_2 into the air will cause some crops and trees to grow bigger and faster.

The latest analysis of observations from the Global Atmosphere Watch (GAW) Programme (WMO 2014) shows that the globally averaged mole fractions of Carbon dioxide (CO_2), Methane (CH_4) and Nitrous Oxide (N_2O) reached new highs in 2013, with CO_2 at 396.0±0.1 ppm, CH_4 at 1824±2 ppb and N_2O at 325.9±0.1 ppb (Table 2).

The change in atmospheric CO_2 levels will have impact on the vegetation. Changes in evapotranspiration over land are influenced not only by the response to Radiative Forcing (RF), but also by the vegetation response to elevated CO_2 concentrations. Physiological effects of CO_2 may involve both the stomatal response, which acts to restrict transpiration (Cao et al. 2009; Field et al. 1995; Hungate et al. 2002; 2010; Lammertsma et al., 2011), and an increase in plant growth and leaf area, which acts to increase evapotranspiration (Bounoua et al. 2010; El Nadi, 1974).

Table 2. Global annual mean abundances (2013) and trends of key greenhouse gases. Units are dry-air mole fractions, and uncertainties are 68% confidence limits

	CO_2	CH_4	N_2O
Global abundance in 2013	396.0 ± 0.1 ppm	1824 ± 2 ppb	325.9 ± 0.1 ppb
2013 abundance relative to year 1750[a]	142%	253%	121%
2012–2013 absolute increase	2.9 ppm	6 ppb	0.8 ppb
2012–2013 relative increase	0.74%	0.33%	0.25%
Mean annual absolute increase during last10 years	2.07 ppm/yr	3.8 ppb/yr	0.82 ppb/yr

[a]Assuming a pre-industrial mole fraction of 278 ppm for CO_2, 722 ppb for CH_4 and 270 ppb for N_2O. Stations used for the analyses numbered 124 for CO_2, 121 for CH_4 and 33 for N_2O.

[Source: WMO (2014)]

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PROSPECTS FOR ADAPTATION MITIGATION

Intergovernmental Panel on Climate Change (IPCC, 2001), suggested that adaptation is gaining attention as an expected answer to the challenges posed by climate change. The increasingly uncertain climatic conditions to which actors are exposed may becoming a constraint for their well-being. Given the range of warming predicted by the scientific community, regional and local variation in impacts on the agricultural production may likely to be high. A critical challenge for farmers in developing countries is how to cope with increased variability and uncertainty in current and future rainfall patterns, a phenomenon which is affecting rain-fed and irrigated farming alike. Further, the concern with climate change is sensitive given the linkage of the agricultural sector to the poverty. It may be anticipated that adverse impacts on the agricultural sector will exacerbate the incidence of rural poverty. Hence, improved water resource management will be vital to sustaining crop productivity in the face of climate variability. Food insecurity may continue to be a serious issue in coming decades. Climate change may significantly increase production risk and rural vulnerability, particularly in regions that already suffering from chronic soil and water resource scarcity, high exposure to climatic extremes including droughts, flooding, poverty and hunger.

In order to sink with the climatic variability and retain enhanced flow of food production, some measures in the form of adaptation and mitigation will be required. Adaptation to climate impacts in the agricultural sector is not a new phenomenon. According to Rosenzweig & Liverman (1992) and Rosenberg (1992) natural systems have continuously been adapting autonomously, or in accordance with a plan, to a changing environment throughout history.

Adaptation may be defined as a process or action of adjusting to different circumstances or conditions, in this case as a result of a changing climate. Availability of water for agriculture depends on many climatic parameters like precipitation, temperature, atmospheric $CO_{2,}$ etc. Hence judicious management of water resource for sustainable agriculture development may require proper adoption to the changing climatic parameters. The adaptations includes several steps starting from micro level adaptation as farm production adjustments such as diversification and intensification of crop and livestock production; changing land use and irrigation; and altering the timing of operations. The adaptations can also include numerous market responses that have emerged as potentially effective adaptation measures to climate change, development of crop and flood insurance schemes, innovative investment opportunities in crop shares and futures, credit schemes, and income diversification opportunities. The options of adaptations may include government responses and institutional changes, pricing policy adjustments and technological developments. Hence, adaptations can be broadly grouped in to Short-Term and Long-Term adaptations (Figure 5).

Short-Term Adaptations

The short- term adaptations to the climate change may be having benefits to the farmers for shorter period of time and can be implemented immediately. Existing literature suggests that such types of adaptations are more appropriate to address short-term climatic concerns. These adaptations may include the following.

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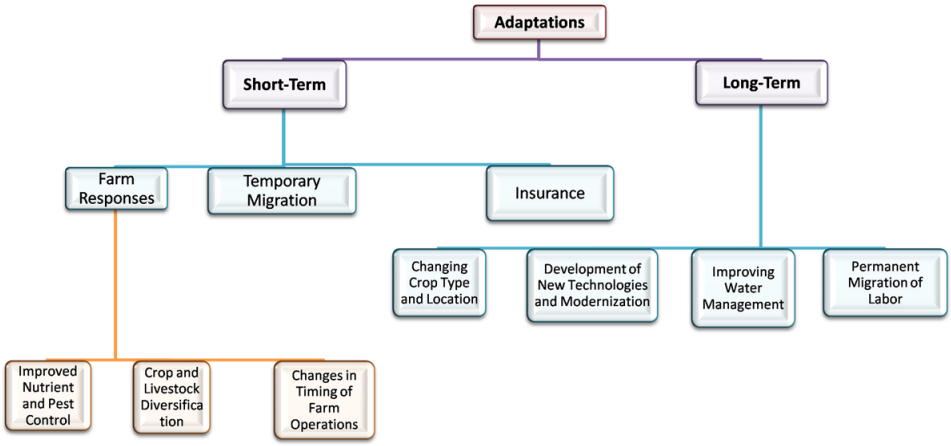
Figure 5. Apaptations in agriculture



Farm Responses

Among the most important and direct current adaptations to climate variability are some of the farm level responses. The farm response adaptations can include the crop and livestock diversification as well as changes in timings of various farm operations. Improved nutrient and pest control management can also be part of adaptation in farm response.

A. Crop and Livestock Diversification and Changes in Timing of Farm Operations

Crop diversification refers to the addition of new crops or cropping systems to agricultural production on a particular farm taking into account the different returns from value-added crops with complementary marketing opportunities. Diversification may be a key factor in reducing risk and means of coping with an uncertain climate and further unpredicted water for agriculture production. Crop is the major activity worldwide for livelihood followed by livestock production. Diversification of crop and livestock varieties, having the potential to increase productivity in the face of temperature and moisture stresses may be helpful. Diversity in seed genetic structure and composition may be an effective defense against numerous factors, including water stress, disease and pest outbreak and importantly climate hazards.

It is also predicted, there may be shift of cropping seasons and adjusting to such situations options include changes in the timing and intensity of production. Delcourt & Van kooten (1995), Brklacich et al. (2000), de Loe et al. (1999) have given following options for addressing impacts on yields and soils from climate change.

- Changing land-use practices such as the location of crop and livestock production.
- Rotating or shifting production between crops and livestock.
- Shifting production away from marginal areas can help reduce soil erosion and improve moisture and nutrient retention.
- Altering the intensity of fertilizer and pesticide application as well as capital and labor inputs.

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- Adjusting the cropping sequence, including changing the timing of sowing, planting, spraying, and harvesting, to take advantage of the changing duration of growing seasons and associated heat and moisture levels.
- Altering the time at which fields are sowed or planted can also help farmers regulate the length of the growing season.
- Changing the timing of irrigation.

Many researchers suggested various adaptation measures for livestock and rangeland management. Following are few suggestions for livestock and rangeland management outlined by Baker and Viglizzo (1998), Chiotti et al. (1997), IPCC (1996).

- Change in grazing timing, duration, and location.
- Varying supplemental feeding.
- Changing the location of watering points.
- Altering the breeding management program.
- Changes in rangeland management practices.
- Modifying operation production strategies as well as changing market strategies.
- In temperate climatic areas, planned adaptation measures in livestock management that are advocated include the use of vegetative barriers or snow fences to increase soil moisture, or windbreaks to protect soil from erosion.
- In warmer climates, adverse climatic conditions such as heat stress can be moderated by the adoption of appropriate technology such as the use of sprinklers in livestock buildings or feedlots.
- Adjusting livestock stocking rates.
- Implementing feed conservation techniques and fodder banks to moderate the consequences for animal production during periods of poor crops.
- Increasing native rangeland vegetation or plant-adapted species.

Working with various adoptions there may be numerous constraints farmers and livestock holders may encounter which make these farm level adaptations difficult. The short term adaptations are not costless. For example (Skees et al. 1999) the most significant problem to overcome is that diversification is costly in terms of the income opportunities that farmers forego (that is, switching crop varieties can be expensive, making crop diversification typically less profitable than specialization). In addition to this traditions can often by difficult to overcome and will dictate local practices. In such situation, if a local region has a long and rich tradition of planting a particular crop variety, the change to newer and more suitable varieties can be hard.

B. Improved Nutrient and Pest Control Management

Increased CO_2 levels and higher temperatures are likely to create stress in crops and livestock and may induce a need for more plant protection. Changes in the application of various chemicals may further enhance the problem. For the climate change situation alternative production techniques and crops, as well as locations, that are resistant to water stress, infestations and other risks may also be relied upon as effective response strategies. Following are a range of management practices have emerged that can

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assist farmers adapt to loss of soil moisture and organic carbon contents and increased soil erosion as a result of changing climate situations (Erda 1996 and Parry 2000).

- Improved nutrient management techniques to maintain soil fertility and prevent erosion.
- For the increased frequency of droughts, farmers can further adapt by changing the selection of crops.
- Introduction of management techniques that conserve soil moisture, such as reduced or no tillage, in order to maintain soil organic carbon contents can result in improved soil structure and fertility.
- Increasing production per unit of evapotranspiration with the use of new and improved varieties.
- Reducing water use in land preparation as well as loss (through seepage and percolation) during the crop growth period.
- Adoption of efficient water use methods.
- The diffusion of appropriate technology to enhance greater water use efficiency like drip-irrigation.

C. Temporary Migration

Temporary migration is also called circular migration in agriculture. It includes seasonal migration, where workers undertake off-farm or non-farm activities for some part of the year, and returning back during harvest time. The temporary migration is the movement of labor from one agricultural area to another area, or across sectors. This also includes migration between and within urban and rural to ensure security in livelihood.

It is not much clear from the available literature to what extent climate change per se can be attributed as the primary factor in the decision making process of households engaged in agriculture on whether or not to migrate. But in case of adverse climate the livelihood of poor and marginal household families may be difficult. However, in such situation the temporary migration to the other agriculture or non-agriculture areas for the period of adverse condition may be an option of livelihood. The option of such types of migration for livelihood may be useful for extreme events in climate change.

D. Insurance

There may be much uncertainty about the agriculture production as successful crop yield depends on the availability of water and climate of the region. So the households engaged in agriculture may face problem for the livelihood in case of crop failure and inherently need insurance mechanisms to cope with income risks. The types of risks faced by the agricultural sector are outlined below (Moreddu 2000).

- Production risks due to weather variation, crop disease and various other causalities,
- Ecological risks from climate change, pollution, and natural resource management,
- Market risks, which depend on input and output price variability, and
- Regulatory or institutional risks due to state intervention in agriculture.

Furthermore, households with extremely low incomes may be at highly risk and will limits their financial ability and willingness to adopt new technologies that can maintain and enhance crop productivity. In such situation, the insurance will help farmers to reduce the financial risk when they adopt for

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new technology or adaptation. The insurance may encourage the farmers to with stand in small climatic variations by reducing financial risk of livelihood in case of failure of the crops.

Long-Term Adaptations

Efforts are necessary to withstand and minimize the adverse impacts of short term climate variability and uneven water availability for agriculture. The measures will be necessary to reduce vulnerability to anticipated future impacts of climate change. So the combination of adaptations both at farm and policy level will be necessary for long term adaptation for future water related consequences scarcity due to climate change. Following paragraphs describes a range of adaptation options as most relevant in water availability and overall climate change.

The interaction of water for agriculture production is governed by climatic situation. However, given that warming is largely a concern of the future, long term adaptation must also be in the future. Kurukulasuriya and Rosenthal (2003) also reported that addressing climate change- a long term phenomena, should entail a comprehensive long term response strategy at the national or local level but will require a dynamic approach. Some of the important long term strategies for adaptation of availability of water for agriculture and climate change are discussed below.

A. Changing Crop Type and Location

The main purpose of changing the crop types or location of cultivation of crops is to cultivate stress resistant crops on its suitable location. The potential options include switching to more robust varieties that are better suited to the changing environment.

Agricultural analyses of future climates indicate also that crops will move poleward with warming (Mendelsohn and Neumann 1999). The extent of this migration depends upon the severity of the warming. This types of adaptation require a number of underlying prerequisites are in place. Obviously, the scope for shifting production to new lands, particularly in developing countries where, may be limited because of population pressures and the availability of cultivable land. There may be another constrain that farmers may not be willing and ability to move. Further, land use regulations on agricultural production are governed by country laws and may hinder such adaptations in some of the countries. In such situation, crop rotations that may not be optimal in interest of available water for agriculture production and a changed environment may be persisted. This may consequence in severe losses in the long term.

Appropriate land reform policies that establish or strengthen property rights in changing demand of water for agriculture need to be enforced. It is also necessary that appropriate measures that boost farmer's financial ability to undertake the necessary adaptation may be necessary. These financial measures may include improving access to credit and banking facilities in rural areas. Furthermore, investment in diffusion of access to sufficient and timely irrigation is important. Appropriate institutional support to promote the dissemination of knowledge through dedicated extension network may play important role in such situations.

There is good amount of debate in agriculture research that the new crops are equally (if not, more) profitable to the farmer. There is also serious concern that changing crop types will not automatically maintain previous levels of food production as well as or nutritional quality levels. While the national objective may be to grow crops that will fulfill food security with minimum water requirement.

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B. Development of New Technologies and Modernization

Agriculture research on the globe has crossed many milestones and has many success stories. Research and technological innovation in crop and animal productivity is important to achieve food security in changing environmental conditions. This will enable farmers to cope with various climatic conditions and may be fundamental to the growth and development of agriculture. There are two basic types of technological options (Smithers and Blay-Palmer 2001), important for agriculture viz. mechanical and biological. Mechanical innovations include irrigation, conservation tillage, and integrated drainage systems. On the other hand, biological options also have an important role in enabling cropping systems to adapt to a wide range of climatic conditions. Investment in crop breeding, the promotion of climate-resistant varieties that offer improved resistance to changing diseases and insects, breeding of heat- and drought-resistant crop varieties, the use of traditional varieties bred for storm and drought resistance, and investment in seed banks may be necessary for success in overcoming vulnerability to climate.

Further, advances in science and biotechnology offer much powerful tools that hold promise to overcome the challenges posed by scarcity of water resources and threats posed to the agricultural production. However, it is not very clear that how much role the advocacy of biotechnology will play as adaptation in climate change scenario. In addition to this the issue of affordability of new technology to poor farmers may be serious concern for effective climate change. Several innovative concepts and technologies like geographical information systems, software-based weather systems, low-cost and decentralized technologies, industrial symbiosis (Rao & Patil, 2015) and as well as innovative waste treatment with simultaneous resource conservation method have also been reported (Patil & Rao, 2015).

C. Improving Water Management

Availability of water is most important for successful agriculture production. Improved water resource management will be vital to sustaining crop productivity levels in the face of both climate variability and longer-term change. In areas that are currently dependent primarily on rain-fed agriculture, the conjunctive use of surface and ground water resources will play an increasingly important role in enabling farmers to adapt to fast changing climatic conditions. However, it is also clear that in the face of rising domestic and industrial demand, additional efforts are necessary to ensure efficient management of water resources. With climate change and variability increasing pressure on available water resources, improved water management is one of the most important long-term adaptation options that countries must pursue. According to recent estimates, irrigation efficiency in developing countries is extremely low. The average efficiency of irrigated agriculture in developing countries is very low.

Preserving water resources using suitable storage may play a crucial role in availability of water in changing climate. However, if the planning of water storage is not improved, it may likely that many investments may fail to deliver intended benefits. McCartney et al. (2013) reported that, national economies, highly dependent on rainfed agricultural production, are exceedingly vulnerable to both intra-annual and inter-annual fluctuations in rainfall and hydrology. In addition to this traditional adaptation techniques may also be effective to deal with shortages in water.

Apart from water storages there may be challenges with regard to water use and availability that also need to be overcome. Increased demand for water by municipal and industrial sectors may further become serious issue in future. Un-sustained and over exploited irrigation may lead to groundwater depletion, soil salinization and water-logging. In some regions, numerous challenges need to be overcome in order

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to increase water supply. As emphasized by Dinar (2000), these challenges include financial crises; low-cost recovery of the investment in the water system; the role of political parties, electoral systems and interest groups. Dinar argues for improved forecasting procedures, simulation models, and improved data monitoring systems. Other necessary preconditions include overcoming economic constraints. The improvements in irrigation and other high-efficiency water conservation technology require major, long-term and costly investments. Furthermore, undertaking requisite institutional reforms that hinder the pursuit of effective water resource management strategies may also be helpful. However, given the uncertainty surrounding forecasts of regional changes in precipitation, it has not yet been proven that making water adaptations in advance of climate changes is in fact very practical.

D. Permanent Migration of Labor

Encompasses permanent migration in the form of the movement of migrants into new economic areas. The possible reasons for migration may be possibly due to policies or permanent changes in their previous environment. The agriculture labor migration may be from poorer agricultural areas in one region to lowlands in other regions. Desanker (2002) stresses, long-lasting climate pressures, such as prolonged drought, which increase the vulnerability of migratory groups to climate change (by limiting the scope of areas to move to), can be disastrous. Short-term migrants may be forced into becoming more permanent migrants, resulting in dire consequences such as pressures on land and water resources.

The adaptations outlined in the above sections may not fully address the concerns of permanent labor migration with short term climate variability may not be adequate in the face of new and long lasting climate conditions. Reilly et al. (2003) reported that even insurance programs will not be sufficient if productivity of land becomes unviable and may in fact act as a deterrent to change despite market signals that indicate otherwise. If unmanaged or uncontrolled, large-scale migration of this type may have consequence in significant impacts on the environmental resource bases as well as indigenous societies.

In such complex situations, a clearly defined system of property rights and enforcement may be necessary to prevent potential stress. The establishment of an appropriate system of property rights both at the individual or community level may be part of the likely solution. Well placed training and extension services may be act as other solutions that would be needed based on the situations.

E. Adaptations Irrespective of the Temporal Dimension of Climate Impacts

Non-climatic parameters are also equally important for agriculture production on sustainable basis. Suitable policies aimed at growing the resiliency of the agriculture sector to other, including non-climatic factors may be necessary and may help in improving capacity to cope with both climate variability and climate change. Further, Smit and Olga (2001) emphasized on solving immediate concerns facing domestic agriculture sectors do not delay the formulation and implementation of efficient responses to promote long term sustainability issues.

Such effective adaptation may also depend considerably on primary local environmental, institutional, and socio-economic conditions. Both domestic, and regional cooperation in science, resource management, and development may be extremely important. Some of the major economic and institutional issues may likely to be beneficial irrespective of the nature of the climate change are as follows.

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- Investment and accumulation of capital.
- Reform of pricing schemes, development of open markets, and other reforms.
- Adoption of new technologies.

F. Promotion of Trade

Suitable market and appropriate return to the agriculture produce is the key to success for the farmers. Suitable market for agriculture produce is important for both buyers and consumers. Here suitable trade may play an important role during periods of variable climatic. There may be possibility that agricultural trade may moderate impacts by enabling farmers in regions less adversely affected to sell their produce in areas more severely affected by climate change. The role of trade policy may important because of repercussions on the prospects for adaptation. Further, regional and international trade may lead to improvements in access to international markets, which in turn may help a country diversify and reduce of risk of food security from water scarcity and climate change.

G. Extension Services

Extension services have played a key role in promoting agricultural productivity in developing countries. Their role in promoting various adaptations to climate change may be very important. Traditionally, extension services have generally been in the purview of services provided by government, given that agricultural research is typically a public good. However, private and non-governmental agencies or the formation of research cooperatives do play a significant role in some countries. Crucially, as Evenson (1997) notes, the economic contribution of extension services is governed by location-specific factors. In this regard, numerous programs have been found to be ineffective given the underperformance of agents, design limitations, and management failures. Overall, efficient, farmer friendly extension policies may coup farmer's efforts to maintain sustainable flow of agriculture production in uneven availability of water in changing climate.

H. Diversification of Income-Earning and Employment Opportunities

Seasonal effects and climatic uncertainty that characterize the agricultural sector effectively mean that diversification of income and employment opportunities may be an important adaptation strategy for households in the agriculture sector. In dryland areas, traditional practices to help cope with drought include the accrual of a surplus in a superior year, in the form of cash or assets (for example, cattle) for use in poorer years (Burton 2001). While measures such as crop storage, sales, and household savings can and do offer relief from temporary or seasonality effects, risk and market imperfections that abound in rural settings render diversification into off-farm opportunities necessary to reduce income instability (Alderman and Paxson 1992). Consequently, policies that provide the opportunities to pursue alternative livelihood options need to be encouraged.

I. Dissemination of Climate Data

A reason in literature frequently cited for not adapting in time to climatic impacts is the lack of reliable climate monitoring and forecasting data. Barnett (2001) argues that an increase in the availability of

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information to understand the biophysical and social environment is necessary. The timely dissemination of climate forecasting information and early warning to farmers including information on risks can strengthen the ability of farmers to cope and optimize the management of hydrological variability and change. Monitoring data and indicators of change are also necessary across all sectors in society, not just policy makers. Along with information on risks, the information on suitable mitigation measures may be helpful to farmers.

J. Institutional Planning and Implementation

Insufficient institutional and decision making structures to support long-term planning in governments in developing countries has long been recognized to be a problem in pursuing general development objectives. At World Bank report underscored the finding that in some countries, such as Bangladesh, planning for climate change is not even mandatory, an outcome of planning agencies' being "formed not by law but by administrative resolution" (Kurukulasuriya and Rosenthal 2003). Long term institutional planning related to climatic variability and suitable implementations are important.

Mitigation

Mitigation is human intervention to reduce the extent of climate change. It includes strategies to reduce greenhouse gas sources and emissions, and enhancing greenhouse gas sinks. A number of mitigation strategies in the agriculture and forestry sectors have been identified as useful in achieving the goal of stabilization of atmospheric concentrations between 450-550 ppm CO_2. These include reduced deforestation and degradation of tropical forests (REDD), sustainable forest management (SFM) and forest restoration (FR), including afforestation and reforestation (A/R). In agriculture, they involve reduction of non-CO_2 gases through improved crop and livestock management and agroforestry practices, enhanced soil carbon sequestration in agricultural soils via reduced tillage and soil biomass restoration (Table 3).

Table 3. Mitigation potential in agriculture and forestry in 2030

Sr. No.	2030 Reductions	G tonnes CO_2 e yr^{-1}
1	Global	15-25
2	Agriculture	1.5-5.0
3	Methane, N_2O	0.3-1.5
4	Agroforestry	0.5-2
5	Agricultural soils	0.5-1.5
6	Forest	2.5-12
7	REDD	1-4
8	Sustainable forest management (SFM) SFM	1-5
9	Forest Restoration (FR)	0.5-3
10	Bioenergy	0.1-1.0
	Total	4-18

Source: IPCC (2007)

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Global reductions in 2030 correspond to those needed to achieve stabilization of atmospheric concentrations between 450-550 ppm CO_2, under a mid-range IPCC SRES.

In case of long term sustainable availability of water for agriculture can be achieved by investing in wider best practices. These practices can include the following.

I. Reducing Emissions of Green House Gases

The greenhouse gases include CO_2, methane and nitrous oxide and keep green gases under the limit, by adopting the effective ways. The practices that will help to reduce Carbon dioxide (CO_2) levels may include land conversion, reduced deforestation, improved ways to manage wildfires and alternatives to the burning of crop residues. The Methane and Nitrous Oxide in the environment can be managed using practices like improved nutrition for ruminant livestock, efficient management of livestock waste, and efficient management of irrigation water on rice fields, efficient applications of nitrogen fertilizer on cultivated fields and reclamation of treated municipal wastewater for aquifer recharge and irrigation.

The mitigation practice may also include reduction of emissions from commercial fishing operations and more efficient energy use by forest dwellers, commercial agriculture and agro-industries.

II. Sequestering Carbon

Sequestering Carbon is fixing the excess of Carbon dioxide in to ecosystem. The some of the means for such sequestering CO_2 includes improved management of soil organic matter, conservation agriculture involving permanent organic soil cover with minimum mechanical soil disturbance and appropriate crop rotation. The Carbon sequestering can also be achieved by reducing use of fossil fuel, improving management of pastures and sustainable grazing practices on natural grasslands. In the agriculture introduction of integrated agro-forestry systems, proper use of degraded and marginal lands and planting of carbon sink trees will also help in sequestering Carbon in the ecosystem.

FUTURE RESEARCH DIRECTIONS

The increased demand for other uses coupled with recurrent drought and climatic changes in countries of limited water resources, is producing unprecedented pressure for reducing the share of fresh water used in irrigation. Many countries give priority of water allocation to the domestic sector followed by tourism and industry, and what is left is allocated to agriculture. At the same time that agriculture is asked to give water to other uses, the increasing population demand requires increase in food production. This creates a conflict that may be resolved and by examining different options of water uses for sustainable agriculture. Increasing the efficient use of water is a key non-structural approach to water resources management. The agriculture water use efficiency and water productivity is very important as they are largely inefficient in many countries due to poor distribution systems and excess irrigation. The average agricultural water use efficiency in developing countries is very poor. Water planners and decision makers as well as researchers are facing with difficulties and challenges. Some options for

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such constraint may be helpful to sustain agriculture in changing climate in the various regions on the globe. The probable solution to this conflict requires greater understanding and systematic research. The future agriculture production depends on water resources and their allocation and management in agriculture. The domains of future research may include: improving water use efficiency, reducing crop consumption of water, irrigation with reclaimed water, practicing deficit irrigation and irrigation with desalinated water. The research vision for the next few years could include the few set of actions *viz.* have more efficient use and allocation for water use in irrigation; improved water productivity by introduction of new management measures such as deficit irrigation; and introduction of high yielding low water demanding varieties.

Desalination of brackish and sea water can offer limitless fresh water that can be used for agriculture. There is a need to find cheap methods of desalination such as the use of solar and renewable energy. Therefore, researchers should consider these needs in setting up their research priorities.

CONCLUSION

The world's climate is changing, and the changes will have an enormous impact on people, ecosystems, and energy use on the globe. There is threat that climate change will impact food availability, access, and utilization due to change in the climatic parameters like temperature, precipitation, CO_2.etc. The change in environmental parameters may change availability of water for agriculture. The demand of growing population for food security is crucial and uneven availability of water due to climate change will exaggerate the problem to greater extent. The impact of non-availability of sufficient and timely water for agriculture will lead to more poverty and degradation of land resources. Apart from this there is also increasing requirement of water for urban and industries. So increasing agriculture production, sharing water for nonagricultural uses and uneven availability of water due to climate change may exaggerate the problem to the greater extent in the future. Though researchers and water managers are trying hard for the solution and the complexity of the issue will be more serious in coming decades.

The aggregate impact of climate change on the water resources of the globe is not fully understood. The changing climate is playing central role in availability of water for agriculture production and individual climatic parameters and their interactions are equally important. There is an emerging consensus that changes in water resources can have detrimental impacts on the food security, in the absence of adaptation. Most of the impacts are not easy to quantify because they depend on a range of assumptions. The available quantitative scientific studies suggest that the wet regions will be more wet and dry will be more dry in coming decades which is serious concern for food security. This may reduce crop yields and the land suitable for agricultural production or change in cropping pattern and planting and harvesting schedules. Institutional development will have to play a greater role through polices supported by efficient extension programmes for mitigation of the future impact of climate change. Overall, the climate change may be having positive as well as negative effect on the water resources, agriculture production and food security of the world. This seems a huge challenge on the globe and require proper mitigations and adaptations measures.

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REFERENCES

Ainsworth, E. A., & Rogers, A. (2007). The response of photosynthesis and stomatal conductance to rising (CO_2): Mechanisms and environmental interactions. *Plant, Cell & Environment*, *30*(3), 258–270. doi:10.1111/j.1365-3040.2007.01641.x PMID:17263773

Alderman, H., & Paxson, C. H. (1992). *Do the Poor Insure? A Synthesis of the Literature on Risk and Consumption in Developing Countries.* World Bank Policy Research Working Paper WPS 1008. Retrieved February 10, 2015, from https://www.princeton.edu/rpds/papers/Alderman_Paxson_Do_the_Poor_Insure_1994.pdf

Allan, R. P., Soden, B. J., John, V. O., Ingram, W., & Good, P. (2010). Current changes in tropical precipitation. *Environmental Research Letters*, *5*(2), 025205. doi:10.1088/1748-9326/5/2/025205

Anonymous. (2007). *Coping with water scarcity challenge of the twenty - first century*. Retrieved February 05, 2015, from http://www.fao.org/nr/water/docs/escarcity.pdf

Baker, B., & Viglizzo, E. F. (1998). Rangeland and Livestock. In J. F. Feenstra, I. Burton, J. B. Smith, & R. S. J. Tol (Eds.), *Handbook on methods for climate change impact Assessment and Adaptation Strategies*. Amsterdam: UNEP.

Barbier, E. B. (2004). Water and economic growth. *The Economic Record*, *80*(248), 1–16. doi:10.1111/j.1475-4932.2004.00121.x

Barnett, J. (2001). Adapting to Climate Change in Pacific Island Countries: The Problem of Uncertainty. *World Development*, *29*(6), 977–993. doi:10.1016/S0305-750X(01)00022-5

Bounoua, L., Hall, F. G., Sellers, P. J., Kumar, A., Collatz, G. J., Tucker, C. J., & Imhoff, M. L. (2010). Quantifying the negative feedback of vegetation to greenhouse warming: A modeling approach. *Geophysical Research Letters*, *27*, L23701.

Brklacich, M., Bryant, C., Veenhof, B., & Beauchesne, A. (2000). Agricultural Adaptation to Climatic Change: A comparative assessment of two types of farming in central Canada. In H. Millward, K. Beesley, B. Ilbery, & L. Harrington (Eds.), *Agriculturaland Environmental Sustainability in the New Countryside*. Winnipeg: Hignell Printing Limited.

Brown, C., & Lall, U. (2009). Water and economic development: The role of variability and a framework for resilience. *Natural Resources Forum*, *30*(4), 306–317. doi:10.1111/j.1477-8947.2006.00118.x

Burton, I. (2001). *Vulnerability and Adaptation to Climate Change in the Drylands*. Washington, DC: The Global Drylands Partnership.

CA (Comprehensive Assessment of Water Management in Agriculture). (2007). *Water for food, water for life: A comprehensive assessment of water management in agriculture.* Sri Lanka: IWMI.

Cao, L., Bala, G., Caldeira, K., Nemani, R., & Ban-Weiss, G. (2009). Climate response to physiological forcing of carbon dioxide simulated by the coupled Community Atmosphere Model (CAM3.1) and Community Land Model (CLM3.0). *Geophysical Research Letters*, *36*(10), L10402. doi:10.1029/2009GL037724

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Cao, L., Bala, G., Caldeira, K., Nemani, R., & Ban-Weiss, G. (2010). Importance of carbon dioxide physiological forcing to future climate change. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(21), 9513–9518. doi:10.1073/pnas.0913000107 PMID:20445083

Chiotti, Q., Johnston, T., Smit, B., & Ebel, B. (1997). Agricultural Response to Climate Change: A preliminary Investigation of Farm-level Adaptation in Southern Alberta. In B. Ilbery, Q. Chiotti, & T. Rickard (Eds.), *Agricultural Restructuring and Sustainability: A Geographical Perspective*. CAB International.

Chou, C., Neelin, J. D., Chen, C. A., & Tu, J. Y. (2009). Evaluating the rich-get-richer mechanism in tropical precipitation change under global warming. *Journal of Climate*, *22*(8), 1982–2005. doi:10.1175/2008JCLI2471.1

Chou, C., Tu, J. Y., & Tan, P. H. (2007). Asymmetry of tropical precipitation change under global warming. *Geophysical Research Letters*, *34*(17), L17708. doi:10.1029/2007GL030327

Christensen, J. H., Krishna Kumar, K., Aldrian, E., An, S. I., Cavalcanti, I. F. A., de Castro, M., ... Zhou, T. (2013). Climate Phenomena and their Relevance for Future Regional Climate Change. In T. F. Stocker, D. Qin, G. K. Plattner, M. Tignor, S. K. Allen, J. Boschung, ... P. M. Midgley (Eds.), *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press.

de Loë, R. C., Kreutzwiser, R., & Mararu, L. (1999). *Climate Change and the Canadian Water Sector: Impacts and Adaptation*. Guelph: Natural Resources Canada. Retrieved March 01, 2016, from http://www.uoguelph.ca/~c-ciarn/documents/World_Bank_Paper.pdf

Desanker, P. V. (2002). Impact of climate change on Africa. Center for African Development Solutions.

Dinar, A. (2000). *The Political Economy of Water Pricing Reforms*. Washington, DC: World Bank.

El Nadi, A. H. (1974). The significance of leaf area in evapotranspiration. *Annals of Botany*, *38*(3), 607–611.

Erda, L. (1996). Agricultural Vulnerability and Adaptation to Global Warming in China. *Water, Air, and Soil Pollution*, *92*(1-2), 63–73.

Evenson, R. (1997). Rice Varietal Improvement and International Exchange of Rice Germplasm. In P. L. Pingali & M. Hossain (Eds.), *Impact of Rice Research*. Manila: International Rice Research Institute.

FAO. (2013). *FAO Statistical Yearbook 2013. World Food and Agriculture*. Rome: Food and Agriculture Organization of the United Nations.

Field, C. B., Jackson, R. B., & Mooney, H. A. (1995). Stomatal responses to increased CO_2-Implications from the plant to the global-scale. *Plant, Cell & Environment*, *18*(10), 1214–1225. doi:10.1111/j.1365-3040.1995.tb00630.x

Fischer, E. M., Seneviratne, S. I., Vidale, P. L., Luthi, D., & Schar, C. (2007). Soil moisture- atmosphere interactions during the 2003 European summer heat wave. *Journal of Climate*, *20*(20), 5081–5099. doi:10.1175/JCLI4288.1

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Fuglie, K. (2012). Productivity growth and technology capital in the global agricultural economy. In K. Fuglie, S. L. Wang, & V. Eldon Ball (Eds.), Productivity growth in agriculture: An international perspective. Oxfordshire, UK: CAB International.

Grey, D., & Sadoff, C. (2006). *Water for growth and development.* Thematic documents of the IV World Water Forum. Mexico City: Comision Nacional del Agua.

Hanjra, M. A., Ferede, T., & Gutta, D. G. (2009). Pathways to breaking the poverty trap in Ethiopia: Investments in agricultural water, education and markets. *Agricultural Water Management*, *96*(11), 1596–1604. doi:10.1016/j.agwat.2009.06.008

Hartmann, D. L., Klein Tank, A. M. G., Rusticucci, M., Alexander, L. V., Brönnimann, S., Charabi, Y., ... Zhai, P. M. (2013). Observations:Atmosphere and Surface. In T. F. Stocker, D. Qin, G. K. Plattner, M. Tignor, S. K. Allen, J. Boschung, ... P. M. Midgley (Eds.), *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge UniversityPress.

Held, I., & Soden, B. (2006). Robust responses of the hydrological cycle to global warming. *Journal of Climate*, *19*(21), 5686–5699. doi:10.1175/JCLI3990.1

Hungate, B. A., Reichstein, M., Dijkstra, P., Johnson, D., Hymus, G., Tenhumen, J. D., ... Drale, B. G. (2002). Evapotranspiration and soil water content in a scrub-oak woodland under carbon dioxide enrichment. *Global Change Biology*, *8*(3), 289–298. doi:10.1046/j.1365-2486.2002.00468.x

Hussain, I., & Hanjra, M. A. (2004). Irrigation and poverty alleviation: *Review of the empirical evidence. Irrigation and Drainage*, *53*(1), 1–15. doi:10.1002/ird.114

ICOLD (International Commission on Large Dams). (2003). *World Register of Dams, 2003*. Paris, France: International Commission on Large Dams.

IPCC. (1996). *Impacts, Adaptations, and Mitigation of Climate Change: Scientific-Technical Analyses - Contribution of Working Group II to the IPCC Second Assessment Report*. Cambridge, UK: Cambridge University Press.

IPCC. (2001). Impacts, Adaptation and Vulnerability. In J. J. McCarthy, O. F. Canziani, N. A. Leary, D. J. Dokken, & K. S. White (Eds.), *Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press.

IPCC. (2007). Climate Change 2007: *Mitigation of Climate Change*. In B. Metz, O. R. Davidson, P. R. Bosch, R. Dave, & L. A. Meyer (Eds.), *Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007*. Cambridge University Press.

Kirtman, B., Power, S. B., Adedoyin, J. A., Boer, G. J., Bojariu, R., Camilloni, I., ... Wang, H. J. (2013). Near-term Climate Change: Projections and Predictability. In T. F. Stocker, D. Qin, G. K. Plattner, M. Tignor, S. K. Allen, J. Boschung, ... P. M. Midgley (Eds.), *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Kurukulasuriya, P., & Rosenthal, S. (2003). *Climate change and agriculture: a review of impacts and adaptations. Climate Change Series Paper No. 91*. Washington, DC: World Bank.

Lambert, F. H., & Webb, M. J. (2008). Dependency of global mean precipitation on surface temperature. *Geophysical Research Letters*, *35*(16), L23803. doi:10.1029/2008GL034838

Lammertsma, E. I., de Boer, H. J., Dekker, S. C., Dilcher, D. L., & Lotter, A. F. (2011). Global CO_2 rise leads to reduced maximum stomatal conductance in Florida vegetation. *Proc. Acad. Sci. U.S.A.*, *108*(10), 4035–4040. doi:10.1073/pnas.1100371108 PMID:21330552

Lobell, D. & Gourdji, S. (2012). The influence of climate change on global crop productivity. *Plant Physiology*. .112.208298 doi:10.1104/pp

Londhe, S. L. (2016). Climate Change and Agriculture: Impacts, Adoption, and Mitigation. In *Handbook of Research on Climate Change Impact on Health and Environmental Sustainability*. IGI Global. doi:10.4018/978-1-4666-8814-8.ch019

Lu, J., & Cai, M. (2009). Stabilization of the atmospheric boundary layer and the muted global hydrological cycle response to global warming. *Journal of Hydrometeorology*, *10*(1), 347–352. doi:10.1175/2008JHM1058.1

McCartney, M., Rebelo, L. M., Xenarios, S., & Smakhtin, V. (2013). *Agricultural water storage in an era of climate change: assessing need and effectiveness in Africa.* Colombo, Sri Lanka: International Water Management Institute (IWMI). Retrieved February 21, 2015, from http://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/PUB152/RR152.pdf

Mendelsohn, R., & Neumann, J. E. (1999). *The Economic Impact of Climate Change on the Economy of the United States*. Cambridge, UK: Cambridge University Press. doi:10.1017/CBO9780511573149

Moreddu, C. (2000). Overview of Farm Household Strategies and Government Intervention. In Income Risk Management in Agriculture. Paris: OECD.

Myhre, G., Shindell, D., Bréon, F. M., Collins, W., Fuglestvedt, J., Huang, J., ... Zhang, H. (2013). Anthropogenic and Natural Radiative Forcing. In T. F. Stocker, D. Qin, G. K. Plattner, M. Tignor, S. K. Allen, J. Boschung, ... P. M. Midgley (Eds.), *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press.

Nelson, G. C., Rosegrant, M. W., Koo, J., Robertson, R., Sulser, T., Zhu, T., . . . Lee, D. (2009). *Food Policy Report- Climate Change, Impact on Agriculture and Costs of Adaptation*. International Food Policy Research Institute. Retrieved February 19, 2015, from http://www.ifpri.org/sites/default/files/publications/pr21.pdf

Parry, M. L. (2000). *Assessment of Potential Effects and Adaptations for Climate Change in Europe. The Europe Acacia Project*. University of East Anglia.

Patil, Y., & Rao, P. (2015). Industrial waste management in the era of climate change - A smart sustainable model based on utilization of active and passive biomass. In W. L. Filho (Ed.), *Handbook on Climate Change Adaptation* (pp. 2079–2092). Springer-Verlag Berlin Heidelberg. doi:10.1007/978-3-642-38670-1_49

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Peterson, D. F., & Keller, A. A. (1990). Effects of climate change on U.S. irrigation. *Journal of Irrigation and Drainage Engineering*, *116*(2), 194–210. doi:10.1061/(ASCE)0733-9437(1990)116:2(194)

Priestley, C. H. B. (1966). The limitation of temperature by evaporation in hot climates. *Agricultural Meteorology*, *3*(3-4), 241–246. doi:10.1016/0002-1571(66)90031-8

Rao, P., & Patil, Y. (2015). Climate Resilience in Natural Ecosystems in India: Technology Adoption and the Use of Local Knowledge Processes and Systems. In Handbook of Climate Change Adaptation. Springer Berlin Heidelberg.

Reilly, J., Tubiello, F., McCarl, B., Abler, D., Darwin, R., Fuglie, K., ... Rosenzweig, C. (2003). U.S. Agriculture and Climate Change: New Results. *Climatic Change*, *57*(1/2), 43–69. doi:10.1023/A:1022103315424

Rhein, M., Rintoul, S. R., Aoki, S., Campos, E., Chambers, D., Feely, R. A., ... Wang, F. (2013). Observations: Ocean. In T. F. Stocker, D. Qin, G. K. Plattner, M. Tignor, S. K. Allen, J. Boschung, ... P. M. Midgley (Eds.), *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press.

Rosenberg, N. J. (1992). Adaptation of Agriculture to Climate Change. *Climatic Change*, *21*(4), 385–405. doi:10.1007/BF00141378

Rosenberg, N. J., Kimball, B., Martin, P., & Cooper, C. (1988). Climate change, CO_2 enrichment and evapotranspiration. In P. E. Waggoner (Ed.), *Climate and Water: Climate Change, Climatic Variability, and the Planning and Management of U.S. Water Resources*. New York, NY: John Wiley and Sons.

Rosenzweig, C., & Liverman, D. (1992). Predicted Effects of Climate Change on Agriculture: A Comparison of Temperate and Tropical Regions. In S. K. Majumdar (Ed.), *Global Climate Change: Implications, Challenges, and Mitigation Measures.* Guelph: Natural Resources Canada.

Seneviratne, S. I., Corti, T., Davin, E. L., Hirschi, M., Jaeger, E. B., Lehner, I., ... Teuling, A. J. (2010). Investigating soil moisture-climate interactions in a changing climate: A review. *Earth-Science Reviews*, *99*(3-4), 125–161. doi:10.1016/j.earscirev.2010.02.004

Seneviratne, S. I., Nicholls, N., Easterling, D., Goodess, C. M., Kanae, S., Kossin, J., . . . Zhang, X. (2012). Changes in climate extremes and their impacts on the natural physical environment. In A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC SREX Report). doi:10.1017/CBO9781139177245.006

Skees, J. R., Hazell, P., & Miranda, M. (1999). *New Approaches to Crop Insurance in Developing Countries.* EPTD Discussion Paper No. 55. International Food Policy Research Institute.

Smit, B., & Olga, P. (2001). Adaptation to Climate Change in the Context of Sustainable Development and Equity. In J. J. McCarthy, O. F. Canzianni, N. A. Leary, D. J. Dokken, & K. S. White (Eds.), *Impacts, Adaptation, and Vulnerability - Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

Smithers, J., & Blay-Palmer, A. (2001). Technology Innovation as a Strategy for Climate Adaptation in Agriculture. *Applied Geography (Sevenoaks, England)*, *21*(2), 175–197. doi:10.1016/S0143-6228(01)00004-2

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

United Nations. (2011). *Seven billion and growing: the role of population policy in achieving sustainability.* Technical Paper No. 2011/3. Retrieved Feb 26, 2015, from http://www.un.org/esa/population/publications/technicalpapers/TP2011-3_SevenBillionandGrowing.pdf

Waggoner, P. E. (1983). *Agriculture and a climate changed by more carbon dioxide. Changing climate*. Washington, DC: National Academy Press.

White, W. R. (2005). *World water storage in man-made reservoirs: A review of current knowledge*. Marlow, UK: Foundation for Water Research.

WMO. (2014). WMO Greenhouse. *Gas Bulletin, 10*. Retrieved February 18, 2015, from http://www.wmo.int/pages/prog/arep/gaw/ghg/documents/GHG_Bulletin_10_Nov2014_EN.pdf

KEY TERMS AND DEFINITIONS

Adaptation: Adaptation is the process by which living organism changes to become better suited to survive in their environment. Adaptation can be a physical or genetic trait that helps an organism to be better suited to survive in the environment.

Agricultural Productivity: Agricultural productivity is the ratio of agricultural outputs to agricultural inputs. The agriculture inputs may include water, chemicals, fertilizers etc. used to grow crops to achieve desired yield as output.

Climate: It can be described as average temperature and precipitation over a period of time. Climate can be defined as an area's long-term weather patterns. The useful elements for describing climate include the type and the timing of precipitation, amount of sunshine, average wind speeds and directions, number of days above freezing, weather extremes, and local geography.

Climate Change: Climate change refers to any significant change in the measures of climate parameters lasting for an extended period of time. Climate change includes major changes in temperature, precipitation, or wind patterns, among other effects, that prevailing in a region over several decades or longer.

Mitigation: Mitigation in the context of climate change is an intervention intended to reduce adverse human influence on the climate system which includes strategies to reduce greenhouse gas sources, emissions and enhance greenhouse gas sinks.

Resilience: Resilience is the capacity of organism or system to withstand stress and catastrophe. In case of climate change the capacity of crop and livestock to withstand and sustain in the changing environment is the resilience.

Water Use Efficiency (WUE): Water use efficiency is the amount of water uptake by the plant and the amount of water used for metabolism and transpiration by the plant. WUE is simply ratio of water used in plant metabolism to water lost by the plant through transpiration.

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Chapter 58
Does Nonfarm Income Affect Agricultural Income and Investment in Pakistan?

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ABSTRACT

The study investigates the impact of nonfarm income (NFI) on agricultural income and investment using the Pakistan Social and Living Measurement survey data for the year 2005-06. Results show that NFI negatively affects agricultural income and investment whenever it is statistically significant; and these effects are not same across the four provinces of Pakistan. The one to one comparison between the four provinces of the country shows that the effects of NFI on agricultural income and investment differ across provinces. The policy implication is that as compared to other sectors of the economy, agriculture generates low returns and consequently NFI is invested in other more productive sectors of the economy.

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INTRODUCTION

Not all people receive their earnings from a single source, hold their wealth as one asset and employ their labor in one activity. Multiple motives encourage families and individuals to diversify their assets and income generating activities (Barett and Reardon, 2001). Participating in the nonfarm income (NFI) generating activities are one of the ways for rural households to diversify their earning sources and increase their gross income. In return, these earnings affect farm productivity by enhancing investment in farming. Studies show that NFI has positive effects on farm investment (Heartz, 2009) and increase expenditure on inputs (Kilic et al.,2009; Oseni & Winters, 2009; Pfeiffer et al., 2009). Consequently, farm productivity increases (Huang et al., 2009) and poverty reduces (Kijima et al., 2006; Ruben & Van Den Berg, 2001). NFI can also finance longer term on-farm capital investment such as construction of irrigation channels, purchase of machinery which can positively affect farm productivity (Barett and Reardon, 2001). Little et al. (2006) found that farm households diversify their earning sources to improve insurance against the risks of agro-climatic natural shocks, help overcome credit constraints and stabilize aggregate income flows. However, contrary to studies cited above, Pfeiffer et al. (2009) show that NFI negatively affects crop production, but positively effect the purchase of inputs. Hence, NFI has divergent effects on production and inputs use.It is the focus of this research in Pakistan, where agriculture is the second largest sector of country's economy contributing 21 percent to the GDP and provides livelihoods to 40 percent of the population.

It is generally believed that only poor households may diversify their earning sources to increase their aggregate income. However, this may not be true. Rich rural households diversify their earning sources to further maximize their profit while poor diversify to minimize risk, stabilize income and secure food access (Kilic et al., 2009). Haggblade et al. (2010) and Davis et al. (2007) identified the growth linkages between the agriculture sector and rural nonfarm employment. These linkages are: 1) the increase in income, increasing effective consumption of nonfarm products, affecting nonfarm employment; 2) the effect of demand-induced changes on downstream production linkages from processing and distribution; and 3) the changes in input-demand and its effect on production. This study focuses on the third linkage that is the nonfarm-income-induced demand for agricultural inputs and its effect on agricultural productivity. The selection is motivated by our lack of knowledge of the effect of NFI on agriculture sector in Pakistan. In an emerging economy like that of Pakistan, it is important to understand that why some farmer perform better than others? Does NFI create positive spillover effects on agriculture and livestock investment and consequently income? The four provinces of the country are agriculturally very different. Punjab and Sindh produce cash crops like cotton, rice and sugarcane while Baluchistan and Khyber Pakhtunkhwa have small natural resource base supporting livestock keeping. These differences raise the question that whether NFI have divergent effects on agriculture and livestock income and ivestment across these regions. This study estimates the effect of NFI on expenditure made on farm inputs and consequently farm income in Pakistan. Alternatively, the study investigates whether farmers who diversify their income have higher farm incomes as compared to other producers.

The study makes a three important contributions to the existing literature. First, it develops empirical models illustrating the effect of NFI on agricultural income and expenditures on crops and livestock raising in the country. Second, these models are used to test specific hypotheses about the effect of NFI on agricultural income and expenditures on crops and livestock raising across the four provinces of Pakistan. It is also important to mention that understanding behavior of agricultural households with respect to income and investment is important to analyze the effects of government interventions (e.g.,

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pricing policies, investment projects) and external changes in market conditions on the rural economy and livelihoods. Such knowledge becomes more important for a country like Pakistan where agriculture is the second largest sector of the economy. Third, the study provides empirical evidence on the effect of NFI on agricultural income and expenditures on crops and livestock raising which can help in developing the relevant policies for creating and promoting opportunities of earning NFI.

The next section presents the empirical model used to estimate the effect of NFI on agricultural income and investment, followed by discussion about data used in the analysis in section three. The estimated results are presented and discussed in section four, followed by conclusions given in section five.

The Agricultural Sector in Pakistan

Pakistan has two seasons, namely the '*kharif*' and '*rabi*'. *Kharif* begins in April-June and ends during October-December when *rabi* begins which ends in April-May. *Kharif* crops include rice, sugarcane, cotton, maize, mong and mash while *rabi* crops include wheat, gram, lentil, tobacco, rapeseed, barley and mustard. The agriculture sector is divided into crops, livestock, forestry and fishing sub-sectors. Crops sector is further divided into important crops, other crops and cotton ginning. Important crop sector includes cotton, sugarcane, wheat, rice and maize while the other crop sector consists of lentils, peas, potatoes, onions and chilies. The Agriculture sector accounts for 20.9 percent of the country's Gross Domestic Product (GDP) in 2015. The crop sector accounts for 43.7 percent of the 20.9 percent agricultural sector contributions to a country's GDP in 2015. In the crop sector, important crop sub-sector contributes 64.6 percent to the value added in the crops sector, followed by other crops (28.1%) and cotton ginning (7.3%). The livestock sector contributes 11.8 percent to the country's GDP and 56.3 percent to the agricultural GDP (GoP, 2011). The collective contribution of forestry and fishing to a country's GDP is less than one percent.

The Empirical Model

Consider an agrarian household endowed with land, capital, and inputs. The household faces decision variables of consumption, investment, and purchase of inputs for production. The household is assumed to maximize profit as producer and utility as a consumer. In case of capital constraint, the household can get any amount of credit from a perfect financial market. However, given the imperfect financial market in a developing country like Pakistan, household faces credit constraint. In such a case, household production and consumption decisions are inseparable (Taylor and Martin, 2001; de Janvry and Sadoulet, 2003). Hence, the household sacrifices its leisure time and participate in the NFI generating activities to earn more income and overcome the credit constraint. The NFI is then available for investment in the crops and livestock sectors. Consequently, agricultural (collectively crops and livestock) investment and income are expected to increase. Our specification of the econometric model is based on Kilic et al. (2009), and Osenia and Winters (2009). The empirical model postulates that the variable of interest (Y_i)in thousand rupees[1] is the function of socioeconomic variables, NFI of household i ($NFIii$) in thousand rupees and regional dummies (RD_i). Regional dummies (RDi) represent the four provinces of Pakistan such that RD_{i1}. represents Punjab, RD_{i2} represents Sind, RD_{i3} represents Khyber Pakhtunkhwa and RD_{i4} represents Baluchistan. The variable of interest includes agricultural income and expenditure made on crops production and livestock keeping. In the empirical model, farm charac-

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teristics such as land, poverty status (Evans and Nagau, 1991), education (Ellis, 2000), family size and marital status of the respondents are included. Marital status and family size are included in the model because these factors directly affect the supply of labor to NFI generating activities. Larger families can release more labor from farm production towards NFI generating activities.

$$\begin{aligned} Y_i = {} & \alpha_0 + \alpha_1 lNFI_i + \alpha_2 RD_{i1} + \alpha_3 RD_{i2} + \alpha_4 RD_{i3} + \alpha_5 RD_{i3} + \\ & \alpha_6 Poor_i + \alpha_7 lAge_i + \alpha_8 lFSize_i + \alpha_9 lFArea_i + \alpha_{10} Urban_i + \\ & \alpha_{11} lExpc_i + \alpha_{12} lExpl_i + \alpha_{13} Married_i + \alpha_{14} Literate_i + \varepsilon_i \end{aligned} \quad (1)$$

where i indexes households, Age_i represents age of the household head in years, $FSize_i$ is family size measured as number of family members, $FArea_i$ is farm area in hectares, $Urban_i$ is dummy, one representing urban areas zero otherwise, $Expc_i$ represents expenditure on crops in thousand rupees, $Expl_i$ is expenditure on livestock in thousand rupees, $Married_i$ is dummy, one for married household head zero otherwise, *Literatei* is a dummy, one for literate households zero otherwise, ε_i represents the random error assumed to be distributed normally with mean zero and variance σ^2, l stands for logarithm and α_i are the parameters to be estimated. The parameter α_1 indicates the effect of NFI (in thousand rupees) on the variable of interest in Pakistan. It is interpreted as the elasticity of NFI with respected to either agricultural income or farm investment.

Following Haq and Meilke (2010), and in order to compare the effects of NFI_i on Y_i across the provinces of Pakistan, regional (provincial) slope-shifters of NFI_i. were derived using the following relationship. These slopes allow testing regional specific hypotheses about the effect of NFI_i on variable of interest.

$$NFI_{iP} = Y_i * RD_{i1}\ NFI_{iS} = Y_i * RD_{i2} \quad (2)$$

$$NFI_{iK} = Y_i * RD_{i3}\ NFI_{iB} = Y_i * RD_{i4}$$

where NFI_{iP} represents nonfarm income of household i in Punjab, NFI_{iS} represents nonfarm income of household i in Sind, NFI_{iK} represents nonfarm income of household i in KP and NFI_{iB} represents nonfarm income of household i in Baluchistan. Augmenting equation (1) with the regional NFI_i shifters yields equation (3).

$$\begin{aligned} Y_i = {} & \delta_0 + \delta_1 lNFI_{ip} + \delta_2 lNFI_{iS} + \delta_3 lNFI_{iK} + \delta_4 lNFI_{iB} + \\ & \delta_5 Poor_i + \delta_6 lAge_i + \delta_7 lFSize_i + \delta_8 lFArea_i + \delta_9 Urban_i + \\ & \delta_{10} lExpc_i + \delta_{11} lExpl_i + \delta_{12} Married_i + \delta_{13} Literate_i + \varepsilon_i \end{aligned} \quad (3)$$

Consider Y_i Y_i to be agricultural income than the following hypotheses are tested using equation (3).

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H_1: Nonfarm income does not determine agricultural income in the provinces of Pakistan.
H_2: The effect of NFI on agricultural income is similar across the four provinces of the country.

Similarly other hypotheses are tested using the same equation, results of which are compiled in tables 5 and 6.

DATA

This study uses the cross-sectional data collected under the Pakistan Social and Living Measurement Survey (PSLM) for the year 2005-06. The survey was carried in all the four provinces of the country. The survey is conducted by Federal Bauru of Statistics (FBS) bi-annually. FBS has developed its own sampling frame for urban and rural areas. Each frame is split into enumeration blocks. Each enumeration block consists of 200 to 250 households. Each block is divided into lower, middle and high income groups. FBS obtains list of villages from the Population Census Organization of the country. Urban domain consists of big cities like Islamabad, Lahore, Gujranwala, Faisalabad, Rawalpindi, Multan etc. Stratum from urban areas also classified according to income levels. After excluding population of the large sized cities, the remaining urban population in each defunct Division in all the provinces has been grouped together to form a stratum. Each district in the provinces are grouped to constitute a stratum, whereas defunct administrative division has been treated as stratum in Baluchistan province.

FBS determined a sample size of 15512 households in the country. This sample size is obtained from 1113 sample enumeration blocks. Our sample includes only those households who cultivate land. In this way the sample reduces to 3704 households. Detail of the sample frame across the four provinces is given in Table 1.

RESULTS AND DISCUSSION

This first part presents the effect of NFI on agricultural income and investment (Table 2), followed by similar effects estimated for crops (Table 3) and livestock (Table 4) sectors. Each table consists of four models, two each for expenditure and income both distinguished by the inclusion/exclusion of regional dummies.

Table 1. Distribution of sample across provinces

Province	Count	Percent
Punjab	1631.0	44.0
Sindh	844.0	22.8
NWFP	796.0	21.5
Balochistan	433.0	11.7
Pakistan	3704.0	100.0

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Table 2. OLS estimates of the effect of nonfarm income on agricultural income and farm investment

Variables	Model-1	Model-2	Model-3	Model-4
	Agricultural Income		Agricultural Investmen	
Poverty (Poor is 1, otherwise 0)	0.048	0.167***	0.004	0.410***
	(0.066)	(0.030)	(0.098)	(0.044)
Age (Years)	0.107	0.066	-0.005	0.037
	(0.104)	(0.048)	(0.145)	(0.073)
Family Size (No. of persons)	0.089	0.159***	0.402***	0.337***
	(0.057)	(0.026)	(0.087)	(0.050)
Farm Area (Hectares)	0.055*	0.017	0.301***	0.447***
	(0.028)	(0.015)	(0.040)	(0.026)
Urban (Urban is 1, otherwise 0)	-0.253*	0.025	-0.319*	-0.097
	(0.141)	(0.055)	(0.172)	(0.102)
Expenditure on Crops (Rs/Year)	0.414***	0.485***	----	----
	(0.029)	(0.014)	----	----
Expenditure on Livestock (Rs/Year)	0.278***	0.214***	----	----
	(0.042)	(0.016)	----	----
Nonfarm Income (Rs (000)/Year)	-0.032	----	0.178***	----
	(0.032)	----	(0.048)	----
Punjab (Punjab is 1, otherwise 0)	0.068	----	0.730***	----
	(0.111)	----	(0.147)	----
Sind (Sind is 1, otherwise 0)	0.345**	----	0.898***	----
	(0.119)	----	(0.169)	----
KP (KP is 1, otherwise 0)	0.202*	----	-0.478**	----
	(0.121)	----	(0.163)	----
Married (Married is 1, otherwise 0)	-0.09	-0.078	0.293	0.015
	(0.125)	(0.069)	(0.196)	(0.111)
Literate (Literate is 1, otherwise 0)	0.159	0.322	0.635	0.221
	(0.337)	(0.233)	(0.626)	(0.314)
Nonfarm Income-Punjab (Rs (000)/Year)	----	-0.042***	----	-0.005
	----	(0.009)	----	(0.017)
Nonfarm Income-Sind (Rs (000)/Year)	----	0.023	----	0.009
	----	(0.017)	----	(0.031)
Nonfarm Income-KP (Rs (000)/Year)	----	-0.019*	----	-0.249***
	----	(0.012)	----	(0.016)
Nonfarm Income-Baluchistan (Rs (000)/Year)	----	-0.058	----	-0.275***
	----	(0.039)	----	(0.046)
R-squared	0.668	0.728	0.399	0.309
Number of observations	3704	3704	3704	3704
F-Statistics	75.01***	373.2***	41.56***	88.6***

Note: *, ** and *** denote variables significant at 0.1, 0.05 and 0.01 level of probability respectively. All the standard errors are corrected for heteroscadasticity.

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Table 3. OLS estimates of the effect of nonfarm income on crops' income and expenditure

Variable	Dependent Variable			
	Log of Crops Expenditure		Log of Crops Income	
Poverty (Poor is 1, otherwise 0)	0.115	0.530***	0.057	0.085***
	(0.112)	(0.050)	(0.056)	(0.025)
Age (Years)	-0.153	-0.045	-0.033	0.01
	(0.154)	(0.080)	(0.077)	(0.039)
Family Size (No. of persons)	0.336***	0.294***	0.129**	0.177***
	(0.096)	(0.050)	(0.052)	(0.023)
Farm Area (Hectares)	0.337***	0.577***	0.060**	0.065***
	(0.050)	(0.027)	(0.022)	(0.011)
Urban (Urban is 1, otherwise 0)	-0.252	-0.044	-0.158	0.039
	(0.160)	(0.103)	(0.106)	(0.042)
Expenditure on Crops (Rs/Year)		----	0.715***	0.711***
		----	(0.027)	(0.010)
Nonfarm Income (Rs (000)/Year)	0.182**	----	-0.052*	----
	(0.057)	----	(0.029)	----
Punjab (Punjab is 1, otherwise 0)	0.442**	----	-0.160*	----
	(0.169)	----	(0.087)	----
Sind (Sind is 1, otherwise 0)	0.789***	----	0.071	----
	(0.188)	----	(0.100)	----
KP (KP is 1, otherwise 0)	-1.023***	----	-0.008	----
	(0.185)	----	(0.098)	----
Nonfarm Income-Punjab (Rs (000)/Year)	----	-0.019	----	-0.052***
	----	(0.020)	----	(0.007)
Nonfarm Income-Sind(Rs (000)/Year)	----	0.024	----	0.012
	----	(0.034)	----	(0.018)
Nonfarm Income-KP (Rs (000)/Year)	----	-0.310***	----	-0.028**
	----	(0.017)	----	(0.010)
Nonfarm Income-Balochistan (Rs (000)/Year)	----	-0.223***	----	0.012
	----	(0.057)	----	(0.028)
Married (Married is 1, otherwise 0)	0.487**	0.189	0.097	-0.037
	(0.206)	(0.120)	(0.102)	(0.054)
Literate (Literate is 1, otherwise 0)	0.815	0.074	0.498**	0.347**
	(0.863)	(0.457)	(0.177)	(0.138)
Summary Statistics				
R-squared	0.449	0.385	0.774	0.818
Number of observations	3704	3704	3704	3704
F-Statistics	51.94***	137.50***	142.77***	778.36***

Note: *, ** and *** denote variables significant at 0.1, 0.05 and 0.01 level of probability respectively. All the standard errors are corrected for heteroscadasticity.

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Table 4. OLS estimates of the effect of nonfarm income on livestock income and expenditure

Variable	Dependent Variable			
	Log of Livestock Expenditure		Log of Livestock Income	
Poverty (Poor is 1, otherwise 0)	-0.04	0.367***	-0.051	0.145**
	(0.110)	(0.046)	(0.108)	(0.049)
Age (Years)	0.151	0.123*	0.112	0.177**
	(0.143)	(0.073)	(0.143)	(0.078)
Family Size (No. of persons)	0.210**	0.233***	-0.014	0.090**
	(0.088)	(0.047)	(0.086)	(0.042)
Farm Area (Hectares)	0.200***	0.287***	0.019	-0.050**
	(0.034)	(0.019)	(0.033)	(0.019)
Urban (Urban is 1, otherwise 0)	0.326**	0.087	-0.417*	-0.079
	(0.125)	(0.088)	(0.226)	(0.090)
Expenditure on Livestock (Rs/Year)			0.601***	0.638***
			(0.081)	(0.030)
Nonfarm Income (Rs (000)/Year)	0.232***		0.031	
	(0.044)		(0.046)	
Punjab (Punjab is 1, otherwise 0)	0.723***		0.288*	
	(0.173)		(0.170)	
Sind (Sind is 1, otherwise 0)	0.574**		0.554**	
	(0.243)		(0.177)	
KP (KP is 1, otherwise 0)	-0.108		0.446**	
	(0.186)		(0.166)	
Nonfarm Income-Punjab (Rs (000)/Year)	0.079	-0.084	-0.208	-0.228**
	(0.176)	(0.102)	(0.169)	(0.091)
Nonfarm Income-Sind(Rs (000)/Year)	-0.126	0.347	0.177	0.409
	(0.449)	(0.300)	(0.432)	(0.374)
Nonfarm Income-KP (Rs (000)/Year)		0		0
		(0.016)		(0.015)
Nonfarm Income-Balochistan (Rs (000)/Year)		-0.058		0.079***
		(0.061)		(0.024)
Married (Married is 1, otherwise 0)		-0.170***		0.019
		(0.016)		(0.015)
Literate (Literate is 1, otherwise 0)		-0.255**		-0.06
		(0.079)		(0.059)
Summary Statistics				
R-squared	0.262	0.209	0.339	0.341
Number of observations	3704	3704	3704	3704
F-Statistics	21.99***	52.13***	19.95***	64.97***

Note: *, ** and *** denote variables significant at 0.1, 0.05 and 0.01 level of probability respectively. All the standard errors are corrected for heteroscadasticity.

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In case of agricultural income and investment, results are compiled in table 2. Model-1 shows the effect of NFI on agricultural income while Model-2 shows the same effect for the four provinces of Pakistan. Model-3 and 4 shows the effect of NFI on farm investment in the country and across the four provinces respectively. Results show that all the estimated models fit the data as well as the coefficient of determination ranges from 30.9% for model-4 to 72.8 for model-1. F-statistics show that all the estimated models are statistically significant, indicating that the hypotheses that the coefficients of regression models except the intercept are zero, is rejected at the 0.01 level of significance.

Table 2 further shows that as compared to poor households, non-poor households invest more in agricultural production and generate more agricultural income. Non-poor invest 50.7[2] percent of agricultural production and generate 18.2 percent more agricultural incomes, keeping other variables constant. However, with the inclusion of provincial slope shifters in the model (Model-1 and 3), this effect fades away. Age of the household head does not statistically significantly affect agricultural income and farm investment. Family size is statistically significant determinant when NFI provincial slope shifters are included in the model (Model-2). The effect of farm area on agricultural income and farm investment is statistically significant, but inelastic implying that increase in the farm area increases investment cost more, but yields proportionately less income. Its coefficient in model-4 shows that a one percent increase in the farm area increases farm investment by 0.45 percent, keeping other variables constant. However, its effect on farm investment is high as compared to its effect on agricultural income. Households located in the urban areas invest 37.6 percent less (model-3) and generate 28.7 percent more income. The effect of marriage and literacy on agricultural income as well as investment is statistically insignificant in all the models. Further, the effect of NFI on agricultural income is statistically not significant (Model-1), however, it is an important determinant of the farm investment (Model-3). The regional dummies show that as compared to Baluchistan, agricultural income is high by 41.2 percent in Sind and 22.4 percent in Khyber Pakhtunkhwa. Similarly, as compared to Baluchistan, production costs are higher by 107.5 percent in Punjab, 145.5 percent in Sind and lower by 38 percent in Khyber Pakhtunkhwa. Hence, production costs and agricultural income vary across the provinces.

The table also shows that the effect of Niño agricultural income in Punjab and Khyber Pakhtunkhwa (KP) is statistically significant while its effect on agricultural investment is also statistically significant and negative in KP and Baluchistan. The estimated results show that a ten percent increase in NFI decreases agricultural income by 0.4 percent in Punjab and by 0.2 percent in Khyber Pakhtunkhwa. Similarly, a ten farm increase in nonfarm in Khyber Pakhtunkhwa and Baluchistan decreases farm investment by 2.5 and 2.8 percent, respectively. The collective implications of these results are that returns in agriculture sector as compared to other sectors of the economy are low. Further, NFI may not be readily available to the farm sector for investment due to many reasons including the consumption, social and financial requirements of rural households. Also, the effect of the NFI on farm income and investment may be different not only across the crops and livestock sectors but also across time and regions. Hence, farm households do not invest the additional income in agriculture production and consequently its effect on agricultural income is negative.

Agricultural income and investment are then split into crops and livestock income and investments and the effect of the NFI is separately estimated on these sectors. Estimated results for the crops and livestock sectors are given in tables 3 and 4 respectively. However, separately estimating the models for crops and livestock sectors did not change the effect of most of the variables on both income and investment. For both the sectors (Tables 3 and 4), the effect of NFI on the variable of choice is negative when statistically significant with the exception of livestock sector in Balochistan (Table 4). In Balochistan,

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a ten percent increase in the NFI marginally (0.8%) increases investment in livestock sector. Hence, on an overall, the direction of the results presented in table 2 hold for both crops and livestock sectors.

The estimated parameters of NFI are then used to estimate a number of hypotheses about agricultural income and investment and results are compiled in Tables 5 and 6, respectively.

Results show that NFI is an important determinant of both agricultural investments (Table 5) and income (Table 6). The impact of NFI on agricultural investment (Table 5) and income (table 6) differs across the four provinces of the country. Its effect on agricultural income between Punjab and Sindh, Punjab and KP, Sind and KP and Sind and Baluchistan are statistically different. Similarly, the effect of NFI on agricultural investment is also statistically significant (Table 6). Its effect on agricultural investment between Punjab and KP, Punjab and Baluchistan and Sind and KP and Sind and Baluchistan are statistically different.

Table 5. Test of the hypotheses about the role of nonfarm income in farm investment

Hypothesis	F-Statistics
Nonfarm income does not affect agricultural production cost.	71.19***
The effect of nonfarm income on agricultural production cost is same across the provinces of Pakistan	56.93***
The effect of nonfarm income on agricultural production cost in Punjab is similar to its effect in Sind	0.17
The effect of nonfarm income on agricultural production cost in Punjab is similar to its effect in Khyber Pakhtunkhwa.	135.14***
The effect of nonfarm income on agricultural production cost in Punjab is similar to its effect in Baluchistan	31.39***
The effect of nonfarm income on agricultural production cost in Sind is similar to its effect in Khyber Pakhtunkhwa.	58.33***
The effect of nonfarm income on agricultural production cost in Sind is similar to its effect in Baluchistan.	26.88***
The effect of nonfarm income on agricultural production cost in Khyber Pakhtunkhwa is similar to its effect in Baluchistan.	0.28

Note: *, ** and *** denote variables significant at 0.1, 0.05 and 0.01 levels, respectively.

Table 6. Test of the hypotheses about the role of nonfarm income in agricultural income

Hypothesis	F-Statistics
Nonfarm income does not affect agricultural income.	7.20***
The effect of nonfarm income on agricultural income is same across the provinces of Pakistan	4.44**
The effect of nonfarm income on agricultural income in Punjab is similar to its effect in Sind	11.66**
The effect of nonfarm income on agricultural income in Punjab is similar to its effect in Khyber Pakhtunkhwa.	2.83*
The effect of nonfarm income on agricultural income in Punjab is similar to its effect in Baluchistan	0.17
The effect of nonfarm income on agricultural income in Sind is similar to its effect in Khyber Pakhtunkhwa.	4.22*
The effect of nonfarm income on agricultural income in Sind is similar to its effect in Baluchistan.	3.74*
The effect of nonfarm income on agricultural income in Khyber Pakhtunkhwa is similar to its effect in Baluchistan.	0.93

Note: *, ** and *** denote variables significant at 0.1, 0.05 and 0.01 levels, respectively.

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CONCLUSION

Nonfarm income can be used to timely purchase crops and livestock inputs and undertake scheduled farm production and harvesting activities. However, there is no evidence suggesting that NFI has positive effects on agricultural income and investment in Pakistan. This study underscores the existing literature by providing the evidence on the effect of NFI on agricultural productivity in Pakistan using the Pakistan Social and Living Measurement survey.

The econometric analysis investigating the effect of NFI on agricultural income and expenditure shows that nonfarm is an important determinant of agricultural income. The effect of NFI on agricultural income is not same across the four provinces of Pakistan. Its effect on agricultural income between Punjab and Sindh, Punjab and KP, Sind and KP and Sind and Baluchistan are statistically different. Similarly, the effect of NFI on agricultural investment is also statistically significant. Its effect on agricultural investment between Punjab and KP, Punjab and Baluchistan and Sind and KP and Sind and Baluchistan are statistically different.

The authors highlighted that if there are negative linkages between NFI and agricultural production, then understanding the nature of these linkages could prove useful in designing programs to facilitate agricultural households' adjustment to rural economic change.

LIMITATIONS AND FUTURE DIRECTION

The study uses PSLM data in the analysis. PSLM data provides enterprise specific output data but does not provide similar data for inputs. Hence, using PSLM data it is not possible to determine the effect of NFI on major crops raised in different agro-ecological zones of the country. Hence, an investigation of the effect of NFI on major crops in different agro-geographical regions of the country is required. Further, since agriculture is one of the biggest sectors of the economy and is a source of livelihood for about one-half of the population, it is important to understand the effect of NFI on poverty in the country. This study also ignored the effect of NFI on variability and distribution of rural household's income.

REFERENCES

Barett, C. B., & Reardon, T. (2001). *Asset, activity, and income diversification among African agriculturists: Some practical issues*. UASID Basis CRSP.

Davis, B., Winters, P., Carletto, C., Covarrubias, K., Quinones, E., & Zezza, A. (2007). Rural income generating activities: Across country comparison. *World Development*, 119–123.

deJanvry, A., & Sadoulet, E. (2003). *Progress in the modeling of rural households' behavior under market failures. Chapters in Honor of Erik Thorbecke*. New York: Kluwer Publishing.

Ellis, F. (2000). *Rural Livelihoods and Diversity in Developing Countries*. Oxford, UK: Oxford University Press.

Evans, H. E., & Ngau, P. (1991). Rural-urban relations, household income diversification and agricultural productivity. *Development and Change*, *22*(3), 519–545. doi:10.1111/j.1467-7660.1991.tb00424.x

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

GoP. (2011). *Economic survey of Pakistan. Economic Advisory Wing. Finance division*. Islamabad: MINFAL Pakistan.

Haggblade, S., Hazell, P., & Reardon, T. (2010). The Rural Non-farm Economy: Prospects for Growth and Poverty Reduction. *World Development*, *38*(10), 1429–1441. doi:10.1016/j.worlddev.2009.06.008

Haq, Z., & Meilke, K. (2010). Do the BRICs and Emerging Markets Differ in their Agrifood Trade? *Journal of Agricultural Economics*, *61*(1), 1–14. doi:10.1111/j.1477-9552.2009.00229.x

Hertz, T. (2009). The effect of nonfarm income on investment in Bulgarian. *Agricultural Economics*, *2*(40), 161–176. doi:10.1111/j.1574-0862.2009.00367.x

Huanga, J., Wu, Y., & Rozelle, S. (2009). Moving off the farm intensifying agricultural production in Shandong: A case study of rural labor market linkages in China. *Agricultural Economics*, *2*(40), 203–218. doi:10.1111/j.1574-0862.2009.00370.x

Kijima, Y., Matsumoto, T., & Yamano, T. (2006). Nonfarm employment, agricultural shocks, poverty dynamics: Evidence from rural Uganda. *Agricultural Economics*, 459-467.

Kilic, T., Carletto, C., Miluka, J., & Savastano, S. (2009). Rural nonfarm income its effect on agriculture: Evidence from Albania. *Agricultural Economics*, *2*(40), 139–160. doi:10.1111/j.1574-0862.2009.00366.x

Little, P., Stone, P., Mogues, T., Castro, P., & Negatu, W. (2006). Moving in place drought and poverty dynamics in South Wollo, Ethiopia. *Development Studies,* (42), 200-225.

Oseni, G., & Winters, P. (2009). Rural nonfarm activities and agricultural crop. *Agricultural Economics*, *2*(40), 189–201. doi:10.1111/j.1574-0862.2009.00369.x

Pfeiffer, L., Feldman, L. A., & Taylor, J. (2009). Is off-farm income reforming the farm? *Evidence from Maxico.*, *2*(40), 125–138.

Ruben, R., & Van Den Berg, P. (2001). Nonfarm employment and poverty alleviation of rural farm households in Honduras. *World Development*, *3*(29), 549–560. doi:10.1016/S0305-750X(00)00107-8

Taylor, J. E., & Martin, P. (2001). Human capital: Migration and rural population change. In B. Gardener & G. Rausser (Eds.), *Handbook of Agricultural Economics* (Vol. 1, pp. 457–511). Amsterdam: Elsevier.

ENDNOTES

1 One average, one US$ = 85.5 Rupees during the study period.

2 Proportionate effect of a dummy variable is calculated as (Exponent (α)-1)*100. Hence, (Exponent (0.41)-1)*100=50.68 ≈ 50.7.

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Chapter 59
Social and Environmental Impacts on Agricultural Development

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ABSTRACT

Addressing environmental and social impacts on agricultural development and food security is a global priority since increased food production of 60-70% is estimated to be required by 2050 to feed the growing world population. In developing nations, the situation is more acute since fewer social, technological and financial resources are available to combat climate change, which is expected to have negative effects on agricultural production, and there are other constraints to achieving food security. This chapter explores the social and environmental issues affecting agricultural production facing farmers and other agricultural practitioners, policy makers, institutions and stakeholders in the developing world. It will also address how progress in research in emerging economies can be put to maximum benefit in the face of these existing social and environmental challenges. A cohesive strategy to address these challenges is presented.

INTRODUCTION

The world's population is expected to increase to 9 billion by 2050 (Hubert, Rosegrant, Van Boekel & Ortiz, 2010), and it is estimated that a 60-70% global increase in food production is needed to feed this growing population (Consultative Group for International Agricultural Research (CGIAR), 2015; FAO, 2007, 2014; Mba, Guimaraes, & Ghosh, 2012). Currently, approximately 2 billion persons are food insecure since they do not meet one or several of the Food and Agriculture Organisation's (FAO's) dimensions of food security (access to adequate food, availability and utilization of nutritious food and stable supply (Hubert et al., 2010; Wheeler & von Braun, 2013)). Furthermore, 805 million persons did

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not have access to sufficient food during 2012-2014 (Maggio, Van Criekinge, & Malingreau, 2015). Food availability must increase to meet demand by 100% in developing countries (CGIAR, 2015). This can be achieved through increasing production as well as reducing losses (food waste). Improving agriculture[1] to meet the Millennium Development Goals[2] of the United Nations, which include halving extreme poverty and hunger by 2015 and eliminating it by 2030 (under the sustainable development agenda), requires optimisation of agricultural practices and systems, and dealing effectively with technological, social, environmental as well as economic issues that influence the sustainability of agricultural production. The United Nations Framework Convention on Climate change (UNFCCC) (2007) described the developing nations as most vulnerable to climate change impacts that are expected to have negative effects on agricultural production and food security, as described by the International Food Policy Research Institute (IFPRI, 2009). This is attributed to the limited social, technological and financial resources available to address climate change in these countries.

Currently, sustainable food security and agricultural development are constrained globally by degradation and loss of agricultural land, the loss of biodiversity, depletion of water and other resources and pollution (Chaudhury, Vervoort, Kristjanson, Ericksen, & Ainslie, 2103; Sonnino, Moragues Faus, & Maggio, 2014). These factors are exacerbated by the negative impacts of climate change and may also contribute to climate change.

This chapter explores the social and environmental issues facing agricultural practitioners (producers and entrepreneurs alike) in the developing world, who are striving to contribute to food security in their communities and, by extension, the world. It will also address how the progress in research in emerging economies can be put to maximum benefit in the face of existing social and environmental challenges in developing nations, as described by Ejeta (2009).

Heat stress could affect developing countries by 2030 (Inter-Governmental Panel on Climate Change (IPCC), 2007, 2013). Expenditure of USD 200 and 250 billion a year may be required to address negative impacts of climate change in developing countries (Peterson, 2011). These impacts can significantly reduce sustainability of livelihoods and the well-being of citizens in developing nations (Noble et al., 2014).

A multi-sector approach is advocated to deal with the challenges and potential impact of social and environmental factors such as climate change on food security. The proposed model encompasses the role of farmers, entrepreneurs, social policy makers, governments, the private sector, scientists and organisations in a cohesive strategy. The role of education and extension in preparing for the impacts of climate change, as described by Bekele and Ganpat (2014) in the context of small island developing states (SIDS), is also discussed.

In order to illustrate the current situation, constraints and putative solutions to social and environmental impacts on agricultural development and food security in developing countries, several staple crops in Africa, Latin America and the Caribbean (LAC) and the commodity, cocoa, are highlighted in this chapter.

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CURRENT STATUS OF AGRICULTURAL DEVELOPMENT AND FOOD SECURITY IN DEVELOPING NATIONS

1. Africa

In Africa, the agriculture sector employs 60% of the total population, contributes 20% to the gross domestic product (GDP) and earns more than 10% of export revenues (Sasson, 2102). It is expected that access to adequate and secure food would be a priority in Africa. However, in 2010, the number of food insecure persons in Sub-Saharan Africa was estimated at 239 million, and in North Africa it was 37 million (Sasson, 2012). The main cause of food insecurity in Africa was identified as insufficient food production (Beddington et al., 2012; Sasson, 2012). Soaring world food prices and rural migration have exacerbated the situation, and the impacts of climate change could be detrimental. High food prices have resulted in a significant percentage of the African population spending more than half their income on food. There have been recurrent droughts in the Horn of Africa since 2009 as well as a history of famines due to drought. Mba et al. (2012) described Africa as one of the most vulnerable continents to climate change and variability. The expected decrease in the length of the growing seasons of African crops (Thornton & Herrero, 2015) will result in the further loss of production in marginal agriculture.

Crop yields in Africa can decrease by as much as 50% by 2020 due to climate change, and this could result in lower calorific intake by humans (by as much as 500 calories per capita in 2050, a 21% decline) (Toulmin, 2009). Jarvis, Ramirez-Villegas, Campo, and Navarro-Racines (2012) found that while cassava is likely be affected positively by climate change in many areas of Africa (−3.7% to +17.5% changes in climate suitability across the continent), other major food staples in Africa are expected to face negative impacts, with the most significant predicted for beans ($-16\% \pm 8.8$), potato (-14.7 ± 8.2), banana ($-2.5\% \pm 4.9$), and sorghum ($-2.66\% \pm 6.45$). For resource-poor farmers in developing countries such as Africa, the use of fertilizers that could improve plant vigour, root growth and access to soil moisture, and irrigation to combat drought may not be feasible options to address climate change (Beebe et al., 2011).

Mixed farming (crop-livestock) systems form the mainstay of African agriculture and have certain benefits (Thornton & Herrero, 2015). The adaptation potential of these systems must be examined in the face of climate change since they are complex. Furthermore, there is very little data currently available on putative climate change impacts on these systems.

2. Latin America and the Caribbean

In Latin America and the Caribbean (LAC), approximately 15.9% of the labour force is directly involved in agriculture (Andersen et al., 2014). LAC's agricultural market share increased from 9.5% in 1980 to 18.1% in 2010 (Flachsbarth et al., 2015). The largest agricultural sectors in LAC are based on livestock, feedstuff and biofuel crops (Flachsbarth et al., 2015).

The contribution of agriculture to overall GDP ranges from 3.1% in Mexico to more than 5.5% in Brazil and to 7.8% in Peru (Andersen et al., 2014). From 1961 to 2007, LAC had the highest growth rate in agricultural productivity among developing regions (1.9%) (Ludena, 2010). The LAC countries with the highest land availability, such as Brazil, Argentina, Chile, Colombia, Mexico and Venezuela, have the most significant agricultural production (Ludena, 2010). Caribbean countries experienced limited growth by comparison (0.5%) (Ludena, 2010). Most of that growth occurred in the livestock sector,

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especially for non-ruminants (pigs and poultry). The most valuable agricultural export products from LAC currently are soybeans and cane sugar (Flachsbarth et al., 2015).

Wickham (1992) underscored the need for further development in vegetable production in the Caribbean to foster self-sufficiency in this area. Priority areas identified were germplasm enrichment and enhancement, selection of superior cultivars, development of more efficient production systems (including disease and pest management) and application of post-harvest technologies to promote the shelf-life of vegetables. Several other issues related to agricultural development and food security have been identified as requiring attention in LAC. These include improved partnerships among public sector, agencies, research institutions and the private sector to deliver food production programmes and transfer post-harvest and other technologies to farmers to assure food quality and availability (Roberts, Ganpat, Narine, Heinert, & Rodriguez, 2015). Farmer training through extension services is essential.

Climate change can also adversely affect crop production in LAC. Andersen et al. (2014) modelled the impact of climate change in the major agricultural producing countries in LAC, *viz.*, Brazil, Peru and Mexico. They projected that in Brazil, the effect on soybean production could be of the magnitude of –0.5 and +0.3% per annum. In Mexico, maize is the main agricultural product and accounts for 14 to 22% of the regional agricultural GDP. A decrease of 0.3% per annum was predicted for this crop. In Peru, the production of potatoes was forecasted to change by –0.6 to +0.2%.

Jarvis et al. (2008) predicted reductions in rice yields in Latin America by the 2020s, but increases in soybean production due to possible increases in carbon emissions. They also forecasted:

- Reduced acreage of land available for coffee production in Brazil,
- Lower coffee production in Mexico,
- Salinization and desertification of agricultural lands in drier areas of Latin America, and
- Probable increased incidence of the coffee leaf miner (*Perileucoptera coffeella*) and the nematode *Meloidogyne incognita* in Brazilian coffee-growing areas.

In addition, the risk of *Fusarium* head blight in wheat may increase under climate change in southern Brazil and Uruguay (Fernandes et al., 2004).

Overall, the combined impacts of climate change are estimated to amount to less than 1% of household incomes during the next 40 years in Brazil, Peru and Mexico (Andersen et al., 2014). The negative impacts on agricultural production in these countries were forecasted to be somewhat balanced by increased commodity prices. This was based on the premise that any large increases in the global prices of agricultural products, caused by climate change, will tend to benefit these agricultural producers of the respective commodities. However, for the land-constrained Caribbean countries, any further reduction in agricultural productivity will restrict the likelihood of achieving food security and poverty reduction. These countries are currently mainly net food importers. The Windward Islands have suffered significantly with the removal of the European Union preferential trade tariffs for banana imports. According to Ganpat and Isaac (2014) and Hutchinson et al. (2013), these SIDS are very vulnerable to the impact of climate change.

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ENVIRONMENTAL ISSUES CRITICAL TO AGRICULTURAL DEVELOPMENT AND FOOD SECURITY

The following are some of the pertinent environmental issues to be considered with regard to agricultural development and food security in developing nations:

- Environmental impacts on production, productivity and product quality;
  - Impacts of climate change on agriculture and post-harvest production;
- Ensuring a reliable supply of produce or commodity under climate change;
- Use of superior (in terms of yield/productivity, vigour and pest and disease resistance) and climate-smart crop varieties;
- Improving energy efficiency of crop and livestock production (reduction in carbon emissions and prudent use of energy):
  - Application of eco-friendly sustainable practices such as organic fertilisation and pruning of crops;
  - Choosing the most efficient crop production system for specific crops and environments (such as terrains on steep slopes and multi-cropping on impoverished soils (Bekele & Ganpat, 2014)); and
- Monitoring land conversion/biodiversity losses.

Climate-Change Impacts on Agricultural Development and Food Security

According to FAO (2007), climate change impacts can be classified into two groups, *viz.*, biophysical impacts:

- Physiological effects on crops, forests and livestock (quantity, quality) and availability of fodder and pastures;
- Changes in land, soil and water resources (quantity, quality);
- Increased weed and pest challenges;
- Shifts in spatial and temporal distribution of impacts;
- Sea level rise, changes to ocean salinity and
- Sea temperature rise causing fish to inhabit different ranges.

and socio-economic impacts:

- Decline in yields and production;
- Reduced GDP from agriculture;
- Fluctuations in world market prices;
- Changes in geographical distribution of trade regimes;
- Increased number of people at risk of hunger and food insecurity and
- Migration and civil unrest (increased crime).

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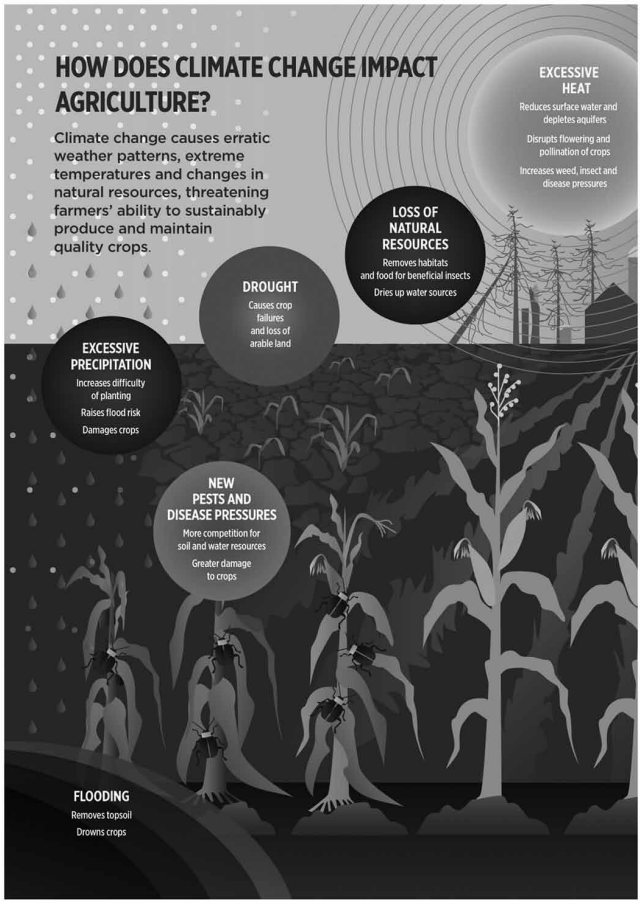
Climate Change Impacts on Crop Production

Global

Global warming and the El Niño effect, with the attendant drought, floods, increased temperature of the atmosphere and oceans and salinity and shifts in weather patterns, have the capacity to significantly reduce yields of food crops (refer to Figure 1) including staples such as rice, wheat, corn and barley (Beddington et al., 2012; Rosegrant, 2011). The potential impacts in small island developing states (SIDS) have been discussed by Roberts and Rodriguez (2014). The situation is compounded by the need to produce bio-fuels to reduce the carbon footprint of nations and meet the increasing demand for energy/fuel. This implies competition for food crops with biomass attributes favoured for biofuel production. Crop production will also be constrained by the spread of invasive species such as pests and fungi that may proliferate under altered climatic conditions (Leishman & Gallagher, 2015). It has been reported that even a 2-degree change in temperature over time can affect agricultural productivity adversely in the absence of adaptation (Ramirez-Villegas & Thornton, 2015; Wheeler & von Braun, 2013).

Figure 1. The effects of climate change on agricultural production
Source: http://croplife.org/news/infographic-how-does-climate-change-impact-agriculture/



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In Africa

In a Working Paper of the CGIAR Research Program on *Climate Change, Agriculture and Food Security* (CCAFS), Ramirez-Villegas and Thornton (2015) have provided a detailed overview of the potential (based on published studies) and projected (based on crop model simulations) effects of climate change (extreme and changing weather conditions) on the production of maize, common bean, sorghum, cassava, yam, pearl millet, groundnut, banana and coffee in rainfed Africa. Projections were analysed and it was concluded that climate change affects crops and regions differently in Africa. For instance, in the Sahel, it was predicted that some crops may no longer be suitable for cultivation and a shift to drought and heat-resistant varieties of crops such as cassava (Jarvis et al., 2012), yams and sorghum may be a necessary adaptation measure to consider. By comparison, the production of maize in South Africa may be reduced by 30% (Sasson, 2012), but northern South Africa, Botswana, Namibia, Zimbabwe and Lesotho are not expected to experience any significant change in maize production (Ramirez-Villegas & Thornton, 2015).

The yield of common bean is very responsive to climate and the areas suitable for its cultivation in Africa can be reduced by unfavourable climatic conditions (Ramirez-Villegas & Thornton, 2015). The same applies for maize, banana and finger millet as well as coffee in different regions of Africa. For coffee, a reduction in suitable growing area for *Coffea arabica* in Ethiopia is projected with increased temperatures. Cultivation of this premium variety may need to be shifted towards higher elevations and more heat-tolerant *Coffea robusta* may be required at altitudes of less than 1500 m above sea level. Maize productivity (yield) could be reduced by 5-10% in Africa for every degree of warming (Knox, Hess, Daccache, & Wheeler, 2012). This is alarming since maize contributes the greatest portion of calories in the African diet (a mean of 16% and range of 0 – 60% across the continent). The current production is roughly 42 million tons per year (Ramirez-Villegas & Thornton, 2015). The most at risk area in terms of maize production under climate change is the Sahel.

STRATEGY TO MAINTAIN SUSTAINABLE CROP PRODUCTION INTENSIFICATION (SCPI) IN DEVELOPING COUNTRIES

Increased agricultural production requires higher yields and improved management strategies to reduce abiotic and biotic stresses. However, in order to avoid the depletion of land, energy and water resources, sustainable intensification has become crucial (Flachsbarth et al., 2015). Achieving SCPI may be realised through the following practices:

- Maintaining healthy soil to enhance soil-related ecosystem services and crop nutrition;
- Cultivation of a wider range of species and varieties in rotations, sequences and combinations to minimize overall risk of crop failure;
- Using quality seeds and planting material of well-adapted, high-yielding varieties;
- Adopting integrated management of nutrients, pests, diseases and weeds; and
- Efficient water use (FAO, 2013).

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SCPI requires effective use of technological and scientific innovations so that food supply may be increased without converting larger acreages to agricultural production or unleashing negative impacts on the environment and human health (Dempewolf et al., 2014; FAO, 2011; Sonnino et al., 2014).

ADAPTATION AND MITIGATION STRATEGIES TO OFF-SET THE IMPACT OF CLIMATE CHANGE ON AGRICULTURAL DEVELOPMENT AND FOOD SECURITY

Several adaptation strategies have been proposed to combat the potential negative impacts of climate change such as rising temperatures, intense and more frequent storms, droughts *etc*. These include diversification of livelihoods through agroforestry, integration approaches such as crop-livestock systems and rice-fish systems (Palombi & Sessa, 2013) and cultivation of heat, drought and other abiotic stress tolerant crops. The latter, described as climate-smart varieties, can be developed through crop varietal selection and breeding and should be cultivated under improved crop and eco-system management systems through precision agriculture, tailored to optimise production of particular crops under specific growing environments (FAO, 2009a; Palombi & Sessa, 2013).

Improved crop production management techniques can contribute to mitigating climate change by reducing greenhouse gas (GHG) emission. This may be achieved by limiting the use of inorganic fertilisers, avoiding soil compaction or flooding to reduce methane emissions, as in paddy rice systems, and sequestering carbon by planting perennial crops, forest trees (Dawson et al., 2011) and grass species (Palombi & Sessa, 2013). The latter practices fall under the umbrella of conservation agriculture.

Agricultural Approaches and Practices That Contribute to Climate Change Adaptation

Certain approaches and practices for sustainable crop production can contribute to climate change adaptation. They provide options for location-specific scenarios and should be adapted with local farmers/farming communities. Examples, provided by Palombi and Sessa (2013, p. 203), include SCPI listed above (FAO, 2013) and others such as:

- Mulch and cover cropping;
- Landscape-level pollination management; and
- Land fragmentation (riparian[3] areas, forest land within the agricultural landscape) (FAO, 2008, 2009b, 2012; FAO-PAR, 2011; Lin, 2011).

Tol (2002) presented comparative values of adopting versus not adopting measures to off-set climate change impacts on agriculture for a 2.5°C increase in global mean temperature. In LAC, the projected change in GDP from agriculture without climate change adaptation was –0.8 (0.6) whereas it was 0.6 (0.7) with adaptation measures. In Africa, the projected GDP adjustment was –0.2 (0.2) without adaptation measures compared to 0.5 (0.3) with adaptation measures. This research effectively underscores the value of adaptation measures.

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Agricultural Approaches and Practices That Contribute to Climate Change Mitigation

As with climate change adaptation, approaches and practices for climate change mitigation can provide options for specific locations and should also be adapted in conjunction with local farmers/farming communities. Examples, provided by Palombi & Sessa (2013, 204), include in addition to some of the adaptation strategies listed above:

- Soil compaction management;
- Promotion of legumes in crop rotations;
- Restoration of cultivated peaty soils and degraded lands;
- Soil management practices that reduce fertilizer use (*e.g.* deep placement of urea);
- Growing nutrient-use efficient crop varieties;
- Integrated crop and livestock systems (also recommended by Boland et al., 2013; FAO, 2010a);
- Dedicated production of energy crops to replace fossil fuel use;
- Emission control and reduction (combustion engines, animal waste);
- Improved rice cultivation techniques; and
- Agroforestry (FAO, 2004, 2008, 2009b, 2012).

FAO (2007) has also recommended harnessing the knowledge and experience of farmers to select types of animal breeds or varieties that can best withstand changing climatic conditions. In addition, FAO (2007) also advocated mitigating the negative impact of ruminants on GHG emissions via animal husbandry practices such as adjusting ruminant diets and stocking ratios. Monitoring and rapid appraisal of the impacts of disasters on local fishing communities and aquatic ecosystems so that immediate and longer-term remedial action could be implemented in a timely manner were also recommended. FAO has adopted an Ecosystem Approach to management of fishery resources and the ecosystems on which they depend, in the face of climate change.

Climate-adapted companion cropping is another sustainable agricultural approach that can contribute to climate change mitigation. In sub-Saharan Africa, a push-pull companion cropping practice has been adopted to address constraints of the parasitic weed, *Striga hermonthica*, stem borer (lepidopterous insect) attack and poor soil fertility (Midega et al., 2015). The climate-adapted, drought-tolerant *Brachiaria* cv mulato (bred by the International Center for Tropical Agriculture (CIAT)) is used as a border crop with cereals such as maize, and greenleaf desmodium is used as an inter-crop. Desmodium fixes nitrogen, and thus provides some fertilizer to the crop. Highly significant reductions in *Striga* and stem borer damage to maize along with improved plant height, grain yield and soil fertility were achieved via this climate-adapted, push-pull system studied (Midega et al., 2015). *Brachiaria* cv mulato also serves as feed for livestock and, as stated previously, is drought-tolerant unlike traditional fodder, Napier grass (*Pennisetum purpureum*). Similarly, in St. Vincent and the Grenadines, the research of Isaac, Brathwaite, Cohen, and Bekele (2007) demonstrated that *Desmodium heterocarpon* controls weeds such as *Commelina diffusa* and nematodes and improves soil fertility when intercropped with banana (*Musa* spp.).

This push-pull approach provides a renewable, organic, affordable source of herbicide, insecticide, fertilizer and fodder for rural farmers such as those in sub-Saharan Africa and LAC. Thus it can improve food security, allow diversification of the farming system and contribute to poverty alleviation in the face of climate change.

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Implementation of Early Warning and Risk Management Systems

Early warning and risk management systems can facilitate the timely implementation of adaptation measures to address climate variability and change. These are listed by FAO (2007) as:

- A historical climate data archive; an archive on climate impacts on agriculture;
- Monitoring tools using systematic meteorological observations;
- Climate data analysis (to determine the patterns of inter-annual and intra-seasonal variability and extremes);
- Information on the characteristics of system vulnerability and adaptation;
- Monitoring evidence of resilience under climate change as well as critical meteorological and environmental thresholds for manifestation of negative impacts of climate change; and
- Crop weather insurance indices to reduce the risk of climate impacts for lower-income farmers.

Adaptation Strategies for Crop Production in Africa

The crucial role of adaptation in countering the putative negative impacts of climate change in Africa, particularly that of global warming, was emphasised by Ramirez-Villegas and Thornton (2015). In general, these authors advocated complex systemic and transformational changes in farming systems in Africa to cater for increased temperatures. Shifts in cropping patterns to allow for cultivation of new crops that are more drought-tolerant are recommended along with a concomitant adjustment in diets and trade policies.

Yield losses for maize can be minimised by shortened cropping seasons and heat stress during the crop's reproductive phase (Ramirez-Villegas & Thornton, 2015). For the common bean (highly sensitive to climate change), Ramirez-Villegas and Thornton (2015) projected decreases in yield across Africa. However, a heat-tolerant accession of a wild relative of the common bean (*Phaseolus vulgaris*), tepary bean (*Phaseolus acutifolius*) was identified at CIAT for use in breeding heat-tolerant common bean lines (Beebe et al., 2011). Thus far, breeding lines in the greenhouse have been found to maintain productivity at +3 °C over the current temperature limit of common bean. The potential for such heat tolerant lines will be achieved with further investment in research and incentives for farmers to test and adopt promising new varieties in developing countries.

THE ADOPTION OF CLIMATE-SMART AGRICULTURE

Climate smart agriculture and landscapes are widely regarded as the panacea for addressing social and environmental impacts that threaten agricultural development and food security in the face of climate change. The widespread cultivation of climate-smart crops that are well-adapted to climatic change and changing growing environments will assure food security in a sustainable manner (Harvey et al., 2014; Neufeldt et al., 2013). Smart crops are better able to withstand drought than wheat or rice and do not require as much water to thrive (Swaminathan, 2012). They can be grown by rural families without irrigation. They are also nutritionally rich and have much higher protein and thus nutritional value. Consequently, these crops, many of them currently orphan crops (Cheng, Mayes, Dalle, Demissew &, Massawe, 2015), have ecological, social and nutritional benefits. Swaminathan thus recommended diversification

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of cropping patterns and the cultivation of more climate-smart crops to address the potential impact of climate change and year-to-year variability in weather patterns.

Features of Climate-Smart Agricultural Landscapes

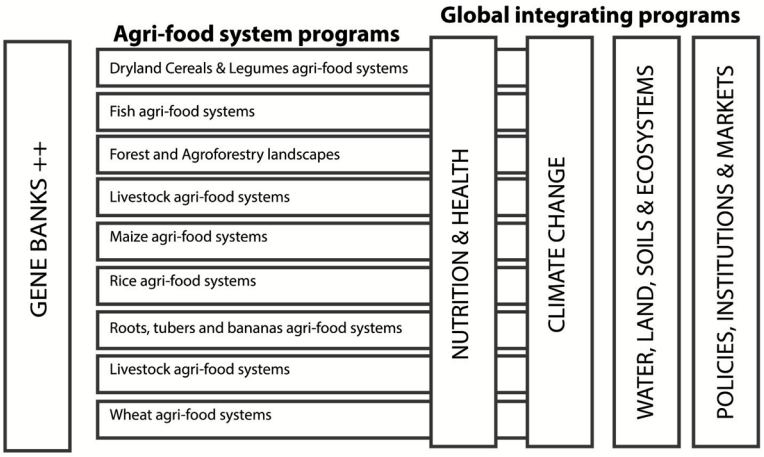
Climate-smart agriculture will mitigate against the impact of climate change by harnessing natural biological processes to improve production in a more environmentally-friendly way and avoiding degradation of natural resources (Branca, McCarthy, Lipper and Jolejole, 2011; Palombi & Sessa, 2013). This sustainable system will be less vulnerable to shocks and stresses. It will harness the best of crop varieties and livestock breeds under optimum agro-ecological and agronomic management (Beddington et al., 2012).

Mba et al. (2012) recommended that in order to achieve food security under worsening climatic conditions and with constrained natural resources, higher yields must be achieved per unit of input; yield efficiency must be optimised. In Brazil, Martinelli, Naylor, Vitousek, and Moutinho (2010) emphasised the importance of this sustainable approach of increased productivity on existing agricultural land without further environmental degradation and deforestation. The cultivation of diverse, climate-smart crop varieties that can produce more with less is the objective of climate-smart agriculture. High yielding, well-adapted, resilient crop varieties that use inputs such as water and nutrients efficiently are required. They must combine superior genetic constitutions and be managed optimally. The case of the New Rice for Africa (NERICA) (West African Rice Development Association, 2001) was cited as an example of climate smart agriculture, which has already accounted for significant increases in rice production in sub-Saharan Africa.

Strategy for Achieving Climate-Smart Agricultural Landscapes

CGIAR's new strategy and research programmes: Answering to poverty, health and climate change (CGIAR, 2015) is an excellent example of a strategic and integrated approach towards achieving food security in developing countries (refer to Figure 2).

Figure 2. CGIAR's new strategy and research programmes: Answering to poverty, health and climate change
(CGIAR, 2015)



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THE APPLICATION OF SCIENCE AND TECHNOLOGY AND KNOWLEDGE TRANSFER IN SECURING FOOD PRODUCTION

Pollinator-Friendly Management Practices

Pollinator-friendly management practices are also essential for climate-smart landscapes since they will enhance yields, quality, diversity and resilience of crops and cropping systems. Such practices include:

- Conservation of wild habitats;
- Managing of cropping systems and environs to protect habitats and forage;
- Cultivation of shade trees;
- Protection of bee and other pollinator nest sites;
- Reduced applications of pesticides and other hazards in production systems and
- Establishing landscapes with natural habitats and resources that favour pollinator population survival and services (FAO, 2009a).

In Costa Rica, it was found that coffee farms located in close proximity to forested areas benefit from greater diversity and number of pollinators visiting the coffee plants. This translates into increased coffee yields and improved coffee quality (FAO, 2009a). Furthermore, the maintenance of forests provides other ecosystem services such as carbon sequestration.

Maintaining pollination biodiversity in agricultural landscapes serves the dual role of ensuring pollination of crop species while serving as insurance against pest and disease threats among managed pollinator populations (FAO, 2009a). However, the system requires that farmers be trained about the value of adopting this strategy and the resources that pollinators require so as to encourage their proliferation in niches in the landscape.

Management of Soils: Nutrient Status, Porosity and Structure

Climate-smart landscapes must be characterised by healthy, fertile soils that support intensive production systems. Optimal crop production cannot be achieved on degraded soils with nutrient deficiencies and soil-borne pests and diseases. The cultivation of pulses is recommended in climate-smart landscapes since legumes fix nitrogen and thus reduce the need for inputs such as nitrogen fertilizers.

A case for conservation agriculture that includes zero soil tillage has been advanced by FAO (2007, 2012) and Mba et al. (2012). Reichert et al. (2015) recommended the latter for common beans based on their observations under highly variable weather conditions on sandy soils in a sub-tropical environment (Brazil). Conservation agriculture involves the maintenance of soils in an undisturbed state with a sufficient supply of organic matter that provides a good habitat for soil fauna. The avoidance of mechanical tillage increases the populations of earthworms, millipedes and other micro fauna that take over the role of tillage and build soil porosity and, with organic matter, improve soil structure. This makes land less susceptible to flooding and erosion (Palombi & Sessa, 2013). Knowledge transfer to farmers of these sustainable soil management practices is thus crucial.

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Developing Climate Smart Crop Varieties Through Research in Breeding and Technological Advances

The threat of crop failures due to biotic and abiotic stress under climate change may be addressed through breeding climate-smart varieties (refer to Table 1). In 1982, Swaminathan advocated that Third World countries should master all recent developments in genetics. This should be widened now to embrace all areas of advanced crop breeding and biotechnology including molecular biology, next-generation sequencing (Bansal, Lenka and Mondal, 2014; Edwards & Batley, 2010); genomics, genomic selection and marker-assisted selection and breeding (Tester & Langridge, 2010), gene pyramiding (Gennaro et al., 2007) and tissue culture. Landscape genomics can be employed to identify the environmental factors that affect adaptive genetic variation and gene variants that facilitate local adaptation (Anami et al., 2015; Rellstab, Gugerli, Eckert, Hancock, & Holderegger, 2015). Mba et al. (2012) concluded that a re-invigorated plant breeding approach is necessary to translate climate-smart heritable variations into crop varieties to achieve increased yields and enhanced adaptation to abiotic and biotic stresses due to climate change.

Fereres, Orgaz, and Gonzalez-Dugo (2011) identified the recommended strategy towards developing smart crop varieties as combining research on plant breeding, crop physiology, and agronomy, and exploiting their interactions. Furthermore, they advocated more balanced funding of agricultural research disciplines to achieve success.

Conservation of Biological Diversity: *In Situ* and *Ex Situ*, Protection of Landraces and Farmers' Selections

One of the strategies towards achieving climate-smart crop varieties is the widening of the genetic base or sources of heritable variations in crops (FAO, 2009c; Mba et al. 2012). This is in keeping with the Global Crop Diversity Trust's efforts to promote the collection, conservation and use of wild relatives of crops in pre-breeding and breeding (Dempewolf et al., 2014; Guarino & Lobell, 2011). The value of national and national genebanks for *ex situ* conservation and conservation plots in farmers' fields as well as of wild types in their natural habitats (*in situ* conservation) cannot be over-emphasised (FAO, 2010b).

The advantage of using the tepary bean (a wild relative of the common bean) in developing heat-tolerant common bean lines at CIAT has already been discussed (Beebe et al., 2011). Gur and Zamir (2004) reported on the success achieved using a wild relative of tomato, *Solanum pennelli*, to introduce genes for drought tolerance into the commercial *Solanum lycopersicum* tomato variety with an attendant yield increase of 50%. At IITA, Nigeria, several genes of wild relatives of cassava were used to introduce genes to enhance cassava mosaic disease resistance, as well as to improve nutritional quality and extend shelf life of a commercial variety (Mba et al., 2012).

An Example of an *Ex-Situ* Collection Used to Cater for the Impact of Climate Change: The *Seeds for Needs* Project in Ethiopia

The Seeds for Needs project in Ethiopia uses *ex-situ* collections to help farmers, mainly women, cope with impact of climate change on crop production (Bioversity International, 2013). Accessions, maintained at the Ethiopian National Genebank's Institute of Biodiversity and Conservation, were catalogued

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Table 1. Adaptive traits to introduce through crop improvement/breeding in select climate-smart crop varieties

Crop	Adaptive traits
	Drought
Rice	Early flowering, deeper and thicker roots, root pulling resistance, root penetration, osmotic adjustment (OA), rapid stomatal closure, water-use efficiency (WUE), membrane stability, leaf rolling score, and leaf relative water content
Wheat	Early flowering, stem water-soluble carbohydrate (SWSC), green flag-leaf persistence, WUE, transpiration efficiency (TE)
Maize,	Early flowering, anthesis silking interval (ASI), ears per plant, stay-green chlorophyll content, osmotic adjustment (OA), root traits, leaf abscisic acid (L-ABA)
Barley	Early flowering, plant stature, ear type, WUE, OA, high biomass combined with SWSC, water extraction, and transpiration efficiency (TE)
Sorghum	Early flowering, stay-green, SWSC, TE, rooting depth and patterns, epicuticular wax
Pearl millet	Early flowering, few tillers, low biomass and high harvest index including panicle harvest index, grain yield, individual grain mass Profuse rooting in the deeper layers of soil
Chickpea	Early flowering, deep rooting and higher root length density
Groundnut	Early flowering, WUE, transpiration, TE, specific leaf area (SLA), and chlorophyll meter reading
	Heat
Rice	Time of day when flowering (TDF) commences (early TDF protects fertility from high temperature), high temperature tolerance at grain filling (pollen shedding, pollen germination and pollen tube extension) Higher leaf transpiration rate to maintain lower leaf temperature combined with opening of flowers in morning (*O. glaberrima*)
	Salinity
Rice	Early vegetative stage: salt exclusion or low uptake, compartmenting of toxic ions in structural and older tissues, higher tissue tolerance by compartmenting salt into vacuoles, stomata that close faster upon exposure to salt stress Reproductive development stage: salt exclusion from flag leaves and developing panicles
Wheat and barley	Na+ exclusion, K+/Na+ discrimination, sheath retention of ions, tissue tolerance, ion partitioning into different-aged leaves, OA, enhanced vigour, WUE, and early flowering
Maize	OA and abscisic acid (ABA)
Sorghum	Whole plant tolerance resulted from reduced shoot Na+ concentration, a major mechanism involved in salt tolerance
Pearl millet	Whole plant tolerance associated with reduced shoot N content, increased K+ and Na+ contents; with shoot Na+ concentration a potential non-destructive selection criterion at vegetative-stage screening
Chickpea	Ability to maintain large number of filled pods; shoot Na+ or K+ not related to salinity
Pigeon pea	Reduced shoot Na+ concentration
Groundnut	Pod numbers per plant
	Flood Tolerance/Submergence
Rice	Vigorous seedling growth, elongation ability, submergence tolerance, resistance to lodging or recovery from lodging after water level reduction

(Adapted from Jarvis et al., 2008)

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in terms of climate profiles. Accessions most likely to be adapted to future growing conditions in areas with similar environmental profiles were identified using the collection, characterisation and evaluation data from germplasm collections and Geographic Information System (GIS) technology. Varieties were then tested by selected farmers under their respective growing conditions, and based on their indigenous knowledge and adaptation strategies. After the testing process, the best performing and most adaptable varieties were distributed to farming communities for multiplication and observation.

Utilisation of Crop Genetic Diversity in Selecting Climate Adaptation Traits

Conservation, characterisation, evaluation and utilisation of diverse crop genetic resources should facilitate the identification (selection) and breeding of climate-smart crop varieties (Heisey & Rubenstein, 2015; McCouch et al., 2013). Plants under abiotic stress are affected physiologically and biochemically and undergo changes in gene expression and regulation, in the short and long term, in response to unfavourable environmental conditions (Saibo, Lourenço, & Oliveira, 2009). Adaptation to water deficits (drought stress) can thus be mediated through morphological, physiological and biochemical mechanisms in crops (Beebe et al., 2011) and requires a diverse genetic base for the identification of favourable genotypes with adaptive traits for drought tolerance. The latter includes deeper root systems, stomatal control and improved translocation of nutrients within the plant. Beebe et al., (2011) advocated research to *fit the right root system to specific common bean production environments* under drought conditions, and reliable screening methods to evaluate waterlogging tolerance of genotypes under flooded conditions.

With regard to heat stress, acclimation to high temperatures in certain genotypes may favour selection of heat tolerant varieties. A method of screening pollen to determine heat tolerance in soybean was developed by Salem, Kakani, Koti, and Reddy (2007) and may be useful for screening of the common bean (Beebe et al., 2011).

Detailed data on the responses to climate change (changing temperature and rainfall patterns) of the pests and diseases affecting crops in developing countries are necessary. An understanding of these phenomena and the identification of adapted or tolerant genotypes will facilitate the implementation of adaptation strategies to deal with the biotic stress due to pests and diseases.

Marker-Assisted Selection and Genomic Breeding

Molecular markers are currently the most powerful tools for elucidating the inheritance of target regions of plant and animal genomes in breeding material, and environment-neutral markers allow marker-assisted selection (MAS) and genomic breeding (Edwards & Batley, 2010). Marker assisted selection could be a useful tool to identify (abiotic) stress tolerant traits such as specific rooting depth in common bean, once quantitative trait loci (QTL) for this quantitative trait have been located. It leverages the burgeoning available molecular data on completely or nearly completely sequenced plant genomes to select for candidate genes, protein sequences, and favourable genotypes, while taking into account genotype by environment interaction and targeting adaptive/morpho-physiological traits (Jha, Bohra, & Singh, 2014; Lasky et al., 2015). The advances in bioinformatics and computational molecular biology facilitate valid inferences to be made from the large and complex volumes of data involved in these processes. The usefulness of MAS is particularly outstanding in breeding programmes that involves polygenic traits. MAS allows quick progress in accumulating two or more genes (pyramiding) for desirable traits in segregating breeding material compared to conventional breeding methods. The latter is constrained

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by the length of the breeding cycle and the dependence on screening, based on phenotypes, which often has to be conducted on mature plants when reproductive traits are involved. The time required to breed a new crop variety may be decreased by half when MAS is employed (Mba et al., 2012). The negative side is the cost involved (Ribaut, Vicente, & Delannay, 2010). However, high-throughput molecular biology assays are becoming increasingly available and costs are decreasing. Furthermore, human capacity building in using these techniques and putting the results at the disposal of farmers in developing countries is in progress.

High-Throughput Phenotypic Evaluations

High throughput imaging of living plant organs can also be valuable for unravelling complex traits affected by climate change such as drought and salinity tolerances (Ghanem, Marrou, & Sinclair, 2015). Access to the technology required for thermal infra-red and near-infrared fluorescence spectrometry and magnetic resonance imaging allow non-destructive physiological, morphological and biochemical assays that can be used to investigate these complex traits (Fahlgren et al., 2015). However, the high establishment costs and technical expertise required to conduct high-throughput phenotyping may also restrict access to it, in the short-term, by developing countries.

CASE STUDY

Harnessing Research and Technology to Combat Climate Change in Cacao (Theobroma cacao L.)

Research and application of research findings and technology to combat the threat of climate change in cacao[4] have been ongoing (Stigter, 2008). The impact of soil, water and climate (drought, flooding, high temperature and irradiance) pose a threat to sustainable cocoa production (Oyekale, Bolaji, & Olowa, 2009). There is a need to increase efficiency to manipulate water use, soil and microclimate and to use improved (climate-smart/well adapted) stress tolerant planting material. Technological approaches such as genome-wide association studies and breeding with genomics and other technological advances may be applied in developing superior cacao varieties to combat the impact of climate change. The completed mapping of the cacao genome will facilitate the identification of marker-trait associations in cacao germplasm that can be used to breed varieties with biotic and abiotic stress tolerance.

The selection of well-adapted varieties with drought, heat (high irradiance) stress and other forms of abiotic stress tolerance is a major goal of cocoa breeding in West Africa (Läderach, Martinez-Valle, Schroth, & Castro, 2013). Studies on the effects of soil water deficit (Antwi, 1994) and irradiance (Galyuon, McDavid, Lopez & Spence, 1996a, b) have been conducted in Trinidad & Tobago, and an investigation on climate change adaptation to drought and heat in cacao is currently in progress.

In Brazil, dos Santos et al., (2014) found that the best traits to screen for drought tolerance were leaf and total dry biomass, relative growth rate and magnesium content of leaves. These authors also found increased expression of drought tolerance candidate genes (as those associated with ABA biosynthesis and biosynthesis of proteins of PSII of the photosynthetic pathway) in genotypes classified as non-tolerant after exposure to soil water deficit for a period of time. dos Santos et al. (2014) also observed that in tolerant genotypes, there were significant increases in guaiacol peroxidase activity, reflecting a

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more efficient antioxidant metabolism. This increased activity of oxidative stress enzymes is a response to soil water deficit.

In Ghana, where drought is the major abiotic stress affecting cacao (Anim-Kwapong & Frimpong, 2005), Ofori, Padi, Acheampong, and Lowor (2015) examined genetic variation and the relationship of traits associated with drought tolerance in cacao under shade versus non-shade conditions. These authors reported that stem growth, percentage survival, leaf chlorophyll content and plant vigour were important traits to screen for drought tolerance under these conditions.

In order to mitigate the potential adverse effects of climate change in cacao, Stigter (2008) stressed the role of good managerial practices (proper shade management, application of organic fertiliser and bio-control of pests), inter-planting with agro-forestry species and extension to educate farmers on good agricultural practices (GAPs), in Climate Field School classes (CFSs), to cope with the impact of climate change. In addition, biodiversity friendly cacao cultivation can be practised such that a favourable balance between yield, farmer income and biodiversity conservation is achieved, as prescribed by Waldron, Justicia, Smith, and Sanchez (2015). Farmer income can be supplemented by sustainability certification (eco-labelling) and incentives awarded to small farmers for managing eco-friendly cacao agroforestry systems based on the United Nations REDD (reducing emissions from deforestation and forest degradation) initiative (Millard, 2011).

SOCIAL REFORMS FOR OPTIMISED AND SUSTAINABLE AGRICULTURAL PRODUCTION AND DEVELOPMENT

Scherr, Shames, and Friedman (2012) identified several key social factors required in strategies for securing food production and achieve food security. These include:

- Strengthened technical capacities;
- Institutional and political support for multi-stakeholder planning;
- Good governance;
- Spatial targeting of investments and
- Multi-objective impact monitoring.

Sasson (2012) identified several social constraints to be addressed in order to increase agricultural production and achieve food security. These include lack of easy access to land, lucrative employment opportunities in the rural environment, lack of proper access to local markets (with proper road infrastructure and loan arrangements) and inadequate access to training and technologies that will increase production, productivity, food safety, improve food handling and storage, post-harvest activities (including packaging), distribution and marketing and promote sustainable value-addition initiatives. Access to training in best practices and technology (including agricultural diagnostic applications on smart phones) is particularly critical to implement climate change adaptation techniques to address drought, extreme temperatures and other abiotic stresses. Research and development along with dissemination of the resulting information to agriculturists are thus crucial (Ejeta, 2009). Gender inequality was also regarded as a constraint to achieving food security (Flachsbarth et al., 2015; Perez et al., 2015).

Thus a summary of social reforms that can impact positively on agricultural development and food security includes:

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- Poverty alleviation;
- Creating a shorter, more efficient supply and value chain for farmers
- Improving farmer livelihoods;
- Diversification of incomes;
- Adequate access to credit;
- Strengthening of women's position;
- Greater access to social amenities;
- Greater access to an adequate and reliable labour force;
- Improvement in production standards with regards to child labour;
- Attracting youth to agriculture;
- Stability of land ownership rights and land tenure;
- Improving infrastructure (particularly of access roads and bridges);
- Access to equipment and technology for farm/production efficiency;
- Improvement of access to schooling and education;
    - Access to extension services and training in GAPs and good manufacturing practices (GMPs) – through participatory learning;
    - Improving the business acumen of farmers – through farmer field schools (FFS);
- Adoption of food safety and quality assurance practices;
- Avoiding trade-offs between quality of produce and short term revenues;
- Improving access to market information and support services;
- Access to efficient transport/wholesaling markets, refrigeration and post-harvest practices to avoid food spoilage and wastage;
- Creation and strengthening farmer's organisations such as co-operatives to facilitate optimisation of all activities along the food value chain and facilitate sharing of costs among food producers and promoting value addition; and
- Addressing the disconnect between food producers and consumers.

Promoting food security is deemed feasible through the spread of modern farming, crop research and food processing in developing nations (Sasson, 2012). Farming communities must be educated in modern farming through knowledge and technology transfer and equipped to practise such methods.

Investment and resources must be supplied to rural farming communities, particularly of small farmers, and policies implemented to bring about the requisite social and environmental changes and human capacity building to combat climate change. Policy, legal and market environments that encourage innovation and capital investment must be fostered. The role of the International Convention for the Protection of New Varieties (UPOV) is also critical so that there is an equitable balance between Intellectual Property Rights (IPR) and contributions to public good (Mba et al., 2012).

THE ROLE OF EDUCATION AND INSTITUTIONS

Training and education are key catalysts to bring about environmental and social reform to promote agricultural development and food security, particularly in SIDS (Bekele & Ganpat, 2014). The areas of particular concern are:

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- Participatory approaches to social learning to persuade farmers to adopt new and improved agricultural approaches such as the climate-adapted push-pull system (Isaac et al., 2007; Midega et al., 2015) and integrated pest management;
- Technology transfer to food producers along the value chain;
- Sensitization of rural and urban communities to encourage proper nutrition, avoidance of food wastage (according to the FAO, one third of the food produced globally is discarded or spoilt) and adoption of healthier and more energy efficient eating habits;
    - including the acceptance of a diet with protein from vegan and non-red meat sources to reduce the consumption of red meat that contributes to carbon emissions (14% of the global total) and utilisation of large volumes of water; and
- Adoption of modified and healthy diets based on climate-smart agriculture.

Education to change public awareness and practices that affect agricultural production and food security is crucial. According to Bailey, Froggatt and Wellesley (2014), governments and environmental groups are reluctant to pursue policies or programmes to shift consumer behaviour.

Much research has and is being conducted in developing nations to facilitate more sustainable food consumption patterns. Boland et al. (2013) and Lukefahr (2005) identified rabbits as a suitable alternative for animal protein in developing countries, but the populace has to be convinced to utilise this and other alternative animal protein sources such as the collared peccary/quenk and agouti (Mollineau, Garcia, Samayah, Kissoonsingh, & Procope-Garcia, 2000) in future animal protein production and consumption systems. Alternatives for imported staples such as wheat are available in the developing world and consumer appreciation for tropical food crops such as breadfruit (*Artocarpus altilis*, Moraceae) and chataigne (*A. camansi*) is already fairly high (in excess of 61% in Trinidad and Tobago) (Roberts-Nkrumah & Legall, 2013). In other cases, consumer acceptance will have to be encouraged, taboos and fear of the new (neophobia, as explained by Cox and Evans, 2008) will have to be displaced, and ethical issues resolved. A concerted education drive is thus required for potential producers and consumers. Furthermore, accountability and responsibility are necessary to preclude public distrust (Boland et al., 2013).

Social systems could be valuable in addressing food waste. A well organised system for collection of food waste with acceptable nutritional value that is safe for animal consumption can serve the dual role of reducing food waste while providing a source of animal feed. There should be a review of legislation that currently forbids the use of human food waste in animal production (Boland et al., 2013). Education of personnel to sort and manage food waste and to monitor its safety for animal consumption is thus necessary. There will also be safety issues for humans operating the system and for consumers of the resulting animal products that will have to be addressed by research and knowledge transfer.

A key role of education and institutional support is to link science and policy on food security under climate change. This requires multi-stakeholder, participatory scenarios to bring the diverse actors and organizations together to create the necessary policy-making tools, as described by Chaudhury et al., (2013). The knowledge made available by scientists can thus be transferred to policy makers to facilitate implementation of necessary changes and programmes to address food insecurity and the negative impacts of climate change. Institutions such as regional universities and international organisations based in the developing world can undertake the credible, salient and legitimate boundary work required in this process. They can provide fora for assembling farmer representatives, scientists, policymakers, civil society, government and private sector so that multiple perspectives may be aired, scenarios created and policies drafted to implement approved practices and technology. In East Africa, the CGIAR

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programme on Climate Change, Agriculture and Food Security (CCAFS) has adopted this approach to promote climate-smart agriculture and food security, bridging science and non-science boundaries, and have forged the link between knowledge and action (Chaudhury et al., 2013). At multi-stakeholder workshops, they were able to determine common outcomes of interest for food security, *viz*., food affordability, regional production, food distribution and nutritional value for food security, water and soil quality, forest cover, biodiversity status, water sufficiency for environment, and financial wealth, social capital, health, and knowledge and skills for livelihood.

CASE STUDY: SOCIAL ISSUES AFFECTING COCOA PRODUCTION

The cocoa industry, which supports the projected (by 2016) 98.3 billion USD chocolate and cocoa-based industry (World Cocoa Foundation, 2015), has been beleaguered by social as well as environmental challenges. Despite this, the International Cocoa Organisation (ICCO) recognised the importance of the cocoa sector for economic development and poverty eradication, particularly in West Africa, which produces 70% of the world's cocoa. The ICCO affirmed that to secure this important role, stakeholders in the cocoa chain are jointly facing the challenge to promote sustainable development in cocoa production, commercialization, processing, manufacturing and consumption (Ebai, 2004). To rise to these challenges, ICCO launched a Roundtable on a Sustainable Cocoa Economy in 2007 in Accra, Ghana, and a Second Roundtable was convened in Trinidad in 2009. The social issues of serious concern in the cocoa sector pertain to labour, farmer well-being and livelihoods and training in best practices. There is justification in concluding that the monetary benefits of the thriving global cocoa and chocolate industry have not trickled down to the farming communities adequately.

Child Labour: A Serious Social Issue

Child labour in cocoa production became the focus of international attention and disdain in 2002 (Mustapha, 2009). The International Labour Office (ILO) and the International Program on the Elimination of Child Labour (IPEC) presented statistics that indicated that 284,000 children were working under hazardous conditions in West Africa. Since then, the industry has made concerted efforts to address the situation and stop all forms of exploitative or the worst forms of child labour in cocoa production (Grossman-Greene & Bayer, 2009; Schrage & Ewing, 2005). Several initiatives have resulted and groups formed to achieve the goals of the Harkin-Engel law adopted in 2001 to address the worst forms of child labour (Berlan, 2009) as well as assure sustainability of cocoa production. These include the Sustainable Tree Crop programme (STCP) in West Africa and South-east Asia (Abbott, 2003), CocoaAction and Transforming Education in Cocoa Communities (TRECC), which was launched in May, 2015.

CocoaAction was launched in May 2014 to deliver a comprehensive package of services in both productivity and community development to cocoa farmers, their families and their communities. TRECC will reach nearly 200,000 individuals through a series of interlinked interventions in research, capacity building, policy formulation and influence, fundraising, and supporting matching grants to complement CocoaAction. It is an initiative of the Swiss Charitable Foundation, The Jacobs Foundation that will be executed in Côte d'Ivoire. A key element will be education to restrict child labour, which is currently still a serious problem in Côte d'Ivoire.

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Farmer Education to Promote Sustainability in Cocoa Production

Farmer education is included in the aforementioned *CocoaAction*, *TRECC* and *STCP* programmes. In addition, the *Learn To Grow* programme was launched by Hershey and will include more than 60,000 West African cocoa farmers. It is intended to create both better farming practices and better cocoa communities. Hershey has a goal to purchase 100% certified cocoa by 2020. This is envisaged to provide premiums to assist farmers and farmer organizations in adopting modern farming practices, including organic farming, and to develop their communities.

In South-east Asia, (Sulawesi, Indonesia and Papua New Guinea), the Australian Centre for International Agricultural Research (ACIAR) conducted a project, SMAR/2005/074, entitled *Improving cocoa production through farmer involvement in demonstration trials of potentially superior pest/disease resistant genotypes and IPM*). The objectives were to select and test local cacao clones at different locations for disease and pest resistance (Vascular Streak dieback and Cocoa Pod Borer), evaluate IPM options and assess technology uptake by farmers (Neilson et al., 2014). The importance of addressing social and economic constraints in cocoa production, and in educating farmers on how to utilise the available information, based on empirical research as well as technology and improved methods, such as IPM, was emphasised.

Fairtrade in Cocoa

Approximately eighty-five percent of the world's chocolate comes from farms of 5 hectares or less, mainly in the developing countries of West Africa, South-east Asia and Latin America. Cocoa farming families earned as little as US$30 - $110 per family member per year, according to Knapp (2005). Fairtrade chocolate, made from Fair Trade certified cocoa, offers a solution for small farmers and their dependents to break the cycle of poverty. By cutting out middlemen and brokers, Fair Trade allows cocoa farmers to receive a fair share of the final market value of their products (Liu, Byers, & Giovannucci, 2008; Pay, 2009).

Fairtrade certification creates direct trade links between farmer-owned cooperatives and buyers, and it provides access to affordable credit. Fairtrade gives farmers the tools to access the market and to farm in a sustainable manner. In addition, under the terms of Fairtrade, there are strict labour standards that foster healthy working conditions and allow children under the age of 15 to work on their family's farm only if their education is not jeopardized. Children under the age of 18 are not allowed to work with machetes (or other dangerous tools) or to apply pesticides.

A Multi-Stakeholder, Cohesive Approach to Ensure Sustainable Cocoa Production

A structured, multi-sector, international approach to conserve cacao germplasm as a safeguard against the impact of climate change and other threats and to meet emerging needs of cocoa farmers has already been adopted. The United Nations Common Fund for Commodities/International Cocoa Organisation/ Bioversity International (CFC/ICCO/BI) executed a project entitled *Cocoa Germplasm Utilization and Conservation: A Global Approach* (1998 – 2004) (Eskes, Engels, & Lass, 1998; Eskes & Efron, 2006). The main objective for this project at the Cocoa Research Unit (now Cocoa Research Centre, CRC), a partner in the project, was germplasm enhancement for Black Pod (BP) and Witches' Broom (WB) dis-

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ease resistance in cacao. Several primary germplasm varieties were identified, and enhanced genotypes (through pre-breeding (Guarino & Lobell, 2011)) produced at CRC with combined resistance to both WB and BP diseases. The yield potential, bean traits, precocity, vigour and flavour profiles of these individuals were or are still being assessed at CRC (Iwaro et al., 2010). The most promising enhanced cacao varieties were transferred to the International Cocoa Quarantine Centre, Reading University, U.K. to facilitate distribution to the other project partners in cocoa producing countries. Selected progeny are also being used in the Ministry of Agriculture, Trinidad and Tobago's successful Trinidad Selected Hybrid cacao breeding programme (Maharaj et al., 2011) to accumulate resistance genes for BP. This will facilitate the development of further improved, superior planting material to distribute to cocoa farmers in Trinidad and Tobago.

Launching of *Farmer Field Schools* (FFS) and *Farmer Participatory approaches* to improving cocoa production have also received considerable attention within the last decade. The CFC/ICCO/BI project entitled *Cocoa productivity and quality improvement: a participatory approach* was conducted from 2004 to 2009. This project was successful in educating farmers and assisting them in recognising and selecting the best trees within their fields for multiplication and conservation. Techniques to screen for disease and pest resistance and to assess traits of economic interest as well as quality and flavour of cocoa were also put at the disposal of rural cocoa farming communities (Eskes, 2011).

These two, aforementioned CFC/ICCO/BI projects involved 14 cocoa-producing countries, including Trinidad and Tobago, as well as manufacturers (consumers), government bodies and institutions. They are models for a successful, cohesive approach towards achieving agricultural development and food security.

In West Africa, South-east Asia, Latin America and the Caribbean, FFS are now routinely hosted. In Trinidad & Tobago, a project, funded by the Centre for the Development of Enterprise and implemented by the Cocoa Research Centre (CRC), resulted in the training of farmers and entrepreneurs in GAPs and GMPs practices (including for assuring food safety) in six Caribbean countries.

A COHESIVE APPROACH TO ACHIEVE AGRICULTURAL DEVELOPMENT AND FOOD SECURITY

Any strategy to achieve social reform and to foster agricultural development and food security in developing nations requires:

1. A cohesive approach to achieve agricultural development and food security in developing nations;
2. Proper fiscal/economic planning;
3. Social programmes and networking – encompassing collaborative, iterative social learning;
4. A proper environmental framework and
5. Public, private and community based approach.

A comprehensive, multi-sector approach towards addressing the challenges and potential impact of climate change on food security is advocated (Chaudhury et al., 2013; Maggio et al., 2015; Mba et al., 2012). Sonnino et al., (2014) urged that a sustainable food security framework should address the complex relationships between the various stages and actors in the food supply chain (refer to Figure 2) in a holistic manner. The conventional focus on individual components (supply and demand) will not ensure sustainable food security. Participatory, multi-disciplinary and demand-driven breeding programmes,

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which are nurtured by appropriate policy and legal environments and utilise scientific and technological tools to exploit crop and animal genetic resources, are recommended (Mba et al., 2012). Governance and policy structures must be put in place to support food security and sustainability efforts (Sonnino et al., 2014). Without the social support of extensionists, financiers, administrators and policy makers, the positive outcomes of participatory food production initiatives will not become transformative across the agricultural sector, but be confined to isolated sections of the rural and research communities.

Participatory breeding considers the views of farmers, consumers, extensionists, vendors, rural co-operatives and industry in crop improvement. The needs of the growers and stakeholders thus inform the design of the breeding activities, rendering them relevant and efficient. Furthermore, the role and achievements of farmers in selecting and conserving crop landraces can be harnessed in the process of selecting favourable candidates to use as parents in breeding. In addition, the adoption of improved varieties by farmers is facilitated and accelerated when farmers are part of the process.

The benefits of such an integrated approach have been supported by research findings based on analyses of various scenarios (Vervoort et al., 2014). The latter authors advocated more effective and efficient transformation of scientific results into a policy agenda for adaptive action on food security under climate change. Such an approach in SIDS has also been recommended and outlined by Maximay (2014). Integrated adaptation and mitigation strategies, under the umbrella of integrated landscape level planning, were recommended by Harvey et al., (2014) in order to avoid trade-offs that limit success.

There is thus compelling evidence that to achieve food security under climate change in developing countries, an organised programme to breed climate-smart varieties and practise climate-smart agriculture can only be achieved through collaboration. This should also involve international organisations such as the Global Crop Diversity trust, FAO, CGIAR and the Integrated Breeding Platform, the World Bank and the World Trade Organisation. Sonnino et al., (2014) presented a detailed graphic that depicts the key issues to be addressed for a future research agenda that can assure sustainable food security (refer to Figure 3). The broad scope of this agenda demands a multi-sector approach. McCouch et al. (2013) have costed the systematic, concerted, collaborative global effort to feed the future. They estimated it as US $200 million annually.

CONCLUSION

It has been projected by Flachsbarth et al. (2015) that the progress of achieving food security will vary from one developing region to the next. Their outlook for LAC and Southeast Asia and the Pacific is better than for Central-West Africa and other regions of Sub-Saharan Africa. Lobell et al. (2008) also predicted that South Asia and Southern Africa will most likely face negative climatic impacts by 2030 on several important crops if adequate adaptation measures are not adopted. This scenario may be attributed to the fast population increase relative to food production growth, particularly in Africa, as well as continued lack of access to safe water along with limited improvement in female secondary education. Policies are required to remove gender bias that *limits resilience of female farmers* (Perez et al., 2015).

The environmental and social priorities for increasing agricultural development and achieving food security in developing countries, which were identified in this chapter, are included in the CGIAR's strategy (Rijsberman, 2015) (refer to Table 2).

Thus, there are numerous factors that need to be urgently addressed in order to assure agricultural development and food security in developing nations. These include:

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Figure 3. Sustainable food security pillars- key issues for future research
(adapted from Sonnino et al., 2014)

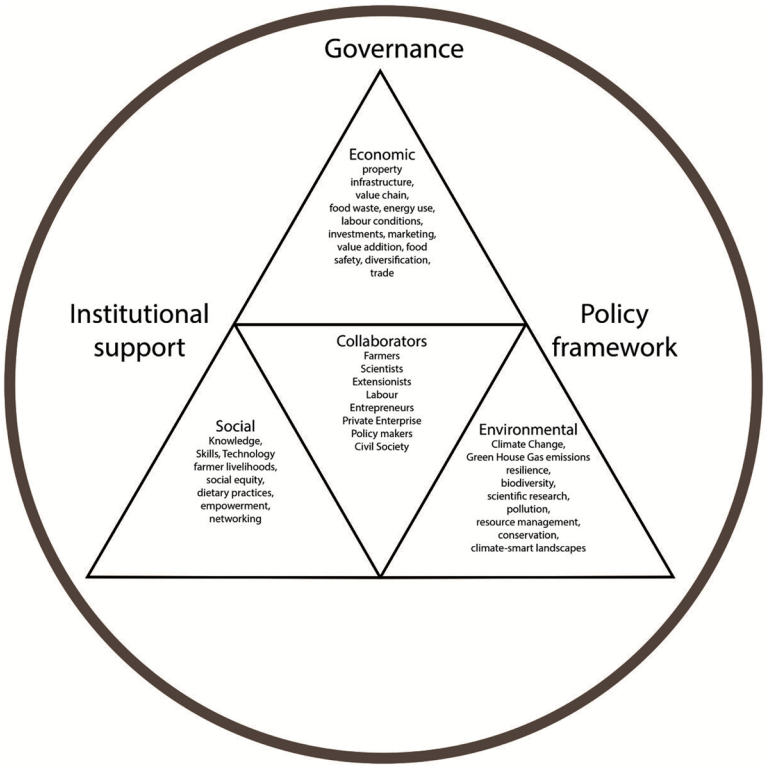

Table 2. Consultative Group for International Agricultural Research (CGIAR's) strategy for 2016-2030

Genetic improvement of crops, livestock, fish and trees, to increase productivity, resilience to stress, nutritional value and efficiency of resource use.
Agricultural systems, adopt a systems approach to optimize economic, social and environmental co-benefits in areas with high concentrations of poor people.
Gender and inclusive growth, creating opportunities for women, young people and marginalized groups.
Enabling policies and institutions, to improve the performance of markets, enhance delivery of critical public goods and services, and increase the agency and resilience of poor people.
Natural resources and ecosystem services, focusing on productive ecosystems and landscapes that offer significant opportunities to reverse environmental degradation and enhance productivity.
Nutrition and health, emphasizing dietary diversity, nutritional content and safety of foods, and development of value chains of particular importance for the nutrition of poor consumers.
Climate-smart agriculture, focusing on urgently needed adaptation and mitigation options for farmers and other resource users.
Nurturing diversity, ensuring that CGIAR in-trust plant genetic resources collections are safely maintained, genetically and phenotypically characterized to maximize the exploitation of these critical resources for food security, productivity, nutrient rich crops and resilient farming systems.

(CGIAR, 2015)

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Social Factors

- Reform of social conditions for rural communities – improvement of basic amenities – health, education, housing and infrastructure;
- Technological knowledge transfer and farmer training and education in GAPs for primary production and GMPs for value chain initiatives along with training to ensure better health and fiscal management as well as socialisation;
- Support of rural communities in terms of financial aid and farmer livelihood enhancement programmes to optimise income generation, eradicate poverty and improve subsistence farming (as for the establishment of co-operatives and farming enterprises that shorten the value chain);
- Provision of technological tools to modernise food production;
- Public co-ordinated programmes to address inadequate access to credit and capital and insecurity of land tenure; and
- Application of science and technology in education to re-engineer the farming culture and inculcate innovative approaches to food production and value-addition enterprises that will attract the youth.

Environmental Factors

- Climate-smart agriculture and landscapes – identifying climate adapted or resilient planting material and adopting energy efficient, sustainable agricultural production practices;
- The application of technology in climate adaptation strategies (next-generation sequencing, genomic selection, marker-assisted selection and breeding with genomics to develop climate-smart varieties); and
- Harnessing conservation and utilisation of crop genetic resources in the face of climate change and other emerging threats such as new pests and diseases.

Meeting the challenges to secure agricultural development and food production in developing nations is indeed daunting. The complex social, environmental as well as economic issues that contribute to the dilemma cannot be addressed without a collaborative approach. Policies must be developed to engender trust and co-operation among the key stakeholders. Furthermore, an agriculture-energy-water nexus approach (Rasul and Sharma, 2015) must be adopted since the impacts of climate change dictate that agriculture can only develop and be sustainable when plant and animal genetic resources and materials, water, energy and land resources are not limiting (Hubert et al., 2010).

Fiscal and rural planning is a key parameter for success in achieving agricultural development and food security in developing nations. The strategies to be adopted require adequate financing along with research and development to benefit concerted genetic conservation efforts, human capacity building, technological applications in plant breeding and selection of adapted and superior plant varieties and animals, ongoing applied research such as genomics and a sophisticated network of food quality, safety, handling, processing, storage, marketing and transportation facilities.

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The successful implementation of the aforementioned strategies should guarantee a stable supply of nutritious food, readily available to growing populations in developing countries into the future. Achieving food security cannot be accomplished without ending poverty in developing nations. Farming communities must be educated, well-equipped, able to access and utilise technology and superior planting material, livestock or fisheries, and practise sustainably intensive (based on natural agricultural processes and biodiversity), modern agriculture on a lucrative scale with the benefit of secure land tenure, co-operative structures, extension services and appropriate financial support.

REFERENCES

Abbott, P. (2003). *Towards more socially responsible cocoa trade.* International Agricultural Trade Research Consortium, working paper 03-3. Retrieved June 20, 2015, from http://nbcgib.uesc.br/cicacau/arquivos/producao_tecnico_cientifica/wp03-03.pdf

Anami, S. E., Zhang, L. M., Xia, Y., Zhang, Y. M., Liu, Z. Q., & Jing, H. C. (2015). Sweet sorghum ideotypes: Genetic improvement of stress tolerance. *Food and Energy Security*, *4*(1), 3–24. doi:10.1002/fes3.54

Andersen, L., Breisinger, C., Mason-D'Croz, D., Jemio, L. C., Ringler, C., Robertson, R. E., . . . Wiebelt, M. (2014). *Agriculture, incomes, and gender in Latin America by 2050: An assessment of climate change impacts and household resilience for Brazil, Mexico, and Peru*. IFPRI Discussion Paper 1390. Retrieved June 15, 2015, from http://ssrn.com/abstract=2539588

Anim-Kwapong, G. J., & Frimpong, E. B. (2005). *Vulnerability of agriculture to climate change-impact of climate change on cocoa production.* Final Report submitted to the Netherlands climate change studies assistance Programme: NCAP, 2. Retrieved June 12, 2015, from http://www.nlcap.net/fileadmin/NCAP/Countries/Ghana/COCOA_DRAFT_FINAL_REPORT.pdf

Antwi, A. (1994). *The effects of water deficit on growth and development in young cocoa plants (Theobroma cacao L).* (Unpublished MPhil thesis). University of the West Indies, St. Augustine, Trinidad and Tobago.

Bailey, R., Froggatt, A., & Wellesley, L. (2014). Livestock – Climate change's forgotten sector. *Global Public Opinion on Meat and Dairy Consumption*. Retrieved June 11, 2015, from http://www.gastronomiaycia.com/wp-content/uploads/2014/12/estudio_consumo_carne.pdf

Bansal, K. C., Lenka, S. K., & Mondal, T. K. (2014). Genomic resources for breeding crops with enhanced abiotic stress tolerance. *Plant Breeding*, *133*(1), 1–11. doi:10.1111/pbr.12117

Beddington, J., Asaduzzaman, M., Fernandez, A., Clark, M., Guillou, M., Jahn, M., . . . Wakhungu, J. (2012). *Achieving food security in the face of climate change: Final report from the Commission on Sustainable Agriculture and Climate Change*. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Retrieved June 2, 2015, from http://www.ccafs.cgiar/commission

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Beebe, S., Ramirez, J., Jarvis, A., Rao, I. M., Mosquera, G., Bueno, J. M., & Blair, M. (2011). Genetic improvement of common beans and the challenges of climate change. In S. S. Yadav, R. J. Redden, J. L. Hatfield, H. Lotze-Campen, & A. E. Hall (Eds.), *Crop adaptation to climate change* (pp. 356–369). Richmond, Australia: John Wiley & Sons, Ltd., Published by Blackwell Publishing Ltd. doi:10.1002/9780470960929.ch25

Bekele, I., & Ganpat, W. (2014). Education, extension, and training for climate change. In W. Ganpat & W.P. Isaac (Eds.), Impacts of Climate Change on Food Security in Small Island Developing States (pp. 361-388). Hershey, PA: IGI Global.

Berlan, A. (2009). Child labour and cocoa: Whose voices prevail? *The International Journal of Sociology and Social Policy*, *29*(3/4), 141–151. doi:10.1108/01443330910947516

Bioversity International. (2013). *Seeds for needs project.* Retrieved June 7, 2015, from http://www.bioversityinternational.org/research/sustainable_agriculture/seeds_for_needs.html)

Boland, M. J., Rae, A. N., Vereijken, J. M., Meuwissen, M. P., Fischer, A. R., van Boekel, M. A., ... Hendriks, W. H. (2013). The future supply of animal-derived protein for human consumption. *Trends in Food Science & Technology*, *29*(1), 62–73. doi:10.1016/j.tifs.2012.07.002

Branca, G., McCarthy, N., Lipper, L., & Jolejole, M. C. (2011). *Climate-smart agriculture: a synthesis of empirical evidence of food security and mitigation benefits from improved cropland management.* Retrieved June 13, 2015, from http://www.fao.org/climatechange/29764-0aa5796a4fb093b6cfdf05558c6dd20bb.pdf

CGIAR (Consultative Group for International Agricultural Research). (2015). *CGIAR's strategy and results framework 2016-2030*. Retrieved June 21, 2015, from http://www.cgiar.org/consortium-news/cgiars-new-strategy-and-research-programs-answering-to-poverty-health-and-climate-change/#

Chaudhury, M., Vervoort, J., Kristjanson, P., Ericksen, P., & Ainslie, A. (2013). Participatory scenarios as a tool to link science and policy on food security under climate change in East Africa. *Regional Environmental Change*, *13*(2), 389–398. doi:10.100710113-012-0350-1

Cheng, A., Mayes, S., Dalle, G., Demissew, S., & Massawe, F. (2015). Diversifying crops for food and nutrition security – a case of teff. *Biological Reviews of the Cambridge Philosophical Society*, n/a. doi:10.1111/brv.12225 PMID:26456883

Cox, D. N., & Evans, G. (2008). Construction and validation of a psychometric scale to measure consumers' fears of novel food technologies: The food technology neophobia scale. *Food Quality and Preference*, *19*(8), 704–710. doi:10.1016/j.foodqual.2008.04.005

Dawson, I. K., Vinceti, B., Weber, J. C., Neufeldt, H., Russell, J., Lengkeek, A. G., ... Jamnadass, R. (2011). Climate change and tree genetic resource management: Maintaining and enhancing the productivity and value of smallholder tropical agroforestry landscapes. A review. *Agroforestry Systems*, *81*(1), 67–78. doi:10.100710457-010-9302-2

Dempewolf, H., Eastwood, R. J., Guarino, L., Khoury, C. K., Müller, J. V., & Toll, J. (2014). Adapting agriculture to climate change: A global initiative to collect, conserve, and use crop wild relatives. *Agroecology and Sustainable Food Systems*, *38*(4), 369–377. doi:10.1080/21683565.2013.870629

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

dos Santos, I. C., de Almeida, A. A. F., Anhert, D., da Conceição, A. S., Pirovani, C. P., Pires, J. L., ... Baligar, V. C. (2014). Molecular, physiological and biochemical responses of *Theobroma cacao* L. genotypes to soil water deficit. *PLoS ONE*, *9*(12), e115746. doi:10.1371/journal.pone.0115746 PMID:25541723

Ebai, S. (2004). Global coordination towards a sustainable cocoa economy: an update. In *Proceedings of the APASTT Seminar – Exhibition entitled Re-vitalisation of the Trinidad & Tobago Cocoa Industry*, (pp. 17-21). St. Augustine, Trinidad: APASTT.

Edwards, D., & Batley, J. (2010). Plant genome sequencing: Applications for crop improvement. *Plant Biotechnology Journal*, *8*(1), 2–9. doi:10.1111/j.1467-7652.2009.00459.x PMID:19906089

Ejeta, G. (2009). Revitalizing agricultural research for global food security. *Food Security*, *1*(4), 391–401. doi:10.100712571-009-0045-8

Eskes, A. B. (2011). *Collaborative and participatory approaches to cocoa variety improvement. Final report of the CFC/ICCO/Bioversity project on cocoa productivity and quality improvement: a participatory approach (2004–2010).* London, UK: Bioversity International.

Eskes, A. B., Engels, J. M. M., & Lass, R. A. (Eds.). (1998). Working procedures for cocoa germplasm evaluation and selection. In *Proceedings of the CFC/ICCO/IPGRI Project workshop* (*vol. 1*, no. 6). Rome, Italy: IPGRI.

Eskes, B., & Efron, Y. (Eds.). (2006). *Global Approaches to Cocoa Germplasm Utilization and Conservation. Final Report of CFC/ICCO/IPGRI Project on Cocoa Germplasm Utilization and Conservation (1998-2004)*. Rome, Italy: Bioversity International.

Fahlgren, N., Feldman, M., Gehan, M. A., Wilson, M. S., Shyu, C., Bryant, D. W., . . . Baxter, I. (2015). A versatile phenotyping system and analytics platform reveals diverse temporal responses to water availability in Setaria. *Molecular plant*. Retrieved June 2, 2015, from http://www.sciencedirect.com/science/article/pii/S1674205215002683

FAO. (2007). Adaptation to climate change in agriculture, forestry and fisheries: Perspective, framework and priorities. Rome: Interdepartmental Working Group on Climate Change, Food and Agriculture Organization of the United Nations (FAO).

FAO. (2008). *Climate change adaptation and mitigation in the food and agriculture sector. High-level conference on food security – the challenges of climate change and bioenergy*. Retrieved June 17, 2015, from ftp://ftp.fao.org/docrep/fao/meeting/013/ai782e.pdf

FAO. (2009a). *Increasing crop production sustainability, the perspective of biological processes*. Retrieved June 18, 2015, from http://www.fao.org/docrep/012/i1235e/i1235e00.htm

FAO. (2009b). *How to feed the world in 2050*. Rome. Retrieved June 18, 2015, from www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf

FAO. (2009c). *Climate change and biodiversity for food and agriculture: taking systemic and second order effects into account*. Rome: Commission on Genetic Resources for Food and Agriculture. Retrieved from June 18, 2015, from ftp://ftp.fao.org/docrep/fao/meeting/017/ak223e.pdf

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

FAO. (2010a). An international consultation on integrated crop-livestock systems for development, the way forward for sustainable production intensification. *Integrated Crop Management*, *13*, 208.

FAO. (2010b). *Gardens of biodiversity – conservation of genetic resources and their use in traditional food production systems by small farmers of the Southern Caucasus*. Rome: Food and Agriculture Organization of the United Nations.

FAO. (2011). *Save and grow: a policymaker's guide to the sustainable intensification of smallholder crop production.* Retrieved June 17, 2015, from http://www.fao.org/ag/save-and-grow/

FAO. (2012). *What is conservation agriculture?* Retrieved June 18, 2015, from http://www.fao.org/ag/ca/1a.html

FAO. (2013). *Climate-smart agriculture sourcebook*. Rome: Food and Agriculture Organization of the United Nations.

FAO. (2014). *The state of food insecurity in the world*. Rome. Retrieved June 17, 2015, from http://www.fao.org/3/a-i4030e.pdf

FAO (Food and Agriculture Organization). (2004). *Carbon sequestration in dryland soils.* Retrieved August 30, 2015 from http://www.fao.org/fileadmin/templates/nr/images/resources/pdf_documents/wsrr102.pdf

FAO-PAR (Platform for Agrobiodiversity). (2011). *Biodiversity for food and agriculture: contributing to food security and sustainability in a changing world.* Retrieved June 16, 2015, from http://agrobiodiversityplatform.org/files/2011/04/PAR-FAO-book_lr.pdf)

Fereres, E., Orgaz, F., & Gonzalez-Dugo, V. (2011). Reflections on food security under water scarcity. *Journal of Experimental Botany*, *62*(12), 4079–4086. doi:10.1093/jxb/err165 PMID:21624976

Fernandes, J. M., Cunha, G. R., Del Ponte, E., Pavan, W., Pires, J. L., Baethgen, W., ... Travasso, M. I. (2004). Modelling Fusarium head blight in wheat under climate change using linked process-based models. In *Proceedings of the 2nd International Symposium on Fusarium Head Blight* (pp. 441-444). East Lansing, MI: Michigan State University.

Flachsbarth, I., Willaarts, B., Xie, H., Pitois, G., Mueller, N. D., Ringler, C., & Garrido, A. (2015). The role of Latin America's land and water resources for global food security: Environmental Trade-Offs of Future Food Production Pathways. *PLoS ONE*, *10*(1), e0116733. doi:10.1371/journal.pone.0116733 PMID:25617621

Galyuon, I. K. A., McDavid, C. R., Lopez, F. B., & Spence, J. A. (1996a). The effect of irradiance level on cocoa (Theobroma cacao L.): I. Growth and leaf adaptations. *Tropical Agriculture, 73*(1), 23-28.

Galyuon, I. K. A., McDavid, C. R., Lopez, F. B., & Spence, J. A. (1996b). The effect of irradiance level on cocoa (Theobroma cacao L.): II. Gas exchange and chlorophyll fluorescence. *Tropical Agriculture, 73*(1), 29-33.

Ganpat, W. G., & Isaac, W. P. (Eds.). (2014). *Impacts of climate change on food security in Small Island Developing States*. Hershey, PA: IGI Global.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Gennaro, A., Forte, P., Carozza, R., Savo Sardaro, M. L., Ferri, D., Bitti, A., ... Ceoloni, C. (2007). Pyramiding different alien chromosome segments in durum wheat: Feasibility and breeding potential. *Israel Journal of Plant Sciences*, *55*(3-4), 267–276. doi:10.1560/IJPS.55.3-4.267

Ghanem, M. E., Marrou, H., & Sinclair, T. R. (2015). Physiological phenotyping of plants for crop improvement. *Trends in Plant Science*, *20*(3), 139–144. doi:10.1016/j.tplants.2014.11.006 PMID:25524213

Grossman-Greene, S., & Bayer, C. (2009). *A History of child labor, child rights, & the Harkin-Engel Protocol*. New Orleans, LA: Tulane University.

Guarino, L., & Lobell, D. B. (2011). A walk on the wild side. *Nature Climate Change*, *1*(8), 374–375. doi:10.1038/nclimate1272

Gur, A., & Zamir, D. (2004). Unused natural variation can lift yield barriers in plant breeding. *PLoS Biology*, *2*(10), 1610–1615. doi:10.1371/journal.pbio.0020245 PMID:15328532

Harvey, C. A., Chacon, M., Donatti, C. I., Garen, E., Hannah, L., Andrade, A., ... Wollenberg, E. (2014). Climate-Smart Landscapes: Opportunities and Challenges for Integrating Adaptation and Mitigation in Tropical Agriculture. *Conservation Letters*, *7*(2), 77–90. doi:10.1111/conl.12066

Heisey, P. W., & Rubenstein, K. D. (2015). *Using Crop Genetic Resources To Help Agriculture Adapt to Climate Change: Economics and Policy (No. 202351)*. Washington, DC: United States Department of Agriculture, Economic Research Service.

Hubert, B., Rosegrant, M., Van Boekel, M. A., & Ortiz, R. (2010). *The future of food: scenarios for 2050.* Retrieved June 11, 2015, from https://dl.sciencesocieties.org/publications/cs/abstracts/50/Supplement_2/S-33

Hutchinson, S., Gomes, C., Alleyne, D., & Phillips, W. (2013). *An assessment of the economic and social impacts of climate change on the agriculture sector in the Caribbean*. Port of Spain: UNECLAC. Retrieved September 27, 2015, from http://200.9.3.103/portofspain/noticias/documentosdetrabajo/5/49705/Agriculture.pdf

IFPRI (International Food Policy Research Institute). (2009). *Climate change: impact on agriculture and costs of adaptation.* International Food Policy Research Institute. Retrieved July 1, 2015, from http://www.ifpri.org/publication/climate-change-impact-agriculture-and-costsadaptation

IPCC. (2013). *Intergovernmental Panel on Climate Change*. Retrieved June 2, 2015, from http://www.ipcc.ch/

IPCC (Intergovernmental Panel on Climate Change). (2007). Technical Summary. In *Climate change (2007): mitigation. Contribution to Working Group III to the Fourth Assessment Report of IPCC*. Cambridge, UK: Cambridge University Press.

Isaac, W. A. P., Brathwaite, R. A., Cohen, J. E., & Bekele, I. (2007). Effects of alternative weed management strategies on *Commelina diffusa* Burm. infestations in Fairtrade banana (*Musa* spp.) in St. Vincent and the Grenadines. *Crop Protection (Guildford, Surrey)*, *26*(8), 1219–1225. doi:10.1016/j.cropro.2006.10.019

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Iwaro, A. D., Bekele, F. L., Butler, D. R., Singh, V., Holder-John, A., Bharath, S., ... Bidaisee, G. G. (2010). Recent progress in breeding for specific traits in cocoa to meet challenges to production. In *Proceedings of the International Congress on Tropical Agriculture: Overcoming Challenges to Developing Sustainable Agri-Food Systems in the Tropics* (pp. 43-52). Port of Spain, Trinidad: The University of the West Indies.

Jarvis, A., Ramirez-Villegas, J., Campo, B. V. H., & Navarro-Racines, C. (2012). Is cassava the answer to African climate change adaptation? *Tropical Plant Biology*, *5*(1), 9–29. doi:10.100712042-012-9096-7

Jarvis, A., Upadhyaya, H. D., Gowda, C. L. L., Agrawal, P. K., Fujisaka, S., & Anderson, B. (2008). *Climate change and its effect on conservation and use of plant genetic resources for food and agriculture and associated biodiversity for food security*. Retrieved June 4, 2015, from http://oar.icrisat.org/5810/

Jha, U. C., Bohra, A., & Singh, N. P. (2014). Heat stress in crop plants: Its nature, impacts and integrated breeding strategies to improve heat tolerance. *Plant Breeding*, *133*(6), 679–701. doi:10.1111/pbr.12217

Knapp, S. (2005). *Rich chocolate and poor farmers.* Wellington Aotearoa, New Zealand: Dev-Zone.

Knox, J., Hess, T., Daccache, A., & Wheeler, T. (2012). Climate change impacts on crop productivity in Africa and South Asia. *Environmental Research Letters*, *7*(3), 034032. doi:10.1088/1748-9326/7/3/034032

Läderach, P., Martinez-Valle, A., Schroth, G., & Castro, N. (2013). Predicting the future climatic suitability for cocoa farming of the world's leading producer countries, Ghana and Côte d'Ivoire. *Climatic Change*, *119*(3-4), 841–854. doi:10.100710584-013-0774-8

Lasky, J. R., Upadhyaya, H. D., Ramu, P., Deshpande, S., Hash, C. T., Bonnette, J., . . . Morris, G. P. (2015). Genome-environment associations in sorghum landraces predict adaptive traits. *Science Advances, 1*(6), e1400218. Retrieved August 5, 2015, from http://advances.sciencemag.org/content/1/6/e1400218.full-text.pdf+html

Leishman, M. R., & Gallagher, R. V. (2015). Will there be a shift to alien-dominated vegetation assemblages under climate change? *Diversity and Distributions*. Retrieved August 12, 2015, from http://onlinelibrary.wiley.com/doi/10.1111/ddi.12338/full

Lin, B. B. (2011). Resilience in agriculture through crop diversification: Adaptive management for environmental change. *Bioscience*, *61*(3), 183–193. doi:10.1525/bio.2011.61.3.4

Liu, P., Byers, A., & Giovannucci, D. (2008). *Value-adding standards in the North American food market-trade opportunities in certified products for developing countries*. Rome, Italy: FAO Trade and Markets Division.

Lobell, D. B., Burke, M. B., Tebaldi, C., Mastrandrea, M. D., Falcon, W. P., & Naylor, R. L. (2008). Prioritizing climate change adaptation needs for food security in 2030. *Science*, *319*(5863), 607–610. doi:10.1126cience.1152339 PMID:18239122

Ludena, C. E. (2010). *Agricultural productivity growth, efficiency change and technical progress in Latin America and the Caribbean. Inter-American Development Bank*. IDB Working paper 61, Series No. IDB-WP-186. Washington, DC: Inter-American Development Bank.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Lukefahr, S. D. (2005). Sustainable and alternative systems of rabbit production. In *Proceedings of the 8th World Rabbit Congress* (pp. 1452-1464). World Rabbit Science Association (WRSA).

Maggio, A., Van Criekinge, T., & Malingreau, J. P. (2015). *Global Food Security 2030. Assessing trends with a view to guiding future EU policies*. Foresight Series. European Commission DG Joint Research Centre. Retrieved on August 18, 2015, from http://publications.jrc.ec.europa.eu/repository/bitstream/JRC94867/lbna27252enn.pdf

Maharaj, K., Maharaj, P., Bekele, F. L., Ramnath, D., Bidaisee, G. G., Bekele, I., ... Sankar, R. (2011). Trinidad selected hybrids: An investigation of the phenotypic and agro-economic traits of 20 selected cacao cultivars. *Trop. Agric*, *88*(4), 175–185.

Martinelli, L. A., Naylor, R., Vitousek, P. M., & Moutinho, P. (2010). Agriculture in Brazil: Impacts, costs, and opportunities for a sustainable future. *Current Opinion in Environmental Sustainability*, *2*(5), 431–438. doi:10.1016/j.cosust.2010.09.008

Maximay, S. (2014). The Caribbean's Response to Climate Change Impacts. In W. Ganpat & W. P. Isaac (Eds.), *Impacts of Climate Change on Food Security in Small Island Developing States*. Hershey, PA: IGI Global.

Mba, C., Guimaraes, E. P., & Ghosh, K. (2012). Re-orienting crop improvement for the changing climatic conditions of the 21st century. *Agriculture and Food Security, 1*(7).

McCouch, S., Baute, G. J., Bradeen, J., Bramel, P., Bretting, P. K., Buckler, E., ... Zamir, D. (2013). Agriculture: Feeding the future. *Nature*, *499*(7456), 23–24. doi:10.1038/499023a PMID:23823779

Midega, C. A., Bruce, T. J., Pickett, J. A., Pittchar, J. O., Murage, A., & Khan, Z. R. (2015). Climate-adapted companion cropping increases agricultural productivity in East Africa. *Field Crops Research*, *180*, 118–125. doi:10.1016/j.fcr.2015.05.022

Millard, E. (2011). Incorporating agroforestry approaches into commodity value chains. *Environmental Management*, *48*(2), 365–377. doi:10.100700267-011-9685-5 PMID:21556936

Mollineau, W. M., Garcia, G. W., Samayah, D., Kissoonsingh, W., & Procope-Garcia, A. (2000). The wildlife industry in Trinidad: a case study towards developing a sustainable industry model for a small Twin Island State (Trinidad and Tobago). In *Proceedings of the Conference on Managing Space for Sustainable Living in Small Island Development States*. St. Augustine: The University of the West Indies.

Mustapha, K. (2009). Taste of child labor not so sweet: A Critique of Regulatory Approaches to Combating Child Labor Abuses by the US Chocolate Industry. *Wash. UL Rev.*, *87*, 1163.

Neilson, J., Susilo, A., Mulia, S., Guest, D., Lambert, S., Munawar, N. L., . . . Muhajir, A. S. (2014). *Improving cocoa production through farmer involvement in demonstration trials of potentially superior and pest/disease resistant genotypes and integrated management practices*. Retrieved June 29, 2015, from http://aciar.gov.au/files/smar-2005-074_final_report.pdf

Neufeldt, H., Jahn, M., Campbell, B. M., Beddington, J. R., DeClerck, F., De Pinto, A., ... Zougmoré, R. (2013). Beyond climate-smart agriculture: Toward safe operating spaces for global food systems. *Agric Food Secur*, *2*(12), 1180–1186.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Noble, I. R., Huq, S., Anokhin, Y. A., Carmin, J., Goudou, D., Lansigan, F. P., ... Villamizar, A. (2014). Adaptation needs and options. In C. B. Field, V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, ... L. L. White (Eds.), *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects* (pp. 833–868). Cambridge, UK: Cambridge University Press.

Ofori, A., Padi, F. K., Acheampong, K., & Lowor, S. (2015). Genetic variation and relationship of traits related to drought tolerance in cocoa (Theobroma cacao L.) under shade and no-shade conditions in Ghana. *Euphytica*, *201*(3), 411–421. doi:10.100710681-014-1228-8

Oyekale, A. S., Bolaji, M. B., & Olowa, O. W. (2009). The effects of climate change on cocoa production and vulnerability assessment in Nigeria. *Agricultural Journal*, *4*(2), 77–85.

Palombi, L., & Sessa, R. (2013). Climate-smart crop production system Module 7. In *Climate-smart agriculture: Sourcebook*. Retrieved June 23, 2015, from http://www.fao.org/3/a-i3325e/i3325e07.pdf

Pay, E. (2009). *The market for organic and fair-trade cocoa.* Rome, Italy: FAO. Retrieved August 5, 2015, from: http://www.fao.org/fileadmin/templates/organicexports/docs/Market_Organic_FT_Cocoa.pdf

Perez, C., Jones, E. M., Kristjanson, P., Cramer, L., Thornton, P. K., Förch, W., & Barahona, C. (2015). How resilient are farming households and communities to a changing climate in Africa? A gender-based perspective. *Global Environmental Change*, *34*, 95–107. doi:10.1016/j.gloenvcha.2015.06.003

Peterson, S. (2011). International technology transfer-not quite the silver bullet in international climate policy. *Climate Change: Current Issues*, 20-21. Retrieved August 13, 2015, from https://www.ifw-kiel.de/pub/e-books/climate_change.pdf

Ramirez-Villegas, J., & Thornton, P. K. (2015). *Climate change impacts on African crop production*. CCAFS Working Paper no. 119. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Retrieved June 22, 2015, from https://cgspace.cgiar.org/bitstream/handle/10568/66560/WP119_FINAL.pdf?sequence=1

Rasul, G., & Sharma, B. (2015). The nexus approach to water–energy–food security: an option for adaptation to climate change. *Climate Policy*, 1-21. Retrieved August 11, 2015, from http://www.tandfonline.com/loi/tcpo20

Reichert, J. M., Rodrigues, M. F., Awe, G. O., Riquelme, U. F. B., Kaiser, D. R., & Reinert, D. J. (2015). Common bean in highly variable weather conditions, on sandy soils, and food security in a subtropical environment. In *Food and Energy Security*. John Wiley & Sons Ltd. and the Association of Applied Biologists. Retrieved August 7, 2015, from http://onlinelibrary.wiley.com/doi/10.1002/fes3.65/epdf

Rellstab, C., Gugerli, F., Eckert, A. J., Hancock, A. M., & Holderegger, R. (2015). A practical guide to environmental association analysis in landscape genomics. *Molecular ecology*. Retrieved August 9, 2015, from http://onlinelibrary.wiley.com/doi/10.1111/mec.13322/epdf

Ribaut, J. M., de Vicente, M. C., & Delannay, X. (2010). Molecular breeding in developing countries: Challenges and perspectives. *Current Opinion in Plant Biology*, *13*(2), 213–218. doi:10.1016/j.pbi.2009.12.011 PMID:20106715

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Rijsberman, F. (2015). *CGIAR's new strategy and research programs: Answering to poverty, health and climate change.* News from the CGIAR Consortium. Retrieved August 3, 2015, from http://www.cgiar.org/consortium-news/cgiars-new-strategy-and-research-programs-answering-to-poverty-health-and-climate-change/

Roberts, T. G., Ganpat, W. G., Narine, L., Heinert, S. B., & Rodriguez, M. T. (2015). Trinidad Food Producers' Training Needs for Food Security and Implications for Extension. *Journal of International Agricultural and Extension Education*, *22*(1), 7–20. doi:10.5191/jiaee.2015.22101

Roberts, T. G., & Rodriguez, M. T. (2014). An Overview of climate change and impacts on food security in small island developing states. In W. Ganpat & W. P. Isaac (Eds.), *Impacts of Climate Change on Food Security in Small Island Developing States* (pp. 1–30). Hershey, PA: IGI Global.

Roberts-Nkrumah, L. B., & Legall, G. (2013). Breadfruit (*Artocarpus altilis*, Moraceae) and Chataigne (*A. camansi*) for Food Security and Income Generation: The Case of Trinidad and Tobago. *Economic Botany*, *67*(4), 324–334. doi:10.100712231-013-9250-7

Rosegrant, M. W. (2011). Impacts of climate change on food security and livelihoods. In *Food security and climate change in dry areas* (pp. 24-26). Aleppo: International Center for Agricultural Research in the Dry Areas (ICARDA).

Saibo, N. J., Lourenço, T., & Oliveira, M. M. (2009). Transcription factors and regulation of photosynthetic and related metabolism under environmental stresses. *Annals of Botany*, *103*(4), 609–623. doi:10.1093/aob/mcn227 PMID:19010801

Salem, M. A., Kakani, V. G., Koti, S., & Reddy, K. R. (2007). Pollen-based screening of soybean genotypes for high temperatures. *Crop Science*, *47*(1), 219–231. doi:10.2135/cropsci2006.07.0443

Sasson, A. (2012). Food security for Africa: an urgent global challenge. *Agriculture & Food Security, 1*(2), 1-16. Retrieved June 12, 2015, from http://www.biomedcentral.com/content/pdf/2048-7010-1-2.pdf

Scherr, S. J., Shames, S., & Friedman, R. (2012). From climate-smart agriculture to climate-smart landscapes. *Agriculture and Food Security, 1*, 12. Retrieved June 17, 2015, from http://www.biomedcentral.com/content/pdf/2048-7010-1-12.pdf

Schrage, E. J., & Ewing, A. P. (2005). The cocoa industry and child labour. *Journal of Corporate Citizenship*, *2005*(18), 99–112. doi:10.9774/GLEAF.4700.2005.su.00013

Sonnino, R., Moragues Faus, A., & Maggio, A. (2014). Sustainable food security: An emerging research and policy agenda. *International Journal of Sociology of Agriculture and Food*, *21*(1), 173–188.

Stigter, K. (2008). Cocoa and climate change. *Can the lame help the blind*. Retrieved June 19, 2015, from http://sitp.rpn.co.id/uploads/riset/kakao/Prosiding%20Kakao%202008%20Cocoa%20And%20Climate%20Change.pdf

Swaminathan, M. (1982). Biotechnology research and third world agriculture. *Science*, *218*(4576), 967–972. doi:10.1126cience.218.4576.967 PMID:17790573

Swaminathan, M. S. (2012). Role of genetic modification in developing climate smart agriculture to ensure sustained food security. *Agricultural Research*, *1*(4), 295–298. doi:10.100740003-012-0041-7

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Tester, M., & Langridge, P. (2010). Breeding technologies to increase crop production in a changing world. *Science*, *327*(5967), 818–822. doi:10.1126cience.1183700 PMID:20150489

Thornton, P. K., & Herrero, M. (2015). Adapting to climate change in the mixed crop and livestock farming systems in sub-Saharan Africa. *Nature Climate Change*, *5*(9), 830–836. doi:10.1038/nclimate2754

Tol, R. S. J. (2002). Estimates of the damage costs of climate change, Part I: Benchmark Estimates. *Environmental and Resource Economics*, *21*(1), 47–73. doi:10.1023/A:1014500930521

Toulmin, C. (2009). *Climate change in Africa*. London: Zed Books.

UNFCCC (United Nations Framework Convention on Climate Change). (2007). *Climate change: impacts, vulnerabilities and adaptation in developing countries*. Bonn, Germany: UNFCCC Secretariat. Retrieved June 4, 2015, from http://unfcc.int/resource/docs/publications/impacts.pdf

Vervoort, J. M., Thornton, P. K., Kristjanson, P., Förch, W., Ericksen, P. J., Kok, K., ... Jost, C. (2014). Challenges to scenario-guided adaptive action on food security under climate change. *Global Environmental Change*, *28*, 383–394. doi:10.1016/j.gloenvcha.2014.03.001

Waldron, A., Justicia, R., Smith, L., & Sanchez, M. (2012). Conservation through chocolate: A win-win for biodiversity and farmers in Ecuador's lowland tropics. *Conservation Letters*, *5*(3), 213–221. doi:10.1111/j.1755-263X.2012.00230.x

West African Rice Development Association. (2001). NERICA: Rice for life. *WARDA/ADRAO, Bouaké*. Retrieved June 18, 2015, from http://www.warda.org/publications/NERICA.pdf

Wheeler, T., & von Braun, J. (2013). Climate change impacts on global food security. *Science*, *341*(6145), 508–513. doi:10.1126cience.1239402 PMID:23908229

Wickham, L. D. (1992). The potential for increasing the productivity and quality of vegetables produced in the Caribbean region: UWI research and perspectives. In G. Villanueva, J. Corven & A. Campos (Eds.), Proceedings of Taller regional centroamericano y consulta sobre planificacion de investigacion horticola (pp. 245-251). San José, Costa Rica: IICA.

World Cocoa Foundation (WCF). (2015). *President's message*. Retrieved June 27, 2015, from: http://worldcocoafoundation.org/wcf-may-june-2015-2/#2&utm_source=WCF+May+%26+June+2015+Newsletter&utm_campaign=WCF+Newsletter&utm_medium=email

KEY TERMS AND DEFINITIONS

Climate Change Adaptation: Human actions or responses in nature taken to adjust to risks posed by *climatic* changes or to benefit from any advantages.

Climate Change Mitigation: Action taken to permanently eliminate or reduce the long-term risk and hazards of climate change to the environment, human life and property.

Climate-Smart Agriculture: Agricultural practices that sustainably increase agricultural productivity and incomes, facilitate adaptation and build resilience to climate change and reduce or remove emission of greenhouse gases.

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Conservation Agriculture: Encompasses cost-effective soil management practices that minimize the disruption of the soil's structure, composition and natural biodiversity. It takes advantage of soil fauna and properties that improve fertility that can improve crop yields while protecting the environment.

***Ex Situ* Conservation:** Protecting species of a plant or animal outside its natural habitat (*in situ*).

Functional Genomics: Study of genes, their resulting proteins, and the role played by the latter in the biochemical processes of plants and animals.

Gene Pyramiding: A process of combining or assembling multiple desirable *genes* from multiple parents into a single genotype.

Genomewide Association Analysis: Involves scanning markers across the complete sets of DNA or genomes for a particular species such as *Oryza sativa* subspecies (e.g. *indica*), examining many common genetic variants in different individuals to see if any variant is associated with a trait of interest.

Genomic Selection: A process used to identify potentially favourable organisms (animals or plants) based on specific genetic information they harbour.

Genotype: Genetic makeup of a particular organism or group of organisms.

Marker Assisted Selection: A process where a trait of interest is *selected*, not based on the physical trait itself (such as plant height), but on a molecular or genetic *marker* linked to it.

Phenotype: Observable characteristics of an individual (such as seed size) resulting from the interaction of its genotype with the environment.

ENDNOTES

1 Agriculture includes food crops, pastures and livestock, industrial crops and biofuels, forestry (commercial forests), aquaculture.

2 The Millennium Development Goals (MDGs) are the world's time-bound and quantified targets for addressing extreme poverty, hunger, disease, lack of adequate shelter, and exclusion while promoting gender equality, education, and environmental sustainability.

3 Riparian vegetation is composed of plant habitats and communities along river/stream margins and banks, and a riparian area is the interface between water and land.

4 'Cacao' is the term used to describe the plant of *Theobroma cacao* L. 'Cocoa' describes the commercial product - the nibs/seeds.

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Chapter 60
Marketing of Agricultural Commodities in India

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ABSTRACT

Commodity market is a fast paced dynamic market with liquidity and Commodity Exchange providing a platform for trading in various agri and non agri commodities at nationalized exchanges for discovering the price of agricultural goods in India since 2003. This also provides an opportunity to farmers, manufacturers or individuals for hedging and arbitrage to minimizes the losses due to fluctuations in the futures as well as spot prices. Though the Government has taken many steps time to time to control the prices of listed commodities by imposing restrictions like imposing daily margin limits and banning futures trading in speculative commodity/commodities if required but it is still being questioned. This chapter emphasizes on the working of the National Level Commodity Exchanges in India in general, the share of major agricultural commodities traded across National Level Commodity Exchanges in India, the marketing mix for agricultural commodities in India and the benefits and challenges of commodity futures derivatives for investors in India.

OBJECTIVES OF THE CHAPTER

1. Agricultural commodities are listed and traded at various commodity exchanges in India and globally as well. Readers would understand the working of the National Level Commodity Exchanges in India.
2. Readers would come to know about the share of major agricultural commodities traded across National Level Commodity Exchanges in India.
3. Readers would understand the marketing mix for agricultural commodities in India that how commodities are bought and sold at warehouses of commodity exchanges in India.
4. The commodity exchanges provide benefits and challenges of commodity futures derivatives for investors in India.

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CASE LET

Commodity market is a place where listed agricultural and non-agricultural commodities are bought and sold. There are nationalized and regional commodity exchanges in India. Indian commodity sector has also been experiencing tremendous surge since its inception. This has given a new option to investors to hedge their positions against fluctuations in the prices of commodities in near future. People are also using this platform for gaining from ups and downs in the prices without having commodities in physical but it is more specifically beneficial for farmers, jewelers and manufacturers who require raw materials and want to take delivery of traded commodities but they face warehousing issues. There are other different kinds of issues faced by participants in commodity markets such as legal, regulatory, infrastructural and others. Earlier the commodity market was regulated by the Forward Markets Commission (FMC), which has recently been merged with Securities Exchange Board of India (SEBI) on 28th Sep., 2015 after the scam of National Spot Exchange Ltd.(NSEL). This risk was faced by all the investors in this market and their confidence was also shaken which resultant in the low business of commodity exchanges but now SEBI is regulating this market and building up the confidence of the investors while implementing the more strict rules and regulations for commodity market in India.

INTRODUCTION

Indian markets have provided a new opportunity for retail investors and traders, who want to diversify their portfolios beyond shares, bonds and real estate, to participate on commodity exchanges. The spectacular growth of commodity markets has also attracted many investors around the world to expand their investment to emerging markets like India, as more and more investors are realizing the potential opportunities of these markets. Like any other market, the commodity market also plays a vital role in risk management of derivatives.

It is well-known that commodities are the foundation of the economies of most developing countries by way of providing food, creating income generating opportunities and export earnings to the people directly involved in agricultural activities. In most of the agriculture driven economy, it has been commonly observed that the agricultural policy made by the Government tends to protect and promote the agriculture sector through different procurement and administered price mechanism. Historically, the Government intervention is found at every stage of the marketing of major agricultural products. These includes, setting Minimum Support Prices for selected commodities, regulation of every activity of marketing such as transportation, storage, credit supply and international trading of these commodities, etc. But Government intervention has significantly declined after the initiation of liberalization and economic reforms since 1991. The impact of agricultural commodity is of great importance in the stabilization of Indian economy, as reflected through the share of primary goods, especially the food items in derivation of the price indices like inflation based on Wholesale Price Index and Consumer Price Index in India. This clearly indicates the necessity of significant growth and stability of agricultural sector to foster the overall growth of Indian economy. For managing the risk of pricing of agricultural goods because of commodities futures trading, regular attempts are made worldwide. It has been clearly observed that prices of agricultural commodities are determined increasingly by market forces of demand and supply. Hence fluctuation in demand and supply of agricultural commodities is expected to result in high price risk for agri-business. Application of several market-based instruments to deal with the commodity price

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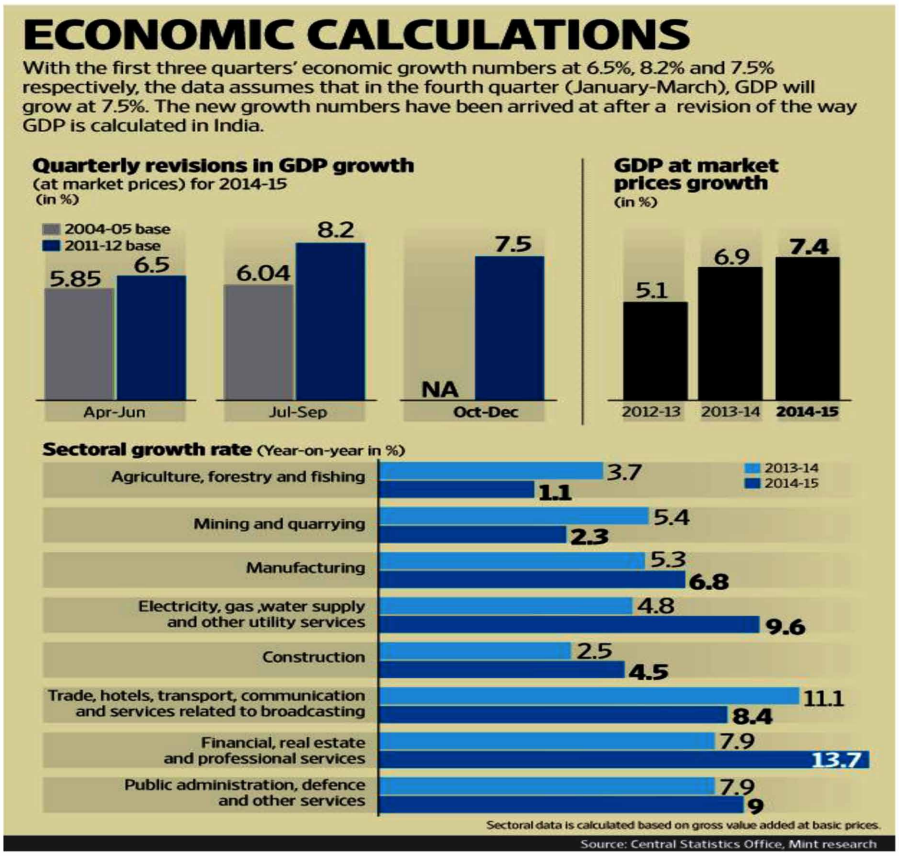
risk basically focuses on the introduction of derivatives viz. futures and options contract on several commodities. In other words, it is widely proposed to setup an efficient derivative market for commodities to strengthen the agricultural market. Generally trading in commodity derivatives and futures is done to get the necessary support from any variation in the commodity prices. This is called as Hedging. This strategy helps to offset the loss expected to incur from the adverse price movements of the underlying commodities. Therefore it is very important to develop futures and other forms of derivative trading in all commodities.

Commodity Market

Commodity market is a regulated place, in which listed commodities are bought and sold through the intervention of members (brokers) of commodity exchange, by following an open system of two way quotations; the settlement of trades is done according to the bye-laws of commodity exchange.

A commodities market serves the purpose of allowing two individuals to exchange the rights to goods without visual inspection. Commodity markets require the existence of agreed standards opposed to spot markets where delivery either takes place immediately, or with a minimum lag and normally involves visual inspection of the commodity or a sample of the commodity.

Figure 1. Sector wise growth rate in 2013-14 and 2014-15
Source: Testbook (2015).



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According to Indian Forward Contracts (Regulation) Act (FCRA), 1952 "goods" means "every kind of movable property other than actionable claims, money and securities". Any product that can be used for commerce or an article of commerce which is traded on an authorized commodity exchange is known as commodity. The article should be movable of value, something which is bought or sold and which is produced or used as the subject or barter or sale. In short commodity includes all kinds of goods.

A forward contract is an agreement between two parties to exchange at some fixed future date a given quantity of a commodity for a price defined today (buy now, pay later). Forward contracts have evolved and have been standardized into what we know today as futures contracts.

A futures contract is a type of derivative instrument, or financial contract, in which two parties agree to transact a set of financial instruments or physical commodities for future delivery at a particular price. If you buy a futures contract, you are basically agreeing to buy something that a seller has not yet produced for a set price. But participating in the futures market does not necessarily mean that you will be responsible for receiving or delivering large inventories of physical commodities - remember, buyers and sellers in the futures market primarily enter into futures contracts to hedge risk or speculate rather than to exchange physical goods (Wilson, n.d.).

Commodity Derivatives

Commodity derivatives have had a long presence in India and it provides opportunities to investors for minimizing their future price risk.

A derivative is a product whose value is derived from the value of one or more underlying variables or assets in a contractual manner. The underlying asset can be equity, forex, commodity or any other asset (Bhat, 2009).

Derivative contracts are of different types. The most common ones are forwards, futures, options and swaps. Participants who trade in the derivatives market can be classified under the following three broad categories - hedgers, speculators, and arbitragers. In India, the National Commodity Exchanges are Multi Commodity Exchange, Mumbai (MCX), National Commodity and Derivatives Exchange, Mumbai (NCDEX), National Multi Commodity Exchange, Ahmedabad (NMCE), Indian Commodity Exchange Ltd., Mumbai (ICEX), ACE Derivatives and Commodity Exchange, Mumbai (ACE) and Universal Commodity Exchange Ltd., Navi Mumbai (UCX) but ACE and UCX have suspended their operations in India recently. These exchanges are playing very important role in the trading of agricultural as well as non-agricultural commodities in India. Derivative contracts in 113 commodities are available for trading. National Commodity and Derivatives Exchange (NCDEX) is the largest commodity derivatives exchange. Forward Markets Commission (FMC) introduced futures contracts on these exchanges in new commodities time by time for increasing trading level.

The Forward Markets Commission (FMC), established under the Forward Contracts (Regulation) Act, 1952, regulates commodity derivatives trading in India in the same way as Securities Exchange Board of India (SEBI) does for securities markets but FMC has been merged with SEBI on 28th Sep. 2015 and now SEBI will also regulate the commodity futures market in India.

The commodities traded at these Exchanges comprise the following:

- **Edible Oilseeds Complexes:** Mustard seed, Cottonseed, Soybean oil etc.
- **Food Grains:** Wheat, Bajra, and Maize etc.
- **Metals:** Gold, Silver, Copper, Zinc, Aluminium, Steel etc.

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- **Spices:** Turmeric, Pepper, Jeera, Chilli etc.
- **Pulses:** Chana.
- **Fibres:** Cotton, Jute etc.
- **Others:** Sugar, Gur, Rubber, Natural Gas, Crude Oil etc.

BACKGROUND

Trading in derivatives started to protect farmers from the risk of the value of their crop going below the cost price of their produce. Derivative contracts were offered on various agricultural products like cotton, rice, coffee, wheat, pepper, etc. The first organized exchange the Chicago Board of Trade (CBOT) was established in 1848. In 1874, the Chicago Produce Exchange, which is now known as Chicago Mercantile Exchange, was formed (CME). These both are the largest commodity derivatives exchanges in the world. The Indian Commodity markets also have a long presence. The commodity derivative market has been functioning in India since the nineteenth century with organized trading in cotton through the establishment of Cotton Trade Association in 1875. Over the years, there have been various bans and suspensions on various contracts.

Commodity futures, which were introduced for risk management purposes in 2003, are now catching the eyes of investors as an investment tool. People, who are not having commodities in physical form and even don't require any commodity, are trading in the commodity derivatives market. They are just speculating in the direction of the prices of listed commodities for making money but it is affecting pricing of agricultural goods in India as many of the agricultural goods like pepper, jeera, channa, potato, guarseed, mustard oil, wheat are available for trading on commodity exchanges. Prices of these commodities are getting affected due to speculation done by the traders and it is leading to high inflation in India.

These markets are basically used to hedge commodity price risks and also provide transparent mechanism for discovering future prices by providing a platform for exchanging demand and supply information about all listed commodities. The hedging and price discovery functions of future markets promote more efficient production, storage, marketing and agro-processing operations and help in improvement in overall agricultural marketing performance. Foreign institutional investors, banks and insurance companies are not allowed to trade on the Indian commodity Markets and a majority of volumes come from jobbers, arbitrageurs, retail traders and corporates for hedging.

Although India has a long history of trade in commodity derivatives, this sector remained underdeveloped due to government intervention in many commodity markets to control prices. The production, supply and distribution of many agricultural commodities are still governed by the state. Free trade in many agricultural commodities items is restricted under the Essential Commodities Act (ECA), 1955 and Agriculture Produce Marketing Committees (APMC) Acts of various State Governments. The forward and futures contracts were, till April 2003, limited to only a few commodity items under the Forward Contracts (Regulation) Act (FCRA), 1952. However, in 2003, GOI removed all restrictions on commodities, which could be traded on commodity exchanges.

Important Milestones in Commodity Futures Trading in India

- **1875 - Bombay Cotton Trade Association:** While there is a viewpoint that Futures Trading has existed in India for thousands of years, the first organised futures market was established only in

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1875 by the Bombay Cotton Trade Association to trade in cotton contracts. This occurred soon after the establishment of trading in Cotton Futures in UK, as Bombay was a very important hub for Cotton Trade in the British Empire.

- **1893 - Bombay Cotton Exchange Ltd:** Following widespread discontent amongst leading cotton mill owners and merchants over the functioning of the Bombay Cotton Trade Association, a separate entity, by the name "Bombay Cotton Exchange Ltd." was constituted.

Soon after the commencement of Cotton Futures, Futures trading in Oil Seeds was started by the formation of Gujarat Vyapari Mandali, which was established in the year 1900 in Mumbai. It is currently known as "The Bombay Commodity Exchange Limited" (BCE).

Futures trading in Raw Jute and Jute Goods began in Calcutta with the establishment of the Calcutta Hessian Exchange Ltd., in 1919. Later East Indian Jute Association Ltd. was set up in 1927 for organising futures trading in Raw Jute. These two associations amalgamated in 1945 to form the present East India Jute & Hessian Ltd., to conduct organized trading in both Raw Jute and Jute goods. Futures trading in raw jute suspended in 1964 reportedly on the insistence of the then State Government (WB Govt.) as there were too many reports and allegations of price manipulations which left the farmer in the lurch. The Government had no other alternative but to suspend it. The announcement to reintroduce it was made in February 2003 after the Union Government had pressed for its return (Essays, 2015).

The functioning of futures markets came under suspicion because of rising prices of some commodities during 2006–07 and the government ordered a possible delisting of futures contract commodities like Urad, Tur, Wheat and Rice to avoid the abnormal rise in their domestic spot prices. Followed by this, Sugar, Oil, Rice and Potato were also banned in 2007, but were subsequently delisted in 2008. In a similar way, the India Government again banned future trading in Chana, Potato and Soya oil in May 2008. However, a steady process of opening up has been visible in future market for commodities over the last two years. As a result of significant policy change, liberalization of world markets and other developments, Indian commodity markets have shown phenomenal growth in terms of number of products, participants, technology, transparency and volume of trade.

Characteristics and Scope

- Hedging is done in the commodity futures market with the objective of transferring risk related to the possession of physical assets through any adverse movements in futures and spot prices.
- Price stabilization along with balancing demand and supply position. Futures trading leads to predictability in assessing the domestic prices, which maintains stability, thus safeguarding against any short term adverse price movements.
- Flexibility, certainty and transparency in purchasing commodities facilitate bank financing. Predictability in prices of commodity would lead to stability, which in turn would eliminate the risks associated with running the business of trading commodities. This would make funding easier and less stringent for banks to commodity market players.

Scope

Researches done in this field are mostly related to overview of commodity market, price discovery of various commodities, behavior of investors and price volatility of some agricultural commodities but

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the problem of analyzing the impact of commodities trading on agricultural commodities at national level as a whole is still lacking.

Bhagwat Shree Dr., Maravi Singh Angad, More Ritesh, and Chand Deepak (2015) in their research paper have discussed the growth of commodity futures market in India, taking into consideration the history of commodity futures market as well as the mechanism of trading, segments and regulatory framework of commodity market in India. According to them, commodity futures market has witnessed several developments since 2002-03. There has been tremendous growth in commodity futures market in terms of volume of trade, number of products on offer participants and technology. Commodity futures market is instruments to achieve price discovery and price risk management as futures markets provide liquidity and facilitated to hedge against future price risk. Commodity trading also offers a change for financial leverage to hedgers, speculators and other traders. A structural system has been created for commodity trades. There are 26 exchanges operating in India and carrying out futures trading activities in as many as 146 commodity items. As per the recommendation of the FMC, the Government of India recognized the National Multi Commodity Exchange (NMCE), Ahmedabad; Multi Commodity Exchange (MCX); National Commodity and Derivative Exchange (NCDEX), Mumbai and Indian Commodity Exchange (ICEX) as nationwide multi-commodity exchanges. MCX has a major market share and the exchange turnover has been increased on every year. The growth of commodity futures market of India will lead to further development in the field of electronic warehouse receipts which may facilitate seamless nationwide commodity spot market. It would strengthen the Indian economy to face the challenge of globalization.

Dash, Solanki, and Shobana (2015) found in their study that derivative markets have attained more than eighteen times in trading volume when compared to the spot markets. They analyzed the impact of trading volume, inflation and other macroeconomic factors on spot and futures price movements using GARCH model. The study explored commodity prices from several different angles. First, they found the possibility of lead-lag relationships between commodity spot and futures prices of different categories of commodities such as Precious Metals, Base Metals and Agro products traded on MCX. Second, they analyzed the inter-relationship of spot and futures prices and trading volume, for the same commodity, and between substitute and/or complementary commodities such as between gold & silver, crude oil & natural gas, the base metals, and agricultural commodities. Third, another area they explored in the study was the impact of trading volume and inflation on commodity price volatility for selected commodities. While trading volume was found to have significant impact on volatility, inflation was found to have significant impact on crude oil price volatility only.

Bansal Rohit, Dadhich Varsha and Ahmad Naveed (2014) in their study found that in its long history of trading in commodities and related derivatives, Indian commodity market has seen several developments between two extreme scenarios: protection of the essential commodity market through government intervention and the opening up of the sector and getting the necessary protection through market based instruments like commodity futures contract. After a long period of suspension commodity derivative market was reintroduced in India in early 2000s. Since its resumption, however, the market has been growing at a very high pace. The growth is evident in the spread of market network as well as in volume of trade. Almost 100 commodities (agricultural and non- agricultural) are traded in different exchanges. The volume of trade has increased from Rs. 34, 84,485 crore in 2006 to Rs. 11948942 crore in 2011. It indicates a positive growth in the commodity market sector in India.

Dhole Suresh Sagar (2014) in his research paper investigated the antiquity of commodity futures market in India epoch back to the ancient times citied in Kautialya's 'Arthasastra', and have been commodity heard in Indian markets for centuries, seems to be coined in 320 BC, referred in Forward Contracts

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(Regulation) Act, 1952. They found the markets have made enormous advancement in terms of technology, transparency and the trading activity. Interestingly, this has happened only after the Government protection was removed from a number of commodities, and market forces were allowed to play their role. Rational Government policies and the plinth of effective laws have benefited in many ways like Credit accessibility, improved product quality, predictable pricing, Import-export competitiveness, and price risk management and price discovery.

Rajamohan, Vethamanikam, Arul Hudson and Vijaykumar (2014) in their study examined that the commodity trading has a long history and it has been modernized in the market. The commodities trading are occupied an important place in the economy it depends on the international trade A structural system has been created for commodity trades. It is creating awareness and the more opportunity to the investors and public. They found the market volatility is based on these commodities performance. However the commodity market has provided huge support to the Indian economy.

Brajesh Kumar and Pandy Ajay (2013) in their research work investigated the short run and long run market efficiency of Indian commodity futures market. They had tested four agricultural and even nonagricultural commodities for market efficiency and un biasedness. The result confirmed the long run efficiency of commodity futures prices and inefficiency of futures prices in short run.

Chhajed and Mehta (2013) found that the price discovery mechanism is quite effective for most commodities, but may not be very effective for some commodities. In particular, causality in commodities markets can be used to either hedge or speculate price movements: if changes in spot prices drive changes in futures prices, efficient hedging strategies can be formulated; whereas if changes in futures prices drive changes in spot prices, efficient speculation strategies can be formulated. Further, causality can be used in forecasting commodity spot and futures prices.

As majority of Indian investors are not aware of organized commodity market; their perception about is of risky to very risky investment. Many of them have wrong impression about commodity market in their minds. It makes them specious towards commodity market. Concerned authorities have to take initiative to make commodity trading process easy and simple. Along with Government efforts, NGO‟s should come forward to educate the people about commodity markets and to encourage them to invest in to it. There is no doubt that in near future commodity market will become Hot spot for Indian farmers rather than spot market. And producers, traders as well as consumers will be benefited from it. But for this to happen one has to take initiative to standardize and popularize the Commodity Market.

Sehgal, Rajput, and Dua (2012) analyzed in their research study the destabilization effect which is a relationship of futures liquidity and spot market volatility by using Hedrick Prescott (HP) filter and unexpected variable (unexpected liquidity) on seven agricultural commodities. As per the results of the study, in case of Guarseed, Turmeric, Soybean, Maize and Castor Seed the study confirmed that Futures market liquidity (based on trading volume) tends to drive spot market volatility i.e. stating destabilizing effect. As futures and spot markets are interlinked, any information shock should affect both the markets. Results of the lead lag relationship between spot price volatility and futures trading activity (unexpected) suggested that in most of the commodities the unexpected futures trading volume causes spot price volatility confirmed by Granger causality test. In case of Black pepper reversed destabilization effect was observed because of strong speculative interest in the market and lack of transparency. In case of Barley the study confirmed that Futures market liquidity (based on trading volume) does not affect spot market volatility.

Malyadri G. Dr. and Kumar Sudheer B. (2012) studied the history of commodity market. Commodity derivatives arrived in India as early as 1875, barely about decade after they arrived in Chicago. The

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commodity market in India has experienced an unprecedented boom in terms of the number of modern exchanges, the number of commodities allowed for derivative trading as well as the values of futures trading in commodities. However, there are several impediments to be overcome and issues to be settled for a sustained development of the market.

Agnihotri and Sharma (2011) studied the degree to which commodity spot prices have converged with future market with a view to measure this convergence, and to find out arbitrage opportunity in MCX, and NCDEX, the correlation, regression, and standard deviation was used for the period of five years from 2005 to 2010. The results indicated that correlation coefficients themselves are not capable of detecting convergence and that the regression – linear tests was more powerful detecting any convergence between the future and spot prices of Zeera, Zink, Chana, and natural gas. It was observed that there is a need of another commodity exchange to overcome many functional inadequacies of the existing three national online commodity exchanges, particularly with respect to delivery-based settlement as a mechanism of efficient price discovery as MCX and NCDEX do not trade in all the commodities and hence do not provide opportunity for arbitrage. There is a clear delinking of futures prices of commodities traded at these exchanges and the prevailing spot prices, thereby leaving arbitrage opportunities, because of which actual hedgers do not find these exchanges useful for managing their commodity price risks. Some commodities such as iron ore and coal, wherein India is a large producer, consumer, importer and exporter are not traded at these exchanges. Third, unlike the existing exchanges, which hardly promote delivery-based trading, the new exchange should aim to integrate warehouse delivery by providing an online trading platform so that it becomes a true platform for delivery-based hedging. All this has potential to improve India's share in international trade substantially. The new exchange will provide not only arbitrage opportunity but also attract more investors.

Dharmbeer and Singh Barinder (2011) emphasized the theoretical and empirical research on the growth and prospects of emerging commodity markets and the resulting implication on policy and regulation. They found from the previous studies that derivatives markets have supported the hedging role of emerging derivatives markets. All commodities are globally traded and the global demand-supply situation is widely known and available to anyone who reaches out for it. The commodity markets are nowhere as volatile as stock futures. Since commodity exchanges promote price transparency, he refuses to buy the story that commodity exchange fuel inflation.

The scope of the study revolves around the parties like Govt. & Regulatory bodies, intermediaries, investors, trading exchanges and other researchers. Agricultural commodities depend on rain fall, weather conditions, seasons and government support in terms of subsidies and minimum support price extended by Government to help the farmers. There is a much scope for researchers to find out the linkage between pricing behavior of future contracts and nature of agricultural commodities traded on national level commodity exchanges. There is also a scope related to analyzing the impact on working and efficiency of commodity exchanges after the merger of FMC with SEBI.

Growth of Traded Commodities at All National Commodity Exchanges and Share of All National Commodity Exchanges to Total Value Traded From 2004-14

The year 2003 was a watershed in the history of commodity futures market. The group of 54 prohibited commodities was opened up for forward trading, along with establishment and recognition of three new national exchanges with on-line trading and professional management in the year 2003. Not only

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prohibition on forward trading was completely withdrawn, including in sensitive commodities such as wheat, rice, sugar and pulses which earlier committees had reservations about, the establishment of new exchanges brought capital, technology and innovation to the market.

Futures contracts are available for major agricultural commodities, metals and energy. Commodity group-wise value of trading since 2004-05 is given below in the table.

During the year 2013-14, forward trading in 113 commodities, was regulated at the 6 National Exchanges, viz. Multi Commodity Exchange, Mumbai; National Commodity and Derivatives Exchange, Mumbai, National Multi Commodity Exchange, Ahmedabad, Indian Commodity Exchange, Gurgaon, and ACE Derivatives & Commodity Exchange Limited (ACE). Besides, there were 11 regional exchanges recognized for regulating trading in various commodities approved by the Commission under the Forward Contracts (Regulation) Act, 1952. The total value of trade in agricultural commodities at all the exchanges during the year was 16.02 lakh crore as against 21.56 lakh crore in 2012-13 indicates a decline of 21.7% over the year. During 2013-14, NCDEX accounted for 11.30% of the total value of trade in the commodity market.

It is clearly shown in the above graph that MCX contributed major share 84.89% in terms of value in the total value traded across at commodity exchanges in the year 2013-14 and NCDEX accounted 11.30% during the year.

Challenges and Benefits

Commodity exchange is a platform for trading of agri and non agri commodities and providing a transparent price discovery to all the investors. Though it is beneficial for the participants, but commodity exchanges are also facing following challenges:

1. **Lack of Knowledge About Commodity Futures Trading:** Investors are finding commodity markets as an investment option where they can hedge their risk like farmers can hedge physical positions of their crops but they don't have proper knowledge about commodity futures trading. This is one of the disadvantages of commodity market otherwise more participation of the investors can be seen.

Table 1. Commodity group-wise value of trade (Rs. Lakh Crores)

Commodity Groups	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
Bullion and other metals	1.80 (31.47)	7.79 (36.15)	21.29 (57.90)	26.24 (64.55)	44.00 (67.14)	49.66 (63.97)	81.82 (68.47)	130.79 (72.00)	111.23 (65.00)	60.07 (60.00)
Agriculture	3.90 (68.18)	11.92 (55.31)	13.17 (35.82)	9.41 (23.15)	6.64 (10.13)	12.18 (15.69)	14.56 (12.19)	21.96 (12.00)	21.56 (13.00)	16.02 (16.00)
Energy	0.02 (0.35)	1.82 (8.45)	2.31 (6.28)	5.00 (12.30)	14.89 (22.73	15.78 (20.34)	23.11 (19.34)	28.51 (16.00)	37.68 (22.00)	24.72 (24.00)
Others	0.00 (0.00)	0.02 (0.09)	0.001 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.000 (0.00)	(0.00) (0.00)	(0.00) (0.00)
Total	5.72 (100.00)	21.55 (100.00)	36.77 (100.00)	40.65 (100.00)	65.53 (100.00)	77.62 (100.00)	119.49 (100.00)	181.26 (100.00)	170.47 (100.00)	100.81 (100.00)

Source: FMC Annual Report from 2004 to 2014.

Note: Figures in parenthesis indicate percentage to total value.

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Figure 2. Percentage of commodity exchange to the value traded during 2013-14
Source: FMC Annual Report 2013-14.
Note: Annual Report of FMC 2014-15 is not available.

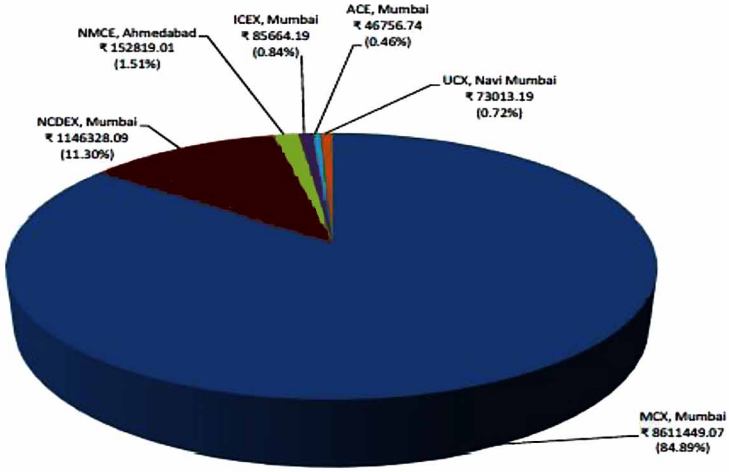
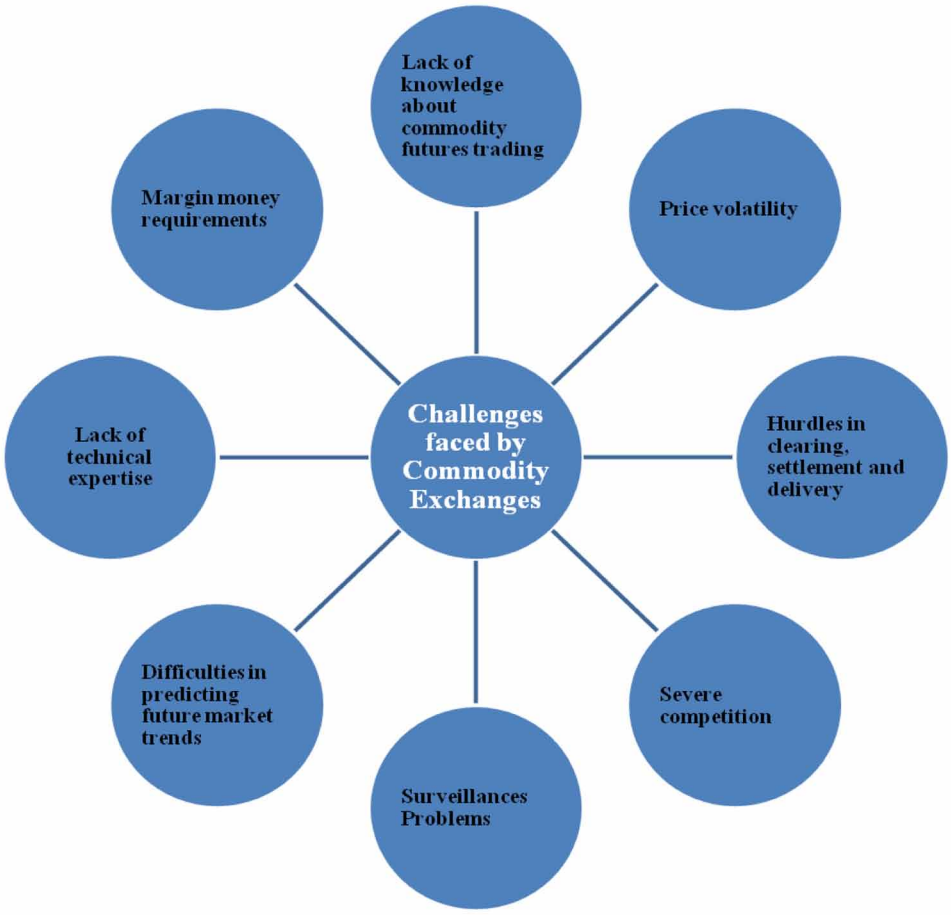


Figure 3. Challenges of commodity futures market



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2. **Price Volatility:** People do futures trading on commodity exchanges to minimize their risk from the price fluctuations but as we know that no one can predict the future. Hence they incur loss sometimes.
3. **Hurdles in Clearing, Settlement, and Delivery:** The traders have to give intention to the exchange for taking/giving delivery for the commodities before expiry of a futures contract. In this context, they should know about warehouse clearing and settlement of commodities in physical form otherwise they face hurdles in this.
4. **Severe Competition:** Everyone has to face severe competition in this cut throat competition. There are regional and commodity exchanges in the market but existence of local commodity players can not be avoided in terms of brokerage and delivery charges.
5. **Surveillances Problems:** Monitoring of commodity futures market is necessary to avoid frauds such as scam of National Spot Exchange Ltd. in 2014-15. After this scam, the regulatory authority of commodity market Forward Markets Commission (FMC) has been merged with Securities Exchange Board of India (SEBI) on 28th Sep. 2015. So the surveillance problems faced by the participants in commodity derivatives market are one of the main issues.
6. **Difficulties in Predicting Future Market Trends:** No one can predict trends of futures market even though futures trading is based on technical and fundamental analysis but they also provides the support and resistance levels for trading in volatile futures market.
7. **Lack of Technical Expertise:** Experience is required to predict the trends of futures market. Technical expertise should be there to deal with high volumes of trading on the basis of market knowledge which is a lacuna and due to this; most of the investors don't get benefit from trading in commodity market.
8. **Margin Money Requirements:** Risk management is very important aspect of trading in futures market. Margin money is required for this purpose and it is fixed by the exchange for every traded commodity. A special margin is imposed by the exchange in case of volatility. So the investors and traders have to pay additional margin money in this case.
9. **Price Discovery:** Based on inputs regarding specific market information, the demand and supply equilibrium, weather forecasts, expert views and comments, inflation rates, Government policies, market dynamics, hopes and fears, buyers and sellers conduct trading at futures exchanges. This transforms in to continuous price discovery mechanism. The execution of trade between buyers and sellers leads to assessment of fair value of a particular commodity that is immediately disseminated on the trading terminal.
10. **Price Risk Management:** Hedging is the most common method of price risk management. It is strategy of offering price risk that is inherent in spot market by taking an equal but opposite position in the futures market. Futures markets are used as a mode by hedgers to protect their business from adverse price change. This could dent the profitability of their business. Hedging benefits who are involved in trading of commodities like farmers, processors, merchandisers, manufacturers, exporters, importers etc.
11. **Import- Export Competitiveness:** The exporters can hedge their price risk and improve their competitiveness by making use of futures market. A majority of traders which are involved in physical trade internationally intend to buy forwards. The purchases made from the physical market might expose them to the risk of price risk resulting to losses. The existence of futures market would allow the exporters to hedge their proposed purchase by temporarily substituting for actual

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purchase till the time is ripe to buy in physical market. In the absence of futures market it will be meticulous, time consuming and costly physical transactions.

12. **Predictable Pricing:** The demand for certain commodities is highly price elastic. The manufacturers have to ensure that the prices should be stable in order to protect their market share with the free entry of imports. Futures contracts will enable predictability in domestic prices. The manufacturers can, as a result, smooth out the influence of changes in their input prices very easily. With no futures market, the manufacturer can be caught between severe short-term price movements of oils and necessity to maintain price stability, which could only be possible through sufficient financial reserves that could otherwise be utilized for making other profitable investments.
13. **Benefits for Farmers/Agriculturalists:** Price instability has a direct bearing on farmers in the absence of futures market. India is traditionally an agricultural economy and fluctuation in prices during the harvesting period has always been a major concern for the farming community. Futures trading have emerged as a viable option for providing a greater degree of assurance on the price front. For instance, a farmer growing soybean is exposed to risk of fall in prices when his harvest comes out. Using futures market, he can sell the soybean contract today at the futures platform and lock in the price which could eliminate his risk from price fluctuations.

Further, farmers sometimes go for distress selling during the harvest time due to lack of storage facilities. Using the futures platform, farmers can store their produce in the exchange designated warehouse till the time their produce fetches reasonable returns.

14. **Credit Accessibility:** The absence of proper risk management tools would attract the marketing and processing of commodities to high-risk exposure making it risky business activity to fund. Even a small movement in prices can eat up a huge proportion of capital owned by traders, at times making it virtually impossible to pay back the loan. There is a high degree of reluctance among banks to fund commodity traders, especially those who do not manage price risks. If in case they do, the interest rate is likely to be high and terms and conditions very stringent. These possess a huge obstacle in the smooth functioning and competition of commodities market. Hedging, which is possible through futures markets, would cut down the discount rate in commodity lending.
15. **Improved Product Quality:** The existence of warehouses for facilitating delivery with grading facilities along with other related benefits provides a very strong reason to upgrade and enhance the quality of the commodity to grade that is acceptable by the exchange. It ensures uniform standardization of commodity trade, including the terms of quality standard: the quality certificates that are issued by the exchange-certified warehouses have the potential to become the norm for physical trade.

Commodities have become an established asset class in the Indian markets in the past few years. While a future trading is relatively new to the Indian commodity markets, the global commodity futures exchanges have been functioning for several decades.

What has attracted investors to trading in commodity futures is the transparency in the price mechanism, low margins, risk management, benefits to farmers by way of price clarity and an organized marketplace. Other than these, commodities also offer a different investment avenue, are less volatile when compared with equities and bonds, are a highly liquid asset class and offer investors an opportunity to gain from the price movements in the commodity space.

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Figure 4. Benefits of commodity futures market

Marketing Mix

The government intervened at every stage of the marketing of major agricultural commodities during last three decades. In order to protect farmers from risks and to maintain price stability, every activity of marketing of essential commodities such as procurement, distribution control and administrated price mechanism is under Government control. Government regulation has declined after implementation economic reforms in 1991.

Agriculture sector in India has always been a major field of government intervention since long back. Government tries to protect the interests of the poor Indian farmers by procuring crops at remunerative prices directly from the farmers without involving middlemen in between. This way Government maintains sufficient buffer stocks and at the same time provides the farmers safeguard against the fluctuating food crop prices. But government at the same time has restricted this traditional sector by fixing prices of crops at a particular level and also by imposing several other restrictions on export and import of agricultural commodities.

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Agricultural marketing is mainly the buying and selling of agricultural products. In earlier days when the village economy was more or less self-sufficient the marketing of agricultural products presented no difficulty as the farmer sold his produce to the consumer on a cash or barter basis.

Today's agricultural marketing has to undergo a series of exchanges or transfers from one person to another before it reaches the consumer. There are three marketing functions involved in this, i.e., assembling, preparation for consumption and distribution. It is done under the Agricultural Produce (grading and marketing) Act of 1937. In India, there are several central government organizations, who are involved in agricultural marketing like, Commission of Agricultural Costs and Prices, Food Corporation of India, Cotton Corporation of India, Jute Corporation of India, etc.

Marketing Mix involves the decisions regarding product, place, price, promotion, people, process, and physical evidence.

Product

It is related to the design of the services offered to a customer according to the need as well as demand. Indian economy is based on agriculture. Farmers produce different agricultural products like cereals, pulses, spices etc. These are traded at commodity exchanges as well.

The products or agricultural commodities traded at National Exchanges comprise the following:

- **Edible Oilseeds Complexes:** Mustard seed, Cottonseed, Soybean oil etc.
- **Food Grains:** Wheat, Bajra, Maize etc.
- **Metals:** Gold, Silver, Copper, Zinc etc.
- **Spices:** Turmeric, Pepper, Jeera etc.
- **Pulses:** Channa.
- **Fibres:** Cotton, Jute etc.
- **Others:** Sugar, Gur, Rubber, Potato, Natural Gas, Crude Oil etc.

Place

It is related to the location for offering agricultural products. This involves all the regional and national commodity exchanges. Online and offline trading of agricultural commodities are done at these exchanges.

Currently 4 national exchanges are working in India and rests are regional commodity exchanges.

- Multi Commodity Exchange, Mumbai (MCX).
- National Commodity and Derivatives Exchange, Mumbai (NCDEX).
- National Multi Commodity Exchange, Ahmedabad (NMCE).
- Indian Commodity Exchange Ltd., Mumbai (ICEX).

Price

It is related to the price charged for trading of listed agricultural products offered by the commodity exchanges. Such as brokerage, commodity transaction tax, delivery chargers, warehousing charges etc Brokerage is decided by the broking firms but all other charges are decided by the regulatory authority.

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Promotion

It relates to the type of media to be chosen by the commodity exchanges to make customers aware about their products and services. It is necessary to take decisions about communication media channel, so as to bring out the salient features of the traded products. The promotion of the product can be done by advertising in media such as radio, newspaper, TV commercials to make customers aware.

People

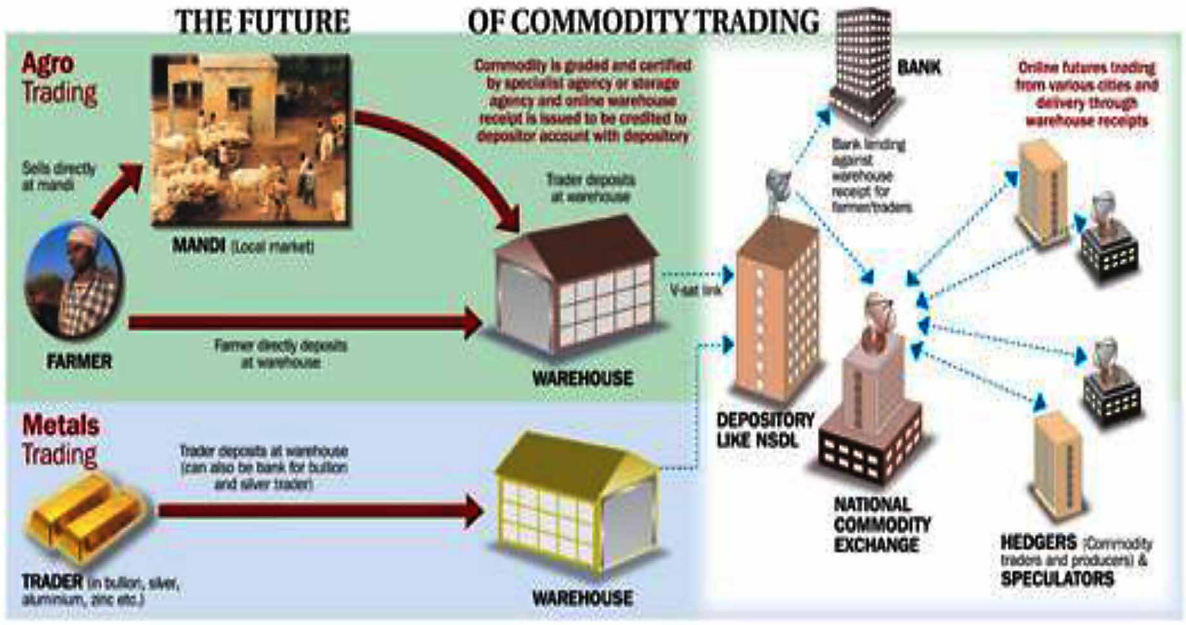
The target customers for all the regional and commodity exchanges are individuals, farmers, manufacturers, producers, and jewelers etc. who can invest in commodities.

Process

It is related to the flow of activities, rules and regulations. All the major activities of regional and national commodity futures market are followed by regulatory authority. Earlier Forward Markets Commission (FMC) was the regulator of commodity futures market but it is merged with Securities Exchange Board of India (SEBI). Now SEBI will regulate the commodities future market from 28th Sep. 2015 to strengthen the rules and regulations and control the speculative practices. There has to be adherence to certain rules and regulations in trading commodities related to the standardization and customization. This involves commodity transaction tax, delivery charges, warehousing charges etc.

Figure 5 gives a fair idea about working of the Commodity market.

Figure 5. Working of commodity futures market



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A commodity exchange is a market place like a stock market to buy and sell the listed and traded commodities. This market eliminates the need for middle men and allows the market to fix up a price that is driven by demand and supply of the particular commodity.

Trading can be done in two ways:-cash/spot and futures market. The buyer and seller agree upon a common price of the commodity, and actual physical delivery of that commodity takes place in the cash/spot market. Where as, Futures contract do not compulsory involve physical delivery of commodities. Delivery of commodities is fixed for a future date at a price agreed by both the parties but for this, buyer/seller has to give intention before expiry of the futures contract to commodity exchange otherwise buyer or seller can close their positions by squaring off his buy/sell position. Squiring off is done by taking an opposite contract so that the net outstanding is nil. The broker maintains an account of all dealing parties in which the daily profit or loss due to changes in the futures price is recorded.

For the purpose of delivery, a person deposits certain amount of say, good X in a warehouse and gets a warehouse receipt, which allows him to ask for physical delivery of the good from the warehouse. For commodity futures to work, the seller should be able to deposit the commodity at warehouse nearest to him and collect the warehouse receipt. The buyer should be able to take physical delivery at a location of his choice on presenting the warehouse receipt. But at present in India very few warehouses provide delivery for specific commodities.

As spot prices are determined by supply and demand, they are very sensitive to various types of uncontrollable forces that affect commodity production. Bad weather conditions, political turmoil, government intervention, and changing consumer preferences are some of the factors that may contribute to a constantly fluctuating and unpredictable commodities market.

To counter this unpredictability, buyers and sellers created the futures contract. A futures contract is simply an agreement made that will take place some time in the future. These agreements between buyers and sellers include the date the commodity will be delivered, the price to be paid on a specific date, and the quantity and quality of the commodity. A ten percent margin deposit is required of both buyers and sellers to insure that neither of the participants backs out of the contract.

Trading in the spot exchanges is being done in the following ways:

- Farmer/Seller bring his goods to the warehouse.
- The stocks are assayed – Quality checked and the goods weighed.
- If the quality is validated, the warehouse receipt is issued.
- The seller goes to the designated Spot Exchange member with the receipt and a limit is opened for the quantity to be traded on the Exchange.
- Once the transactions are completed at the mutually agreed price between buyer and seller, the delivery and settlement aspects are done as per rules of the Exchanges.

Physical Evidence

Physical evidence is the material part of a service. There are many examples of physical evidence such as Financial Reports, Brochures, Furnishings, Business cards, Building, logo, punch lines, employee's dress code, other tangible items etc. But here in case of commodity futures market, financial reports and services provided by the broking firms in terms of protecting interest of the investors are considered in physical evidence.

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Service Quality and Customer Satisfaction

Service Quality means the quality of service delivered by the commodity exchanges and how far the clients of broking firms are satisfied with that. As quality is an intangible concept therefore, it's very difficult to measure. It can be measured by calculating the difference in the expectation of the client from the service delivered by the broking firms and the perception of the clients about the service rendered by the broking firms. Service quality of a product depends upon the reliability, responsiveness, assurance and empathy. In a broking firm, services like daily buy & sell call, margin requirements, risk management of their clients by tracking their open positions are rendered by the brokers on daily basis. So, every broking firm makes sure about these services rendered by the brokers.

Customer Satisfaction

Investors always expect maximum return from their investment. So they should have an idea about the preferences available in the commodity market as investing in commodity market is one of the modes of investment which is catching eyes of the investors now a days. For which, it is required by the broking firms to assist the investors and bring out the knowledge of various investment opportunities available in the commodity market such as arbitrage, hedging etc. Investors are trading on commodity exchanges in online as well as offline mode as per their convenience. But they want proper follow up of their margin money as well as open positions because when they buy or sell an underlying asset, the value of that underlying asset is deducted from the margin money and profit or loss is also get adjusted. So the investors should know about their amount of margin money deposited and daily updates about market movements by the brokers on time to minimize their price risk.

FUTURE RESEARCH DIRECTIONS

There is a much scope for doing research related to the linkage between pricing behavior of future contracts and nature of agricultural commodities traded on national level commodity exchanges. Forward Markets Commission (FMC) had merged with Securities Exchange Board of India (SEBI) in the month of sep. 2015. Now SEBI is regulating the commodity futures market to strengthen and prevent from speculative practices. SEBI has to look at delivery of commodities from the warehouses as there is no physical settlement of stocks in cash market. This can also be the area for further research to find out the effect of followed rules and regulations of SEBI in commodity futures market after FMC.

CONCLUSION

Commodity Futures market has occupied a very important place in Indian economy. Agricultural commodity futures are market-based instruments for managing risks and they help in orderly establishment of efficient agricultural markets. Future markets are used to hedge commodity price risks. They also serve as a low cost, highly efficient and transparent mechanism for discovering prices in the future by providing a forum for exchanging information about supply and demand conditions. The hedging and price discovery functions of future markets promote more efficient production, storage, marketing and

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agro-processing operations and help in improvement in overall agricultural marketing performance. Although India has a long history of trade in commodity derivatives, this sector remained underdeveloped due to government intervention in many commodity markets to control prices. The commodities derivatives market has seen ups and downs, but seem to have finally arrived now. The market has made enormous progress in terms of technology, transparency and trading activity. Interestingly, this has happened only after the Government protection was removed from a number of commodities, and market forces were allowed to play their role.

REFERENCES

Agnihotri, A., & Sharma, A. (2011). Study of Convergence of Spot and Future Prices in Commodity Market (With reference to Zeera, Chana, Zink and Natural Gas for 2005-2010). *ZENITH International Journal of Multidisciplinary Research, 1*(2), 101–113.

Bansal, R., Dadhich, V. & Ahmad, N. (2014). Indian Commodity Market – A Performance Review. *International Research Journal of Management and Commerce, 1*(5), 19-34.

Bhagwat, S., Maravi Singh, A., More, R. & Chand, D. (2015). Commodity Futures Market in India: Development, Regulation and Current Scenario. *Journal of Business Management & Social Sciences Research, 4*(2), 215-231.

Chhajed, I., & Mehta, S. (2013). Market Behavior and Price Discovery in Indian Agriculture Commodity Market. *International Journal of Scientific and Research Publications, 3*(3), 1-4.

Dash, M., Solanki, A., & Shobana, T. (2015). *A Study on Commodity Market Behaviour, Price Discovery and Its Factors*. Retrieved from http://ssrn.com/abstract=1988812

Dharmbeer & Singh Barinder. (2011). Indian Commodity Market: Growth and Prospects. *International Journals of Multidisciplinary Research Academy, 1*(2), 78-85.

Dhole Suresh Sagar. (2014). Commodity Futures Market in India: The Legal Aspect and its Rationale. *International Journal of Research in Management and Business Study, 1*(2), 38-45.

Essays. (2015). Commodity Futures in India the Prospectus and Challenges –Finance Essay. *Essays.* Retrieved December 31, 2015 from https://essays.pw/essay/commodity-futures-in-india-the-prospects-and-challenges-finance-essay-146089

Kumar, B., & Pandy, A. (2013). Market Efficiency in Indian Commodity Futures Markets. *Journal of Indian Business Research*, *5*(2), 101–121. doi:10.1108/17554191311320773

Malyadri, G., & Kumar Sudheer, B. (2012). A Study on Commodity Market. *International Journal of Computer Science and Management, 1*(5).

Rajamohan S., Vethamanikam Arul Hudson G. & Vijaykumar, C. (2014). Commodity Futures Market in India. *International Journal of Advanced Research in Management and Social Science, 3*(10), 5258.

Sehgal, S., Rajput, N., & Dua, R.K. (2012). Futures Trading and Spot Market Volatility: Evidence from Indian Commodity Markets. *Asian Journal of Finance & Accounting, 4*(2).

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Testbook. (2015). Indian Banking Sector: Getting to Newer Horizons in 2015. *Testbook*. Retrieved December 28, 2015 from http://testbook.com/blog/indian-banking-sector-getting-newer-horizons-2015/

Wilson, R. (n.d.). Future and commodities market. *Hedge Fund Blogger*. Retrieved from: http://richard-wilson.blogspot.in/2009/07/futures-and-commodities-market.html

ADDITIONAL READING

Agriculture Market Report. (2015-16). Retrieved January 14, 2016 from http://agriexchange.apeda.gov.in

Agritech Portal, T. N. A. U. Agricultural Marketing & Agri Business. Retrieved January 15, 2016 from http://agritech.tnau.ac.in/agricultural_marketing/agrimark_India.html

Biswas Anirban. (2004, July 13). Agricultural Marketing in India. Retrieved January 08, 2016 from http://www.domain-b.com/economy/agriculture/20040713_marketing.html

Department of Economic Affairs, Ministry of Finance, Government of India, New Delhi, (April, 2014), Report of the Committee to suggest steps for fulfilling the objectives of Price-discovery and Risk Management of Commodity Derivatives Market.

How Does A Commodities Exchange Function? Which Are the Major Commodity Exchanges in India. Retrieved January 08, 2016 from http://www.smarterwithmoney.in/Trading/Commodity/Articles/How_Does_A_Commodities_Exchange_Function_Which_Are_the_Major_Commodity_Exchanges_in_India Forward Markets Commission (n.d.) Retrieved from: www.fmc.gov.in NCDEX (n.d.) Retrieved from: www.ncdex.com

Mathur Naveen. (2013, November 11). Benefits of Trading in Commodity Futures. Retrieved January 15, 2016 from http://articles.economictimes.indiatimes.com/2013-11-11/news/43929989_1_commodity-futures-commodity-space-commodity-traders

Ministry of Consumer Affairs, Food and Public Distribution Department of Consumer Affairs (2013-14), Annual Report.

Ministry of Consumer Affairs, Food and Public Distribution Department of Consumer Affairs (2012-13), Annual Report.

Ministry of Consumer Affairs, Food and Public Distribution Department of Consumer Affairs (2011-12), Annual Report.

Ministry of Consumer Affairs, Food and Public Distribution Department of Consumer Affairs (2010-11), Annual Report.

Ministry of Consumer Affairs, Food and Public Distribution Department of Consumer Affairs (2009-10), Annual Report.

Ministry of Consumer Affairs, Food and Public Distribution Department of Consumer Affairs (2008-09), Annual Report.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Singhal, K. Praveen (2015, March 24). Manage Commodity Price Risk via Derivative Exchanges Retrieved January 14, 2016 from http://www.dnaindia.com/money/column-manage-commodity-price-risk-via-derivative-exchanges-2071404

United Nations Conference on Trade and Development (Feb.2013), Recent developments and new challenges in commodity markets, and policy options for commodity-based inclusive growth and sustainable development.

KEY TERMS AND DEFINITIONS

Arbitrage: It means the simultaneous buying and selling of securities, currency, or commodities in different markets or in derivative forms in order to take advantage of differing prices for the same asset.

Derivatives: These are financial contracts, which derive their value from an underlying asset. (Underlying assets can be equity, commodity, foreign exchange, interest rates, real estate or any other asset.) Four types of derivatives are trades forward, futures, options and swaps. Derivatives can be traded either in an exchange or over the counter.

Exchange: Central market place for buyers and sellers. Standardized contracts ensure that the prices mean the same to everyone in the market. The prices in an exchange are determined in the form of a continuous auction by members who are acting on behalf of their clients, companies or themselves.

Futures Contract: It is an agreement between two parties to buy or sell a specified and standardized quantity and quality of an asset at certain time in the future at price agreed upon at the time of entering in to contract on the futures exchange. It is entered on centralized trading platform of exchange. It is standardized in terms of quantity as specified by exchange. Contract price of futures contract is transparent as it is available on centralized trading screen of the exchange. Here valuation of Mark-to-Mark position is calculated as per the official closing price on daily basis and MTM margin requirement exists. Futures contract is more liquid as it is traded on the exchange. In futures contracts the clearing-house becomes the counter party to each transaction, which is called novation. Therefore, counter party risk is almost eliminated. A regulatory authority and the exchange regulate futures contract. Futures contract is generally cash settled but option of physical settlement is available. Delivery tendered in case of futures contract should be of standard quantity and quality as specified by the exchange.

Futures Market: It facilitates buying and selling of standardized contractual agreements (for future delivery) of underlying asset as the specific commodity and not the physical commodity itself. The formulation of futures contract is very specific regarding the quality of the commodity, the quantity to be delivered and date for delivery. However it does not involve immediate transfer of ownership of commodity, unless resulting in delivery. Thus, in futures markets, commodities can be bought or sold irrespective of whether one has possession of the underlying commodity or not. The futures market trade in futures contracts primarily for the purpose of risk management that is hedging on commodity stocks or forward buyers and sellers. Most of these contracts are squared off before maturity and rarely end in deliveries.

Hedging: Means taking a position in futures market that is opposite to position in the physical market with the objective of reducing or limiting risk associated with price.

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Margin Money: Cash or equivalent posted as guarantee of fulfillment of a futures contract (not a down payment).

Mark to Market: The practice of crediting or debating a trader's account based on daily closing prices of the futures contracts he is long or short.

Spot Market: Here commodities are physically bought or sold on a negotiated basis.

Spot Price: The price at which the spot or cash commodity is selling on the cash or spot market.

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APPENDIX: ABBREVIATIONS

FMC: Forward Markets Commission
FCRA: Forward Contracts (Regulation) Act
SEBI: Securities Exchange Board of India
APMC: Agriculture Produce Marketing Committees
NCDEX: National Commodity & Derivatives Exchange
MCX: Multi Commodity Exchange
NMCEIL: National Multi Commodity Exchange of India Ltd.
ICEX: Indian Commodity Exchange Ltd.
ACE: Ace Derivatives and Commodity Exchange Ltd.
UCX: Universal Commodity Exchange Ltd.

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Chapter 61
An Analysis of Mobile Phone Use in Nigerian Agricultural Development

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ABSTRACT

This study used 328 smallholder farmer respondents to investigate its objectives of how farmers use mobile phone technology, what benefits they have gained from the use, and the constraints encountered during the process. The quantitative data collected through a process of questionnaire administration were analysed using Stata 12 software. The results indicate that mobile phone usage for farm and other social purposes has increased with farmers. The farmers also spend almost 40% of their phone bills on farm-related activities and that seeking market information represented 17.32% of the total phone bill in a month. Increased efficiency in input delivery, market access, and output distribution were reported as some of the advantages of using mobile phones. This study was conducted in a region where its general characteristics may not reflect that of the entire country thus generalisation of the study may be limited, so the data should be cautiously use.

INTRODUCTION

Sub-Saharan Africa's rural economy remains agriculture dependent relative to other regions and it employed 62% of the population in 2005 (Staatz & Dembele, 2007). In Nigeria, agriculture employed 70% of the work force and accounted for more than 40% of the Gross Domestic Product (USAID, 2013). It is mainly characterised by subsistent farming. The efforts at developing agriculture in Nigeria have taken many approaches such as rural development strategies which included formation of cooperative organisations, provision of access to credit and technical information, and others (Ogbeide, 2014).

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The process of actualising rural development has led to the adoption of mobile phone technology as a farming tool for contact and business transactions. This study investigates how much the farmers have taken advantage of this technology and the benefits derived from it. In considering these objectives, the study is to provide answers to such questions as: (1) do farmers practically use mobile phone for agricultural purposes in Nigeria? (2) does mobile phone usage drive improvement in productivity? (3) what benefits do the farmers derive using mobile phone?

This study is important as it will help to capture and evaluate the progress of mobile phone adoption and uses and also identify, assess, and judge the benefits the smallholder farmers obtain with the device. It is critical that the success and use of this device be studied for improvement and adaptation purposes. The background to the study approach was to explore the three main interdependent players: the provider of inputs, the converter of inputs, and the users of the output and the relationships that exist among them. An understanding of the relationship amongst these players will help to show how important mobile phone is in the order. The providers of inputs in agriculture are diverse and often time distantly located away from the converters.

Farm input providers such as financial institutions, agribusiness/farm management organisations, technical services, chemical and planting materials suppliers, and donor agencies are often situated in the cities or local government headquarters (Karamagi & Nalumansi, 2009). The physical distance between the input providers and the users creates a gap in access and communication. The input converters are the farmers. Farmers particularly in Nigeria are mainly small-scaled with limited contacts to exchange and share crucial information, knowledge and skills needed for production, processing and marketing (Alleman et al., 2002; FAO, 2005). Consequently, yields are low, and incomes from agriculture leave little for the farmer to turn over. Access to crucial inputs is poor or denied due to difficulty in information flow either from the provider of inputs or the users of output (FAO, 2005).

The users of outputs include manufacturers that represent the secondary inputs providers and the final consumers of farm produce. The users of agricultural outputs in like manner to the input converters are most times geographically located far away from the farmers. The road network is poor and the distance from the farm to the market towns and other service providers is very long. The result of these slack relationships is high production cost, inefficiency, non-competitiveness, and corruption (Sebastian, 2008; Dorosh, 2009; WDI, 2010; Livingston et al., 2011).

For example, fertilizer distribution to farmers in Nigeria was hijacked by middle men with no farming interest who either divert them to un-intended markets or resell to the farmers at exorbitant prices (Allafrica, 2013). The diversion results in farmers not receiving the fertilizer at all or on time, and in most cases at a higher price. The delay in getting the inputs, the corruption in the process, and the increase in cost creates inefficiency in the supply chain and causes production to be uncompetitive (Chorn, Sisco, & Pruzan-Jorgensen, 2010; Livingston et al., 2011).

LITERATURE REVIEW

This study assumes readers have prior knowledge of the underlying theory of diffusion of innovation that defined how innovation is adopted by a social group with the result that the innovation becomes part of the existing social system. Adoption of a new technology does not happen instantaneously in a social system; instead, it is a process whereby some individuals are quicker to adopt the technology than others. However, innovation must have the capacity to improve and create better social economic

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conditions for the adopters while leveraging on ability of the target group to apply it from an assumed or learned standpoint (Robinson, 2009).

Mobile Phone and Agriculture

Improving efficiency in agriculture production processes is important to increasing productivity and reducing poverty. Creating a more efficient value chain involves productive engagement of the members of the chain and how information around these members is managed. One of the ways to improve efficiency in the agriculture is the use of mobile phone technology (Halewood & Surya, 2012).

Mobile phone technology application in diverse agribusiness situations has recorded growth in Nigeria and many other developing countries; it provides different opportunities to transfer knowledge and information among players in the agribusiness value or supply chain, including government. Despite mobile phone being mainly used by urban residence, Aker and Mbiti (2010) found its social and economic usefulness for the rural populace in terms of information gathering on weather, market, and other related issues.

The Syngenta Foundation (2011) reported adaptation of mobile phone technology for agricultural purpose has been boosted as manufacturers and software designers had either aligned their products to suit agricultural use or created specific products for agricultural use. For example, in Nigeria Nokia has focused since 2010 on providing mobile learning (mLearning) applications for the transfer of production skills in crops and livestock management, and fisheries using state-of-the-art technologies. Additionally, national governments have worked assiduously towards comprehensive internet platforms extended on mobile phone to provide farmers access to all relevant information (Syngenta Foundation, 2011). According to Qiang, Kuek, Dymond, and Esselaar (2011), and Martin and Abbott (2011), mobile phone applications usage in Nigeria has increased tremendously. The potential benefits to farmers is diverse, aiding connection and communication with different stakeholders in agricultural value chain.

Mobile Phone as an Important Tool in Nigeria Agriculture

According to Livingston et al. (2011), more than one third of all Sub-Saharan rural Africans are so geographically and economically isolated from market towns that, at present, they are virtually condemned to a life of subsistence agriculture, regardless of their access to modern inputs, irrigation infrastructure or financial services. A spatial analysis of 5,000 people indicated 34% of the rural population in Sub-Saharan Africa live more than five hours from a market town (Sebastian, 2008). While Livingston et al. (2011) argued that the high price of road transport in Sub-Saharan Africa countries is widespread and that the high price of agricultural products has been attributed to the poor state of the transportation network, and inefficient logistics and endemic corruption.

The density of Nigeria's road network is low for agricultural purpose usually bush path or unsealed and with access difficulty. According to Tunde and Adeniyi (2012), and Ajiboye and Afolayan (2009), road transport despite its very poor state is the most readily available means of movement of goods and passenger traffic over short, medium, and long distances. Nigerian agriculture as the engine of economic growth runs below its potential because inputs, be they financial, agronomic or technical, are, all too often, not being delivered in a timely manner by the donor institutions, ministries of agriculture, the project implementation units, the banks or the agricultural cooperatives. This has had an extremely negative impact on productivity and decreased revenues of smallholder farmers. Therefore, successful

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agricultural campaigns are all about planning and timing and rigorous project management, without which the farmers will not gain the full benefits of the new proffered solutions (FAO, 2009; Livingston et al., 2011; Inoncencio et al., 2007; World Bank, 2009).

Mobile Phone Innovation and Its Agricultural Usage

The theory of diffusion of innovations is central to the adoption, use, and the attendant benefits of mobile phone application to agriculture particularly by smallholders (Martin & Abbott, 2011). Robinson (2009) noted that when an innovation is introduced into any settings, it offers three valuable intuitions into the process of social change. Such intuitions include what are the quality attributes in the innovation that will make it to spread, understanding the needs of the different user groups and the role played by peer networks in ensuring the spread of adoption of the technology. According to Avgerou (2010), understanding the use of mobile phones to aid agricultural development requires an adequate knowledge of the technology and the perceived impacts it possesses, as well as an assessment of the opportunities and barriers reinforced by the local social structure of the user communities.

Aker and Mbiti (2010) and Aminuzzaman, et al. (2003) noted that mobile phone adoption by farmers is predicated on the perception that it is better than most other communication means, as it is convenient to handle, provides economic advantages, and enhances social status of users. The use of mobile phone rests within the core value of communities communicating within and between groups members for social or economic interactions. It enhances communication experiences by removing the cumbersomeness associated with other communication methods (Qiang, Kuek, Dymond, & Esselaar, 2011; Martin & Abbott, 2011). This perceived relative advantage of mobile phone arguably increases the rate of growth of mobile phone ownership among community members and farmers in particular.

Benefits of the Mobile Phone

Agriculture as a business or at least as a means of earning income involves many interactions which can include hiring labour, gathering market and price intelligence, procurement of farm inputs, seeking technical assistance from the extension or expert agents, or obtaining weather information (Okello et al., 2012). However, the location of the parties in the interaction, travel distances, and ineffective and costly transportation all inhibit the ability of the farmers to improve productivity and improve the family and community wellbeing (Okello et al., 2012; GSMA, 2013). Important to these interactions is the need for them to be done in a manner that is timely, effective, and efficient. Farmers must adopt a means by which they are able to gain access to required information and inputs at the appropriate time in a cost-effective manner.

According to FARM-Africa (2007) and Martin and Abbott (2011), the mobile phone is a handy tool for identification and management of livestock diseases, and for coordinating greater attendance and participation in organisations' meetings. Karamagi and Nalumansi (2009) noted that in Central Uganda, farmers adopting the use of mobile phones were able to connect to FoodNet – a service that supplies current price information on agricultural commodities, as well as contact details for interested buyers via short message service (SMS).

Mobile phones have been found to help improve the productivity of individuals and organizations within resource-constrained environments as it increases efficiency, effectiveness, and reach (Burrell, 2008; Qiang, Kuek, Dymond, & Esselaar, 2011; Hudson, 2006). The rapid uptake and popularity of

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mobile phone applications by rural farmers have led to the development of unique and innovative approaches to using these applications in solving some salient issues faced by farmers. Several studies have revealed some innovative examples; it has been reported that farmers use mobile phones to coordinate access to agricultural inputs (Martin & Abbott, 2011; Ansari & Pandey, 2013; Syngenta Foundation, 2011; Das, Basu & Goswami, 2012); accessing market information (Odhiambo, 2014; Das, Basu, & Goswami, 2012; Martin & Abbott, 2011); for financial transactions (Qiang, Kuek, Dymond, & Esselaar, 2011; Martin & Abbott, 2011; Kirui, Okello, & Nyikal, 2010); and to seek agriculture emergency assistance and expert advice (Qiang, Kuek, Dymond, & Esselaar, 2011; Martin & Abbott, 2011; Churi, Mlozi1, Tumbo, & Casmir, 2012).

Mobile phones assist in mining information. According to Wyche and Steinfield (2015), efficient market information provision has positive benefits for farmers, traders, and policymakers. Current and updated market information is more easily obtained and enables farmers to negotiate with traders from a position of strength. It also facilitates spatial distribution of products from rural areas to urban areas and between urban markets by sending clear price signals from urban consumers to rural producers regarding quantities and varieties required.

Studies have been conducted on ways and which system applications best suit the rural dwellers for social and business communication. Martin and Abbott (2011), Okello et al. (2012), and GSMA (2013) argued that the mobile phone is best suited for rural people including the farmers. Interactions with mobile phones are cost effective ways for smallholder farmers to stay connected with other stakeholders while the phone itself provides them with a sense of security and social status.

Other studies have also analysed mobile phone to be a beneficial product whose access can be limited to socially excluded community members, and as a hazardous consumption (Moisio 2003; Chigona, Beukes, Vally, & Tanner, 2009). Moisio (2003) argued that the perceived negative consequences of mobile phone as a hazardous consumption is not a reflection of the properties of technology, but rather the ways in which it was consumed. While mobile phones may foster negative experiences on health, crime, and physical interaction, they merely do so in a set of categories of thought and practice that enable or disable particular consumption practices and their experiences. However, inequality among the farmers can hinder the use of mobile phone. Chigona, Beukes, Vally, and Tanner (2009) noted that for the socially excluded people in a community, the use of mobile technology may still be limited because the majority of people in that category cannot access or afford it (Chigona, Beukes, Vally, & Tanner, 2009).

Factors That Influence Mobile Phone Technology Application by Smallholder Farmers

In the review of the relevant literature, a number of factors were noted to affect the use the mobile phone by farmers for both social and agriculture related purposes. Mobile phone ownership in developing countries is still low despite the increase in the past several years. However, gender plays a role in mobile phone ownership and use. In short, a woman is still 21% less likely to own a mobile phone than a man and this figure increases to 23% if she lives in Africa (GSMA, 2013). Closing this gender gap would bring the benefits of mobile phones to an additional 300 million women, and by extending the benefits of mobile phone ownership to more women a host of social and economic goals can be advanced (GSMA, 2013).

According to Okello, Kirui, Njirani, and Gitonga (2012), young persons are more servile with technology irrespective of their locality and therefore have a positive correlation with the use of the mobile phone. Therefore, it is expected that young farmers will be inclined to use this technology for most of

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the day-to-day transactions. Kirui et al. (2010) noted the education level of smallholder farmers was low and had thus created challenges to adoption and use of modern technology such as mobile phones. The work of Kirui et al. (2010) corroborated that of Okello et al. (2009) which suggested the literacy level of the farmers was important to the use of mobile phones for information access and can also impact their level of difficulty in navigating through the phone menus, often written in international languages like English.

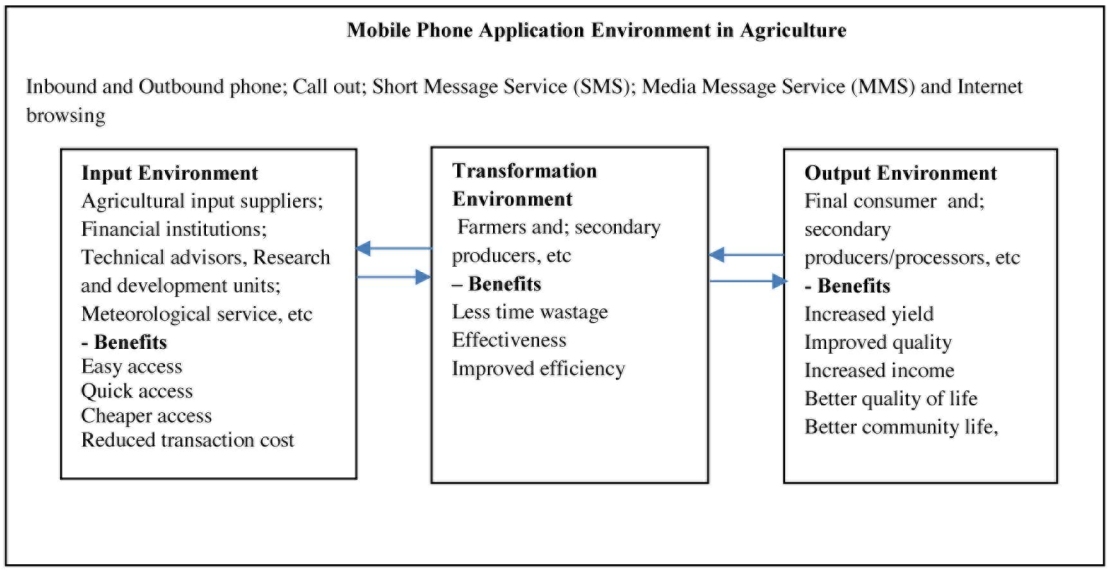
Therefore, the level of literacy and social inclusion of farmers had affected mobile phone use differently (Chigona, Beukes, Vally, & Tanner, 2009) and can influence the level of adoption across the various Nigerian communities. The high usage of mobile phone by adopter farmers buttressed its capability to act as a tool for education and gaining knowledge as well as spreading viewpoints and communication with family members and the larger social community (Okello et al., 2012).

CONCEPTUALISATION OF THE MOBILE PHONE ENVIRONMENT FOR THE STUDY

The essence of adopting an innovation such as mobile phone technology applications for agricultural purposes hinges on its ability to transform an existing way of doing things into a better and more efficient one. The ultimate result is to provide increased and quality output to the market, guaranteed income for farmers and a dynamic and prosperous community (see Figure 1).

The mobile phone use by farmers is well-known as an exemplary case of a technology enabling bottom-up empowerment through information access, driven by agribusiness and end-user innovation (GSMA, 2013; Sherry, n.d.). The major mobile phone functionalities applicable are the voice call, SMS,

Figure 1. Mobile phone application environment in agriculture



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multimedia service (MMS), and the internet. The use of these functionalities is impacted by users' level of literacy generally and the specific knowledge of the technology available to the consumers.

The farmers often originate communication, but are generally in the middle of the communication chain transforming the information and inputs they source into products for the market. In this model, the inputs environment relates to where farmers and secondary producers are able to access inputs critical to production. Inputs such as weather information, insurance, localised geospatial and real time information, technical knowledge, and stock and machineries are not only required but must be acquired in a quick, easy, and inexpensive manner (Szilagyi & Herdon, 2006; Lio & ChunLiu, 2006). This creates efficiency leading to decreased cost of doing business, improved revenue and better market knowledge.

The farmers apply the inputs obtained from the different input providers and transform them into output. With the mobile phone, farmers and other stakeholders in the value chain can make a call or send SMS or MMS to each other. In this regard, inputs and outputs information are obtained faster with little or no travel time involved (Qiang, Kuek, Dymond, & Esselaar, 2011; Martin & Abbott, 2011). Farmers are able to convert the inputs on time; plant the seeds at the right time, get weather warnings before disaster happens and are able to communicate to the technical expert of any anomalies observed in their farms for quick intervention. Market information obtained on time helps the farmers to determine the cropping pattern, estimate inputs price, plan what to sell and at what price (Qiang, Kuek, Dymond, & Esselaar, 2011).

Obtaining and utilising inputs at the appropriate time is crucial to the success of any enterprise, particularly the ones that can be influenced adversely by weather. Mobile phone enables farmers to obtain quickly information that impacts on inputs transformation, thus causing them to act on time. The result is that all things being equal, maximum and quality yield can be reasonably guaranteed. The farmer can take advantage of the best market price leading to increased income, better social and community life (Odhiambo, 2014; Das, Basu, & Goswami, 2012; Ansari & Pandey, 2013).

METHODOLOGY

The study involved a quantitative analysis of data collected through a process of questionnaire administration that yielded 328 smallholder farmer respondents. The study was conducted in the Cross River State of Nigeria which politically has 18 Local Government Areas (LGAs). Agriculturally, the Cross River State is divided into three zones: the Calabar, the Ikom, and the Ogoja. A multi-stage sampling procedure was adopted to select the respondents for the study (see Figure 2).

First, a random sampling of the LGAs yielded two LGAs from each of the agricultural zones giving a total of six LGAs (Akpabuyo, Calabar Municipal, Abi, Yakurr, Bekwarra, and Ogoja). The second stage was comprised of a purposive sampling of five communities from each LGA. These communities are among those connected to the various mobile phone networks. A total of 30 communities were identified from the purposive sampling. Stage 3 involved the purposively selection of 12 farmer respondents from the communities based on ownership of mobile phones and engagement in agricultural production. The list of respondents from each community was compiled by the community leaders. Data analysis included sample descriptive statistics and regression model analyses and were all conducted using Stata 12 software.

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Figure 2. Map of survey area: Cross River State of Nigeria

RESULTS AND DISCUSSION

The results presented in the study were comprised of descriptive statistics of the surveyed farmers, their mobile phone ownership status, and the associated operating cost and its structure. Others include an analysis of the benefits of using mobile phone and the factors that influence mobile phone usage by smallholder farmers.

Descriptive Analysis of Respondents

This study found there was an active involvement of people in the use of mobile phone for agricultural purposes across the age groups particularly the younger farmers, a majority of whom were married and educated. It is not uncommon that farmers within the combined age group of 18 – 49 will generally be mobile phone servile as they are young and would take advantage to apply the skill and technology in any situations. This is consistent with the finding of Okello, Kirui, Njirani, and Gitonga (2012).

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As more young people enter agriculture, it is expected that mobile phone use for its related activities will continue to increase. More and new applications will be utilised by farmers making them take advantage of the ever-increasing technology offerings available. Young farmers are more socially active and can share knowledge faster, thus creating a learning environment for themselves and the older farmers. Under this circumstance, the older farmers can break away from their traditional or conservative ways of interaction.

The older groups of farmers can be driven by the need to be more efficient in doing business and will apply every measure including mobile phone technology to improve efficiency. Table 1 also shows that more than 82 percent of the survey possess at least secondary school certificate; an indication that the farming population is increasingly becoming literate. This may not reflect the educational pattern across the entire country; however, a series of programs adopted by governments and other stakeholder are attracting more young people into agriculture. Therefore, the use of the mobile phone will not be a difficult task to learn and adopt for all purposes including agriculture. The farmers can read, understand, and apply instructions manually on how to use the various functionalities of the phone.

Mobile Phone Ownership and Duration of Ownership/Usage

This study investigated the farmers' mobile phone ownership and the duration of ownership/use of mobile phone to determine its acceptance as an essential tool for agricultural development (see Figure 3). The result shows that all the surveyed farmers possessed a mobile phone and more than 65 percent of the surveyed farmers had used mobile phones for more than six years. This is an indication of strong adoption of the technology and confirmed Qiang, Kuek, Dymond, and Esselaar (2011) finding that the adoption of information technology in agriculture is increasing in Sub-Saharan Africa.

Table 1. Descriptive analysis of respondents. Sample size = 328

Variable	Variable characteristics	Frequency	Percentage of respondents
Gender	Male	248	75.610
	Female	80	24.390
Age Group	18 - 29 years	3	0.910
	30 - 39 years	112	34.150
	40 - 49 years	45	13.720
	50 - 59 years	45	13.720
	60 years and over	123	37.500
Educational qualification	First School leaving certificate	57	17.380
	Secondary School certificate	118	35.980
	OND/NCE	24	7.320
	Bachelor's degree/HND	114	34.760
	Higher degrees	12	3.660
	Others (Please specify)	3	0.910
Marital Status	Single	51	15.550
	Married	277	84.450

Note: OND/NCE = Ordinary National Diploma/National Certificate of Education; HND = Higher National Diploma

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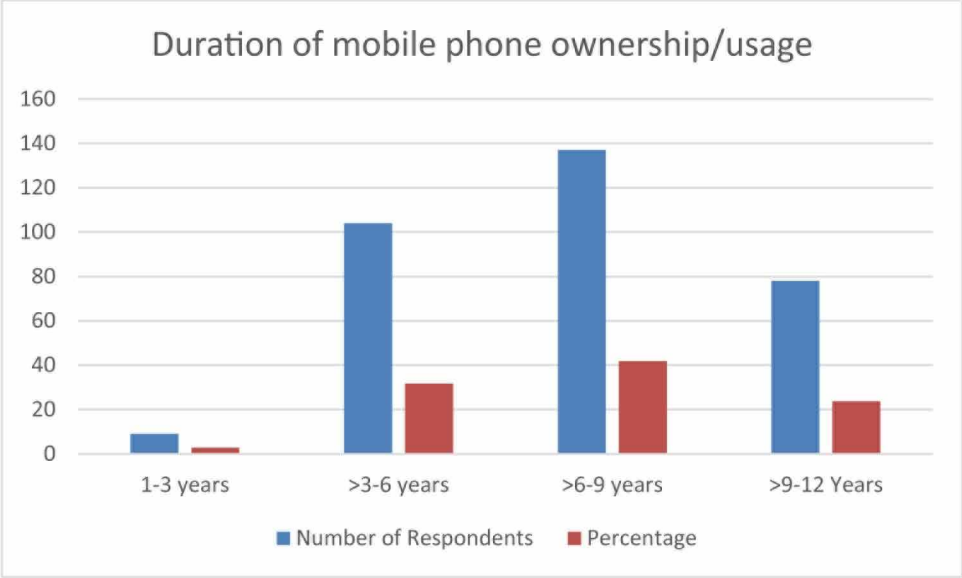
Figure 3. Duration of mobile phone ownership/usage



Ownership is one of the major attempts toward the use of mobile phones. Ownership creates the willingness/power to explore the product and its functionalities, and increases the willingness/ability to use them for diverse situations. This 'use' process resulting from ownership increases the farmers' product knowledge. This long period of ownership/usage is also inferred to be predicated on the benefits accrued to the farmers not just in the economic sense alone, but also the cultural transformation of the business environment and the community's communication settings. Ownership of a mobile phone also symbolises high social status in the farming communities. It is not uncommon for people in the cities and major towns to buy a mobile phone for their parents to stand out among their contemporaries in the community. This social symbolism of the mobile phone is consistent with the studies by Martin and Abbott (2011), Okello et al. (2012), and GSMA (2013).

Farmers' Mobile Phone Bill and Use Pattern

While Figure 3 showed mobile phone ownership/usage, Figures 4 and 5 below show farmers mobile phone bill and the apportionment to activities consumed respectively.

More than 88% of the surveyed farmers spend a maximum ₦6,000.00 or less per month on a mobile phone bill. Despite this study not investigating the amount spent in relation to total income or cost, the mobile phone bill can be a measure of the farmers' need-to-call, network coverage, and projected amount to be spent on the service. The farmers' phone bills structure can also be influenced by the number of inbound calls received from farm business stakeholders like input suppliers, extension agents and customers. Competitive input suppliers are more likely to initiate contacts to farmers to market their products. Such contacts reduce the amount of outbound calls the farmers make.

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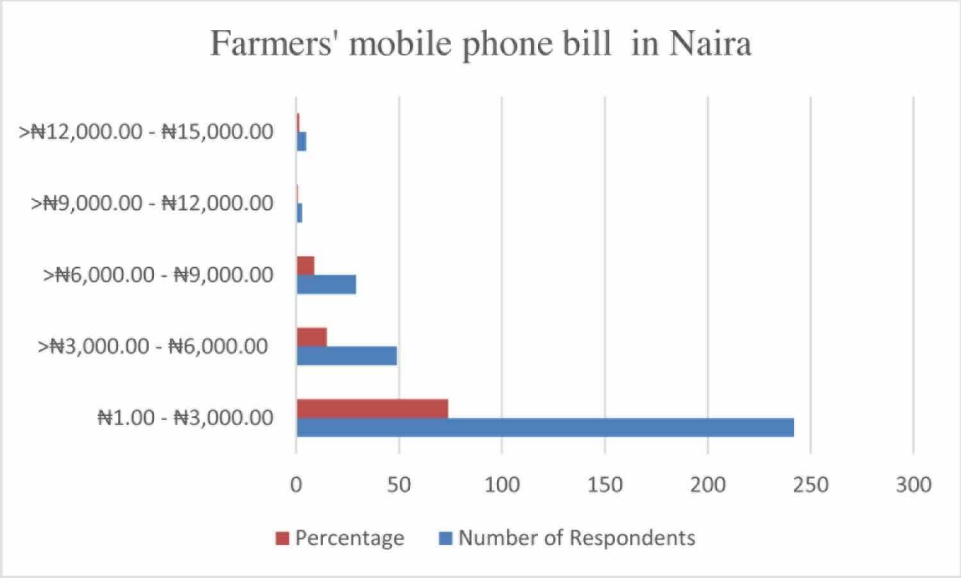
Figure 4. Farmers' mobile phone bill. (₦1.00 = $0.007 USD)



Farmers' Mobile Phone Bill According to Use Pattern

As interesting as the result is in Figure 4, more importantly are the components of the phone bill in Figure 5. Family and community uses accounted for about 62 percent of the phone bill. This indicates a higher usage compared to the farm related use. The high domestic usage is sequel to its capability to act as a tool to educate and gain knowledge as well as spreading viewpoints with family members and the rest of the larger community. Mobile phone interactions are cost effective ways to stay connected with others and provide the user with a sense of security and social value. The result was consistent with the findings of Okello et al. (2012) and GSMA (2013).

Despite the fact that approximately 62% of the surveyed farmers' mobile phone bills were incurred through family and other social interactions, the remaining part of the bill goes into several agriculture related activities. The farmers spent more than 17% of the mobile phone bill seeking market information about agricultural products. This represented the largest agriculture related component of the bill. The high percentage of farmers using mobile phone to source input and output markets was consistent with the result of Odhiambo (2014), Das, Basu, and Goswami (2012), and Ansari and Pandey (2013). This is an important result, considering the capability for mobile phones to bridge the wide divide that exists between the various players in the agricultural landscape. The input and output markets can be several kilometres apart and it can be time consuming and mentally draining for the smallholder farmers to make travel trips for every transaction.

Although the sourcing of inputs, outputs, and markets information represented the largest single agriculture related activity for which a mobile phone was utilized, this study found that farmers' phone bill on financial transactions with lenders represented almost 11% of the total mobile phone bill. Smallholder farmers require financing to purchase inputs and are known to have financial relationships with banks, particularly agricultural and community banks. Produce buyers also provide credit to smallholders to

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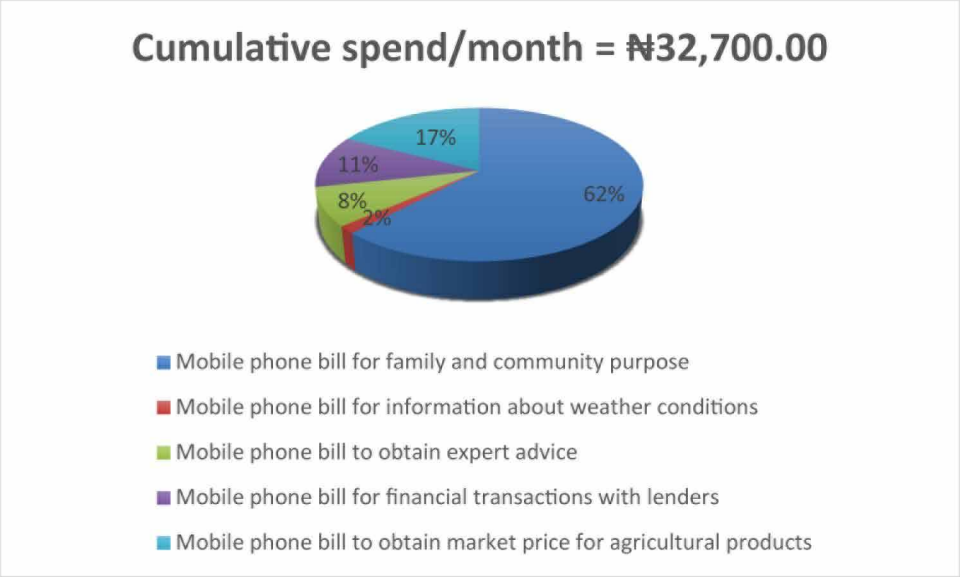
Figure 5. Farmers' mobile phone bill according to use pattern



purchase inputs and to cover some operating cost in exchange for a promise to purchase the crops upon maturity or harvest. These kinds of transaction are enabled through mobile phone discussion without the farmers having to make physical presence.

The almost 11% of the total mobile bill spent on agricultural financial related interaction showed the reliance of the farmers on it as an effective way of business interaction and was consistent with Qiang, Kuek, Dymond, and Esselaar (2011), Martin and Abbott (2011), and Kirui, Okello, and Nyikal (2010). The percentage of mobile phone bill the smallholder farmers incurred on gathering weather information represented less than two percent of the total phone bill per month. The justification for the low spending will be revealed when the discussion on benefit of the use of the mobile phone by farmers is presented.

The Agricultural Uses of Mobile Phone

The various agricultural purposes to which smallholders use mobile phone were also tested. No specific research result exists for this test in the study area; a theoretical consideration was adopted that the t-test result for each variable will be the same as the assumed (hypothesised) mean value.

The t-test test statistics result is shown in Table 2. The result shows that for two variables – "Use of mobile phone to access market information", and "Use mobile phone for financial transactions" – the p-value associated with the t-test was 0.001 which is evidence that the mean of the two variables was different from the hypothesized value. For the variables "Use mobile phone to coordinate access to agricultural inputs", "Use mobile phone to seek agriculture emergency assistance", and "Use mobile phone to obtain expert advice", the p-value associated with their t-tests were 0.594, 1.000, and 0.512, respectively. Using the decision rule, "if the p-value associated with the t-test is not small ($p > 0.05$), then the null hypothesis is not rejected", it was concluded that the mean of each of these variables was not different from the hypothesized value.

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Table 2. The agricultural uses to which mobile phone was put

Variable	mean	standard deviation	t - statistics	P-Value
Use mobile phone to coordinate access to agricultural inputs	17.384	8.783	16.430	0.594
Use mobile phone to access market information	30.036	5.063	29.485	0.001
Use mobile phone for financial transactions	22.292	7.375	21.487	0.001
Use mobile phone to seek agriculture emergency assistance	14.573	6.538	13.863	1.000
Use mobile phone to obtain expert advice	17.486	8.119	16.602	0.512

Sample size = 328

The result indicates the use of a mobile phone to access market information has increased and this emphasised how important access to market information is to farmers. Effective and efficient market information provision has benefits for smallholder farmers, inputs suppliers, and consumers. When farmers have up-to-date market information; are better able to negotiate with other stakeholders.

Relating the result from output sales perspective, the increased use of mobile phones for market information facilitates spatial distribution of products from production areas to consumer market with a clear price signals from the consumer market to farmers. With this information, farmers are able to adjust product quantity, quality, and variety as required according to their target markets. Furthermore, due to the increasing need for market intelligence, farmers use their mobile phones more often to obtain current relevant information and well-analysed historical market information to make production decisions, such that relate to what and when to plant or breed, at what stage should harvesting be done or what market should production be directed.

Considering the magnitude of the effort required to obtain market information across regional, national and at time international boundaries, mobile phone technology can be widely deployed by smallholder farmers in the study area to ensure they are current with market environments. The number of farmers that use mobile phone for financial transactions has also increased, as indicated in the result in Table 2. Governments, financial institutions, and other private lenders of fund are located often time remotely away from the smallholder farmers.

In some States in Nigeria, for example, some smallholder farmers obtain their loan through the ministry of Agriculture and the FADAMA program. They are able to use the phone to make quick calls to arrange loans and contracts that enable them to expand an existing farm enterprise or form new ones. Smallholder farmers can also explore the advantage mobile phone provides, to perform their social responsibility of paying the relevant taxes without making any travel to the Tax Office.

Benefits of Using Mobile Phone by Farmers

The surveyed farmers were presented with benefits options and were asked to agree or disagree with the options base on how these perceived benefits applied to them. Table 3 shows the result; a mean value that was “more than 4” indicated that more smallholders agreed the mobile phone provided the benefits for which investigation were made while a mean value of “less than 4 suggested otherwise.

Aside from the “Gets advance warning of weather risks” for which the surveyed farmers indicated no benefit, the farmers agreed to all the other benefits. The study does not explain why getting advance weather warning benefit was disagreed upon, despite it been one of the main benefits as shown in other

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Table 3. Benefits of using mobile phone by farmers

Variable	Obs	Mean	Std. Dev.	Min	Max
Timely acquisition of price, market and farming practice information.	328	5.920	0.923	1	7
Facilitates access to technical and financial services	328	3.909	2.505	1	7
Easy to connect with other farmers for more effective collective action as producers, traders and buyers	328	5.979	1.277	1	7
Reduced cost of doing business	328	6.253	0.746	2	7
Reduced travel hours	328	6.289	0.707	1	7
Increased social networks	328	4.301	2.418	1	7
Empowers negotiations with wholesalers, traders and transport providers	328	5.526	1.786	1	7
Easier to link my products to distant markets and higher-end agricultural value chains	328	4.832	2.237	1	7
Gets advance warning of weather risks.	328	2.088	1.916	1	7
Enabled faster response to situational changes	328	5.655	1.246	1	7

studies such as Churi, Mlozi1, Tumbo, and Casmir (2012), Qiang, Kuek, Dymond, and Esselaar (2011), and Martin and Abbott (2011).

However, it can be inferred that in the study area, the meteorology services to farmers is still in its infancy. The weather information could be available yet not accessible to the farmers due to inability to gather, harmonise, and provide location specific information to the farmers. Effective weather services rely upon locally relevant data tailored to farmers' needs. When the meteorological service providers are deficient in capacity, they are not able to provide the relevant services to farmers as precisely and accurately to be useful for agricultural planning and operations. Another inference regarding the response to receiving advanced weather warning benefit is that over an extended period of time, farmers have used local knowledge and traditional coping strategies to adapt to changes in weather conditions. For instance, they can predict the arrival of the rainy season by a change in wind patterns and imminent rain fall event by changes in cloud colour.

Factors That Influence Mobile Phone Usage

This study also investigated the influencer of adoption of mobile phone usage. The education status of farmers, their gender, mobile phone ownership, and usage knowledge of the farmers were tested to determine their influence on the farmers' use of the phone for agricultural purposes (see Table 4).

The four predictors of mobile phone ownership, mobile phone usage knowledge, gender, and the educational status of farmers were statistically significant. This result indicates that the use of a mobile phone and its functionalities by farmers has been influenced by these variables. The farmers' knowledge of the use of the phone has increased enabling them to use the functionalities of the phone to meet agricultural purpose. One of the ways farmers acquired knowledge of how to the use mobile phone is through their children. Adult children teach their parents, particularly the less educated ones, how to make and receive calls, store and retrieve data, send, and receive MSM and MMS.

The gender of the farmer plays a part in the usage of a mobile phone for agriculture. Cultural issues, such as traditional roles of men and women in Nigeria affect, delay or even prevent women's acquisition

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Table 4. Factors that influence mobile phone usage. N = 328

Variable	coefficient	P-Value
Mobile phone ownership	3.696117	0.001
Mobile phone usage knowledge	6.631437	0.001
Gender	16.40994	0.001
Educational status of farmers	5.047578	0.001

Note: 0.001 Indicates estimated coefficient is significant at the .01 level; coef. indicates coefficient.

of mobile phones. Agriculture is still a male-dominated sector in which the head of household often determines what goes on in the family and their means of livelihood. The relationship usually impacts women in many ways such that Martin and Abbott (2011) concluded that women are later adopters of technology than their male counterparts. The male dominance in the use of mobile phone also corresponds with the overall levels of economic development and women's role and participation in farming environment.

The level of educational attainment of the farmers had an effect on their ability to read, comprehend, and apply knowledge. The educational status of the farmers was instrumental to the adoption and use of mobile phone. As more and more educated smallholders are involved in agriculture, so will the use of mobile phone technology increase.

CONCLUSION

Nigeria has a larger rural population than the urban and is very agrarian. The agriculture is dominated by smallholder farmers who are positioned to become a key driver of future economic growth and prosperity if the confronting challenges are overcome. The spirit of this study looked into the contribution of mobile phone as an input-of-change for the country to achieve its agriculture and development potentials.

This study investigated the extent to which farmers have taken advantage of mobile phone technology and the benefits they have derived from it. In view of these objectives, the study sought and provided answers to the questions raised in the objectives. Mobile phone created many benefits for the smallholder farmers aside from its unique characteristics of being handy, customised content delivery and convenience. As mobile phone providers continue to penetrate their services into the rural communities where farming is predominant, the tendency is that there will be expansion in the adoption of mobile phone and increased use of the product to cover more aspects of agricultural activities.

The impact of geographic isolation, high transport costs, time lost to poor road networks and conditions, and the failure to deliver inputs on-time to farmers, or from the farmers to the market when prices are more favourable, can significantly impact revenue, profitability, and the overall social economic wellbeing of the rural communities.

Considering all these issues, the use of the mobile phone technology has reasonably reduced most of these problems. It has assisted farmers to gain easy and timely access to market, market information and financial institutions – formal or informal. However, the low use of mobile phones for obtaining weather information is worrying. Weather information is an important detail upon which modern agriculture relies. Apart from providing normal agricultural weather information, it is relied upon to provide sudden

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extreme weather forecast that can be devastating. This study did not investigate the reason for the low mobile phone use to obtain this service; however, smallholder farmers generally are conservative and would often rely on tradition and local intuition to predict weather patterns. Moving forward, a review of the use of weather predicted data is first necessary to ascertain the availability of the data to farmers, secondly whether the farmers can access the data, and finally whether the data can be made available through mobile phone applications.

Cogitating the benefits farmers claimed to have obtained from the use of a mobile phone, the realisation of the full potential of mobile phones usage can be constrained by lack of social inclusion and physical infrastructure. Electricity is a critical infrastructure for this service for both the phone service providers and the user farmers. The farmers rely on electricity to charge their phones and often it is not available or epileptic in supply; however, farmers are excited about the benefits a mobile phone provides.

The role of the extension service/agents cannot be overstated; it often involves the visit to the farmers at home or on the farm by the extension agents. The discussions in such meetings often can be managed via mobile phone. Adoption of mobile phone for this purpose will save time and enable targeted messages to reach more farmers within the shortest possible time. The role of weather information in agriculture in modern time cannot be overestimated considering the volatility in the weather conditions due to the effects of climate change. It is important that every government should intensify effort to improve weather advice systems and to ensure the advice gets to the farmers. Governments in collaboration with mobile phone producers and network providers should develop applications that can provide weather information to farmers.

The study has limitations; despite the similarity generally in mobile phone adoption and use in the survey area, the information may not be sufficient to generalise. Therefore, caution should be taken when using the data. The depth of the agricultural activities for which the mobile phone is used could vary considerably within and between the States in Nigeria. This study presented results on female mobile phone users, thus it did not specifically examine the differences in adoption rate and ownership between men and women smallholder farmers. Furthermore, the study is a cross sectional one, so it may not be capable of providing consistent information about the study population over time. Future studies should be directed towards determining female farmers' adoption and use of mobile phone and a longitudinal survey should be conducted to confirm this study's outcomes.

REFERENCES

Ajiboye, A. O., & Afolayan, O. (2009). The Impact of transportation on agricultural production in a developing country: A case of kolanut production in Nigeria. *International Journal of Agricultural Economics & Rural Development*, *2*(2), 49–57.

Aker, J. C., & Mbiti, I. (2010). Mobile phones and economic development in Africa. *The Journal of Economic Perspectives*, *24*(3), 207–232. doi:10.1257/jep.24.3.207

Allafrica. (2013). *Nigeria: Cell Phones for Farmers to Cut Corruption, Deliver Services*. Retrieved from http://allafrica.com/stories/201301150001

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Alleman, J., Hunt, C., & Michaels, D. (2002). *Telecommunications and Economic Development: Empirical Evidence from Southern Africa* (Technical Report). Sydney: International Communications Society. Retrieved from http://www.colorado.edu/engineering/alleman/print_files/soafrica_paper.pdf

Aminuzzaman, S., Baldersheim, H., & Jamil, I. (2003). Talking back! Empowerment and mobile phones in rural Bangladesh: A study of the village phone scheme of Grameen Bank. *Contemporary South Asia*, *12*(3), 327–348. doi:10.1080/0958493032000175879

Ansari, M. A., & Pandey, N. (2013). Assessing the potential and use of mobile phones in Agriculture. *Kamantaka Journal of Agricultural Science*, *26*, 388–392.

Avgerou, C. (2010). Discourse on ICT and development. *Information Technologies & International Development*, *6*, 1–18.

Burrell, J. (2008). *Livelihoods and the mobile phone in rural Uganda*. Retrieved from http://www.grameenfoundation.applab.org/section/ethnographic-research

Chigona, W., Beukes, D., Vally, J., & Tanner, M. (2009). Can mobile internet help alleviate social exclusion in developing countries? *The Electronic Journal of Information Systems in Developing Countries*, *36*(7), 1–16.

Chorn, B., Sisco, C., & Pruzan-Jorgensen, P. M. (2010). *The Business Case for Supply Chain Sustainability: A Brief for Business Leaders*. Retrieved from http://www.bsr.org/reports/Beyond_Monitoring_Business_Case_Brief_Final.pdf

Churi, A.J., Mlozi, M.S., Tumbo, S.D., & Casmir, R. (2012). Understanding Farmers Information Communication Strategies for Managing Climate Risks in Rural Semi-Arid Areas, Tanzania. *International Journal of Information and Communication Technology Research*, *2(11)*, 838–845.

Das, A., Basu, D., & Goswami, R. (2012). Accessing Agricultural Information through Mobile Phone: Lessons of IKSL Services in West Bengal. *Indian Research Journal of Extension Education*, *12(3)*, 102–107.

Dorosh, P., Wang, H.-G., You, L., & Schmidt, E. (2009). *Crop Production and Road Connectivity in Sub-Saharan Africa: A Spatial Analysis*. Africa Infrastructure Country Diagnostic. Retrieved from http://infrastructureafrica.org/system/files/library/2011/05/WP19_Crops_roads.pdf

FAO. (2005). *Nigeria's Agriculture and Food Security Challenges.* Retrieved from http://www.fao.org/tc/tca/work05/nigeriappt

FAO. (2009). *How to Feed the World in 2050*. Forum Background document. Retrieved from www.fao.org/wsfs/forum2050/wsfs-background-documents/hlef-issues-briefs/en/

FARM-Africa. (2007). *Keeping up with technology*: The use of mobile telephony in delivering community based decentralized animal health services in Mwingi and Kitui Districts, Kenya. Retrieved from http://www.farmafrica.org.uk/view_ publications.cfm?DocTypeID_11

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

GSMA. (2013). *Women and Mobile phone*: A Global Opportunity, A study on the mobile phone gender gap in low and middle-income countries. Retrieved from http://www.gsma.com/mobilefordevelopment/wp-content/uploads/2013/01/GSMA_Women_and_Mobile-A_Global_Opportunity.pdf

Halewood, N. J., & Surya, P. (2012). Mobilizing the Agricultural Value Chain. Retrieved from http://siteresources.worldbank.org/EXTINFORMATIONANDCOMMUNICATIONANDTECHNOLOGIES/Resources/IC4D-2012-Chapter-2.pdf

Hudson, H. (2006). *From rural village to global village: Telecommunications for development in the information age*. Danbury, CT: Lawrence Erlbaum.

IFAD. (2014) *Investing in smallholder family farmers… for the future we want*. Retrieved from http://www.ifad.org/events/gc/37/doc/concept%20note_e.pdf

Inoncencio, A., Kikuchi, M., Tonosaki, M., Maruyama, A., Merry, D., Sally, H., & de Jong, I. (2007). *Costs and Performance of Irrigation Projects: A Comparison of Sub-Saharan Africa and Other Developing Regions*. IWMI Research Report 109. IWMI, Colombo, Sri Lanka. Retrieved from http://www.ifad.org/events/hs/doc/irrigation_projects.pdf

Karamagi, H., & Nalumansi, L. (2009). No more spilt milk: Mobile phones improve the supply of milk to the market in Uganda. *ICT Update,* 47. Retrieved from http://ictupdate.cta.int/ index.php/en/layout/set/print/Feature-Articles/No-more-spilt-milk

Kirui, O. K., Okello, J. J., & Nyikal, R. A. (2010, September 19-23). Awareness and use of m-banking services in agriculture: The case of smallholder farmers in Kenya. *Contributed Paper presented at the Joint 3rd African Association of Agricultural Economists (AAAE) and 48th Agricultural Economists Association of South Africa (AEASA) Conference*, Cape Town, South Africa.

Lio, M., & Chun Liu, M. (2006). ICT and Agricultural Productivity: Evidence from Cross Country Data. *Journal of Agricultural Economics*, *34*(3), 221–228. doi:10.1111/j.1574-0864.2006.00120.x

Livingston, G., Schonberger, S., & Delaney, S. (2011, January 24-25). Sub-Saharan Africa: The state of smallholders in agriculture. *Paper presented at the IFAD Conference on New Directions for Smallholder Agriculture*. Retrieved from http://www.ifad.org/events/agriculture/doc/papers/livingston.pdf

Martin, B. L., & Abbott, E. (2011). Mobile Phones and Rural Livelihoods. *Diffusion, Uses, and Perceived Impacts Among Farmers in Rural Uganda Information Technologies & International Development*, *7*, 17–34.

Moisio, R. J. (2003). Negative Consequences of Mobile Phone Consumption: Everyday Irritations, Anxieties and Ambiguities in the Experiences of Finnish Mobile Phone Consumers. In P. A. Keller & D. W. Rook (Eds.), *Advances in Consumer Research* (Vol. 30, pp. 340–345). Valdosta, GA: Association for Consumer Research.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Odhiambo, F. (2014) Unlocking the market. Retrieved from http://ictupdate.cta.int/Feature-Articles/Unlocking-the-market

Ogbeide, O. A. (2014). An Assessment of Cooperative Society as a Strategy for Rural Development in Edo State of Nigeria. *Journal of Rural and Community Development*, *9*(4).

Okello, J., Kirui, O. K., Njirani, G. W., & Gitonga, Z. M. (2012). Drivers of Use of Information and Communication Technologies by Farm Households: The Case of Smallholder Farmers in Kenya. *The Journal of Agricultural Science*.

Okello, J. J., Okello, R. M., & Adera-Ofwona, E. (2009). Awareness and use of mobile phones by smallholder farmers in Kenya. In B. Maumbe (Ed.), *E-Agriculture and E-Government for Global Policy Development: Implications and Future Directions*. Hershey, PA: IGI Global.

Qiang, C. Z., Kuek, S. C., Dymond, A., & Esselaar, S. (2011). Mobile Applications for Agriculture and Rural Development. Retrieved from http://siteresources.worldbank.org/INFORMATIONANDCOMMUNICATIONANDTECHNOLOGIES/Resources/MobileApplications_for_ARD.pdf

Robinson, L. (2009). *A summary of Diffusion of Innovations*. Retrieved from http://www.enablingchange.com.au/Summary_Diffusion_Theory.pdf

Sebastian, K. (2008). GIS/Spatial Analysis Contribution to 2008 *WDR*. Market Access dataset. Retrieved from http://siteresources.worldbank.org/INTWDRS/Resources/477365-1327599046334/8394679-1327599874257/SebastianK_ch2_GIS_input_report.pdf

Sherry, J. M. (n. d.). *Mobile Phone Applications: Information Technology For Individuals In The Developing World*. Retrieved from http://www.eecs.berkeley.edu/~justine/taskforce.pdf

Staatz, J. M., & Dembele, N. N. (2007). *Agriculture for Development in Sub-Saharan Africa. Background Paper for the World Development Report 2008*. Retrieved from http://siteresources.worldbank.org/INTWDR2008/Resources/2795087-1191427986785/StaatzJ&DembeleN_AgriForDevtInSSve19.pdf

Syngenta Foundation. (2011). *Mobile Applications in Agriculture*. Retrieved from http://www.syngentafoundation.org/__temp/Report_on_mAgriculture_abridged_web_version.pdf

Szilagyi, R., & Herdon, M. (2006, July 24-26). Computers in Agriculture and Natural Resources. *Paper presented at 4th World Congress conference*, Orlando, Florida United States of America.

Tunde, A. M., & Adeniyi, E. E. (2012). Impact of Road Transport on Agricultural Development: A Nigerian. *Ethiopian Journal of Environmental Studies and Management*, *3*(5), 232–238.

USAID. (2013). *Agriculture and Food Security*. Retrieved from https://www.usaid.gov/nigeria/agriculture-and-food-security

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

World Bank. (2009). *World Development Report 2009*. Washington, DC: World Bank. Retrieved from http://siteresources.worldbank.org/INTWDRS/Resources/477365-1327525347307/8392086-1327528510568/WDR09_18_GIM04web.pdf

World Development Indicators. (2010). Washington, DC: World Bank. Retrieved from http://data.worldbank.org/sites/default/files/wdi-final.pdf

Wyche, S., & Steinfield, C. (2016). Why Don't Farmers Use Cell Phones to Access Market Prices? Technology Affordances and Barriers to Market Information Services Adoption in Rural Kenya. *Journal of Information Technology for Development*, *22*(2), 320–333. doi:10.1080/02681102.2015.1048184

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Chapter 62
Farmer Suicides in India: A Case of Globalisation Compromising on Human Rights

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ABSTRACT

Indian farmers are facing a crisis of their extinction caused by their suicides. A suicide, every thirty minutes, reflects towards a deeply rooted structural and policy defect in the country. A defect so extreme that many call the same to be state genocide. The State has several obligations towards its farmers, both nationally and internationally. However, the pressures of globalization combined with the influence of bodies like the WTO and IMF has managed to defeat these obligations. This has resulted in a state where ideas like profit, free trade and removal of barriers are being forced upon 'sovereign' States, who have allocated their power to decide on economic issues to supranational bodies due to their inability to operate in isolation like a Westphalian State. The aim of this chapter is to explore and elaborate upon the adverse consequences of globalization on the lives of farmers in India due to enhanced competition and policies which have been influenced by MNCs such as Monsanto and capitalist, north dominated supranational bodies like the WTO and World Bank.

I. INTRODUCTION

Indian farmers are facing a crisis, a crisis of their extinction caused by their suicides. The region of Vidharba in India is infamous for its suicide rate. In the two years preceding 2015, about three thousand farmers have committed suicide in the six districts of Vidharba itself (Purohit, 2015). Studies have found that over nine hundred, or nearly one in three farmers, had debts ranging between ten to fifteen thousand rupees. (Purohit, 2015). In the year 2009 itself, over seventeen thousand farmers had committed suicide (Ministry of Home Affairs, 2009). In other words, one famer died every thirty minutes.

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A suicide, every thirty minutes, reflects towards a deeply rooted structural and policy defect in the country. A defect so extreme, whether by way of active acts or omissions, that many call the same to be State genocide. The State has several obligations towards its farmers, both under the Constitution of India and under international conventions like ICCPR and ICSCR, which it is deplorably deflecting.

However, busy with crafting a pleasant picture of "shining" India, the media too, barring a few rural journalists like P. Sainath, has neglected its duty to report on the lives and livelihoods of the largest group of working people in India, the farmers. Agriculture has transformed into a negative economy which is reflected in the rapid increase in indebtedness faced by the farmers (Katakam, 2009). Policies of trade liberalization and corporate globalization are at the root of the farmer distress.

The pressures of globalization combined with the influence of bodies like the WTO and IMF has managed to defeat the human right obligations. The influence of these bodies on national economies so extreme that a Mexican farmer had to stab himself to death to hinder the world trade talks in Cancun in September 2003 (Watts, 2003). The farmer was protesting against the north's efforts to open agricultural trade, whilst the global south wanted to deliberate on older issues that affected them the most, especially the impact of European and U.S. subsidies on their own agriculture and lack of access to those markets (Watts, 2003).

Globalization and liberalization has resulted in a state where ideas like profit, free trade and removal of barriers are being forced upon 'sovereign' States, who have allocated their power to decide on economic issues to supranational bodies due to the current trade scenario where a country cannot operate in isolation like a Westphalian State. The aim of this chapter is to explore and elaborate upon extensively the adverse consequences of liberalization and globalization on the lives of farmers in India due to enhanced competition and policies which have been influenced by MNCs such as Monsanto and capitalist, global north dominated supranational bodies like the WTO and World Bank.

II. BACKGROUND

Recently, a lot of reliable studies have reported the rate of farmer suicides in India. The rate of farmer suicides reported in the region of Vidarbha is alarming. The Indian Government compiled statistics for farmer suicides between 1995 and 2009 and according to the report, over two lakh forty five thousand farmers had committed suicide in that period of time (Ministry of Home Affairs, 2009). In the year 2009 itself, over seventeen thousand farmers had committed suicide (Ministry of Home Affairs, 2009). In other words, one famer died every thirty minutes. The hypothesis of this chapter is that the problem of farmer suicides in India is a result of the policy of the Indian state which is influenced by global pressure. The globalization of agriculture has resulted in this situation of producers of our food dying of hunger. The problem of farmer suicides in India can be addressed by way of states asserting their sovereignty, the developing and under-developing countries asserting and negotiating their rights and not succumb to the pressures of the international bodies like WTO, IMF, World Bank and the MNCs.

III: INDEBTEDNESS: THE ROOT CAUSE OF FARMER SUICIDE

There is no dispute to the fact agricultural growth is required for overall economic development in a country like India where 2/3rd of the people are involved in the agricultural sector (Singh, 2015). Agri-

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cultural growth depends upon the growth of productivity (Chand, 2005). Productivity in turn requires infusion of capital (Chand, 2005). Farmers in most developing countries require more capital than they can afford to generate through their savings (Chand, 2005).

Agricultural Credit Review Committee projected the demand for credit both for production and investments at Rs. 389990 million by 2000 (Reddy & Reddy, 2003). This demand has just been steeply increasing since. As can be seen, farmers require huge credit. A startling 48.6% of the farmer households are in debt according to the 66th NSSO survey (Indian Sociology Institute, 2009).

A farmer is unable to meet the exigencies of cash requirements due to several factors. Most of them are directly a result of globalization and active State policies influenced by supranational bodies, while some are omissions or failures on part of the State to adequately remedy this problem by provision of credit facilities which aren't exploitative in nature.

1. Factors Leading to Indebtedness

As stated in the previous head, globalization and supranational bodies are the main cause for the indebtedness leading to farmer suicides. The economic growth that India is witnessing is indeed a result of its supra-nationally influenced policies, but the very same policies have led to an uneven growth and pushed the farmers to a stage where they want to end their lives (Motlagh, 2008). The factors identified in this chapter are as follows,

2. Market Access

The Agreement on Agriculture under the WTO regime, aiming at liberalized trade in agriculture and for a 'fair' international market for agricultural products, is resulting into upheaval in the lives of farmers (Aksoy & Beghin, 2004). Market Access is an essential ingredient of the Agreement on Agriculture (Smith, 2009). The clauses on market access require that the countries open up their economies and allow a free flow of agricultural products. There are two basic elements attached to it:

1. The non- tariff barriers are to be replaced by tariffs. Non- tariff barriers are in the nature of quantitative restrictions, licensing etc (WTO Legal Affairs Division, 2011);
2. Maintaining a minimum level of imports (WTO Legal Affairs Division, 2011).

The implication of the Agreement on Agriculture is that India and other developing countries had to do away with the quantitative restrictions on market access (Order & Josling, 2011). This resulted in increasing the competition many fold, often to a level where domestic players could no longer compete, and the State couldn't implement protectionist strategies (Order & Josling, 2011). Most policies aimed at promoting the domestic sector were violative of the WTO regime. This also made farmers vulnerable to price volatility. India was undergoing a balance of payment crisis, which was worsening with increased imports into the country (McCalla & Nash, 2007). The exports weren't able to keep up due to decreased subsidies, and lack of the same amount to market access in other developed nations (Order & Josling, 2011). Also, the entrants to Indian markets were able to set the price of products artificially low due to subsidies available in their home country. (Chand, 2005).

These points will be elaborated upon in the next heading. Consequently, India attempted to continue some quotas and import restrictions which were challenged by the United States in the *India Quantitative*

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Restrictions on Imports of Agricultural, Textile and Industrial Products case. After failed consultations, a panel was set up by WTO to resolve the issue. India argued that the quantitative restrictions were to protect its balance of payment situation which was permitted under GATT Article XVIII (Westin, 2001).

The GATT Panel held that there is a general prohibition on quantitative restrictions under Article XI:1 and India's measures such as its import licensing system were quantitative restrictions which were inconsistent with Article XI:1 (Westin, 2001) . The panel concluded that the monetary reserves were adequate and there was no threat, or serious decline in reserves within the meaning of Article XVIII:11, to afford India its exception (Thomas, 2001).

Naturally, when these quantitative restrictions were abolished in 2001, a standing committee of group of concerned ministers was established to deal with the crisis that ensued (Stern & Mattoo, 2005). With phasing out of these restrictions, India had to re-negotiate tariff concession for several agricultural items. As many as 715 agricultural items were freed from quantitative restrictions in 2000 (Goldar, 2005). The result was that the aggregate of imports of such commodities increased by 70% in 2003-04 from the level of imports in 1999-2000 (Goldar, 2005). The Indian farmers all of a sudden were facing an exponentially high level of competition. Even if WTO didn't consider India's import licensing system as consistent with the GATT agreement, WTO could have allowed India some time to bring about changes so that the agricultural sector is not in a state of crisis post its finding. Certainly there is no room for socio-economic and human rights considerations under the WTO decision making framework.

An interesting pointer hinting towards WTOs bend towards the developed countries is its decision making process. In the above mentioned quantitative restrictions case, the dispute brought by the US against India, the panel had this to say: "Article 13.1 of the DSU entitles the panel to consult with the IMF in order to obtain any relevant information relating to India's monetary reserves and balance-of-payments situation *which would assist us in assessing the claims submitted to us.*"(Schott & Watal, 2000).

However, in the United States — Rules of Origin for Textiles and Apparel Products, the dispute was brought by India against USA's rules of origin on textiles and the panel held that India hasn't substantiated its claims while recognizing that the information was readily available with IMF and other international bodies (Schnitzer, 2007).

3. Fall in Prices of Produce, Subsidies, and Other Domestic Support

In order to industrialize more and comply with IMF and World Bank dictates, fiscal reforms took place in India which had an adverse consequence on public investment in critical areas like agriculture. The public expenditure on agriculture as a percentage of GDP fell significantly. There was decline in institutional credit to famers as a result of financial policies of the government (Reddy & Reddy, 2003). There was overall decline in expenditure on agriculture in the budget which was garbed in the name of fiscal constraint.

Similarly, opening up India's markets resulted in banks wanting to enhance their performance to compete globally. 4750 branches of rural schedules banks were closed (Chand, 2005). Loans given to the agricultural sector decreased from 18% to 12% almost immediately (Chand, 2005).

Another pressure Indian farmers started facing was the dramatic fall in prices of farm produce as a result of the WTO's free trade policies. The WTO rules for trade in agriculture are, in essence, rules for dumping. They have allowed wealthy countries to increase agribusiness subsidies while preventing other countries from protecting their farmers from artificially cheap imported produce. Four hundred billion dollars in subsidies combined with the forced removal of import restriction is a ready-made recipe for

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farmer suicide. Global wheat prices have dropped from $216 a ton in 1995 to $133 a ton in 2001; cotton prices from $98.2 a ton in 1995 to $49.1 a ton in 2001; Soya bean prices from $273 a ton in 1995 to $178 a ton in 2001 (Diao & Somwaru, 2001). This reduction is due not to a change in productivity, but to an increase in subsidies and an increase in market monopolies controlled by a handful of agribusiness corporations.

Subsidies under the framework of agreement on Agriculture can be in the nature of subsidizing production as one the domestic support measure or can be in the nature of export subsidies (Orden & Josling, 2011). In fact, domestic support and export subsidies are two of the three pillars of the Agreement on Agriculture (the third being market access) (Smith, 2009). Under GATT 1947 -which governed the international trade in agriculture before Agreement on Agriculture came in force- the restrictions on subsidies on export of primary agricultural products were ineffective (Orden & Josling, 2011). The result was that quantum of export subsidies being offered by a country was dependent upon the money in the national treasury. The Agreement on Agriculture, which marked a shift, requires direct export subsidies to be reduced to a level of 36% of the 1986-1990 base year over a span of six years (Orden & Josling, 2011). The developing countries are subject to lesser reduction levels over a span of ten years and the least developed countries are not required to commit anything (Aksoy & Beghin, 2004). This appears good for the developing countries, but is again ineffective like GATT 1947. The exporters in India do not get any direct export subsidy (Chand, 2005). The national treasuries of India and many other developing and least developed countries can't afford subsidizing export marketing cost or transport charges.

The high level of subsidies given by developed countries to its agricultural products is one of the major problems in international trade in agricultural products. If the products are subsidized and consequently cheaper than the domestic products of the developing countries, the farmers in those countries can't compete. As is stated above, the agreement on agriculture, very good in its intentions, aims at resolving this problem by calling for commitments on reduction of domestic support. But at some level, the fairness of the agreement itself is questionable as well. Countries giving subsidies on their agricultural products have to reduce them over time while the countries not giving subsidies at all can't beyond the de-minimus limit (Rosset, 2008). There is no parity.

Cotton producers in the US are given a subsidy of $4 billion annually (Rosset, 2008). This has artificially brought down cotton prices, allowing the US to capture world markets previously accessible to poor African countries such as Burkina Faso, Benin, and Mali (Rosett, 2008). This subsidy of $230 per acre in the US is untenable for the African farmers. African cotton farmers are losing $250 million every year (Rosett, 2008). That is why small African countries walked out of the Cancun negotiations, leading to the collapse of the WTO ministerial conference in 2003 (Watts, 2003).

While MNCs like Monsanto pushes the costs of cultivation up, agribusiness subsidies drive down the price farmers get for their produce. The rigged prices of globally traded agriculture commodities steal from poor peasants of the South. A study carried out by the Research Foundation for Science, Technology and Ecology (RFSTE) shows that due to falling farm prices, Indian peasants are losing $26 billion annually (Reddy & Mishra, 2009). This is a burden their poverty does not allow them to bear. As debts increase — unpayable from farm proceeds — farmers are compelled to sell a kidney or commit suicide (Reddy & Mishra, 2009).

Further there is misclassification, underreporting and omission from notifications to WTO regarding the domestic support given by USA. Members of WTO have to notify the WTO about domestic support they give (Smith, 2009). The Domestic Support clauses in the Agreement for Agriculture are a guide to the quantum of domestic support that a country can give to its farmers. The method through which the

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quantum of domestic support is ascertained is by quantifying the total of the domestic support which is given by the country to a specific category of agricultural product (WTO Legal Affairs Division, 2011). Countries, based on whether they are developed or developing had committed reduction in the total Aggregate Measurement of Support (AMS), which is the quantity of support given by each country (WTO Legal Affairs Division, 2011). Domestic support under the Agreement on Agriculture is subject to three exceptions (Smith, 2009). These are:

1. **Green Box Measures:** These are measures which have a minimum impact on trade. These include measures like direct payment for relief from natural disasters (Smith, 2009);
2. **Special and Differential Treatment Box:** These are available to developing countries. Example of this is investment subsidies (Smith, 2009);
3. **Blue Box Measures:** They are relevant for developed countries only (Smith, 2009);

The domestic support in the nature of traditional price and income support programs (direct payments, countercyclical payments, and loan rate program benefits) (Hoekman & Olareagga, 2002). The US notifies various types of disaster payments in the green box as product specific support, and as non-product specific support (Orden & Josling, 2011). The Canadian request for establishment of a panel in the Total Agreegate Measure of Support case (TAMS) case (WTO 2007) case listed forty-eight separate disaster programs over the period 1999-2005 (Orden & Josling, 2011). Crop insurance and disaster relief payments in the green box range from a low of $100 million in 1995 to a high of $2.3 billion in 2008 (Orden & Josling, 2011). Important questions are whether all disaster programs have been included in the US notifications, whether those notified in the green box satisfied the relevant criteria and whether annual support through these programs has been measured correctly (Orden & Josling, 2011). Some disaster relief programs could be judged to provide product specific payments that do not qualify for the green box (Orden & Josling, 2011).

The EU has also provided the highest level of trade distorting domestic support among WTO members to its agricultural sector (Smith, 2009). The European Union has a Common Agricultural Policy (CAP) for its member states. The level of farm support in the EU has been historically high (Frandsen & Birgitte 2003). The Agreement on Agriculture was negotiated to bring restraints on policies as the EU's CAP (Frandsen & Birgitte 2003).

The EU notifications to the WTO about its domestic support reflect that the it has switched its support away from the trade distorting categories under the Agreement towards those deemed to be non or minimally distorting categories (Frandsen & Birgitte 2003). The notifications from 2008/09 to 2015/16 show that the payments have been decoupled from production and prices. There is clear manipulation of policy instruments to take advantage of the method of calculation. Further there is increased expenditure on initiatives such as rural infrastructure which falls outside the scope of Agreement on Agriculture (Orden & Josling, 2011). The net result is an increase in domestic support.

Subsidies and other domestic support given by US to its farmers is also the center of attention in the ongoing Doha negotiations (Anderson & Martin 2015). The US position has also been to acquire increased market access in the emerging markets (Anderson & Martin 2015). The problematic nature of the Domestic Support by US has emerged in the US-Cotton case (WTO 2005) and the Total Agreegate Measure of Support case (TAMS) case (WTO 2007) (Orden & Josling, 2011). In the US Cotton Case, the appellate body held that USA's measures were causing significant price suppression, violated Agreement on Agriculture and were causing serious prejudice to Brazil's interests (Orden & Josling, 2011).

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In the 9th conference of the WTO at Bali, India demanded that it should be allowed to extend its domestic agricultural subsidies (Food Security Schemes) indefinitely (Basu, 2013). The US opposed it, as they are trade distorting subsidies (Basu, 2013). They eventually reached a compromise that the subsidies will remain, but with future negotiations, and the developed nations will not complain on this issue for the next four years (Basu, 2013). This however, is not a permanent solution and till now there is no move by the WTO/Developed nations/US towards framing the guidelines for a permanent solution to subsidies issue. In the same Bali conference, Trade Facilitation Agreement (TFA) for an easy trade worldwide has also been declared (Jaipuria, 2015). India is aware that once it signs the Trade Facilitation Agreement (TFA) it will be obliged to ease its trade at any cost under which circumstances it will be forced to give up or reduce the minimal level subsidies that it has negotiated to give to its debt ridden farmers (Jaipuria, 2015).

4. Production of Cash Crops: Recolonization of India

From growing wheat and barley, farmers were forced to shift to growing cash crops like tobacco and cotton (Reddy & Reddy, 2003). When the Indian Rupee devalued due to sudden liberalization and opening up of the market, Indian goods became cheaper, which made products them appealable in the international market (Reddy & Reddy, 2003). The State trying to tap this revenue source profitably, urged the farmers to grow cash crops. When India was under the British colonial rule, farmers were forced to grow cash crops, for foreign nations (Reddy and Reddy, 2003). Again after more than fifty years of Independence of India, India returned to the same state of being subservient to the interests of others. So, farmers, at the behest of market demands, stopped producing for self-consumption.

What is important to note is that an average farmer holds approximately an acre of land, which makes profitable cultivation of cash crops and the like impossible (Indian Sociology Institute, 2009). Moreover, the cultivation of cash crops requires pesticides, fertilizers and other inputs much more than the traditional inputs (Indian Sociology Institute, 2009). The subsidies on pesticides was reduced dramatically when India liberalized in the 1990s due to pressure from IMF, as already discussed above (Deshmukh, 2010). Further, the inputs like fertilizers and pesticides were sold in the Indian market by the multinational corporations at costs which made cultivation unviable to farmers (Deshmukh, 2010). Thus the costs increased significantly and there was reduction in subsidies. This put the farmer in a debt trap.

5. Genetically Modified Crops

MNCs sought to benefit from India's structural adjustment policies and the LPG regime by assertively lobbying for the introduction of genetically modified seeds. Global corporations changed the input economy overnight.

In 1998, the World Bank's structural adjustment policies forced India to open up its seed sector to global corporations like Cargill, Monsanto and Syngenta (Sengupta, 2011). The farm saved seeds started getting replaced by corporate seeds, which need fertilizers and pesticides and cannot be saved (Sengupta, 2011). Corporations prevent seed savings through patents and by engineering seeds with non-renewable traits (Gilbert, 2013). As a result, poor peasants have to buy new seeds for every planting season and what was traditionally a free resource, available by putting aside a small portion of the crop, becomes a commodity. This new expense increases poverty and leads to indebtedness.

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In early 2000s, Monsanto's Bt cotton and several other variants were approved by the Genetic Engineering Approval Committee (Indian GMO Research Information System, 2010). Bt cotton is a modified to produce the Bacillus Thuringiensis toxin, and the market cost of Bt cotton is at least double that of normal cotton seeds. Several reports indicate the market cost of these seeds to be much greater than five times (Qayum & Sakhari, 2005). Without availability of bank loans due to lack of collateral, farmers resorted to money lenders offering loans are exorbitant interest rates, which coupled with such high capital outlays put the farmers under severe pressure to generate high yields just to recover their costs of production (Gilbert, 2013). Bt cottonseeds also need a higher amount of water. What makes the situation worse is how the option to purchase non-Bt seeds is no longer available in some regions, nor in government seed banks. This forced farmers to get stuck in an endless debt cycle.

The Monsanto bt-cotton mayhem is perfectly captured by the region in India with the highest level of farmers suicides: the Vidharbha region in Maharashtra — 4000 suicides per year, 10 per day (Purohit, 2015). This is also the region with the highest acreage of Monsanto's GMO Bt cotton. Monsanto's GM seeds create a suicide economy by transforming seed from a renewable resource to a non-renewable input which must be bought every year at high prices. Cotton seed used to cost Rs 7/kg. Bt-cotton seeds were sold at Rs 17,000/kg (Indian GMO Research Information System, 2010). Indigenous cotton varieties can be intercropped with food crops (Qayum & Sakkhari, 2005). Bt-cotton can only be grown as a monoculture (Qayum & Sakkhari, 2005). Indigenous cotton is rain fed. Bt-cotton needs irrigation (Qayum & Sakkhari, 2005). Indigenous varieties are pest resistant (Qayum & Sakkhari, 2005). Bt-cotton, even though promoted as resistant to the boll worm, has created new pests, and to control these new pests, farmers are using 13 times more pesticides then they were using prior to introduction of Bt-cotton (Indian GMO Research Information System, 2010). And finally, Monsanto sells its GMO seeds on fraudulent claims of yields of 1500/kg/year when farmers harvest 300-400 kg/year on an average. High costs and unreliable output make for a debt trap, and a suicide economy (Sengupta, 2011).

6. Reduction of Biodiversity and Crop Failure

The shift from saved seed to corporate monopoly of the seeds also indicates a shift from biodiversity to monoculture in cultivation. The district of Warangal in the State of Andhra Pradesh used to grow diverse legumes, millets, and oilseeds (Shiva, 2004). The imposition of cotton monocultures has led to the loss of wealth of farmer's breeding and nature's evolution.

Monocultures and uniformity increase the risk of crop failure, as diverse seeds adapted to diverse to eco-systems are replaced by the sudden introduction of untested and uniform seeds into the market. When Monsanto first introduced Bt Cotton in 2002, the farmers lost 1 billion rupees due to crop failure. Instead of 1,500 kilos per acre as promised by the company, the harvest was as low as 200 kilos per acre. Instead of incomes of 10,000 rupees an acre, farmers ran into losses of 6,400 rupees an acre (Shiva, 2004). In the state of Bihar, when farm-saved corn seed was displaced by Monsanto's hybrid corn, the entire crop failed, creating 4 billion rupees in losses and increased poverty for desperately poor farmers (Shiva, 2004). Poor peasants of the South cannot survive seed monopolies. The crisis of suicides shows how the survival of small farmers is incompatible with the seed monopolies of global corporations.

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7. Spiral of Indebtedness: Credit Games

So while all the above discussed was taking place, and when effective credit was most needed, the State did not take any steps. It chose to neglect the needs and rights of the farmers. Government's inaction resulted in furthering of the agrarian crisis being faced by India.

Changes in the pace and composition of agricultural credit emerged as a significant issue in the context of farmers' distress in India.

The problem arose due to:

1. Lack of access to credit;
2. Inadequate supply of institutional credit particularly to small, marginal and semi-medium farmers.

This forces the farmers to rely on informal sources accompanied by hefty rates of interest. Prabhakara Reddy rightly noted the near absence of cheaper institutional credit and the rise of suicides in the regions in which input markets, output markets and credit markets are handled by the traders/moneylenders (Reddy, 2013).

Financial institutions do not necessarily prefer to lend to the agricultural sector as can be seen from the number of banks that have reached the stipulated 18% lending requirement to the agricultural sector (Deshpande & Shah, 2012). The total investment to the GDP ratio has declined from 1.6% to 1.3%. The supply of institutional credit works out to just 11%. Thus, of the total short-term credit requirement, nearly 90% of the same is being met by private moneylending (Jaipuria, 2015).

Farmers are unable to avail loans from the institutionalized sector because:

1. In the farm sector, the possibility of assured income is quite low- the banks refuse to give loans;
2. The poor farmers have no collateral to offer;
3. Absence of commercial banks;
4. Lengthy procedures to avail loans;
5. Lack of awareness on part of small, marginalized farmers.

The informal sector lenders exploit the farmer. Indebtedness is not an overnight phenomenon. It is nothing but the result of faulty credit policies followed over the years. Unlike industrialists, farmers do not have access to debt relief under any law. Being indebted to the private moneylenders, they cannot go to public authorities to declare themselves insolvent or to get any kind of debt relief.

With the tentacles of usurious moneylenders spreading fast, the absence of an effective and comprehensive law to curb harassment of borrowers seems to have emboldened the unscrupulous private financiers (Srivastava, 214). Exorbitant rates of interest, at times 10 per cent a day, harassment, threats and physical assault of borrowers for default in repayment to "discipline them" and to serve as a "lesson to others," have come to stay in the `trade', which strangely involves no paper work at all (Srivastava, 2014). As no worthwhile document is involved in the transaction and lenders' muscle power alone works, complaints by unsuspecting borrowers are far and few in between (Indian Sociology Institute 2009). Those who obtain money, who include the poor and the prominent in society, would have to suffer in silence to protect their honour.

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In fact, according to a petition filed before the State Human Rights Commission, the producer, G. Venkateswaran, committed suicide because of the humiliation suffered by him at the hands of a Madurai-based moneylender (Indian Sociology Institute 2009). Informal sources of credit need to be substituted and the best alternative according to Ravikesh Srivastava is credit management through formation of Farmers' Groups or Farmers' Self-help Groups at the village level (Srivastava, 2014).

The government has failed in addressing the situation of such debt- ridden farmers. Though several debt waiver schemes have been launched by the Indian government, they have been ineffective. Moreover, the Governor of RBI, the Central Bank of India, at a conference of the Indian Economic Association questioned the effectiveness of the debt waiver schemes by stating, "In some states on certain occasions we have had debt waivers. How effective these debt waivers have been? In fact the studies that we have typically show that they have been ineffective. In fact they have constrained the credit flow post waiver to the farmers," Governmental steps to provide debt relief or compensation to farmers have not reached those in need and have seen very limited results (Press Trust of India, 2014). In 2008, the then government at Centre had come out with Agricultural Debt Waiver and Debt Relief Scheme (ADWDRS) 2008 under which 3.69 crore small and marginal farmers and 60 lakh other farmers were given debt relief to the extent of Rs 52,516 crore (Press Trust of India, 2014). Government auditor CAG had found in several cases that ineligible farmers were given benefit while deserving were left out, pointing to large-scale possibility of fraud (Press Trust of India, 2014). Complete waivers were available to small farmers, who were described as owning less than two hectares of land (Press Trust of India, 2014). Very little waiver was available to other farmers, who also suffered from extreme indebtedness. This two-hectare limit was arbitrarily fixed without any insight into the plight of the farmers. The other problem was that this scheme applied to bank loans only. Farmers who were indebted to money lenders, which comprised a majority of them, were excluded from any sort of governmental assistance. Further, while the State has introduced financial assistance schemes for the families of the farmers who commit suicide out of helplessness, such schemes have been intermittently and haphazardly implemented. They have served only as short-term solutions limited to very few affected families (Indian Sociology Institute, 2009).

8. State's Obligations Under the Indian Constitution

So far the chapter has discussed how the government's policies, which in turn have been influenced by international pressure for bodies like IMF and WTO, have been responsible for the condition of farmers in India. In this section, it is discussed how the government is not complying with its Constitutional Obligations which obligates it to address the distress of the farmers.

Article 21 of the Constitution of India states that no person shall be deprived of his life or personal liberty except according to procedure established by law. The Supreme Court i.e. the apex court in India, in numerous decisions has held that the right to life under Article 21 includes the right to livelihood. It includes the right to live with dignity. No person can live without means of subsistence and hence right to life would not make much sense if right to livelihood is not a part of it.

The plight of farmers in India is contrary to what is guaranteed under Article 21 of the Indian Constitution. In 2004 an Organic Farming association had written to Bombay High Court over the situation of farmers in the country (Katakam, 2006). The court treated this as a Public Interest Litigation and observed

The Constitution guarantees the right to life and to personal liberty. The values which underlie Article 21 of the Constitution are seriously eroded by deaths on such a systemic scale, as the facts before the

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court in relation to the State of Maharashtra demonstrate…. The suicides that have occurred are as much due to the failure of social and economic development to reach the poor, the landless and those on the margins of existence as it is due to natural calamities. (Katakam, 2006)

This was the first case in India against the plight of farmers. The court had also held that Article 21 is inviolable and the state is the bound to address the condition of farmers and ensure them their right to life enshrined under Article 21 (Katakam, 2006).

In 2006 another PIL was filed in the Supreme Court, the apex court of the country. The petition stated that in the last five years (2001-2006) 5910 farmers ended their life in Karnataka, 1835 in Andhra Pradesh, 981 in Maharashtra and 201 in Kerala (Saxena, 2006). The Supreme Court held that the suicide of farmers is a result of the structural deficiencies in the National Agricultural Policy.

In March 2015, a Public Interest Litigation petition was filed by the Punjab based NGO. The petition stated that the state has failed to address the issue of farmer suicides. Farmers are forced to buy seeds at high costs, every planting season which has resulted in a debt trap for them compelling them to commit suicides (Press Trust of India 2015). It also stated that state's inaction in implementing the recommendation of the National Commission on Farmers is responsible for non-alleviation of the farmers' distress (Press Trust of India 2015). On the filing of this petition, the court sought the government's response on why it has not made any amendments to the National Policy on Farmers which has structural deficiencies causing farmer suicides (Press Trust of India 2015). The government argued that there had been a decrease in farmers. Court though did not believe this assertion to be true, yet remarked, "Decrease in number (of suicides) is not enough, there should be no case of farmer suicide in the country." (Press Trust of India 2015). The court passed an order on October 30th, 2015 slapping fine on the government for not filling affidavit despite Court's direction (Press Trust of India 2015). The matter is now due to hearing on January 15. The laxity of state in the matter before the court reflects how much the government cares about farmers.

Besides Article 21, two more articles under the Indian Constitution impose an obligation on the Indian State to address the condition of Indian farmers. Article 47 of the Indian Constitution states that it's the duty of the State to raise the level of nutrition and the standard of living and to improve public health. The State shall regard the raising of the level of nutrition and the standard of living of its people and the improvement of public health as among its primary duties and, in particular, the State shall endeavour to bring about prohibition of the consumption except for medicinal purposes of intoxicating drinks and of drugs which are injurious to health.

Article 39 is of pertinence too. It states some principles of policy to be followed by the State. The State shall, in particular, direct its policy towards securing that the ownership and control of the material resources of the community are so distributed as best to subserve the common good;And that the operation of the economic system does not result in the concentration of wealth and means of production to the common detriment

IV. TIMES TO COME…

What would be WTO perspective on agriculture and farmers' distress be in future? Would it address the present concerns? The Doha Round is the latest round of trade negotiations among the WTO membership. The Round was officially launched at the WTO's Fourth Ministerial Conference in Doha, Qatar,

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in November 2001. The Doha Ministerial Declaration provided the mandate for the negotiations, including on agriculture. What does the WTO draft on agriculture in Doha Rounds mean for farmers? *I*n substance, the negotiations on agriculture focus on more market access, eliminating export subsidies, reducing distorting domestic support and sorting out a range of developing country issues (Anderson and Martin, 2015). To trade- offs being offered for more liberalized trade in agriculture are in the nature of supporting rural development.

Moreover, the draft on agriculture amongst other things states that wide range of support for agriculture as a whole would be allowed without limit under the "Green Box", ie, for development, infrastructure, research, agricultural extension, structural adjustment, etc. This in a way would mean that the developed countries can continue to manipulate the domestic protection to their farmers in the way they had been doing and a more liberalized trade in agriculture would worsen the situation of farmers in developing countries. The draft on key issues related to Blue Box, Green Box, Export Subsidies and Export Credit that continues to distort trade, manipulate price promote dumping is not very different from the text brought to Cancun which led to the collapse of the WTO Ministerial and suicide by the Korean farmer, Mr. Lee Kyung-hoe, the President of the Korean Advanced Farmers Federation.

At the domestic front, the Indian Government apathetic to the condition of farmers. An example of it is how it is trying to amend its land acquisition legislation which has been met by a lot of opposition by farmers. The land market in India is byzantine, with an absence of reliable official ownership records, competing claims for the same property and complicated government rules over who can buy land and how it can be used. To overcome these difficulties, MNCs and Indian businessmen grew dependent on the government, which used its powers to force compulsory sales by farmers, and then sold the land on to businesses. The presently in force land acquisition law limits the government's land acquisition powers by requiring that most of the affected population consent to any government acquisition of their land (Venkatesan, 2015). It also required a social impact assessment for any proposed project that would dispossess farmers. In August 2015, farmers from across India gathered in the capital city Delhi to protest against the land bill (Ghosh, 2015). Waving flags, and screaming anti-government slogans, they described the neo-liberal government policies as "pro-industrialist and anti-farmer." Farmers demanded proper compensation to farmers, if land is acquired; insurance against crop loss; minimum wage guarantee for the farmers; social security to landless farmers and agricultural labourers and right price for the produce. At the protest site, farmers pledged, "No to suicides; Onwards to united struggles" (Ghosh, 2015).

In light of all this, it doesn't seem that there is any genuine ongoing effort to address the issue of farmer distress.

V. SOLUTION AND RECOMMENDATIONS

The WTO perspective on agriculture and the international discipline that is evolving on agriculture is detrimental to the interest of the vast majority of small and marginal peasants, the agricultural workers, the rural and urban poor. The Government of India must recognize the crisis situation in agriculture and put an end to its anti-people policies. The Indian Government must strike a balance between its constitutional obligations and obligations under the other international covenants like ICCPR and ICESCR on one hand and the pressure of WTO, IMF and other such organizations on the other hand. India is party to a plethora of human right treaties including the ICCPR and ICESCR. Under Article 11 of the ICESCR, the Indian government is obligated to "recognize the right of everyone to an adequate standard of living

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for himself and his family, including adequate food, clothing, housing, and to continuous improvement of living conditions," and to "take appropriate steps to ensure the realization of this right." The ICCPR recognizes that "every human being has the inherent right to life" and obligates States to ensure that "no one shall be arbitrarily deprived of his life".

WTO should allow India and other developing countries to protect its agricultural sector. Review of the Agreement on Agriculture requires reviewing the forced removal of quantitative restrictions (QR's) on agricultural commodities. Indian farmers are annually losing Rs. 100,000 crores due to falling prices. Bringing back QR's is the only real effective safeguard. Developing countries should firmly reclaim and assert their unqualified right to impose quantitative restrictions on imports to promote the development of our agriculture and to safeguard the livelihood of majority of their population, which is seventy percent in the case of India. Farmer suicide is a national security emergency and government must negotiate keeping farmer suicides in mind. The crisis and distress that countries like India are facing in agriculture is a national emergency. The suicides of thousands of farmers and the starvation deaths of thousands of tribals are the direct result of trade liberalization and the commoditization of food and agriculture. The government of India and other countries need to invoke Article 19 of the GATT on "Emergency action on imports of particular product" which states that, "If, as a result of unforeseen developments and of the effect of the obligations incurred by a contracting party under this Agreement, including tariff concessions, any product is being imported into the territory of that contracting party in such increased quantities and under such conditions as to cause or threaten serious injury to domestic producers in that territory of like or directly competitive products, the contracting party shall be free, in respect of such product, and to the extent and for such time as may be necessary to prevent or remedy such injury, to suspend the obligation in whole or in part or to withdraw or modify the concession."

Further, Article 20 on "*General Exceptions*" states that -

Subject to the requirement that such measures are not applied in a manner which would constitute a means of arbitrary or unjustifiable discrimination between countries where the same conditions prevail, or a disguised restriction on international trade, nothing in this Agreement shall be construed to prevent the adoption or enforcement by any contracting party of measure:

1. Necessary to protect public morals;
2. Necessary to protect human, animal or plant life or health;
3. Relating to the conservation of exhaustible natural resources if such measures are made effective in conjunction with restrictions on domestic production or consumption;

VI. FUTURE RESEARCH DIRECTIONS

There can be future research on how the international framework and policies of IMF, WTO and other bodies shape agricultural policies of countries other than India and how such policies are interlinked to the conditions of farmers in those countries. Future studies can also focus on the ongoing negotiations on agriculture in WTO and whether the demands of the developing and under-developed world would address the issues that farmers are facing.

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VII. CONCLUSION

The suicide economy of industrialized, globalised agriculture is suicidal at 3 levels — it is suicidal for farmers, it is suicidal for the poor who are deprived of food, and it is suicidal at the level of the human species as we destroy the natural capital of seed, biodiversity, soil and water on which our biological survival depends.

The country is preparing for a severe drought. The vulnerability to drought has increased as globalisation has replaced our drought resistant crops like millets, pulses and oils seeds with water intensive hybrid cotton and water intensive vegetables and fruits for exports.

Conservation of our water resources are soil and our biodiversity demands that we make a general exception to trade liberalization in agriculture using Rule 20. The protection of human life and the prevention of farm suicides is another reason to invoke this exception.

The globalization of agriculture has resulted in this situation of producers of our food dying of hunger. But states should assert their sovereignty, the developing and under-developing countries should assert and negotiate their rights and not succumb to pressures of the north coming to them via the international bodies like WTO, IMF and World Bank and the MNCs.

The WTO ministerial meeting in Nairobi in December 2015 is the litmus test of whether India will be able to make the lives of its farmers better or would succumb to the International pressure again. The tussle at Nairobi is between India and other developing and under-developing countries on one hand and the USA and the industrialized world on the other hand. India and other developing countries want to increase the subsidies that these countries can give to their farmers.

The suicide economy is definitely not an inevitability. The transformation from Seeds of Suicide to Seeds of Hope requires:

1. A shift from GM crops and non-renewable seeds to organic, open pollinated seed varieties which the agriculturists can save and share;
2. A shift from chemical farming to organic farming; and
3. A shift from unfair trade based on false prices to fair trade based on real and just prices.

India and other developing countries and under-developed countries need to ensure the seed of hope to their farmers in this globalized world by bargaining for these shifts in the WTO framework.

REFERENCES

Aksoy, A., & Beghin, J. (2004). *Global Agricultural Trade and Developing Countries*. Washington, DC: World Bank Publication.

Anderson, K., & Martin, W. (2015). Agricultural Trade Reform and the Doha Development Agenda. *World Economy*, *28*(9), 1301–1327. doi:10.1111/j.1467-9701.2005.00735.x

Basu, N. (n.d.). India agrees to WTO's 4-year peace clause,. *Business Standard*.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Chand, R. (2005). India's Agricultural Challenges, Reflections on Policy, Technology and other issues. *Center for Trade and Development*, *10*, 77–82.

Deshmukh, N. (2010). Cotton Growers: Experience From Vidarbha. In *Agrarian Crisis And Farmer Suicides*. Delhi: Sage Publications.

Deshpande, A., & Shah, V. (2012). Globalisation, Agrarian Crisis and Farmers' Suicides: Illusion and Reality, Agrarian Crisis and Farmers Suicides. *Indian Sociology Institute Journal*, *14*, 137-147.

Diao, X., & Somwaru, A. (n.d.). A Global Analysis of Agricultural Reform in WTO Member Countries. *Columbia Journal of Trade Law, 34*, 56-70.

Frandsen, S., & Birgitte, G. (2003). The Impacts of Redesigning European Agricultural Support. *Review of Urban and Regional Development Studies*, *15*(2), 106–131. doi:10.1111/j.1467-940X.2003.00068.x

Ghosh, A. (2015, August 21). 5,000 farmers begin march to Delhi over land acquisition ordinance. *The Indian Express*.

Gilbert, N. (2013). A hard look at GM Crops. *Nature*, *497*(7447), 23–35. doi:10.1038/497024a PMID:23636378

Goldar, B. (n.d.). Impact On India Of Tariff And Quantitative Restrictions Under WTO. *Indian Council For Research On International Economic Relations, 172*, 5-27.

Hoekman, B., & Olareagga, B. (n.d.). Reducing Agricultural Tariffs versus Domestic Support: What's More Important for Developing Countries? *World Bank Policy Research Working Paper, 2918*, 1-21

Indian GMO Research Information System. (2010). Year wise List Of Commercially Released Varieties Of Bt Cotton Hybrids By Geac. *Indian GMO Research Information System Press*, *20*, 120–135.

Indian Sociology Institute. (2009). Human Rights Documentation: Agriculture-Farmer Suicide. *Indian Sociology Institute Journal*, *6*, 67–77.

Jaipuria, T. (2015, November 19). Food subsidies will continue until a permanent solution is reached. *Hindustan Times*.

Katakam, A. (2003). The Death Trap. *Frontline*, *19*(26), 23–27.

Katakam, A. (2006). The Bombay High Court directs the State government to take more responsibility regarding farmers' suicides. *Frontline*, *23*(17), 23–27.

McCalla, A., & Nash, J. (2007). *Reforming Agricultural Trade for Developing Countries.* Washington, DC: World Bank Publication.

Ministry Of Home Affairs. (2009). Accidental Deaths And Suicides In India. *Nat'l Crime Records Bureau*, *23*, 278–289.

Motlagh, J. (2008). India's Debt-Ridden Farmers Committing Suicide. *San Francisco Chronicle, 33*(2), 43-48.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Orden, D., & Josling, T. (2011). *WTO disciplines On Agricultural Support, Seeking a fair basis for Trade*. London: Cambridge University Press.

Press Trust of India. (2014, December 28). RBI Governor questions debt waiver schemes. *The Indian Express*.

Press Trust of India. (2015, October 30). PIL on farmer suicides: SC imposes Rs 25,000 cost on Centre. *The Indian Express*.

Purohit, K. (2015, July 21). 1 in 3 farmer suicides in Vidarbha over Rs 10,000 debt: Study. *Hindustan Times*, p. 9.

Qayum, A., & Sakkhari, K. (2005). Bt Cotton In Andhra Pradesh: A Three-Year Assessment. *Deccan. Development and Society*, *8*(2), 52–63.

Reddy, N., & Mishra, S. (2009). *Agriculture in the Regime: Agrarian Crisis in India*. Delhi: Oxford University Press.

Reddy, P. (n.d.). Distress and deceased in India: An analysis of Causes of Farmers' Suicides, Agrarian Crisis and Farmer Suicides. *The Chronicle*, *23*(2), 45–65.

Reddy, R., & Reddy, P. (2003). Domestic Price Policies In The Context Of Trade Liberalization, *Indian. Journal of Agricultural Economics*, *11*(3), 28–35.

Rosett, P. M. (2008). *Food is different: why we must get the WTO out of agriculture*. London: Zed Books.

Saxena, R. (2006, August 2). PIL filed in SC to take check suicide by debt-ridden farmers. *The Indian Express*.

Schnitzer, S. (2007). *Understanding The International Trade Law*. Delhi: Universal.

Schott, J. J., & Watal, J. (2000). *Decision making in WTO*. London: Cambridge University Press.

Sengupta, D. (2011). Bt cotton and farmer suicides in India: An evidence-based assessment. *The Journal of Development Studies*, *29*(3), 143–157.

Singh, S. (n.d.). State Of The Indian Farmer- A Millennium Study- Agricultural Credit In India. *Frontline*, *7*(9), 33-38.

Smith, F. (2009). *Agriculture and the WTO: Towards a New Theory of International Agricultural Trade Regulation*. London: Edward Elgar Publication. doi:10.4337/9781848449411

Srivastava, R. (2014). Credit through Participatory Management: The Way For Rural Smile", Agrarian Crisis And Farmer Suicdes. *Center for Trade and Development*, *56*, 120–133.

Stern, R., & Mattoo, A. (2003). *India and the WTO.* New York: Oxford University Press.

Thomas, C. (2001). Balance-of-Payments Crises in the Developing World: Balancing Trade, Finance and Development in the New Economic Order Symposium: Interfaces: From International Trade to Economic Law. *American University of International Law Review, 15*, 45-59.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Vanda. (n.d.). The Suicide Economy of the Corporate Globalisation. *Frontline, 11*(5), 119-130.

Venkatesan, V. (2015). State and Land. *Frontline*, *35*(12), 54–58.

Watts, J. (2003, September 16). Field of tears. *The Guardian*.

Westin, S. (2001). *World Trade Organizations: Issues in Dispute Settlement*. WTO Publications.

WTO Legal Affairs Division. (2011). *WTO Analytical Index 2 Volume Set: Guide to WTO Law and Practice*. WTO Publications.

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Chapter 63
Environmental Change and the Emergence of Infectious Diseases:
A Regional Perspective From South America

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ABSTRACT

In South America in the past decades several infectious diseases have emerged or re-emerged either as part of larger pandemics or as local processes involving autochthonous pathogens. These included arthropod-borne viral diseases, such as Dengue Fever, Chikungunya and Zika as well as viral hemorrhagic fevers, such as Hantavirus Pulmonary Syndrome, Junin, Machupo and Guanarito viruses. Parasitic disease was also important such as Malaria, endemic in the northern part of the continent, Leishmaniasis and Chagas Disease. Carrion disease, a bacterial infection originally from the Andes region, also seems to be expanding geographically. Several social and environmental processes have contributed to the emergence of these pathogens, including human migration, deforestation, road and dam building and climate shifts. Due to its high biological diversity of wildlife, arthropods and virus species in still untouched natural ecosystems in the Amazon has the greatest regional potential for the emergence of new human infections.

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INTRODUCTION

South America is at the Southern part of the America Continent (10ºN; 55ºS) spanning an area of 17,819,000 million km^2, which includes 12 countries and an independent territory (French Guyana). The regional climate is predominantly hot and humid, but subtropical climate is found in mountain regions (e.g. The Andes) and temperate and polar climates occur in the southern tip of the continent, in Chile and Argentina (Canziani & Dias, 1998).

There is a high diversity of ecological areas and ecosystems such as the desert areas in northern Chile; the large plains in Venezuela and Colombia and the vast Amazon forest, which is shared by eight countries. The region has the largest freshwater system in the world due to the network formed by the Prata, Orinoco and Amazon River basins (Comisión Económica para América Latina y el Caribe [CEPAL], 2014).

The regional population is about 410 million people with about 83% living in cities. The regional life expectancy reached 73 years in 2010 (Teixeira, Paixão, & Costa, 2013). According to the Pan-American Health Organization [PAHO] (2014), safe water access reaches 89% of people in the Andes. However, this is not consistent across the region. Bolivia has sewage collection and treatment covering only 46% of households. Gross income per capita ranged from US$12,470 for Chile and Argentina to US$7,784 in Andean countries. Between 1990 and 2010, regional infant mortality rates dropped by 50%; for Brazil it was 14,6/1000 and for Chile 7,8/1000, in 2012 (PAHO, 2014; Teixeira et al., 2013).

Several endemic infectious diseases occur in South America, some with high annual incidence such as Malaria and Dengue Fever; in 2013, Brazil alone reported a total of 1,470,487 cases of Dengue Fever (PAHO, 2014). Several other endemic infections are autochthonous to the region such as Carrion Disease in the Andes and different forms of hemorrhagic infections caused by Arenavirus, such as Junin, Machupo and Guanarito hemorrhagic fever.

South America is considered vulnerable to climatic conditions, especially when combined with land use and land cover changes (Caqui, Quispe, & Zegarra, 2013; Magrin et al.; 2014). The aim of this chapter is to show the impact of environmental change and human activities on the dynamics of some infectious diseases of major importance to public health in South America.

BACKGROUND

The emergence of infectious diseases was identified as a major global health threat in the last quarter of the 20th century. Zoonotic pathogens from wild animals formed the majority of newly emerged human pathogens in the past few decades (Jones et al., 2008). Several factors have been pointed as major contributors to human infectious disease emergence: new strains of the pathogens, increased resistance to antibiotics, reduced resistance of hosts (e.g. infection by HIV), variations in human populations densities, shifts in diversity of populations of vectors and hosts, hunting of wild animals for food, deforestation and loss of biodiversity and climatic anomalies (Jones et al. 2008; Keesing et al, 2010; Pongsiri et al, 2009; Wilcox & Gubler 2005).

In general, it is acknowledged that, for disease emergence to take place, an association of different drivers is necessary. In South America, since the middle of the last century, several diseases have emerged caused by different etiological agents, from Protozoa to viral infections. Some of these were part of larger epidemics/pandemics (e.g. Cholera; Dengue Fever) but other diseases have emerged as autochthonous

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local processes and became endemic, such as viral haemorrhagic fevers caused by Junin and Guanarito Viruses. While some of those that have emerged or re-emerged became widely distributed (e.g. Dengue Fever), others occurred as local outbreaks with a small number of cases, restricted in time, and no more cases were reported (e.g. Sabiá Virus infections).

Field observations by scientists early in the 20th century in some regions of South America (associated with the expansion of economic activities) reported changes in the transmission of human tropical diseases as a consequence of human-induced changes to the natural environment. A classic example was the observations by Brumpt and Pedroso (1913) of outbreaks of Cutaneous Leishmaniasis in the state of São Paulo, Brazil, following the opening of a new railway to the centre of the country. The association between the natural environment and the - then poorly known- parasitic infection can be illustrated by the naming of the disease by these authors: "American Forest Leishmaniasis". These early authors have also observed that Cutaneous Leishmaniasis was more prevalent during the hottest period of the year, from November to April.

Another example of early observations of the linkage between tropical diseases and environmental factors in South America was given by Carlos Chagas, the discoverer of the American Trypanossomiasis. Also in the context of opening up of a new railway in Central Brazil, in 1905, he observed that the incidence of malaria among railroad workers was high during the summer and dropped to almost zero during the cold and dry winter (Chagas, 1907). Since these early observations, about a century ago, the environment in the South America region has undergone dramatic changes due to human encroachment on the natural ecosystems. Road buildings, deforestation for the expansion of agriculture, urban growth, and the building of dams have been the main drivers of environmental changes.

In the following section, representative groups of infectious diseases endemic to South America will be discussed in aspects of dynamic epidemiological shifts in relation to continuous changes in the physical and biological environments.

ENVIRONMENTAL CHANGES AND THEIR LINKAGES TO RELEVANT INFECTIOUS DISEASES IN SOUTH AMERICA

1. Malaria

Malaria is an endemic parasitic disease in the northern part of the South American continent, from where it extends up to the southern parts of Mexico. The disease occurs under two main forms in its various localities and sub-regions: stable transmission of endemic character and sporadic transmission of epidemic type (Cabral, Fé, Suarez-Mutis, Boia, & Carvalho-Costa, 2010).

Among the environmental changes usually associated with Malaria dynamics in South America, two process are considered most important: forest conversion due to deforestation and climatic variability in different scales such as seasonal or inter-annual, El Niño phenomenon, for example. El Niño corresponds to the warming phase of El Niño–Southern Oscillation (ENSO), an irregular and periodical variation in winds and sea surface temperatures over the tropical eastern Pacific Ocean. The cooling phase is known as La Niña. There has been some debate as to the relative importance of El Niño phenomenon in shaping the dynamics of this disease in specific areas of the Amazon. Several authors consider that changes in transmission patterns are more dependent on local aspects, such as failure of preventive measures or human population migration, than on large scale climatic phenomena (Cabral et al., 2010; Conn et al.,

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2002). However, in Colombia and Venezuela, local studies were able to demonstrate a significant influence of the El Niño on the transmission of Malaria (Delgado-Petrocelli et al., 2012; Mantilla, Oliveros, & Barnston, 2009).

In Peru, the larvae of the main Malaria vector in the Amazon region, *Anopheles darlingi*, was shown to be associated with deforestation. Sites with *A. darlingi* larvae had an average of 24.1% of forest cover, compared with 41% for sites without *A. darlingi* (Vittor et. al., 2009). In the eastern part of the Brazilian Amazon region, culicid surveys performed in a pristine national forest revealed no species of Malaria vectors, among twenty-five thousand specimens collected (Confalonieri et al., 2013; Confalonieri & Costa-Neto, 2012).

Using a geospatial model to map Malaria hotspots in the Brazilian Amazon, Valle and Lima (2014) observed that, on a large scale, forest cover and the proximity to gold mining operations were important drivers of disease risk. They have also found that areas with a longer dry season and areas with higher average rural income tended to have highest Malaria risk. The former is related to the creation of water bodies suitable to *Anopheles* sp. breeding when the rivers recede in the dry season and the latter, may be due to greater access to health services available to the high income population, which potentially increases the reporting rate. In Western Brazilian Amazon, da Silva-Nunes et al. (2008) observed, in a frontier settlement, that Malaria morbidity was strongly associated with land clearing and farming and decreased after five years of residence in these areas due to the development of immunity. A spatial clustering of Malaria was observed in the area of most recent occupation, indicating that the influx of non-immune settlers to forest fringe areas perpetuates the cycle of environmental change that favors Malaria transmission. It was also shown that the place of residence – distance of the dwelling from the forest - was important in determining risk. Using a negative binomial model of Malaria for municipalities in the Brazilian Amazon – the model associated the number of cases of Malaria to covariates as sociodemographic characteristics of the population and land cover – researchers were able to show the influence of logging, road building and forest fires on the incidence of Malaria. The overall incidence rate of Malaria was higher in the states were logging is an important activity. The influence of unpaved roads was higher in the municipalities with rates of deforestation higher than 75% (Hahn, Gangnon, Barcellos, Asner, & Patz, 2014).

2. Chagas Disease

Chagas disease, discovered in 1909 in Brazil, has been extensively studied and the knowledge about the eco-epidemiology of this disease is vast (Teixeira et al., 2001). The adaptation of the different species of disease vectors to human dwellings and man=made environments is well known. In the Amazon region, different mechanisms play a role in the increased risk of Chagas disease infection: deforestation (causing the displacement of wild animal reservoirs of the infection), adaptation of wild species of triatomine vectors to man-made structures, and the migration of susceptible hosts, both humans and domestic animals (Coura & Junqueira, 2012).

Recent studies in Panamá (Central America) have shown that anthropogenic landscape disturbance – forest fragments and peridomiciliary sites - increased vector infection with the *Trypanosoma cruzi*, the etiological agent of Chagas disease. Vector infection rates were significantly greater in deforested habitats as compared to contiguous forests. This was due to a combination of factors: although the modified environments have a low diversity of vector species they have a high abundance of mammal reservoirs of the infection and suitable conditions for the reproduction of the insect vectors and, therefore,

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of maintenance of the cycle of the parasite (Gottdenker, Calzada, Saldaña, & Carrol, 2011; Gottdenker, Chaves, Calzada, Saldaña, & Carrol, 2012).

Several decades ago, reports of the influence of temperature on the biology of a major Chagas disease vector – *Triatoma infestans* – found that for the same period of time, two generations of this species occurred in areas with high temperatures and only one generation in the cooler regions (Hack, 1955). Costa, Dornak, Almeida, and Peterson (2014) have modeled the distribution of *T. brasiliensis* complex of vector species according to projected temperatures and precipitation under conditions of climate change in Brazil, for the years 2020 and 2050. *Triatoma brasiliensis* is an important intra-domiciliary and peri-domiciliary transmitter of *T cruzi* in the semi-arid region of Brazil (Coura, 2015). Under scenarios of temperature increase of up to 1,72ºC and a precipitation decrease of 55,6mm, the overall distribution of the species was projected to remain stable. However, the model was able to indicate a great potential for the colonization of new areas by this vector species, a fact important for the planning of epidemiological surveillance.

In Venezuela and Argentina, the study of the future distribution of the species *Rhodnius prolixus* and *T. infestans* using the ecological niche approach, has indicated a possible reduction of the area of distribution of these species under a climatic scenario for 2050 (for future climate conditions, two scenarios were considered: the representative concentration pathways (RCPs) 4.5, 6.0 and 8.5 (hereafter scenarios), which were nested to HadGEM2-ES models and bioclimatic projections for 2050) (Medone, Ceccarelli, Parham, Figuera, & Rabinovich, 2015). Cordovez, Rendon, Gonzales, and Guhl 2014 obtained similar results in Colombia. These authors have concluded that, under scenarios of increased temperature for 2035, as a result of global climate change, a reduction of the area of transmission of Chagas disease currently known in Colombia would be observed.

3. Leishmaniasis

Leishmaniasis, specially the cutaneous forms of the disease, transmitted by vectors of the genus *Lutzomyia* in South America, are known to respond to different types of environmental changes. One aspect frequently reported is the impact of agricultural encroachment in natural forests on the formation of ecological niches for the sandfly vectors of the disease.

In Brazil, coffee plantations using traditional cultivation systems were reported to facilitate the transmission of cutaneous Leishmaniasis. This occurs because coffee trees provide shadow and the decaying leaves of these trees in the soil create adequate niches for the reproduction of sandfly vectors (Alexander et al., 2001, 2009). Other types of plantations such as sugar cane, bananas and cocoa were also reported to increase the risk of Leishmaniasis transmission (Azevedo et al., 1996; Azevedo & Rangel, 1991; da Silva et al., 1999). De Araújo Pedrosa and Alencar Ximenes (2009) and Membrive et al. (2012) reported the high risk of transmission to humans in banana plantations in Brazil due to the proximity of banana trees to the dwellings of peasants.

In French Guyana, Fouque et al. (2007) have reported an expansion of Leishmaniasis transmission into areas of environmental modifications linked to gold mining, agriculture and military training. Also in the Guyana region, an increased rate of cutaneous Leishmanasis transmission was associated with deforestation (Rotureau, 2006). Although in Colombia both the population density and the number of species of sandfly vector were higher in forested areas when compared to degraded areas, in the latter the risk of Leishmaniasis transmission to human and domestic animals was higher due to the adaptation of the most important vector species to the anthropic environment.

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In Brazil, shifts in the epidemiology of cutaneous Leishmaniasis were associated with building of dams (Vilela, Azevedo, Carvalho, & Rangel, 2011) and also roads and railways (Gonçalves Neto et al., 2013). Factors influencing incidence increases and the spread of *Leishmania* spp. range from habitat changes for vectors (as they frequently adapt to man-made buildings) to human population displacements associated with infrastructure projects

Climatic variations have also been associated with epidemiological changes of Leishmaniasis in the Americas (Chaves & Pascual, 2006). In Colombia, associations of El Niño and La Niña climatic phenomena and the incidence of Leishmaniasis in endemic regions of the country showed variable linkages: in some areas El Niño has had a positive correlation with cases of the disease while in others, the cases were influenced by La Niña (Cárdenas, Sandoval, Rodriguez-Morales, & Vivas, 2008). The authors have stressed the need for further studies and emphasized the role of climatic factors in the dynamics of Leishmaniasis in different areas of Colombia.

4. Bartonellosis

American Bartonellosis, also named Carrión Disease, caused by the bacterium *Bartonella bacilliformis* and transmitted by the sandfly species *Lutzomyia verrucarum*, occurs in the region of the Andes, being endemic in altitudes between 800m and 3000m. Environmental factors were reported to influence the dynamics and the spatial distribution of this disease. Chinga-Alayo, Huarcaya, Nasarre, Del Aguila, and Llanos-Cuentas (2004) have reported a positive association between disease transmission and El Niño climatic phenomenon in endemic areas of Peru. The mechanism involved is the increase in vector populations influenced by higher temperatures. Also in Peru, Zhou et al. (2001) have observed a doubling in the number of new cases of the disease during the months of El Niño, in addition to an expansion of the disease to areas not previously affected. High correlations were observed between higher incidence and increased temperatures three months before the outbreaks (Zhou et al., 2001).

Recent reports of human cases of Carrión Disease outside the well-known endemic areas, such as cases in the forest areas and on the coast, indicate a trend of geographic expansion, probably influenced by both the adaptation of the vectors to new niches and human contact during population movements for commercial activities (Maco, Maguiña, Tirado, Maco, & Vidal, 2004).

5. Viral Diseases

In South America, two major groups of endemic viral diseases are reported to be influenced by climatic shifts and environmental changes: arboviral infections and viral haemorrhagic fevers. Some of these diseases have been established in this continent for several decades such as Yellow Fever and, more recently, Dengue Fever. Others seem to be autochthonous to the region, such as the Mayaro and Oropouche fever in the Amazon (Vasconcelos et al., 2001). In the past few years, new viral introductions were reported, such as the West Nile virus (Morales et al., 2006) and Chikungunya virus, which occurred either as isolated cases or slowly expanding to become endemic (Figueiredo & Figueiredo, 2014; Carbajo & Vezzani, 2015).

The emergence of the Hantavirus Pulmonary Syndrome virus in the Americas has been associated with human disturbances of the natural systems, affecting the composition of biodiversity. This is also true for infections caused by arenaviruses, which typically occur in South America: Junin, Machupo and Guanarito (Simpson, 1978; Mills, 2006). These infections have different species of wild rodent reservoirs

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and those considered to be opportunistic – more adaptable to peri-domiciliary environments and presenting high fecundity and shorter life cycles – tend to predominate in the anthropic environment (Mills, 2006). Most outbreaks have been reported in anthropic environments where these species predominate, in a context of reduced diversity of potential host species (Mills, 2006). In the years 1940-1960, the emergence of rodent-borne arenavirus infections causing hemorrhagic fevers in Argentina and Bolivia, have followed a similar mechanism. Agricultural encroachment to natural pastures used for livestock production have caused a change in the local dominant species of rodents: *Calomys musculinus* in the maize crops of Argentina and *Calomys callosus* in the subsistence crops near small forested areas in Bolivia. These two species had their populations numbers greatly increased as well as adapted to the human dwellings where they have shed the virus in the urine (Johnson, 1993). Consequently, outbreaks of Machupo's disease occurred in the northern part of Bolivia during 1960 and Junin viruses have been clinically described since 1953 in Argentina.

The population dynamics of the reservoir rodents also play a role in outbreaks and in the case of the Junin virus in Argentina (Simpson, 1978), it was observed that the clustering of human cases during the harvest of maize was linked to a peak in rodent abundance. In a study of wild reservoirs of hantavirus in Paraguay, a higher rate of infection of rodent species in anthropic landscapes (e.g. agriculture) was found. When compared with areas of low infection, this high infection rate seems to be linked to habitat fragmentation, which changes the mobility of the rodents and facilitates virus transmission due to increased encounters between different rodent species, capable of increasing the probability of virus transfer from an infected animal to an uninfected member of a host population (Goodin, et. al., 2006). The role of climatic change in modulating Hantavirus infection was modeled in Argentina in regard to spatial distribution of the main reservoir rodent species. Different results were obtained according to different climatic scenarios used and for different parts of the country, but the overall distribution of the host was projected to be reduced due to changes in precipitation and temperature (Carbajo, Vera, & Gonzalez, 2009).

6. Arboviruses

The most important arboviral diseases in South America are Dengue Fever and Yellow Fever, because of the high incidence of Dengue, and the high fatality rate of Yellow Fever (Cunha & Nogueira, 2005; Tauil, Santos & Morais, 2005). Both are influenced by climatic variability and change, and Yellow Fever, which is a focal disease rooted in natural ecosystems, is also influenced by changes in land use and land cover (e.g. deforestation) (Monath & Vasconcelos, 2015; Bryant et. al., 2003; Vasconcelos et. al., 2001). Several authors have reported the influence of climate, to variable degrees, on the epidemiology of Dengue Fever in tropical America (Chowell, Cazelles, Broutin, & Munayco, 2011; Herrera-Martinez & Rodriguez-Morales, 2010; Ibarra et al., 2013; Thai & Anders, 2011). Some of these are the higher Dengue incidence during El Niño periods in Venezuela, the rainfall and minimum temperature as a predictor of *Aedes aegypti* oviposition activity in Ecuador and the influence of seasonal temperature in Dengue epidemics in Peru. Reports were also made on the influence of specific types of natural ecosystems on the production of outbreaks of Yellow Fever (Degallier et. al., 1992) and of the micrometeorology of forest on the population dynamics of mosquito's vectors of this disease (Pinto, Confalonieri, & Mascarenhas, 2009).

In regard to Dengue Fever, models have pointed out that, although climate has a role in Dengue increase in the "Southern Cone" (Argentina), other geographic factors (e.g. distance to water bodies) and

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demographic variables have a stronger influence on the determination of disease incidence (Carbajo, Cardo, & Vezzani, 2012). The most critical factor in the emergence/re-emergence of Dengue fever in South America is considered to be the widespread adaptation of its main vector, the mosquito *Aedes aegypti*, to artificial containers in urban settings, a fact observed in most countries of the region. This vector could also pose a major threat for the transmission of urban yellow fever in major cities of the region, a situation reported for the last time more than half a century ago (Downs, 1981). In Brazil, for example, the disease has caused major urban epidemics from the colonial period to the first decades of the 20th century when it was recorded the last urban outbreak in Rio de Janeiro, 1929; sporadic cases appeared in Acre state, in 1942 (Ferreira, Rocha, Caputto, Fonseca, & Fonseca, 2011). Since then, the successful control of the urban form of Yellow Fever, both in Brazil and in the Americas, was made possible for two reasons: the eradication of *A.aegypti* vector and the widespread use of 17D vaccine. The former occurred through the Rockefeller Foundation and the Pan American/ World Health Organization initiative which, between the years 1930 and 1950, have implemented successful programs of eradication of the vector in the Americas (Braga & Valle, 2007). The vaccine appeared in 1937, also through the Rockefeller Foundation with the involvement of Oswaldo Cruz Institute (Ferreira, Rocha, Caputto, Fonseca, & Fonseca, 2011).

Two other frequently reported arboviral infections in the region are the Oropouche and the Mayaro fever viruses. Oropouche virus infections have been epidemic in the Amazon – Brazil, Peru, Colombia – and Panama and Trinidad. Its sylvatic cycle of transmission is poorly understood and involve multiple hosts and vectors, such as sloths, monkeys and birds (Pinheiro, Travassos da Rosa, & Vasconcelos, 1998). Still, epidemics of Oropouche as an anthroponosis are well characterized, with the involvement of a single species of vector – *Culicoides paraensis* (Carpenter, Groschup, Garros, Felippe-Bauer, & Pruse, 2013). Evidence points to an adaptation of the viruses to the peri-urban habitats since their midge vector species breed in holes thumbs and roots of planted trees, and they can bite inside houses. Outbreaks are associated with periods of high rainfall intensity and can reach thousands of cases in short periods of time in the Brazilian Amazon (Pinheiro et al., 1998). In the case of Mayaro fever, outbreaks were also reported from Amazonian countries, especially Brazil, Colombia, Venezuela and Bolivia. It is considered a forest disease similar to Yellow Fever, having the same mosquito species as vector – *Haemagogus janthinomys* - as well as primates as wild reservoirs, but cases transmitted in rural areas have been also reported (Travassos da Rosa et al., 1998). In the Amazon region, the main driver for Mayaro virus occurrence is deforestation, causing limited outbreaks (Vasconcelos et al. 2001). Although few studies have addressed the role of climatic variables in Oropouche and Mayaro fever epidemiology, Vasconcelos et al. (2001) observed that increased precipitation, especially in the first half of the year for the Amazon, seems to favor the reproduction of the vectors of both diseases. In fact, other environmental factors, such as temperature and humidity, play an important role influencing mosquito competence for arboviruses and its population abundance (Aybar, Juri, Santana, Grosso, & Spinelli, 2012; Tabachnick, 2013). Given the projections of temperature rise and reduced precipitation in the Amazon region, the distribution of cases of these two diseases can reduce or increase depending on the site studied.

In regard to other less important arboviral infections in South America, the detection of West Nile virus infections from horses in Argentina was probably associated with migratory birds (Morales et al., 2006). The same mechanism was proposed for a newly emerged infection in forests of Southern Brazil, the Rocio Virus, which was detected by immunological tests in sylvatic birds captured in São Paulo state, Brazil (Lopes, Coimbra, Sacchetta, & Calisher, 1978; Ferreira et al., 1994). The Rocio virus appeared in Ribeira Valley, São Paulo state, Brazil, causing encephalitis epidemics in 1975-1976 – around 1000

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cases and 10% fatality rate (Monath, 1993). A newly emerged arboviral infection in South America is Chikungunya virus, an infection also transmitted by *Aedes* mosquitoes, mainly *A. aegypti*. It is believed to have originated in Africa, where it still circulates enzootically among nonhuman primates, whereas in the Americas it was reported for the first time in 2013 (Vega-Rúa, Zouache, Girod, Failloux, & Lourenço-de-Oliveira, 2014). As of the year 2015, the South American countries Colombia, Venezuela, Brazil, Ecuador and Paraguay have reported local transmission (Carbajo & Vezzani, 2015). Since it is a disease transmitted by urban vectors, its emergence has been associated to urbanization and human migration (Figueiredo & Figueiredo, 2014). Regarding West Nile Virus, the influence of climate on its occurrence is well stablished in temperate countries, where warm winters and spring droughts are pointed out as capable of amplifying the transmission (Epstein, 2001; Paz, 2006). For Chikungunya, as for other diseases transmitted by the *Aedes* genus of mosquitoes, models projecting the distribution of *A. aegypti* vector show a potential for its advance toward South America centre, colonizing areas where the vector is absent (Campbell et al., 2015).

7. Cholera

Cholera, a gastrointestinal infection caused by the bacterium *Vibrio cholera*, has re-emerged in Peru, South America, in 1990. Although strongly influenced by socioeconomic conditions, due to its marked seasonal occurrence in endemic regions, former studies have pointed out to the influence of climatic variability in the dynamics of this disease, especially in Asia (Pascual, Bouma, & Dobson, 2002). In Peru, its emergence has been associated with the 1991-1992 El Niño climatic phenomenon (Pascual et al., 2002). It seems that the bacterium has been present in the environment months before the beginning of the outbreak in Peru and marine ecosystem changes associated with El Niño led to the propagation of *V. cholera* along the coast (Seas et al. 2000).

Recent reassessment of cholera emergence in Peru has indicated that the epidemic may have been linked to ENSO through multiple pathways, including elevated temperatures, rainfall extremes, La Niña phenomenon (cold phase of the ENSO cycle) and social vulnerability (Ramírez, Grady, & Glantz, 2013). A local study in Piura, one of the most affected districts in Peru, showed significant cholera association with sea surface temperatures in the Central Pacific Ocean and on the coast, as well as with rainfall and minimum and maximum temperatures with varying lag times (0-5 months); the strongest consistent impact was with rainfall (Ramírez, 2015).

CLIMATE AND INFECTIOUS DISEASES: ADAPTATION OPTIONS

1. Infectious Disease Control

Regardless of what models project in terms of future infectious diseases profiles, as a consequence of climactic shifts, current actions targeted to the reduction of incidence and geographical expansion of endemic infectious diseases should be considered as part of the adaptation processes. This is particularly critical for those diseases known to be affected by climate variability, such as most vector-borne and water-borne infections (Smith et al., 2014).

These control strategies vary according to disease cycles and the available technologies for their control. The following are some examples of diseases endemic to the South American region:

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- **Leptospirosis:** Usually associated to urban floods following tropical storms (Dutra et al., 2015). The control strategies focus on improvement of drainage of rain water as well as on the control of rodent populations (rats), which are the main reservoirs of the pathogen;
- **Dengue Fever:** A viral disease transmitted by the urban vector species *Aedes aegypti*, a mosquito which also transmits the Zika virus and the Chikunguya virus (Ibarra et al., 2013; Musso, Nilles, & Cao-Lormeau, 2014; Roth et al., 2014; Staples & Fischer, 2014). Since there are no vaccines against these viruses, the main strategy for their control depends on the reduction of the vector populations. This can be more effective through the reduction of the breeding sites for the vector: trash in backyards, discarded tires, flowers pots and other man-made structures that accumulate rain water (Tauil, 2002);
- **Malaria:** A vector-borne disease restricted to the natural environment. The main strategy for its control is the early treatment of the infected human hosts. A secondary strategy, at the local level, is the emergency spraying of insecticides to reduce the vector population (World Health Organization [WHO], 2014);
- **Yellow Fever:** A vector-borne disease known to be associated to climate variability and forest micrometeorology (Vasconcelos et al., 2001; Bryant et al., 2003; Pinto et al., 2009). Its control depends on the preventive vaccination of the population at risk in endemic areas (Ferreira, Rocha, Caputto, Fonseca, & Fonseca, 2011).

2. Healthcare, Education, and Adaptation

Future Public Health impacts of climate change on the epidemiology of infectious diseases and on health care systems are well acknowledged (Confalonieri, Menezes & Margonari de Souza, 2015; Costello et al., 2009; Pereira & Barata, 2014; WHO, 2009). However, current health policies and strategies do not address possible changes to the epidemiological profile of the populations to be affected by climatic change. Adaptation strategies should be focused on both populations currently under climatic stress as well as those expected to be affected by future shifts to the global climate system (Ebi, Lindgren, Suk, & Semenza, 2013). The first step towards this end would be strengthening of the health care systems in order to facilitate the development of adequate responses to climatic hazards (Costello et al.; 2009).

The promotion of secure infrastructure, not affected by extreme weather, is essential for the provision of health care services on a continuous basis. Several Latin American countries have built health care installations resilient to disasters such as Peru, Colombia, Equador, Chile and Costa Rica (WHO, 2009). In the urban environment in South America events like storms, floods and landslides are responsible for a high burden of morbidity and mortality. These require comprehensive preventive actions ranging from public health monitoring and disaster preparedness, in the context of community-based risk reduction strategies (Keim, 2008).

In the municipality of Nova Friburgo, Rio de Janeiro, Brazil, heavy rains (182.8 mm/24 hours) have killed 429 persons, mostly due to trauma, in January 2011. Despite the interruption of several basic services – energy, water, transportation – an efficient health surveillance intervention was able to prevent deaths after outbreaks of dengue fever, leptospirosis and waterborne diarrhea (Porto, 2012; Pereira & Barata, 2014). This can be considered as an example of successful intervention – or reactive adaptation – in the context of climate-associated disasters causing infectious disease epidemics.

Educational approaches are also an important part of the adaptation process. Lima and Layrargues (2014), have emphasized the need for a more comprehensive understanding of the impacts of climate,

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associating the knowledge of climatic hazards and risks to the daily life of the population and also the need for environmental conservation as part of the adaptation strategy.

Since risks associated to climate change are socially and spatially different, a revision of the practices of governance is needed. This entails both individual adaptation strategies that respect the social and economic characteristics of the affected people, especially those more directly dependent on natural resources (Adger, 2001) and an open and participatory decision making processes involving the actors concerned with the impacts, in order to complement the necessary technical knowledge (Jacobi, 2014).] Some local initiatives have demonstrated positive results in regard to public policies targeted to climate change. In the megacity of São Paulo, Brazil, Landin and Giatti (2014) have demonstrated the existence of a positive cross sectoral dialogue in the implementation of policies targeted to climate protection, in the context of a highly complex urban area.

A survey of the population of different countries has found that middle income countries tend to favor technological solutions while developed countries are more skeptical in this regard and people believe the solutions should come from changes in habits and individual behavior (Echegaray & Afonso, 2014).

Of great importance is the need to recognize that adaptation to climate change is also a social process, involving cultural aspects, beyond the economic strategies. Adger, Barnett, Brown, Marshall and O'Brien (2013) have demonstrated that the values adopted by the human groups can influence their interpretation of the problems, their motivation and their ways to respond and adapt to climatic risks; adaptation policies that ignore cultural aspects of the population affected by climate change can fail to increase the resilience of the targeted populations.

DISCUSSION

Infectious disease emergence in South America has been driven by different factors and these depend, in a large extent, on the life cycle of the causative pathogens, their arthropod vectors and animal hosts. Also important are the environmental settings where the infections develop: processes affecting strictly urban disease cycles (e.g. Dengue fever) are quite different from those found in foci historically rooted in pristine natural ecosystems. This is due to the epidemiological complexity of the latter, which can embrace a wider variety of competent hosts and vectors as well as be more influenced by environmental and climatic factors. On the other hand, in urban cycles new human infections usually depend on the massive exposure of the susceptible human population to a high burden of pathogens in the environment or to a high density of insect vectors (e.g. mosquitoes). In the case of vector-borne diseases, emergence is usually associated with environmental shifts, such as changes in temperature or rainfall, that create new ecological niches for both adults and immatures vector species. This applies to man-made environments, such as households and buildings (e.g. in Dengue fever) and also areas with natural vegetation, as in the case of Malaria (Travassos da Rosa, Pinheiro, & Vasconcelos, 2005; Vittor et al, 2009; Carbajo et al., 2012; Hahn et al., 2014).

Another important aspect is the biodiversity richness natural ecosystems. Pathogens circulating in wildlife, independent of the human host, can "spillover" and reach humans, following changes in the animal populations or encroachment of humans into natural systems, or both (Daszak, Cunningham, & Hyatt, 2000). Therefore, areas with rich assemblages of vectors and animal pathogens have a higher potential to support shifts in hosts and emergence of new human infections. In South America, one such region is the Amazon basin, which has the largest extension of tropical forests in the world and harbors

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a rich biological diversity. To date, more than 180 species of arboviruses were identified in animals and insects of the Amazon and around 30 of them infect humans (Gubler, 2002). A recent review has pointed out the role of changes of the Amazon environment, such as those linked to deforestation, road building and hydroelectric dams, in driving the emergence of parasitic infections in humans (Confalonieri, Margonari, & Quintão, 2014).

The Amazon region is one of the most vulnerable part of South America. Major projects in the area are impacting the natural ecosystems and causing alterations in land cover (e.g. forest conversion to pastures, dams), which present great opportunities for infectious disease emergence (Confalonieri et al., 2014). Encroachment to areas where endemic infections are present is also a cause of concern due to the risk of disease spread. For example, the construction of roads linking the Amazon to the Pacific Coast could facilitate the emergence of Bartonellosis – a disease originally restricted to the Andes Mountains – in lowland areas (Cesario & Cesario, 2005). International travel is thought to be the main mechanism involved in the most recently introduced viral infections in South America - Zika and Chikungunya viruses (Figueiredo & Figueiredo, 2014) - a mechanism already identified in other continents (Cordel, Quatresous, Paquet, & Couturier, 2006; Weaver & Reisen, 2010).

Specifically, in relation to disease emergence in the Amazon, monitoring and surveillance strategies necessary to tackle processes leading to regional disease emergence were discussed recently (Confalonieri et. al, 2014). An interdisciplinary approach comprising control measures and clinical management combined with an integrated international surveillance is needed to manage the environmentally driven changes in the disease dynamics in the Amazon in the near future. One important strategy would be to enhance regional epidemiological surveillance, especially to sub-regions where social-environmental modifications are occurring, as is mentioned in the "Amazon Malaria Initiative" (U.S. Agency for International Development [USAID], PAHO, 2010). The epidemiological impacts of environmental change in other parts of the South American continent could also be surveyed using the same association of interdisciplinary studies (parasitology, epidemiology, ecology, land use, climatology) and epidemiological surveillance in hotspot areas.

Further investigations in specific scientific areas - parasitology, epidemiology, climatology, geoprocessing, etc – should be pursued for a broader assessment of risks of infectious disease emergence in South America. Two topics deserve special attention. First, the role of cross-immunity of the population as a "barrier" to the introduction and persistence of new viruses to the region. Herd immunity for Dengue Fever viruses, endemic in this part of the world, could prevent taxonomically close viral species (e.g. West Nile Fever Virus) from becoming endemic in the human population. Cross immunity between different flaviviruses such as those causing dengue fever and the Zika virus is well known, a fact that makes the diagnosis of past infections with these pathogens using immunological tests more complex. Second, the significance of climate warming in the emergence of pathogens in the tropics. The potential to expand the distribution of vectors and enhance the transmission potential through alterations in the life cycle (e.g. shorter gonotrophic cycles and extrinsic incubation periods) of pathogens and vectors are likely to occur in temperate climates. However, in most of the tropics, suitable temperatures and humidity for endemic disease transmission are readily available and global warming may not be a critical factor in epidemiological shifts in this region.

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CONCLUSION

Infectious disease emergence in Latin America, as a consequence of environmental changes, is a complex issue. A high diversity of natural ecosystems and a vast extension of still pristine environments are important sources of microbes that circulate in wild animals and insect vectors and can potentially spill over to the human population due to encroachment of habitats following human activities to expand infrastructure and promote economic growth. Besides changes in land use practices and in land cover, climatic shifts are also expected to facilitate the emergence of pathogens in South America in the next few decades. A high degree of human population density in urban areas in this continent poses an additional risk factor for disease emergence in this region.

REFERENCES

Adger, W. N. (2001). Scales of governance and environmental justice for adaptation and mitigation of climate change. *Journal of International Development*, *13*(7), 921–931. doi:10.1002/jid.833

Adger, W. N., Barnett, J., Brown, K., Marshall, N., & O'Brien, K. (2013). Cultural dimensions of climate change impacts and adaptation. *Nature Climate Change*, *3*(2), 112–117. doi:10.1038/nclimate1666

Alexander, B., Agudelo, L. A., Navarro, F., Ruiz, F., Molina, J., Aguilera, G., & Quiñones, M. L. (2001). Phlebotomine sandflies and leishmaniasis risks in Colombian coffee plantations under two systems of cultivation. *Medical and Veterinary Entomology*, *15*(4), 364–373. doi:10.1046/j.0269-283x.2001.00322.x PMID:11776455

Alexander, B., Agudelo, L. A., Navarro, J. F., Ruiz, J. F., Molina, J., Aguilera, G., ... Quiñones, M. L. (2009). Relationship between coffee cultivation practices in Colombia and exposure to infection with Leishmania. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, *103*(12), 1263–1268. doi:10.1016/j.trstmh.2009.04.018 PMID:19555985

Aybar, C. A. V., Juri, M. J. D., Santana, M., de Grosso, M. S. L., & Spinelli, G. R. (2012). The spatio-temporal distribution patterns of biting midges of the genus Culicoides in Salta province, Argentina. *Journal of Insect Science*, *12*(1), 145. PMID:23461794

Azevedo, A. C., & Rangel, E. F. (1991). A study of sandfly species (Diptera: Psychodidae: Phlebotominae) in a focus of cutaneous leishmaniasis in the municipality of Baturité, Ceará, Brazil. *Memorias do Instituto Oswaldo Cruz*, *86*(4), 405–410. doi:10.1590/S0074-02761991000400005 PMID:1842431

Azevedo, A. C., Vilela, M. L., Souza, N. A., Andrade-Coelho, C. A., Barbosa, A. F., Firmo, A. L., & Rangel, E. F. (1996). The sand fly fauna (Diptera: Psychodidae: Phlebotominae) of a focus of cutaneous leishmaniasis in Ilhéus, state of Bahia, Brazil. *Memorias do Instituto Oswaldo Cruz*, *91*(1), 75–79. doi:10.1590/S0074-02761996000100012 PMID:8734952

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Braga, I. A., & Valle, D. (2007). Aedes aegypti: Histórico do controle no Brasil. *Epidemiologia e Serviços de Saúde*, *16*(2), 113–118.

Brumpt, E., & Pedroso, A. (1913). Pesquisas epidemiológicas sobre a leishmaniose americana das florestas no estado de São Paulo. *Anais Paulistas de Medicina e Cirurgia*, *1*, 97–136.

Bryant, J., Wang, H., Cabezas, C., Ramirez, G., Watts, D., Russell, K., & Barrett, A. (2003). Enzootic transmission of yellow fever virus in Peru. *Emerging Infectious Diseases*, *9*(8), 926–933. doi:10.3201/eid0908.030075 PMID:12967489

Cabral, A. C., Fe, N. F., Suarez-Mutis, M. C., Boia, M. N., & Carvalho-Costa, F. A. (2010). Increasing incidence of malaria in the Negro River basin, Brazilian Amazon. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, *104*(8), 556–562. doi:10.1016/j.trstmh.2010.03.008 PMID:20462621

Campbell, L. P., Luther, C., Moo-Llanes, D., Ramsey, J. M., Danis-Lozano, R., & Peterson, A. T. (2015). Climate change influences on global distributions of dengue and chikungunya virus vectors. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 370(1665), 20140135.

Canziani, O. F., & Diaz, S. (1998). Latin America. In R. T. Watson, M. C. Zinyowera, & R. H. Moss (Eds.), *The Regional Impacts of Climate Change: An Assessment of Vulnerability* (pp. 187–230). Cambridge, UK: Cambridge University Press.

Caqui, K. B., Quispe, C. L. H. A., & Zegarra, R. O. (2013). Disaster risk management in the framework of the UNASUR health. In E. H. Carmo, A. Gemal, & S. Oliveira (Eds.), Health Surveillance in South America: epidemiological, sanitary and environmental (pp. 41-54). Rio de Janeiro: ISAGS.

Carbajo, A. E., Cardo, M. V., & Vezzani, D. (2012). Is temperature the main cause of dengue rise in non-endemic countries? The case of Argentina. *International Journal of Health Geographics*, *11*(1), 26. doi:10.1186/1476-072X-11-26 PMID:22768874

Carbajo, A. E., Vera, C., & González, P. L. (2009). Hantavirus reservoir *Oligoryzomys longicaudatus* spatial distribution sensitivity to climate change scenarios in Argentine Patagonia. *International Journal of Health Geographics*, *8*(1), 44. doi:10.1186/1476-072X-8-44 PMID:19607707

Carbajo, A. E., & Vezzani, D. (2015). Waiting for chikungunya fever in Argentina: Spatio-temporal risk maps. *Memorias do Instituto Oswaldo Cruz*, *110*(2), 259–262. doi:10.1590/0074-02760150005 PMID:25946252

Cárdenas, R., Sandoval, C. M., Rodriguez-Morales, A. J., & Vivas, P. (2008). Zoonoses and climate variability: The example of Leishmaniasis in southern departments of Colombia. *Animal Biodiversity and Emerging Diseases*, *1149*, 326–330.

Carpenter, S., Groschup, M. H., Garros, C., Felippe-Bauer, M. L., & Purse, B. V. (2013). Culicoides biting midges, arboviruses and public health in Europe. *Antiviral Research*, *100*(1), 102–113. doi:10.1016/j.antiviral.2013.07.020 PMID:23933421

Cesario, M., & Cesario, R. R. (2005). Infecção bacteriana rumo ao Brasil: Endêmica nos Andes, Bartonelose se alastra com abertura de estradas e degradação ambiental. *Scientific American Brasil*, *3*(34), 10–11.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Chagas, C. (1907). Adenda: Lassance. In J. R. Cançado & M. Chuster (Eds.), *Cardiopatia Chagásica* (pp. 391–413). Belo Horizonte: Fundação Carlos Chagas.

Chaves, L. F., & Pascual, M. (2006). Climate cycles and forecasts of cutaneous leishmaniasis, a nonstationary vector-borne disease. *PLoS Medicine*, *3*(8), e295. PMID:16903778

Chinga-Alayo, E., Huarcaya, E., Nasarre, C., Del Aguila, R., & Llanos-Cuentas, A. (2004). The influence of climate on the epidemiology of Bartonellosis in Ancash, Peru. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, *98*(2), 116–124. doi:10.1016/S0035-9203(03)00017-8 PMID:14964812

Chowell, G., Cazelles, B., Broutin, H., & Munayco, C. V. (2011). The influence of geographic and climate factors on the timing of dengue epidemics in Perú, 1994-2008. *BMC Infectious Diseases*, *11*(1), 1. doi:10.1186/1471-2334-11-164 PMID:21651779

Comisión Económica para América Latina y el Caribe. (2014). Anuario estadístico de América Latina y el Caribe. Santiago de Chile, Chile. Retrieved from http://www.cepal.org/en/publications/37647-anuario-estadistico-de-america-latina-y-el-caribe-2014-statistical-yearbook-latin

Confalonieri, U. E., & Costa Neto, C. (2012). Diversity of mosquito vectors (Diptera: Culicidae) in Caxiuanã, Pará, Brazil. *Interdisciplinary Perspectives on Infectious Diseases*, 2012, id 741273.

Confalonieri, U. E., Margonari, C., & Quintão, A. F. (2014). Environmental change and the dynamics of parasitic diseases in the Amazon. *Acta Tropica*, *129*, 33–41. doi:10.1016/j.actatropica.2013.09.013 PMID:24056199

Confalonieri, U. E., Menezes, J. A., & Margonari de Souza, C. (2015). Climate change and adaptation of the health sector: The case of infectious diseases. *Virulence*, 6(6), 554-557. PMID:26177788

Confalonieri, U. E. C., Mascarenhas, B. M., Pinto, C. S., Santa Brigida, M., Chagas, E., & Guimarães, D. G. (2013). Distribuição Vertical e Temporal de Culicídeos (Diptera: Culicidae) em sítio na Floresta Nacional de Caxiuanã, Melgaço, Pará. In *P.L. Lisboa (Org.), Caxiuanã: paraíso ainda preservado* (pp. 117–122). Belém: Editora do Museu Paraense Emilio Goeldi.

Conn, J. E., Wilkerson, R. C., Segura, M. N. O., de Souza, R. T., Schlichting, C. D., Wirtz, R. A., & Póvoa, M. M. (2002). Emergence of a new neotropical malaria vector facilitated by human migration and changes in land use. *The American Journal of Tropical Medicine and Hygiene*, *66*(1), 18–22. PMID:12135261

Cordel, H., Quatresous, I., Paquet, C., & Couturier, E. (2006). Imported cases of chikungunya in metropolitan France, April 2005–February 2006. *Eurosurveillance*, *11*(4), E060420. PMID:16809828

Cordovez, J. M., Rendon, L. M., Gonzalez, C., & Guhl, F. (2014). Using the basic reproduction number to assess the effects of climate change in the risk of Chagas disease transmission in Colombia. *Acta Tropica*, *129*, 74–82. doi:10.1016/j.actatropica.2013.10.003 PMID:24416781

Costa, J., Dornak, L. L., Almeida, C. E., & Peterson, A. T. (2014). Distributional potential of the Triatoma brasiliensis species complex at present and under scenarios of future climate conditions. *Parasites and Vectors*, *7*(1), 238. doi:10.1186/1756-3305-7-238 PMID:24886587

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Costello, A., Abbas, M., Allen, A., Ball, S., Bell, S., Bellamy, R., ... Patterson, C. (2009). Managing the health effects of climate change: Lancet and University College London Institute for Global Health Commission. *Lancet*, *373*(9676), 1693–1733. doi:10.1016/S0140-6736(09)60935-1 PMID:19447250

Coura, J. R. (2015). The main scenarios of Chagas disease transmission. The vectors, blood and oral transmissions - A comprehensive review. *Memorias do Instituto Oswaldo Cruz*, *110*(3), 277–282. doi:10.1590/0074-0276140362 PMID:25466622

Coura, J. R., & Junqueira, A. C. (2012). Risks of endemicity, morbidity and perspectives regarding the control of Chagas disease in the Amazon Region. *Memorias do Instituto Oswaldo Cruz*, *107*(2), 145–154. doi:10.1590/S0074-02762012000200001 PMID:22415251

Cunha, R. V., & Nogueira, R. M. R. (2005). Dengue e Dengue Hemorrágico. In J. R. Coura (Ed.), *Dinâmica das doenças infecciosas e parasitárias* (pp. 1755–1766). Rio de Janeiro: Guanabara Koogan.

da Silva, O., de Sousa, M. E., dos Santos, F. A., da Silava, P., Gazin, P., & da Silva, P. (1999). American cutaneous leishmaniasis in the sugar cane-producing area of Pernambuco, North-East Brazil. *Sante (Montrouge, France)*, *10*(2), 123–126. PMID:10960810

da Silva-Nunes, M., Codeço, C. T., Malafronte, R. S., da Silva, N. S., Juncansen, C., Muniz, P. T., & Ferreira, M. U. (2008). Malaria on the Amazonian frontier: Transmission dynamics, risk factors, spatial distribution, and prospects for control. *The American Journal of Tropical Medicine and Hygiene*, *79*(4), 624–635. PMID:18840755

Daszak, P., Cunningham, A. A., & Hyatt, A. D. (2000). Emerging infectious diseases of wildlife--threats to biodiversity and human health. *Science*, *287*(5452), 443–449. doi:10.1126cience.287.5452.443 PMID:10642539

de Araújo Pedrosa, F., & de Alencar Ximenes, R. A. (2009). Sociodemographic and environmental risk factors for American Cutaneous Leishmaniasis (ACL) in the State of Alagoas, Brazil. *The American Journal of Tropical Medicine and Hygiene*, *81*(2), 195–201. PMID:19635869

Degallier, N., Rosa, A. T. D., Hervé, J. P., Vasconcelos, P. F., Rosa, E. S., Rodrigues, S. G., ... Dias, L. B. (1992). A comparative study of yellow fever in Africa and South America. *Ciencia e Cultura*, *44*(2/3), 143–151.

Delgado-Petrocelli, L., Córdova, K., Camardiel, A., Aguilar, V. H., Hernández, D., & Ramos, S. (2012). Analysis of the El Niño/La Niña-southern oscillation variability and Malaria in the Estado Sucre, Venezuela. *Geospatial Health*, *6*(3), 51–57. doi:10.4081/gh.2012.122 PMID:23032283

Downs, W. G. (1981). The known and the unknown in yellow fever ecology and epidemiology. *Ecology of Disease*, *1*(2-3), 103–110. PMID:6148230

Dutra, F. R. L. S., Valadão, R. C., Confalonieri, U. E., Muller, G. V., & da Quadro, M. F. L. (2015). A influência da variabilidade da precipitação no padrão de distribuição dos casos de leptospirose em Minas Gerais, no período de 1998-2012. *Hygeia; Revista Brasileira de Geografia Médica e da Saúde*, *11*(20), 106.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Ebi, K. L., Lindgren, E., Suk, J. E., & Semenza, J. C. (2013). Adaptation to the infectious disease impacts of climate change. *Climatic Change*, *118*(2), 355–365. doi:10.100710584-012-0648-5

Echegaray, F., & Afonso, M. H. F. (2014). Respostas às mudanças climáticas: Inovação tecnológica ou mudança de comportamento individual? *Estudos Avançados*, *28*(82), 155–174. doi:10.1590/S0103-40142014000300010

Epstein, P. R. (2001). West Nile virus and the climate. *Journal of Urban Health*, *78*(2), 367–371. doi:10.1093/jurban/78.2.367 PMID:11419587

Ferreira, I. B., Pereira, L. E., Rocco, I. M., Marti, A. T., Souza, L., & Iversson, L. B. (1994). Surveillance of arbovirus infections in the Atlantic forest region, State of São Paulo, Brazil: I. detection of hemagglutination-inhibition antibodies in wild birds between 1978 and 1990. *Revista do Instituto de Medicina Tropical de Sao Paulo*, *36*(3), 265–274. doi:10.1590/S0036-46651994000300011 PMID:7855491

Ferreira, K. V., Rocha, K. C., Caputto, L. Z., Fonseca, A. L. A., & Fonseca, F. L. A. (2011). Histórico da febre amarela no Brasil e a importância da vacinação antiamarílica. *Arquivos Brasileiros de Ciências da Saúde*, *36*(1), 40–47.

Figueiredo, M. L. G. D., & Figueiredo, L. T. M. (2014). Emerging alphaviruses in the Americas: Chikungunya and Mayaro. *Revista da Sociedade Brasileira de Medicina Tropical*, *47*(6), 677–683. doi:10.1590/0037-8682-0246-2014 PMID:25626645

Fouque, F., Gaborit, P., Issaly, J., Carinci, R., Gantier, J. C., Ravel, C., & Dedet, J. P. (2007). Phlebotomine sand flies (Diptera: Psychodidae) associated with changing patterns in the transmission of the human cutaneous leishmaniasis in French Guiana. *Memorias do Instituto Oswaldo Cruz*, *102*(1), 35–40. doi:10.1590/S0074-02762007000100005 PMID:17293996

Gonçalves Neto, V. S., Barros Filho, A. K. D., Santos, A. M. D., Prazeres, M. P. C. D. S., Bezerril, A. C. R., Fonseca, A. V. D. L., & Rebelo, J. M. M. (2013). An analysis of the spatiotemporal distribution of American cutaneous leishmaniasis in counties located along road and railway corridors in the State of Maranhao, Brazil. *Revista da Sociedade Brasileira de Medicina Tropical*, *46*(3), 322–328. doi:10.1590/0037-8682-0056-2012 PMID:23856875

Goodin, D. G., Koch, D. E., Owen, R. D., Chu, Y. K., Hutchinson, J. M., & Jonsson, C. B. (2006). Land cover associated with Hantavirus presence in Paraguay. *Global Ecology and Biogeography*, *15*(5), 519–527. doi:10.1111/j.1466-822X.2006.00244.x

Gottdenker, N. L., Calzada, J. E., Saldaña, A., & Carroll, C. R. (2011). Association of anthropogenic land use change and increased abundance of the Chagas disease vector Rhodnius pallescens in a rural landscape of Panama. *The American Journal of Tropical Medicine and Hygiene*, *84*(1), 70–77. doi:10.4269/ajtmh.2011.10-0041 PMID:21212205

Gottdenker, N. L., Chaves, L. F., Calzada, J. E., Saldaña, A., & Carroll, C. R. (2012). Host life history strategy, species diversity, and habitat influence Trypanosoma cruzi vector infection in changing landscapes. *PLoS Neglected Tropical Diseases*, 6(11): e1884.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Gubler, D. J. (2002). The global emergence/resurgence of arboviral diseases as public health problems. *Archives of Medical Research*, *33*(4), 330–342. doi:10.1016/S0188-4409(02)00378-8 PMID:12234522

Hack, W. H. (1955). Estudios sobre biología del *Triatoma infestans* (Klug, 1834) (Hemiptera, Reduviidae). *An Inst Med Regional*, *4*, 125–147.

Hahn, M. B., Gangnon, R. E., Barcellos, C., Asner, G. P., & Patz, J. A. (2014). Influence of deforestation, logging, and fire on Malaria in the Brazilian Amazon. *PLoS ONE*, *9*(1), e85725. doi:10.1371/journal.pone.0085725 PMID:24404206

Herrera-Martinez, A. D., & Rodriguez-Morales, A. J. (2010). Potential influence of climate variability on dengue incidence registered in a western pediatric Hospital of Venezuela. *Tropical Biomedicine*, *27*(2), 280–286. PMID:20962726

Ibarra, A. M. S., Ryan, S. J., Beltrán, E., Mejía, R., Silva, M., & Muñoz, Á. (2013). Dengue vector dynamics (*Aedes aegypti*) influenced by climate and social factors in Ecuador: Implications for targeted control. *PLoS ONE*, *8*(11), e78263. doi:10.1371/journal.pone.0078263 PMID:24324542

Jacobi, P. R. (2014). Mudanças climáticas e ensino superior: A combinação entre pesquisa e educação. *Educational Review*, *3*(spe3), 57–72. doi:10.1590/0104-4060.38107

Johnson, K. M. (1993). Emerging viruses in context: an overview of viral hemorrhagic fevers. In S. S. Morse (Ed.), *Emerging viruses* (pp. 46–47). New York: Oxford University Press.

Jones, K. E., Patel, N. G., Levy, M. A., Storeygard, A., Balk, D., Gittleman, J. L., & Daszak, P. (2008). Global trends in emerging infectious diseases. *Nature*, *451*(7181), 990–993. doi:10.1038/nature06536 PMID:18288193

Keesing, F., Belden, L. K., Daszak, P., Dobson, A., Harvell, C. D., Holt, R. D., ... Ostfeld, R. S. (2010). Impacts of biodiversity on the emergence and transmission of infectious diseases. *Nature*, *468*(7324), 647–652. doi:10.1038/nature09575 PMID:21124449

Keim, M. E. (2008). Building human resilience: The role of public health preparedness and response as an adaptation to climate change. *American Journal of Preventive Medicine*, *35*(5), 508–516. doi:10.1016/j.amepre.2008.08.022 PMID:18929977

Landin, R., & Giatti, L. L. (2014). Política de mudança do clima no município de São Paulo, Brasil: Reflexividade e permeabilidade do Setor Saúde. *Ciencia & Saude Coletiva*, *19*(10), 4149–4156. doi:10.1590/1413-812320141910.08972014 PMID:25272124

Lima, G. F. D. C., & Layrargues, P. P. (2014). Climate change, education and environment: beyond Dynamic Conservatism. *Educar em Revista*, (SPE3), 73-88.

Lopes, O. D. S., Coimbra, T. L., Sacchetta, L. D. A., & Calisher, C. H. (1978). Emergence of a new arbovirus disease in Brazil. I. Isolation and characterization of the etiologic agent, Rocio virus. *American Journal of Epidemiology*, *107*(5), 444–449. PMID:665659

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Maco, V., Maguiña, C., Tirado, A., Maco, C., & Vidal, J. E. (2004). Carrion's disease (*Bartonellosis bacilliformis*) confirmed by histopathology in the High Forest of Peru. *Revista do Instituto de Medicina Tropical de Sao Paulo*, *46*(3), 171–174. doi:10.1590/S0036-46652004000300010 PMID:15286824

Magrin, G. O., Marengo, J. A., Boulanger, J. P., Buckeridge, M. S., Castellanos, E., Poveda, G., & Vicuña, S. (2014). Central and South America. In V. R. Barros, C. B. Field, D. J. Dokken, M. D. Mastrandrea, K. J. Mach, T. E. Bilir, ... L. L. White (Eds.), *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 1499–1566). Cambridge, UK: Cambridge University Press.

Mantilla, G., Oliveros, H., & Barnston, A. G. (2009). The role of ENSO in understanding changes in Colombia's annual malaria burden by region, 1960-2006. *Malaria Journal*, *8*(6), 1–11. PMID:19133152

Medone, P., Ceccarelli, S., Parham, P. E., Figuera, A., & Rabinovich, J. E. (2015). The impact of climate change on the geographical distribution of two vectors of Chagas disease: implications for the force of infection. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 370(1665), 20130560.

Membrive, N. A., Rodrigues, G., Gualda, K. P., Bernal, M. V. Z., Oliveira, D. M., Lonardoni, M. V. C., ... Silveira, T. G. V. (2012). Environmental and animal characteristics as factors associated with American cutaneous Leishmaniasis in rural locations with presence of dogs, Brazil. *PLoS ONE*, *7*(11), e47050. doi:10.1371/journal.pone.0047050 PMID:23144799

Mills, J. N. (2006). Biodiversity loss and emerging infectious disease: An example from the rodent-borne hemorrhagic fevers. *Biodiversity*, *7*(1), 9–17. doi:10.1080/14888386.2006.9712789

Monath, T. P. (1993). Arthropod-borne viruses. In S. S. Morse (Ed.), *Emerging Viruses* (pp. 138–148). New York: Oxford University Press.

Monath, T. P., & Vasconcelos, P. F. (2015). Yellow fever. *Journal of Clinical Virology*, *64*, 160–173. doi:10.1016/j.jcv.2014.08.030 PMID:25453327

Morales, M. A., Barrandeguy, M., Fabbri, C., Garcia, J. B., Vissani, A., Trono, K., ... Enría, D. (2006). West Nile virus isolation from equines in Argentina, 2006. *Emerging Infectious Diseases*, *12*(10), 1559–1561. doi:10.3201/eid1210.060852 PMID:17176571

Musso, D., Nilles, E. J., & Cao-Lormeau, V. M. (2014). Rapid spread of emerging Zika virus in the Pacific area. *Clinical Microbiology and Infection*, *20*(10), O595–O596. doi:10.1111/1469-0691.12707 PMID:24909208

Pan American Health Organization. (2014). Health Situation in the Americas: Basic Indicators 2014. Retrieved from http://www.paho.org/chi/index.php?option=com_content&view=article&id=578:situacion-de-salud-en-las-americas-indicadores-basicos-de-salud-2014&catid=681:publicaciones-y-otros-recursos

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Pascual, M., Bouma, M. J., & Dobson, A. P. (2002). Cholera and climate: Revisiting the quantitative evidence. *Microbes and Infection*, *4*(2), 237–245. doi:10.1016/S1286-4579(01)01533-7 PMID:11880057

Paz, S. (2006). The West Nile Virus outbreak in Israel (2000) from a new perspective: The regional impact of climate change. *International Journal of Environmental Health Research*, *16*(1), 1–13. doi:10.1080/09603120500392400 PMID:16507476

Pereira, C. A. R., & de Lima Barata, M. M. (2014). Organização dos serviços urbanos de saúde frente à mudança do clima e ao risco de desastres na América Latina. *Saúde debate*, 38(102), 624-634.

Pinheiro, F. P., Travassos Da Rosa, A. P. A., & Vasconcelos, P. F. C. (1998). An overview of Oropouche fever epidemics in Brazil and neighbour countries. In A. P. A. Travassos da Rosa, P. F. C. Vasconcelos, & J. F. S. Travassos da Rosa (Eds.), *An overview of arbovirology in Brazil and neighbouring countries* (pp. 186–192). Belém, Pará: Instituto Evandro Chagas.

Pinto, C. S., Confalonieri, U. E., & Mascarenhas, B. M. (2009). Ecology of Haemagogus sp. and Sabethes sp.(Diptera: Culicidae) in relation to the microclimates of the Caxiuanã National Forest, Pará, Brazil. *Memorias do Instituto Oswaldo Cruz*, *104*(4), 592–598. doi:10.1590/S0074-02762009000400010 PMID:19722082

Pongsiri, M. J., Roman, J., Ezenwa, V. O., Goldberg, T. L., Koren, H. S., Newbold, S. C., ... Salkeld, D. J. (2009). Biodiversity loss affects global disease ecology. *Bioscience*, *59*(11), 945–954. doi:10.1525/bio.2009.59.11.6

Porto, S. S. (2012). Saúde em desastres: a experiência de Nova Friburgo. *Nova Friburgo: Cap-Net Brasil*, 30.

Ramírez, I. J. (2015). Cholera resurgence in Piura, Peru: Examining climate associations during the 1997–1998 El Niño. *GeoJournal*, *80*(1), 129–143.

Ramírez, I. J., Grady, S. C., & Glantz, M. H. (2013). Reexamining El Niño and Cholera in Peru: A climate affairs approach. *Weather, Climate, and Society*, *5*(2), 148–161. doi:10.1175/WCAS-D-12-00032.1

Roth, A., Mercier, A., Lepers, C., Hoy, D., Duituturaga, S., Benyon, E., & Souares, Y. (2014). Concurrent outbreaks of dengue, chikungunya and Zika virus infections-an unprecedented epidemic wave of mosquito-borne viruses in the Pacific 2012-2014. *Eurosurveillance*, *19*(41), 20929. doi:10.2807/1560-7917.ES2014.19.41.20929 PMID:25345518

Rotureau, B. (2006). Ecology of the Leishmania species in the Guianan ecoregion complex. *The American Journal of Tropical Medicine and Hygiene*, *74*(1), 81–96. PMID:16407350

Seas, C., Miranda, J., Gil, A. I., Leon-Barua, R., Patz, J., Huq, A., ... Sack, R. B. (2000). New insights on the emergence of cholera in Latin America during 1991: The Peruvian experience. *The American Journal of Tropical Medicine and Hygiene*, *62*(4), 513–517. PMID:11220769

Simpson, D. I. H. (1978). Viral haemorrhagic fevers of man. *Bulletin of the World Health Organization*, *56*(6), 819. PMID:310725

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Smith, K. R., Woodward, A., Campbell-Lendrum, D., Chadee, D. D., Honda, Y., Liu, Q., & Sauerborn, R. (2014). Human health: impacts, adaptation, and co-benefits. In C. B. Field, V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, ... L. L. White (Eds.), *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 709–754). Cambridge, UK: Cambridge University Press.

Staples, J. E., & Fischer, M. (2014). Chikungunya virus in the Americas—what a vectorborne pathogen can do. *The New England Journal of Medicine*, *371*(10), 887–889. doi:10.1056/NEJMp1407698 PMID:25184860

Tabachnick, W. J. (2013). Nature, nurture and evolution of intra-species variation in mosquito arbovirus transmission competence. *International Journal of Environmental Research and Public Health*, *10*(1), 249–277. doi:10.3390/ijerph10010249 PMID:23343982

Tauil, P. L. (2002). Aspectos críticos do controle do dengue no Brasil. *Cadernos de Saude Publica*, *18*(3), 867–871. doi:10.1590/S0102-311X2002000300035 PMID:12048612

Tauil, P. L., Santos, J. B., & Moraes, M. A. P. (2005). Febre Amarela. In J. R. Coura (Ed.), *Dinâmica das doenças infecciosas e parasitárias* (pp. 1755–1766). Rio de Janeiro: Guanabara Koogan.

Teixeira, A. R., Monteiro, P. S., Rebelo, J. M., Argañaraz, E. R., Vieira, D., Lauria-Pires, L., ... Costa, J. M. (2001). Emerging Chagas disease: Trophic network and cycle of transmission of *Trypanosoma cruzi* from palm trees in the Amazon. *Emerging Infectious Diseases*, *7*(1), 100–112. doi:10.3201/eid0701.070100 PMID:11266300

Teixeira, M. G., Paixão, E. S., & Costa, M. C. N. (2013). Recent epidemiological changes in South America. In E. H. Carmo, A. Gemal, Oliveira S. (Orgs), Health Surveillance in South America: epidemiological, sanitary and environmental (125-145). Rio de Janeiro: ISAGS.

Thai, K. T., & Anders, K. L. (2011). The role of climate variability and change in the transmission dynamics and geographic distribution of dengue. *Experimental Biology and Medicine*, *236*(8), 944–954. doi:10.1258/ebm.2011.010402 PMID:21737578

Travassos da Rosa, J. F. S., Pinheiro, F. P., & Vasconcelos, P. F. C. (2005). Febres hemorrágicas viróticas. In *J. R. Coura (Org.), Dinâmica das doenças infecciosas e parasitárias* (Vol. II, pp. 1741–1754). Rio de Janeiro: Guanabara-Koogan.

Travassos Da Rosa, J. F. S., Travassos Da Rosa, A. P. A., Vasconcelos, P. F. C., Pinheiro, F. P., Rodrigues, S. G., Travassos Da Rosa, E. S., . . . Cruz, A. C. R. (1998). Arboviruses isolated in the Evandro Chagas Institute, including some described for the first time in Brazilian Amazon region, their known hosts, and their pathology for man. In A. P. A. Travassos Da Rosa, P. F. C. Vasconcelos And J. F. S. Travassos Da Rosa (Eds.), An overview of arbovirology in Brazil and neighbouring countries (pp. 19-31). Belém, Pará: Instituto Evandro Chagas.

U.S. Agency for International Development. Pan American Health Organization (2010). The Amazon Malaria Initiative: Goals and Accomplishments October 2001–May 2009 (pp. 121). Washington.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Valle, D., & Lima, J. M. T. (2014). Large-scale drivers of malaria and priority areas for prevention and control in the Brazilian Amazon region using a novel multi-pathogen geospatial model. *Malaria Journal*, *13*(1), 1–13. doi:10.1186/1475-2875-13-443 PMID:25412882

Vasconcelos, P. F., Travassos da Rosa, A., Rodrigues, S. G., Travassos da Rosa, E. S., Dégallier, N., da Rosa, T., & Jorge, F. S. (2001). Inadequate management of natural ecosystem in the Brazilian Amazon region results in the emergence and reemergence of arboviruses. *Cadernos de Saude Publica*, *17*, S155–S164. doi:10.1590/S0102-311X2001000700025 PMID:11426277

Vega-Rúa, A., Zouache, K., Girod, R., Failloux, A. B., & Lourenço-de-Oliveira, R. (2014). High level of vector competence of *Aedes aegypti* and *Aedes albopictus* from ten American countries as a crucial factor in the spread of Chikungunya virus. *Journal of Virology*, *88*(11), 6294–6306. doi:10.1128/JVI.00370-14 PMID:24672026

Vilela, M. L., Azevedo, C. G., Carvalho, B. M., & Rangel, E. F. (2011). Phlebotomine Fauna (Diptera: Psychodidae) and putative vectors of Leishmaniases in impacted area by hydroelectric plant, state of Tocantins, Brazil. *PLoS ONE*, *6*(12), e27721. doi:10.1371/journal.pone.0027721 PMID:22163271

Vittor, A. Y., Pan, W., Gilman, R. H., Tielsch, J., Glass, G., Shields, T., ... Patz, J. A. (2009). Linking deforestation to Malaria in the Amazon: Characterization of the breeding habitat of the principal malaria vector, *Anopheles darlingi. The American Journal of Tropical Medicine and Hygiene*, *81*(1), 5–12. PMID:19556558

Weaver, S. C., & Reisen, W. K. (2010). Present and future arboviral threats. *Antiviral Research*, *85*(2), 328–345. doi:10.1016/j.antiviral.2009.10.008 PMID:19857523

Wilcox, B. A., & Gubler, D. J. (2005). Disease ecology and the global emergence of zoonotic pathogens. *Environmental Health and Preventive Medicine*, *10*(5), 263–272. doi:10.1007/BF02897701 PMID:21432130

World Health Organization. (2009). Para salvar vidas: hagamos que los hospitales sean seguros en las situaciones de emergencia.

World Health Organization. (2014). *WHO Guidance for Countries on Combining Indoor Residual Spraying and Long-Lasting Insecticidal Nets*. Geneva, Switzerland: World Health Organization.

Zhou, J., Lau, K. M., Laughlin, L. W., Masuoka, M., Chamberlin, J., & Lawyer, P. (2001). The effect of regional climate variability on outbreak of Bartonellosis epidemics in Peru. *Proceedings of the third Symposium on Environmental Applications: Facilitating the Use of Environmental Information*. Orlando, Florida: American Meteorological Society.

KEY TERMS AND DEFINITIONS

Anthropic Environment: New spaces formed by human actions that transforms the natural environment, such as large cities and agricultural fields.

Arboviruses: Viruses transmitted to humans by hematophagous insects and that are kept in natural or urban environment by vertebrate hosts.

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Emerging Infectious Diseases: Diseases that had never been detected in humans before or which have affected a very small number of people in isolated places, such as Hantavirus Pulmonary Syndrome.

Epidemics: A higher than expected incidence of a given disease, when compared to the historical average, that occurs in a short period and in a specific geographic region.

Infectious Diseases: Diseases caused by pathogenic agents such as bacteria, protozoa and viruses that can spread from one individual to another, directly or indirectly.

Peridomiciliary: Spaces or environments surrounding human habitation, like backyard, henhouse, pigsty and barn.

Re-Emerging Infectious Diseases: Diseases that have affected large populations (worldwide or in specific countries) in the past, but were controlled and, at the present, they reappear as a major public health problem, such as Dengue Fever and Malaria.

Vector-Borne Diseases: Infections transmitted by the bite of blood-sucking arthropods such as mosquitoes, midges and bugs.

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Chapter 64
Information Need and Seeking Behavior of Farmers in Laduba Community of Kwara State, Nigeria

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ABSTRACT

The chapter present the report of a study that examined information needs and seeking haviour of farmers in Laduba community, Kwara State, Nigeria. This study adopted a survey research design using simple sampling technique to select 28 respondents from the population. Structured questionnaire was designed for the collection of data. It was discovered from the findings that majority of the farmers were illiterate of the middle aged group between 31-40. The farmers plant many crops, but it is noticeable that the farmers plant cassava mostly, the area which the farmers indicated they need information most is on agriculture, it was also observed that the farmers access information from colleagues (co-farmers), friends and relatives, agricultural extension workers. The information needs of the farmers in this study on agriculture includes how to prevent diseases for their crops on the farm and after harvesting, the farmers also stated that they need information on how to seek for loan, where to get the best market to sell their farm produce and how to get the best agro-chemical for effective use. In this study it was discovered that the challenges the farmers face in acquiring information includes, the inability to read and write in English language, lack of constant electricity supply, conflict among members of various associations and lack of access to agricultural extension workers. It is recommended that the farmers should be given effective adult education, provision of information centre with necessary personnel and information media to boost information accessibility. Also the government was encouraged to negotiate with mobile telecommunication operators to subsidize services so that the farmers who form majority in the rural areas can access information and communicate easily through their mobile phones.

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INTRODUCTION

Information is quite indispensable to the progress of any business (Aziagba & Okede, 2011). The case of farmers is not an exceptional. Availability, accessibility of timely, concise and accurate information is a tool that has the capacity to reduce uncertainty. Hence it is an important resource in an economic planning and other life endeavor.

According to Swanson, (2008) information needs assessment give programme designers the ability to develop interventions that target users with specific information needs. (Swanson & Rajalahli, 2010) explained that the level and effort to search for information either local, national and global information depend on the aspiration of the searchers and the authors added that farmers' ability to search for information depends on the sources that are available to them. Hence, it is expected that local information needs of the farmers could be met by well-organized information acquisition and dissemination system that uses traditional and modern methods.

In Nigeria, according to (Okunade & Williams, 2014) quite a number of Nigerians are rural farmers living in small farming communities. In line with Okunade's view, Laduba is one of the Nigerian rural communities dominated by farmers. The community is subdivided into smaller clans and budoagun which has highest concentration of farmers in the community is one of them. The farmers' population in this community is about 500, it is located in Asa Local Government Area of Kwara State, Nigeria. The farmers in this community practice subsistence agriculture, which (Okunade & Williams, 2014) described as small scale farming using simple implements like hoes and cutlasses to meet the farmer's household needs and with very little for sale.

However, the advantage of availability of vast land in Laduba community and its nearness to Ilorin, the Kwara State capital made the community to attract different categories of elite who wants to engage in farming from Ilorin. In view of its strategic location, the community was selected as an adopted village by Nigerian Stored Products Research Institute (NSPRI), a Research Institute with the national mandate to research into post-harvest management of agricultural crops. Hence, the Research Institute do give her developed technologies through research to farmers at Laduba to use, while personnel from the Institute do regularly visit the farmers using the technologies to determine the efficiency of their research work. This further made Laduba community an attractive farming and research environment.

STATEMENT OF PROBLEM

Nigerian farmers are essentially rural dwellers; they live their lives based on their experiences and traditions that have been passed to them. However, the desire to increase productivity and make a better living through farming is making the scope and source of information required to extend beyond experience and tradition, so, it is observable that farmers now appreciate other sources to get information to improve their life, hence, there is a need to identify these sources and the type of information they get, so that their usage could be maximized or discouraged to enhance the productivity of farmers in Laduba and other similar communities, because without farming, man's existence on the earth would have been a mirage rather than reality (Okunade & Williams, 2014). This study therefore wishes to further support existence of farming and increase in productivity of farmers through determination of information required by them to enhance their productivity.

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LITERATURE REVIEW

Effort had been made through different studies to determine information needs and information seeking behavior of different groups of people and professionals. Momoh, et al. (2015) conducted a study on information seeking behavior in central hospitals in Delta State, Nigeria. The study showed that nurses needed information to carry out their professional duties like health development and current approach to medical treatment. Friends, colleagues, libraries and internet were the identified sources where the nurses got their information.

(Aziagba & Okede, 2011) conducted a study on information seeking behavior of cassava farmers in Upata clan, Ekpeye community of Rivers State of Nigeria. The study confirmed that friends and colleagues are major sources of information for the cassava farmers. Discussion over the radio broadcast were equally strong source of information for the cassava farmers, most especially when it is broadcasted in their languages. The library, seminars, workshops and television broadcast, were revealed as sources where cassava farmers do not get needed information. The findings, equally established that these cassava farmers are still involved in sourcing for information mostly from friends and relatives within the locality.

In the study conducted by Babu, et al. (2012) on information needs and search behavior among farmers in Tamil Nadu, India, the authors grouped the different information sources accessed by farmers into four searching groups based on type of medium which include: print, broadcast, electronic and interpersonal. The findings showed how searchers relied on interpersonal sources such as imprint dealers, state department of agricultural extension workers, family and relatives. Semi medium searchers, according to the authors, accessed all media with most of them using electronic sources. High and medium searchers are revealed to also get information through print and broadcast media. Irrespective of the source used by farmers to obtain information, Babu, (2012) highlighted that the major constraints to information access were poor availability and unreliable information. Also, noticeable constraint that cut across was lack of awareness of information sources available and untimeliness of information the farmers do get. Saravan R. et al (2008) carried the study on information pattern and information need of the tribal farmers in Arunachal Pradesh, India indicated that most of the farmers need information on various topics such as pest management, disease management. Tologbonse D, et al. (2008) carried the study of information need of rice farmers' community in Niger state disclosed that majority of farmers need information about crop production. Meitei & Devi (2009) also conducted a study with farmer's community in Manipur, India to find out the information need of rural farmers' community in Manipur state. This result of the study shows that majority of the farmers did not get access to needed information for their activities. Hence, the farmers requested that ICT based agricultural information support systems should be developed for them. Byamugisha et al. (2009) conducted a study on information seeking and use of urban farmers in Uganda, the researchers found out from the study, that the information needs of the urban farmers in studied area seemed to be as varied as the farming activities and also appeared to vary from one urban farmer to another. Achugbue & Anie, 2011 carried the study in Delta State, Nigeria on Rural Female farmer's information need and importance of ICT in delivering information needs of female farmers. The findings from the research shows that the female farmers do not have enough skills to access information through ICT. Akanda & Roknuzzaman Md (2012) surveyed agricultural information literacy of 160 farmers in the northern region of Bangladesh. The survey shows that farmers need information for various purposes of agricultural activities, and they use different sources and media to access information. The researchers, therefore concluded that conceptualizing information need is a very difficult task. This is because the needs of individuals usually vary from time to time due to several factors.

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UNDERSTANDING INFORMATION SEEKING BEHAVIOUR OF USERS

According to Wilson (1999, 2000), information-seeking behavior includes those activities a person may engage in when identifying his own information needs, searching for such information in any way, and using or transferring that information makes up the processes of information seeking behavior of an individual. Kakai, et al., (2004) have defined information-seeking behavior as an individual's way and manner of gathering and sourcing for information for personal use, knowledge updating, and development. This author explained further that information-seeking behavior of students, researchers, and professors has been the focus of enquiry for decades. He added further that initially, user studies were conducted in libraries and information centres primarily to evaluate library collections. These were said to be followed by studies of the research on habits of individuals or groups that would lead to the design of appropriate information systems and services. According to Kakai, et al., (2004) in mid 1980s, the focus of research shifted to holistic approaches to information-seeking behavior. However, Adereti, et al, (2006), and Aina, (2004) described information need as a piece of information, whether recorded or not, which an individual or a member of a group requires for effective functioning in their daily activities. Information needs can be seen as a set data which enables the user to make appropriate decisions on any related problem facing him or her at a particular time (Solomon, 2002).

In other words, information is needed because it enables individuals to make a decision that affects their living, just as Opeke, (2004) suggest that information represents an ordered reality about the nature of the world people live in. The need for information in any society is individualistic. Individuals need information depending on the motive for such information. Taking the right decisions depends on access to information on all the alternatives and their implications (Ajayi, 2003). Zhang (2001) is of the opinion that a thorough understanding of user information needs and information-seeking behavior is fundamental to the provision of successful information services. Anwar (2007) also reiterates that it is important to understand the information-seeking behaviours of different groups of people, as it helps in the planning, implementation, operation, designing of new information systems and the development of service programmes in the work environment for optimal performance. According to Line (2000), new studies of information users and their needs are even more necessary in the age of the Internet. Researchers such as (Callison, 1997, Devadason and Pratap, 1997, and Ellis, 1993) have explored quantitative and qualitative methodologies for user studies on how Information-seeking behavior differs among user groups. Librarians must understand the information needs of user in order to address those needs. This study explores the information-seeking behavior of farmers. Knowledge about the information-seeking behaviour and information use of individuals is crucial to effectively meet their information needs. The first basic user study in the broader sense was undertaken by Menzel in1966 and he defined information seeking behavior from three angles and they include; when approached from the point of view of the scientists or technologists, these are studies of scientists' communication behaviour; when approached from the point of view of any communication medium, they are user studies; and when approached from the science communication system, they are regarded as studies in the flow of information among scientists and technologists.

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MODEL ON INFORMATION SEEKING

The Information seeking behavior is sub-discipline within the field of library and information science. It describes how people need, seek, manage, give and use information in different contexts. It may also be described as information-seeking behavior or human information behaviour. Information carriers may be in different forms based on the ISB and information-needs studies of various groups. The Information carriers may include a variety of channels, a variety of sources within the channels, and a variety of messages contained within these sources Johnson et al. (2006).

Wilson (1981) has noted that the information seeking results from the recognition of some need perceived by the user. The behavior may take several forms, such as demanding information from the library or from other people who know. The approach has however been criticized because of insufficient theories, concepts and research methods, and because it has not taken into consideration the needs of the information seekers (Dervin & Nilan, 1986; Wilson, 1994). Dervin illustrated information seeking behavior diagrammatically as shown below, illustrating it triangularly with situation for seeking for information at the peak, the base of the triangle has the gap and the outcome sections. The situation, is the information needed or being sought for, the gap is the challenge in retrieving or searching for the information and the outcome is the result of the whole process. However, Dervin explained this process further by using the illustration in Figure 2, according to him, it may be preferred to use the bridge metaphor more directly as presented in the model. The model revealed that the process of seeking for information has a bridge between the situation and outcome, which spans between time and space, which implies that the process of seeking for information has no time limit

Meho & Tibbo (2003) revise Ellis's study and give new model with more features. Among the researchers, Kuhlthau (1993) has conducted empirical research about students' information seeking behavior and developed a general model of the information search process (ISP). The ISP consists of 6 stages as: initiation stage, selection stage, exploration stage, formulation stage, collection stage and presentation stage.

Wilson (1999) believes in the strength of Ellis' and Kuhlthau's models as they are based on empirical research and have been tested in subsequent studies. Wilson, however reviewed Ellis model and created an illustration, it is diagrammatical explained in Figure 3.

Figure 1. Dervin's 'sense-making' triangle

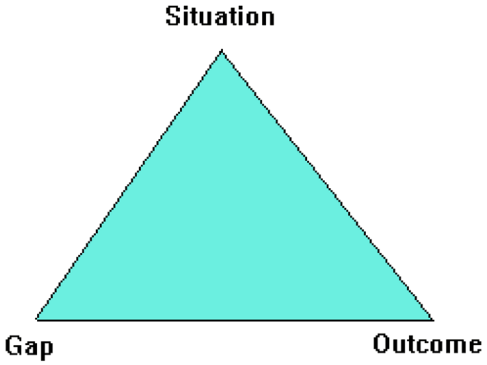

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Figure 2. Dervin's 'sense-making' model re-drawn

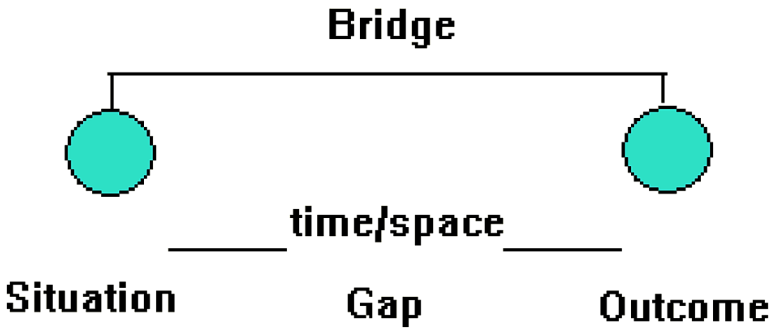
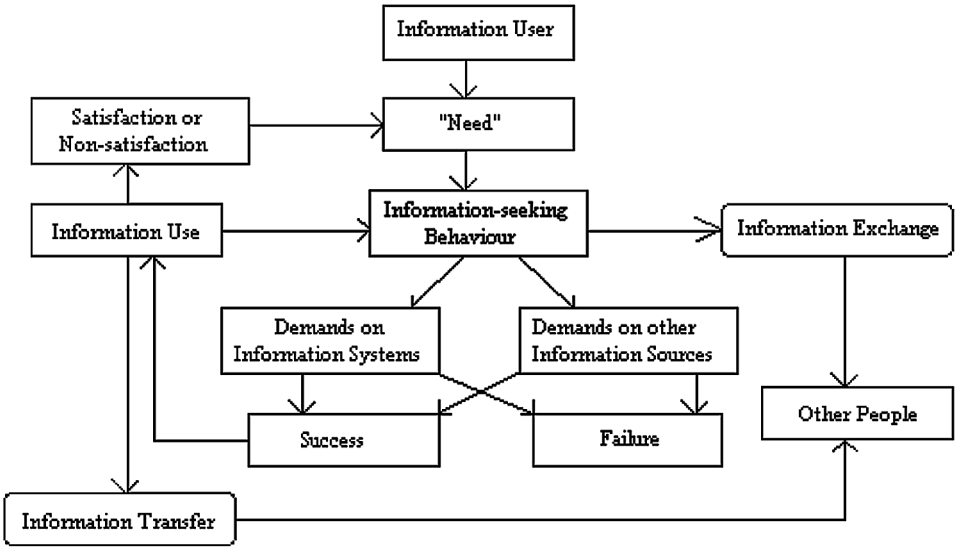


Figure 3. Wilson's information behaviour model



The aim of Wilson's model was to outline the various areas covered by what the writer proposed as information-seeking behaviour, as an alternative to the models indicated in Figures 1 and 2, but it is clear that the scope of the diagram is much greater and that it attempts to cover most of what is included here as information behaviour. The model also shows that part of the information-seeking behaviour may involve other people through information exchange and that information perceived as useful may be passed to other people, as well as being used (or instead of being used) by the person himself or herself. The limitation of this kind of model, however, is that it does little more than provide a map of the area and draw attention to gaps in research: it provides no suggestion of causative factors in information behaviour and, consequently, it does not directly suggest hypotheses to be tested (Figure 4).

Hayden (1999) has studied the different information seeking models like Wilson's model of 1981, Krikelas model of 1983, Kuhlthau model of 1992, Big Six Skills model of 1992 proposed by Eisenberg and Berkowitz. The author says that we need to question who the library community is; we also need to question how we can provide information skills that leads the students towards information literacy. Borgman (2000) defines information seeking as a continuous process, involving active and

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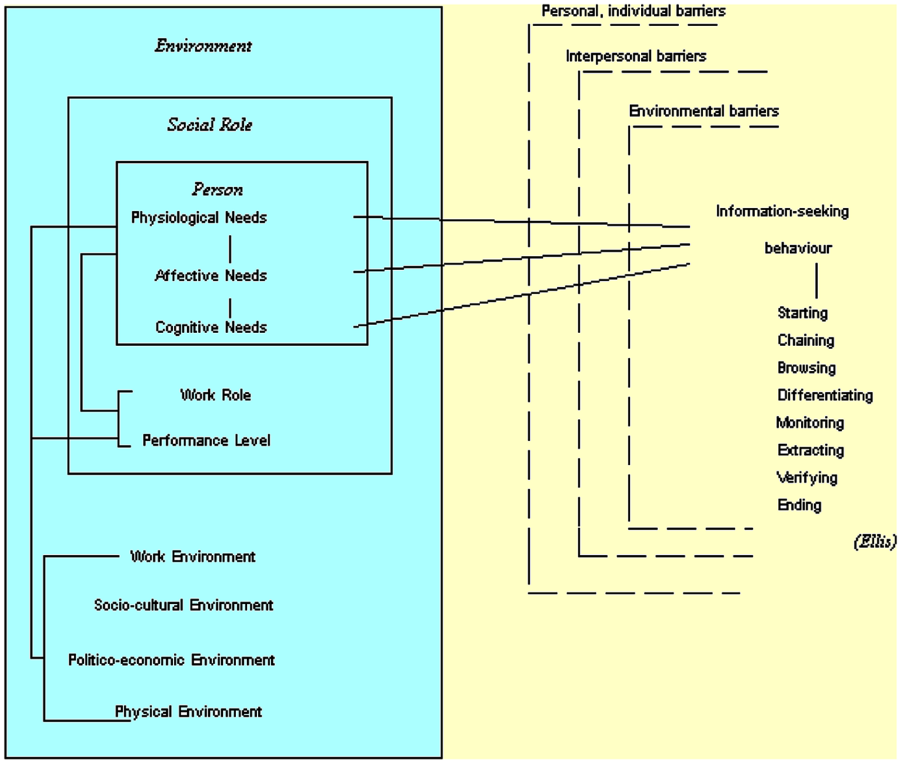
Figure 4. Wilson's information-seeking behaviour model



passive behaviors, and formal and informal communication. She points out the cycle of creating, using and seeking information which can be viewed as series of stages which people move back and forth, and they may be actively, creating, using and seeking information concurrently. Therefore, information seeking behavior refers to the pattern of response to the information need by person or group of persons. (Jarvelin & Wilson, 2003) discuss the functions of conceptual models in scientific research, in IS&R research in particular. What kind of models are there and in what ways may they help the investigators? What kinds of models are needed for various?

Loeber and Cristea (2003) have made an attempt at investigating, analyzing and modelling the visitor and website. Weiler (2004) observes that the first model for study of information-seeking behavior in the general population was developed by James Krikelas in 1983. This model suggestes the steps of information seeking as follows:

1. Perceiving a need,
2. The search itself,
3. Finding the information, and
4. Using the information, which results in either satisfaction or dissatisfaction.

Based on Krikelas' model, people begin to seek for information when they perceive that the current state of knowledge is less than that needed to deal with some issue (or problem). Butterworth (2006) argues that typically Information seeking and retrieval behaviour is a strongly social, but weakly collab-

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orative leisure activity. He discusses how these assumptions fit with the existing information seeking and retrieval (IS&R) models and proposes path for future work. The author touches on the browsing behaviour and searching behaviour and has made a sketch of the characteristics of 'personal history' researchers.

Shah (2008) proposes a model that helps us to understand the requirements for a successful collaboration. The author attempts to formalize the notion of collaboration and proposes a model of Collaborative Information Seeking (CIS) that put collaboration in perspective. His model consists of four layers such as information, tools, user and results.

Of all the models, Ellis model is very much applicable to the 21st century mode of seeking for information, it is in this mode that we adopt the Ellis model on information seeking behavior. Ellis et al. (1993) model on information seeking behaviour includes six generic features. (Ellis & Haugan, 1997) have attempted to propose and describe the characteristics of a general model of information seeking behaviors based on the studies of the information seeking

patterns of social scientists, research physicists and chemists, engineers and research scientists in an industrial firm. Ellis's elaboration model describes the features of information seeking activities as generic. These features are: Starting, Chaining, Browsing, Differentiating, Monitoring, Extracting, Verifying, Ending.

- **Starting:** The means employed by the user to begin seeking information, for example, asking some knowledgeable colleague;
- **Chaining:** Following footnotes and citations in known material or 'forward' chaining from known items through citation indexes;
- **Browsing:** 'Semi-directed or semi-structured searching' (Ellis, 1989: 187);
- **Differentiating:** Using known differences in information sources as a way of filtering the amount of information obtained;
- **Monitoring:** Keeping up-to-date or current awareness searching;
- **Extracting:** Selectively identifying relevant material in an information source;
- **Verifying:** Checking the accuracy of information;
- **Ending:** Which may be defined as 'tying up loose ends' through a final search.

INFORMATION SEEKING IN DIGITAL LIBRARIES

Digital Information Resources

There are various researches have been conducted on information seeking of digital information resources by different researchers around the world. In 2013 Gakibayo et al. carried out a study at Mbrarar University Library Uganda regarding the use of digital information resources by university students. Results were tabularized and it shows that a large number of respondents were aware with the full use of technology in utilizing digital resources. Natarajan et al. (2008) revealed the users of Annamalai University library were aware of digital journals only among all the other digital resources and 50% of the users are fulfilled from digital resources and it was also observed that digital journals were only source used comprehensively by users and the digital dictionaries and digital encyclopedias were the digital resources with the least usage. The study tells that users are not well aware with the provided resources and they cannot identify their actual need properly because of which the satisfaction is below

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average. The use of internet based digital resources at Manipur University, India. This study identified the utilization, rationale, difficulties and satisfaction level of users about internet based digital resources services provided by the library and they conclude that low speed internet, irregular power supply and lack of required full text journals. According to findings the use of internet based digital resources by the students of Manipur University is not found very significant. The reason might be those problems which they are facing while accessing these resources (Singh, et al., 2007). In 2008 a survey was completed by H.R. and Mudhol was completed a survey at College of Fisheries, India. The research study revealed that respondents were highly satisfied about the level of access for the use of digital information sources. The study confirmed that the digital information sources users are very satisfied with their retrieved results and as the sample is limited to faculty, research scholars and post graduate students to the main reason for using digital information sources is the research in which they are currently involved. It seems that they are well aware with the usage of such digital resources. Mostafa (2013) carried out a survey at some selected private universities of Bangladesh about the use and impact of digital resources. According to results, majority of the respondents gave preference to digital thesis among all other digital resources likewise digital books, digital newspapers and digital magazines. The study exposed the fact there are sufficient digital resources available in the campus and students use those digital resources frequently but is need to modify infrastructure and training courses as well. Okiki et al. (2011) had conducted a survey in Nigeria to determine the use of digital information sources by post graduate students in Nigeria. Results showed that a large number of respondents use digital information sources daily they are motivated to use digital information sources for their research projects. According to tabulated results show connection in a major problem faced by the respondents. The post graduate students in Nigeria are being motivated for the utilization of digital information resources because of which the use of digital information is found extraordinary among them. Information Needs: Fabritius (1997) investigated the information seeking behaviour of journalists. The main purpose of the study was to investigate the role of digital information in journalism, how journalists use latest information technology and how new digital technologies sustain news reporting. The journalists' information searching behaviour was examined by means of major hierarchical aspects. Fabritius places information seeking and salvage into a wider framework which have an effect on the loom to information sources and application of information.

Digital Information Seeking Behavior

Research in the domain of information needs, information seeking and information seeking behaviour started in early twentieth century. Whereas tracing the history of information seeking and behavioral studies, few studies were carried out in the early 1900s, Ayres and McKinnie in 1916 revealed the information seeking at the Cleveland Public Library. Tibbo informs that a distinguished production of studies on the subject take placed in the 1960s [e.g. a study by the American Psychological Association, 1963 -1969 and Earle and Vickery's study in 1969]. Wilson (2000) discovered an early importance on the use of information systems with a more person-oriented approach growing later in the 1980s. Although early user-centred research concerted on the scientific community, it rapidly expanded to integrate educational institutions to investigate students and staff's actions and inspirations when using the technology. According to Francis (2008), "Researchers and practitioners in the field of LIS have long held an importance in the information-seeking behaviour of diverse patron groups. Research in this part dates back to the 1940s and the deliberate was on scientists." Since then, studies rapidly improved, preliminary with those proposed to get better collection development, followed by folks that investigated

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the research behavior of individual's approach that observed the system as seen by the user Studies on web information seeking behaviour emerged afterward, and many pen down the mid-90s as the exact initial point. Jansen & Spink (2004) propose that the most primitive studies of web searching behaviour in the mid -90s occurred as web search engine and web browser use began to grow, mainly in academic environments. Author discovered the behavioral outline with special reference to electronic databases and the World Wide Web. Different models of information seeking behaviour were presented and the complexities in the procedure of searching were explored. These researches offer insight into the seeking behaviour in the course of electronic systems (Wilson, 2006). Asemi (2005) agreed to understand the information searching habits of internet users at the Medical University of Isfahan. The purpose of the study was to examine the position of information searching character of the users on internet. Data was collected using a questionnaire trailed by interview with users from five faculties. 188 users responded to the study. Study revealed that students use internet extensively, and it inhabits an important position with diverse sources. Study also revealed that electronic media has not substitutes print media. A study of Brazilian social sciences scholars found that, while print resources are still the most frequently used, electronic resources are becoming more and more accepted. Access to networked computers is the main barrier to the use of databases and other electronic resources. Francis (2005) focused on a study that explained the information seeking behavior of social sciences faculty at the University of the West Indies (UWI). One of this 2005 study's findings was that social scientists have a preference journal articles in electronic format over print. Wang (2007) wrote about disciplinary and cultural differences among information seekers in the Internet age, concluding that there are distinctions across disciplines and cultures in terms of how they rank the importance of these resources and how much they use them. Wang further discussed the information needs, information-seeking behaviors, and resource use of selected special interest groups. Electronic Information retrieval skills as noted by Tsakonas & Papatheodorou (2006), digital libraries, e-journal platforms, portals, e-prints and other web-based information systems provide services supporting users to perform intense work tasks that require complex interaction activities. This implies that users cannot access e-resources without adequate computer skills. According to Toner (2008), advances in technology have made possible virtual classrooms, online courses, and distance learning. This, coupled with the growth in society's access to information via ICT, has altered student perceptions of what the library has to offer. If libraries are to maintain their relevance in the cycle of student needs, then they must adapt and change (Toner 2008). MacWhinnie, (2003) and Thachill (2008), argue that students sometimes lack technical and research skills and so do not find the best and appropriate information, tempting them to use whatever information they can find first, fast and full text. More importantly, even with a good easy to use integrated system, students very often need the expertise of a librarian to apply search techniques and find the information they need (Thachill 2008). Tella et tal (2007) argued that the students' ability to find and retrieve information effectively is a transferable skill useful for their future life as well as enabling the positive and successful use of the electronic resources whilst at school. They noted that in this digital era any student at the higher level who intends to better achieve should have the ability to explore the digital environment. Students are increasingly expected to use electronic information resources whilst at the university. To make use of the growing range of electronic resources, students must acquire and practice the skills necessary to exploit them (Okello-Obura & Magara, 2008). Skills learning is essential in a technology driven environment but can be enhanced tremendously through the use of innovative learning strategies (Lawson 2005). Ray & Day (1998) suggested that the skills required to access the maximum potential of electronic resources are much greater than those required for searching printed sources. These skills include knowledge of the structure of the

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database and the instructions which must be input into the computer by the searcher – as well as an understanding of the ways in which the instructions are linked to one another. Okon (2005) asserts that the core skills traditionally associated with information professionals, which include information handling skills, training and facilitating skills, evaluation skills and concern for the customer, are all still relevant. The ability to find and retrieve information effectively is a transferable skill for enabling the positive and successful use of electronic resources by students while they are at university - as well as in their future lives. As Brophy (1993) argues, libraries must "reach a position where the acquisition of information skills is acknowledged as one of the key learning objectives for every student entering a university, so that no student leaves without being fully equipped to cope up with the information intensive world – the information society - as an end-user." The library has not only ready and free information highway, but also the adequate and efficient information transport means, which allows the readers to use the tools and obtain the information they need (Shuling, 2007). The literature highlights the advantages of electronic over printed sources of information, but also suggests the need for certain skills in order to access and use electronic resources effectively. Given their apparent lack of use of electronic resources, this study set out to determine if LIS postgraduate students at Makerere University have the required skills and ability to access and use electronic resources.

Why Electronic Information Resources?

Higher education is changing rapidly with the advent of technology. According to Shuling (2007), in recent years, electronic information has gradually become a major resource in every university library. The growth and diversity of electronic resources, especially e-journals, in the past few years has led many to predict the extinction of the printed journal (Okello-Obura & Magara, 2008). It has been suggested that a new paradigm is sweeping scholarship (Liew, Foo and Chennupati, 2000; Harper et al, 2006). Majid et al (1999) argue that technological advancements opened up new horizons for the creation, storage, access, distribution and presentation of information. In the global information communications technology (ICT)-dominated world, "place" is much less important (Ferguson, 2006). "The impact of moving from text-based to resource-based learning has involved heavier use of library materials and a demand for more and varied media sources" (Kinengyere, 2007). This makes the provision and use of Electronic Information Systems (EIS) in academic libraries a critical issue for those working in information and library services (Armstrong....et al, 2001; Elam, 2007). The pace at which information resources are being produced and converted into an electronic form is greater today than in previous years (Armstrong ... et al 2001). In today's information age it would seem that library users would not only be eager to take advantage of the convenience electronic resources have to offer, but would be fully immersed in the new technologies (Elam 2007). Electronic information resources offer today's students different opportunities compared to their predecessors. Liew, Foo and Chennupati (2000:302) argued that while reading an e-journal is not the same as reading a printed one, many are beginning to acknowledge the possibility that electronic documents (e-documents) offer users advanced features and novel forms of functionality beyond what is possible in printed form. Years ago Brophy (1993), noted that the advantages of electronic resources over print include speed, ease of use, ability to search multiple files at the same time, ability to save, print and repeat searches, more frequent updating and the ability to access from outside the library (a particular advantage for the distance learner). According to Dadzie (2005), electronic resources are invaluable research tools that complement print-based resources in any traditional library. Their advantages include access to information that might be restricted to the user

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because of geographical location or finances, access to current information, and provision of extensive links to additional resources or related content (Dadzie 2005). E-resources could be stored electronically thereby saving space, the risk of lost, theft or damage is lessened and costs significantly reduced. Attitude towards e-resources Academic libraries now live in a superior new world. The rapid advancement of Information and Communication Technology (ICT) has brought a revolutionary change in the information scenario giving rise to a number of options to the users' community to handle varied information sources conveniently and effortlessly. As a result, e-resources have become the lively substance to the modern library's reserves in satisfying varied needs of students, teachers, and researchers with minimum risk and time (Swain and Panda, 2009). For better planning, it is vital to have knowledge on the attitudes of users towards e-resources. Swain and Panda (2009), say the library users' attitude to information is gradually shifting from the printed documents to electronic resources and thus, it has been their prerogative to know the details of the availability and organization of e-resources like online journals and databases, electronic theses and dissertations (ETDs), government publications, online newspapers, etc. in libraries. Given technology increased use, it is important to understand how technologically rich environments are influencing student attitudes toward e-resources access. Many factors influence attitudes. The introduction of open access journals and other resources for instance is creating another attitudinal tendency towards e-resources. Open access is one of the cheapest routes to electronic resources and over the last few years' open access resources have grown and provided an affordable way to provide access to some journal content (Price, 2009). Supporters of open access argue that, when academic articles, dissertations and theses are put online and open to all, it helps in fighting duplication and plagiarism of other people's intellectual works. Although the open access movement has brought access to many valuable resources, and provided libraries with an invaluable amount of resources, many open access projects still face an uncertain future (Price, 2009). Many critics are not sure that the open access model can survive because some are not considered "financially viable" or as high quality as traditionally purchased or subscribed content (Robinson 2006; Shao and Scherlen, 2007; Turk and Bjork 2008). Where do LIS postgraduate students fall in this case? What are their attitudes towards open access electronic resources? Attitudes towards e-resources access could be attributed to problems faced when accessing e-resources. For instance, in a situation where there are inadequate computer technologies to access e-resources or poor Internet connections, student's positive attitudes could be affected. That is why the problems that affect e-resources access are addressed in higher learning institutions libraries. The arguments for students using electronic resources are compelling. An adequate knowledge of computers and retrieval techniques is desirable to search these resources effectively. It is necessary to establish what computer skills students require to access electronic information resources in libraries. Amidst all the efforts to access e-resources, LIS postgraduate students face a number of challenges. These are reported in another paper by the same author.

SCOPE OF THE STUDY

The study is limited to farmers that cultivate land in Laduba community. Other inhabitants that engaged in other trades and other forms of farming apart from tilling ground were not included.

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Objective of The Study

The specific objectives of the study are to:

1. Identify the information needs of farmers in Laduba community of Kwara State.
2. Determine the source of information and their preferences with regard to sources available to them.
3. Identify constraints the farmers face while searching for information.

Methodology

The Laduba Community is located in Kwara State of Nigeria. They have various occupations, but the main occupation of the natives is farming. This study adopted a survey sampling technique. Structured questionnaire was designed as the instrument for data collection and was supplemented by personal interview with the expertise of the extension personnel of Nigerian Stored Products Research Institute (NSPRI). The population of this study is about 500 farmers who dwells in Budoagun Clan of Laduba community of Kwara State, Nigeria. The Budoagun clan is where this study is based, because the clan is a section of the Laduba community where farmers that cultivates land settled. To obtain information from the respondents, 40 copies of questionnaire were administered to the respondents while 28 copies were recovered and used for analysis. Agricultural extension workers from the Nigerian Stored Products Research Institute (NSPRI) were used as the research assistants to administer the questionnaire. The questionnaire was administered to the respondents who are mostly illiterate on one- to -one basis. The research assistants read the content of the questionnaire and the options available to each of the respondent and the answers from the respondents were reflected on the questionnaire. The questionnaire was divided into two broad sections. Section one deals with the bio data of the respondents. The other section has other units that examined the information seeking behavior of the respondents. The unit in the second section of the questionnaires are five and the sub heading of the units are arranged as follows from B to F respectively; types of crops planted, area of information needs, information need of farmers, medium of accessing information and challenges faced while seeking for information. Also the head of the community, noticeable leaders among the farmers and some youths were interviewed to compliment information gathered from the respondent through the questionnaire. Data collected for the study were subjected to analysis using frequency count, simple percentage and bar charts.

RESULTS AND DISCUSSIONS

Bio Data of the Respondents

- **Age of the Farmers:** The age of the farmers in the community of Laduba shows that 42.9% are between 31-40 years of age, followed by 32.1% of the respondents which is between 41-50 years of age, the research shows that 7.1% of the farmers are between 20-30 (Table 1 and Figure 5).
- **Gender of the Farmers:** From the result shown, 60.7% of respondents were male and 39.3% were females (Table 2 and Figure 6).
- **Mode of Farming:** In response to the mode of farming, it was discovered that 75% of the respondents are into fulltime, while 25% of the respondents are part-time farming (Table 3 and Figure 7).

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- **Level of Education:** The level of education of respondents was grouped into non formal, primary and secondary. The response obtained shows that 50% of the respondents belongs to non-formal, while 35.7% attained the level of primary education, and 14.3% being the least attained the level of secondary education (Table 4 and Figure 8).
- **Size of Farm:** Majority of the farmers' size of farm ranges from 1-2 acres (60.7%), the other size of farm used by other farmers include 2-4 and 4-6 acres with both with a percentage of 17.9% (Table 5 and Figure 9).
- **How Frequent Do You Go to the Farm:** Asked about how frequent they go to the farm, 92.9% of the respondents say they go to the farm every day, 3.6% of the respondents goes to the farm weekly and another 3.6% goes to the farm monthly (Table 6 and Figure 10).

Information on Other Types of Farming Apart from Tilling the Ground

- **Type of Livestock:** In response to types of livestock reared if any, 46.4% of the respondents engage in goat rearing, 39.3% of the respondents are into poultry farming, the percentage of those who are engaged in fish farming, pig rearing and cattle rearing is on the low side with 3.6%, 10.7% and 10.7% of the respondents respectively (Table 7 and Figure 11)
- **Type of Crops Planted:** Majority of the farmers' plants cassava (71.4%), they also plant grain crops and melon with results stating 67.9% and 57.1% respectively, other crops planted include vegetables (50%), yam (42.9%), fruits (42.9%) and groundnut (32.1%) the least crop planted is rice (3.6%) (Table 8 and Figure 12)

Table 1. Age of the farmers

Age Range	Frequency	Percent	Valid Percent	Cumulative Percent
20-30	2	7.1	7.1	7.1
31-40	12	42.9	42.9	50.0
41-50	9	32.1	32.1	82.1
51 and above	5	17.9	17.9	100.0
Total	28	100.0	100.0	

Table 2. Gender of the farmers

Gender	Frequency	Percent	Valid Percent	Cumulative Percent
Male	17	60.7	60.7	60.7
Female	11	39.3	39.3	100.0
Total	28	100.0	100.0	

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Table 3. Mode of farming

Mode	Frequency	Percent	Valid Percent	Cumulative Percent
Full time	21	75.0	75.0	75.0
Part time	7	25.0	25.0	100.0
Total	28	100.0	100.0	

Table 4. Level of education

Education Level	Frequency	Percent	Valid Percent	Cumulative Percent
Non formal	14	50.0	50.0	50.0
Primary education	10	35.7	35.7	85.7
Secondary education	4	14.3	14.3	100.0
Total	28	100.0	100.0	

Table 5. Size of farm

Farm Size	Frequency	Percent	Valid Percent	Cumulative Percent
1-2 acres	17	60.7	60.7	60.7
2-4 acres	5	17.9	17.9	78.6
4-6 acres	5	17.9	17.9	96.4
6 acres and above	1	3.6	3.6	100.0
Total	28	100.0	100.0	

Table 6. How frequently do you go to the farm?

Time	Frequency	Percent	Valid Percent	Cumulative Percent
Everyday	26	92.9	92.9	92.9
Weekly	1	3.6	3.6	96.4
Monthly	1	3.6	3.6	100.0
Total	28	100.0	100.0	

Areas of Information Needs

Majority of the farmers stated that the area they need information most is on agriculture, about 89% of the respondents stated they needed information on agriculture, followed by education where 75% of the respondents also stated they need information in that aspect, about 71% of the farmers also stated they need information on health, 32.1% of the respondents stated they need information about community and rural development, 25% of the farmers said they need information on politics (Table 9 and Figure 13).

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Figure 5.

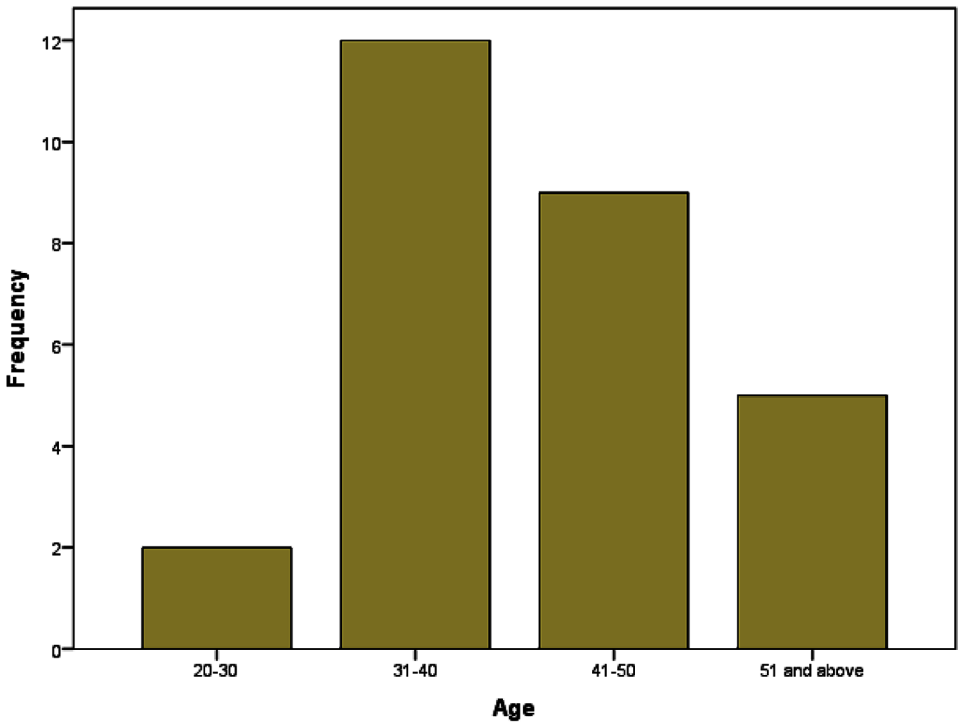

Figure 6.

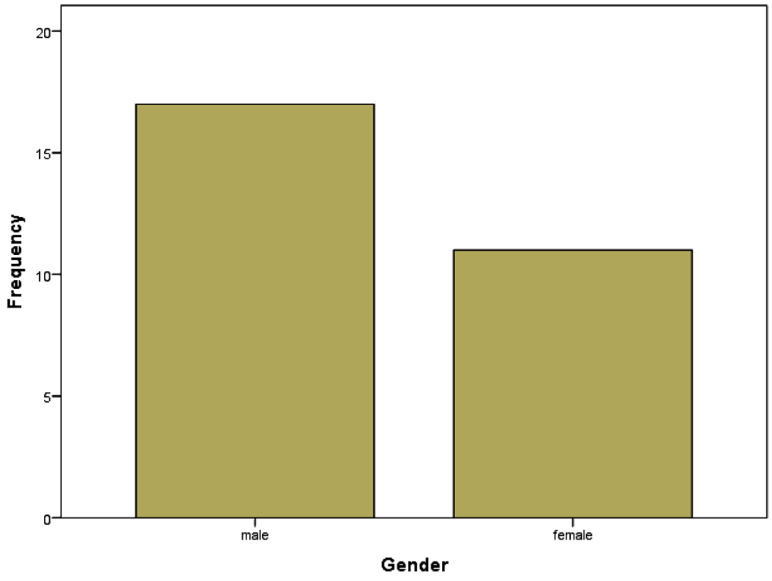

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Figure 7.

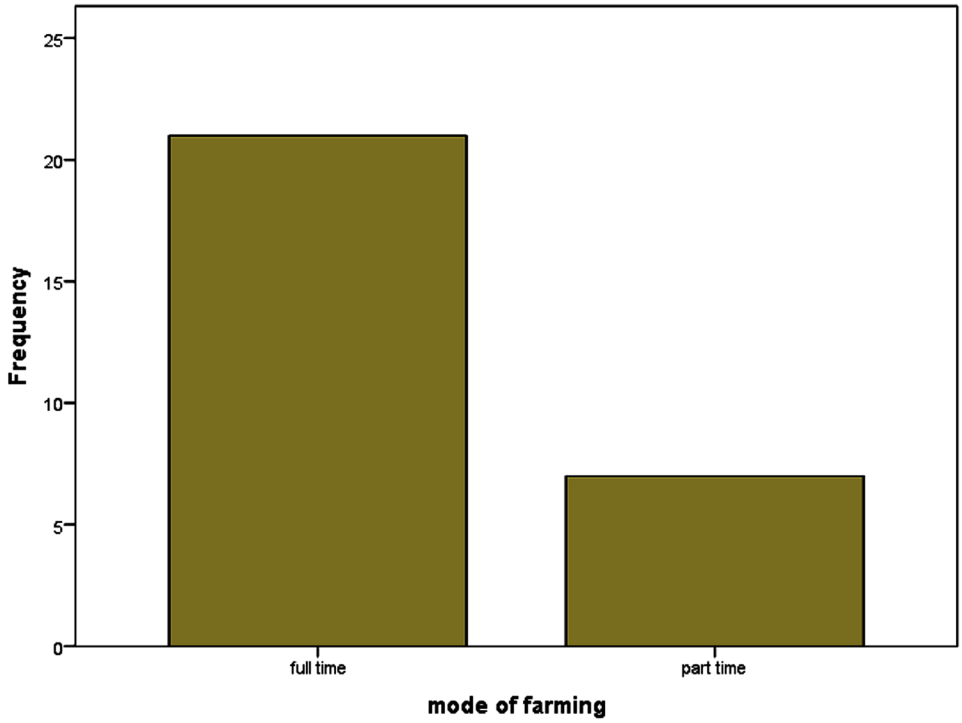

Figure 8.

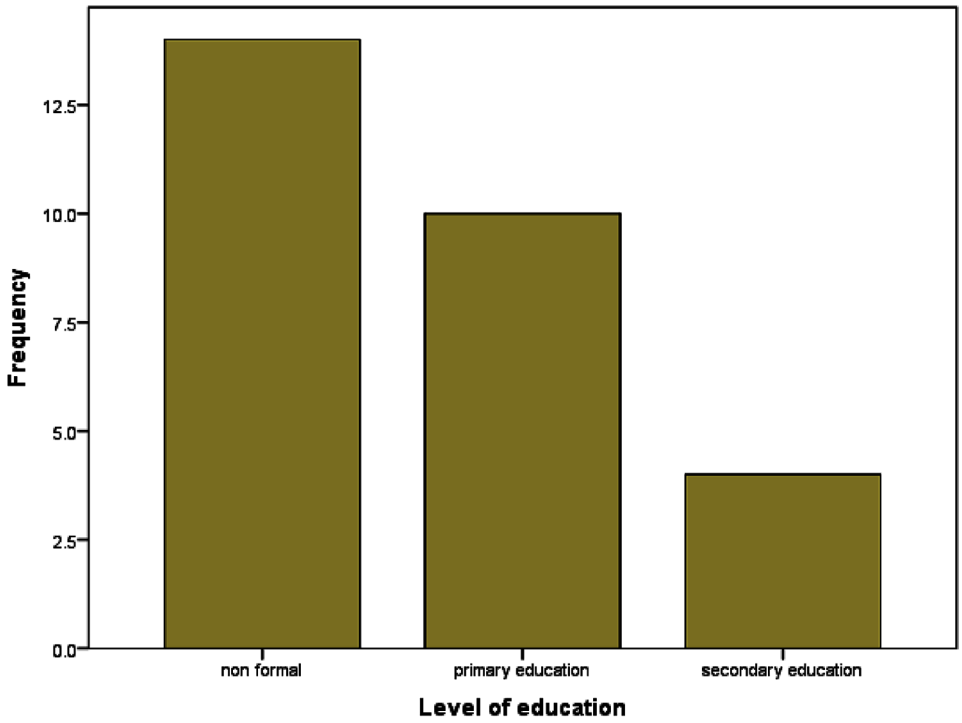

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Figure 9.

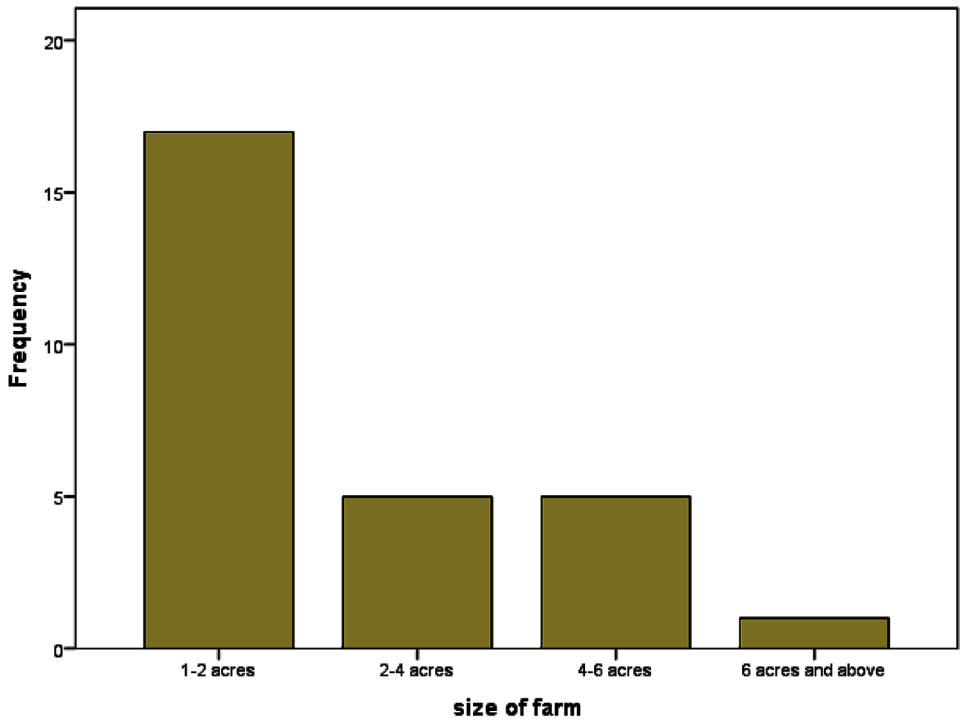

Figure 10.

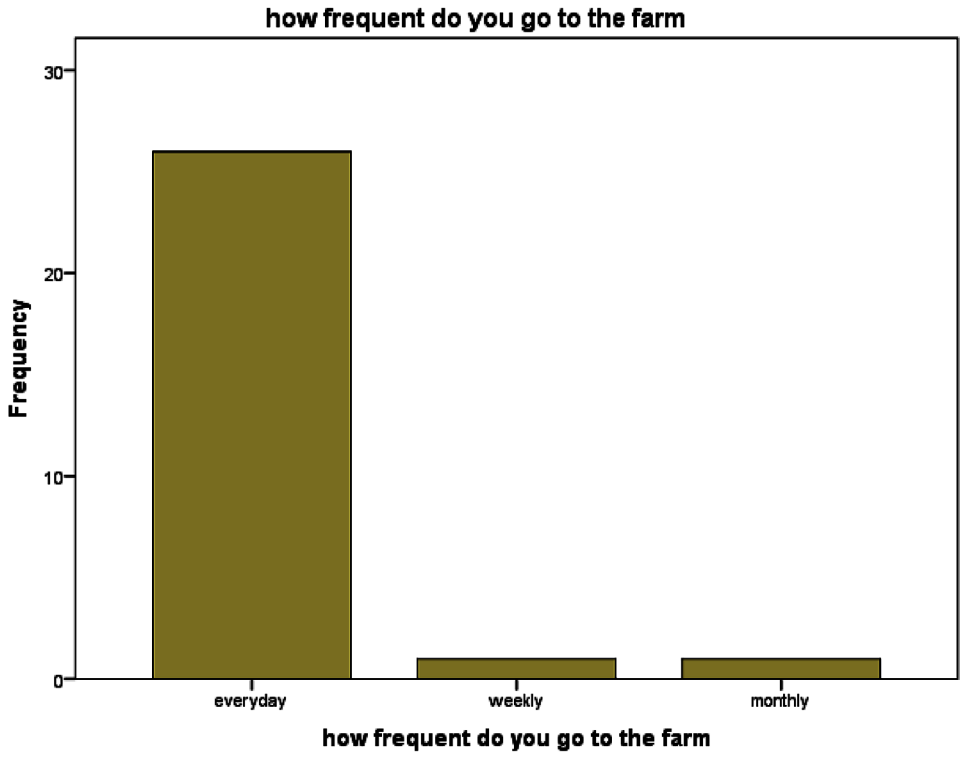

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Table 7. Type of livestock

Type of Livestock	Rating of Type of Livestock				Total
	Very Highly	Highly	Fairly	Not at All	
Cow	10.7%	7.1%	7.1%	75.0%	100.0%
Ram	21.4%	25.0%	17.9%	35.7%	100.0%
Pig	10.7%	7.1%		82.1%	100.0%
Goat	46.4%	21.4%	14.3%	17.9%	100.0%
Poultry	39.3%	28.6%	21.4%	10.7%	100.0%
Fish	3.6%	3.6%	7.1%	85.7%	100.0%
Total	22.0%	15.5%	11.3%	51.2%	100.0%

Table 8. Type of crops planted

Crops	Rating of Crops Planted				Total
	Very Highly	Highly	Fairly	Not at All	
Cassava	71.4%	21.4%	3.6%	3.6%	100.0%
Grains	67.9%	28.6%	3.6%		100.0%
Melon	57.1%	7.1%	17.9%	17.9%	100.0%
Rice	3.6%		3.6%	92.9%	100.0%
Groundnut	32.1%	21.4%	7.1%	39.3%	100.0%
Beans	14.3%	10.7%	32.1%	42.9%	100.0%
Yam	42.9%	39.3%	7.1%	10.7%	100.0%
Fruits	42.9%	25.0%	25.0%	7.1%	100.0%
Vegetable	50.0%	28.6%	17.9%	3.6%	100.0%
Total	42.5%	20.2%	13.1%	24.2%	100.0%

Information Need of Farmers on Agriculture

The information needs of the farmers on agriculture which is their major area of information needs are categorized into disease prevention, knowledge of price of farm produce in the market, source of loan for farming, how to obtain fertilizer, location of market to sell their agricultural produce, best mode of storage, labour cost and land maintenance (Table 10). 82.1% of the farmers agreed that they need to know how to prevent diseases affecting their farm produce. 64.3% of the respondents claimed they need information on how to get best price for their farm produce, 53.6% of the respondents indicated they need information on the best place to seek for loan. 71.4% of the respondents stated they need information on how to get effective agro-chemicals to apply on their farms. 64.3% of the respondents claimed they need information for more locations to sell their agricultural produce. 75% of the respondents indicated they need information on the best available mode of storage for their farm produce. 50% of the respondents indicated that they need information on how they can get labour to till the ground for them. 64.3% of the respondents claimed they need information on how to get tractors to clear their land for farming (Table 10 and Figure 14).

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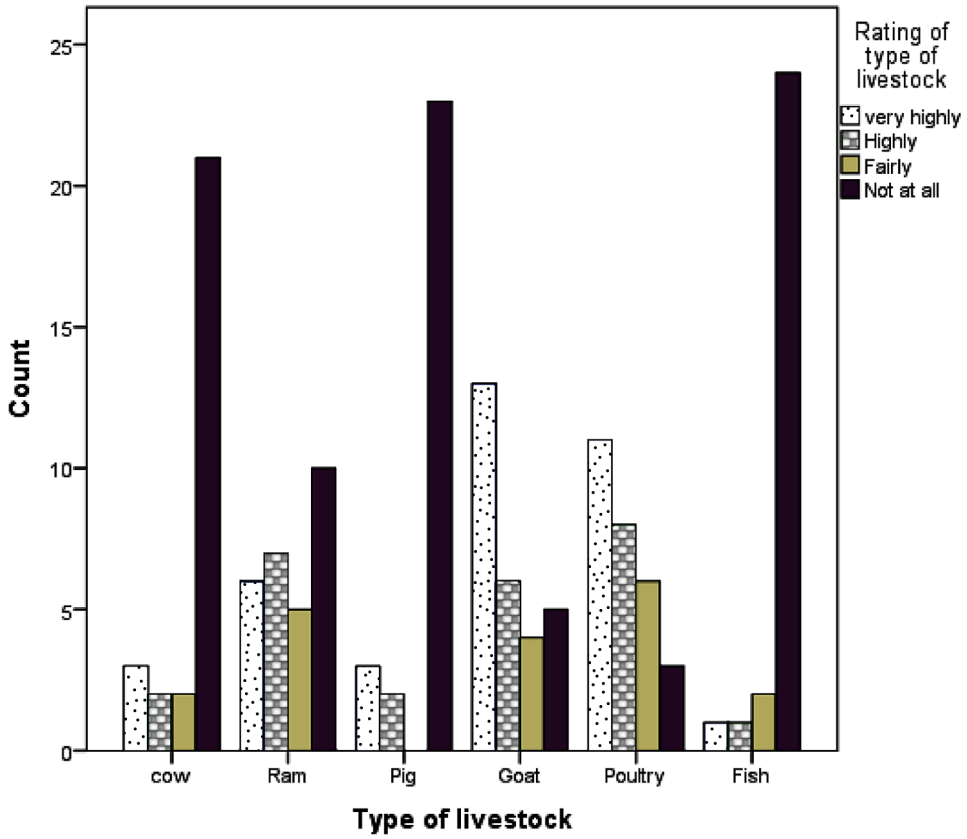
Figure 11.



Medium of Accessing Information

On the topic of accessing information, the farmers were asked orally whether they were aware of the presence of the information center and the library in their locality and if they used the places to seek information. The response from them shows that a majority are aware of the presence of the building but do not go there to seek for information. the response from the respondents from the questionnaire shows that, (see Table 11) 17.9% of these farmers' access information through the information center. 10.7% of the respondents were not aware of the information centre, 35.7% of the respondent who knew of the information centre occasionally use it. Another 35.7% said they don't use the centre at all. On information seeking behavior of the farmers, 57.1%, 60.7% and 60.7% of the respondents claim that they mostly collect information through their colleagues(co-farmers), friends and Association Members, respectively (Table 11). Further results showed that there are other sources where the respondents obtain information apart from the ones earlier stated. The usage of such other means like Radio, community heads, Extension Workers, Newspapers and Magazines by the respondents was 57.1%, 50%, 34.5% and 28.6% respectively. (Table 11). From the oral interview conducted with the respondents, it can be noted that the discussion over the radio broadcast was a strong information source. The respondents value radio broadcasts highly, especially when the broadcast is delivered in their local languages. As shown in (Table 11) seminars and workshop were not popular medium for gathering information by the

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Figure 12.

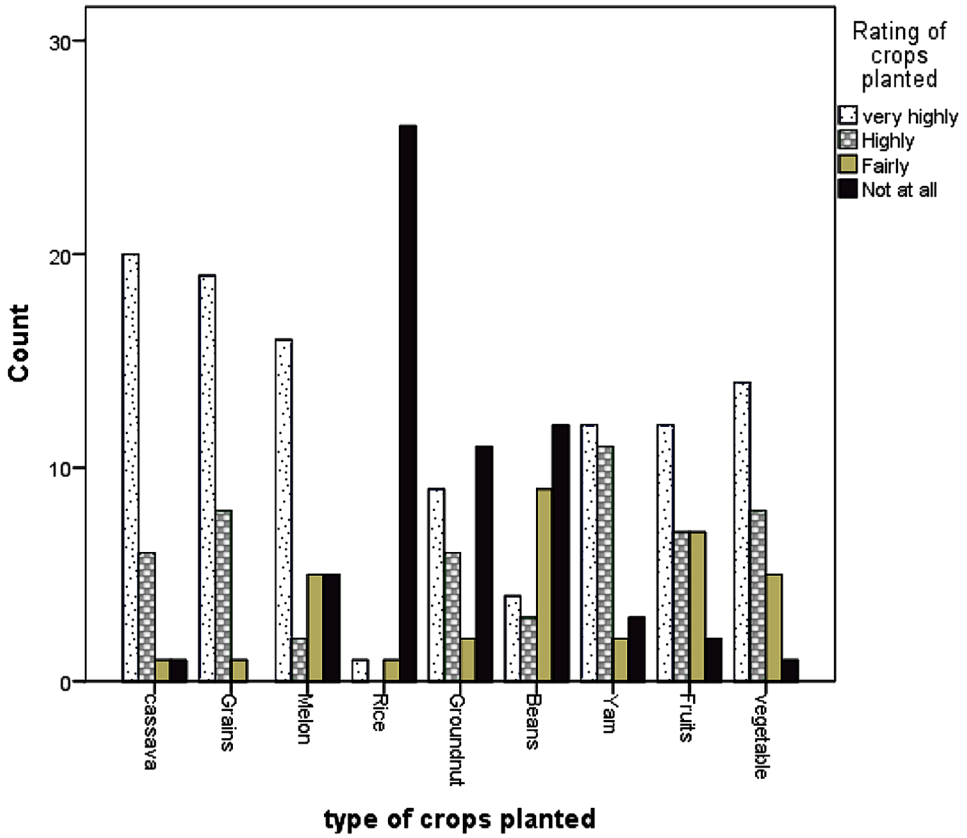

Table 9.

	Rating of Areas of Information Needs				Total
	Very Highly	Highly	Fairly	Not at All	
Politics	25.0%	39.3%	28.6%	7.1%	100.0%
Health	71.4%	25.0		3.6%	100.0%
Agriculture	89.3%	7.1%		3.6%	100.0%
Education	75.0%	21.4%		3.6%	100.0%
Community and rural development	32.1%	57.1%	10.7%		100.0%
Total	58.6%	30.0%	7.9%	3.6%	100.0%

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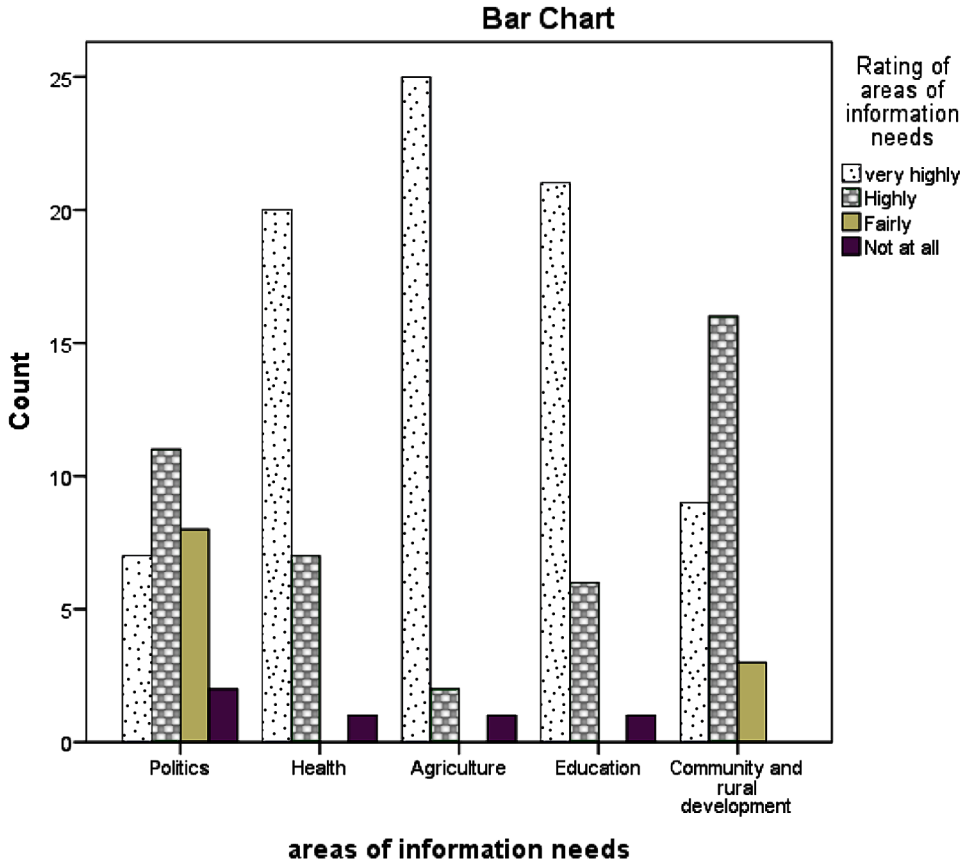
Figure 13.



respondents, only 25.9% of the respondents indicated that seminar and workshop had been a medium of getting information (Table 11 and Figure 15).

Challenges/Problems Highlighted by Respondents When Seeking Information

On challenges faced by the respondents when seeking for information (Table 12) shows that the most common problem the respondents experienced in getting information from other sources apart from their colleagues, friends and relatives is the inability to read and write, with 67.9% of the respondents indicating that they cannot read and write, hence they are constrained in using any information that is in English language. Availability of limited time after farm work is also seen as a constraint to farmers to seek for needed information 46.4% of the respondent agreed very highly to it, while 32.1% of the respondent also agreed highly to it, making a total of 78.5% of the respondents. also other challenges faced by the farmers; another noticeable constraint faced by the farmers is the lack of money to purchase airtime for their mobile phone to obtain information. 32.1% of the respondents agreed very highly to this problem, while 10.7% agreed to it highly and 32.1% said it is occasional and 25.0% of the respondents did not agree at all. Similarly, 39.3% of the respondents indicated that inability to use mobile phone is a challenge, with 14.3% of the respondents agreeing to it highly and 32.1% of the respondents agree-

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Table 10. Information needs of farmers on agriculture

	Rating of Need of Farmers				Total
	Very Highly	Highly	Fairly	Not at All	
How to take care of livestock	57.1%	21.4%	7.1%	14.3%	100.0%
Best price available for my farm produce	64.3%	21.4%	10.7%	3.6%	100.0%
How to prevent diseases for my farm produce	82.1%	17.9%			100.0%
How to get loans	53.6%	28.6%	7.1%	10.7%	100.0%
Best fertilizer for my farm	64.3%	25.0%	10.7%		100.0%
how to marketing my farm product	64.3%	25.0%	10.7%		100.0%
how to store my farm produce	75.0%	14.3%	7.1%	3.6%	100.0%
Cost of labour in my farming	50.0%	32.1%	14.3%	3.6%	100.0%
How to get tractors to clear my land	64.3%	21.4%	3.6%	10.7%	100.0%
How to get agro chemicals	71.4%	21.4%	7.1%		100.0%
How to treat myself from ailments	64.3%	32.1%	3.6%		100.0%
Education of my children	57.1%	39.3%	3.6%		100.0%
Where to get good treatment for my health problem	57.1%	39.3%	3.6%		100.0%
Political situation of the local/ state/federal government	39.3%	42.9%	17.9%		100.0%
Available workshop and capacity building	50.0%	28.6%	21.4%		100.0%
Total	61.0%	27.4%	8.6%	3.1%	100.0%

ing to it fairly, we can say the inability to use mobile phones can be seen as a challenge to accessing information. Also, 32.1% of the respondents indicated that language barrier is a hindrance because from the oral interview, it is noticeable that most of the information available to the respondents from radio, newspapers and documents from government extension officers are written in English language. 39.3% of the respondents indicated very highly that lack of constant electricity is a challenge, while 32.1% of the respondents indicated highly, 25% of the respondents indicated fairly, 3.6% of the respondents did not see it as a challenge at all. From the oral interview, the constraint of electricity was attributed to contribute to their inability to charge their mobile phones, watch television and listen to radio broadcast, 42.9% of the respondents agreed very highly that the fear of going to urban areas to seek for information is a challenge, while 25% of the respondents agreed highly, 25% of the respondents agreed fairly, 7.1% of the respondents did not agree at all. 42.9% of the respondents claimed very highly that lack of reliable source of information in the community is a challenge to accessing information, 25% of the respondents agreed highly, while 21.4% of the respondents agreed to it fairly, while 10.7% of the respondents did not agree at all. The next variable is to confirm how satisfactory the respondents get access to government extension worker so as to get information on issues relating to their farm, the results shows that 17.9% of the respondents indicated very highly that they do not have access to extension workers, while 10.7%

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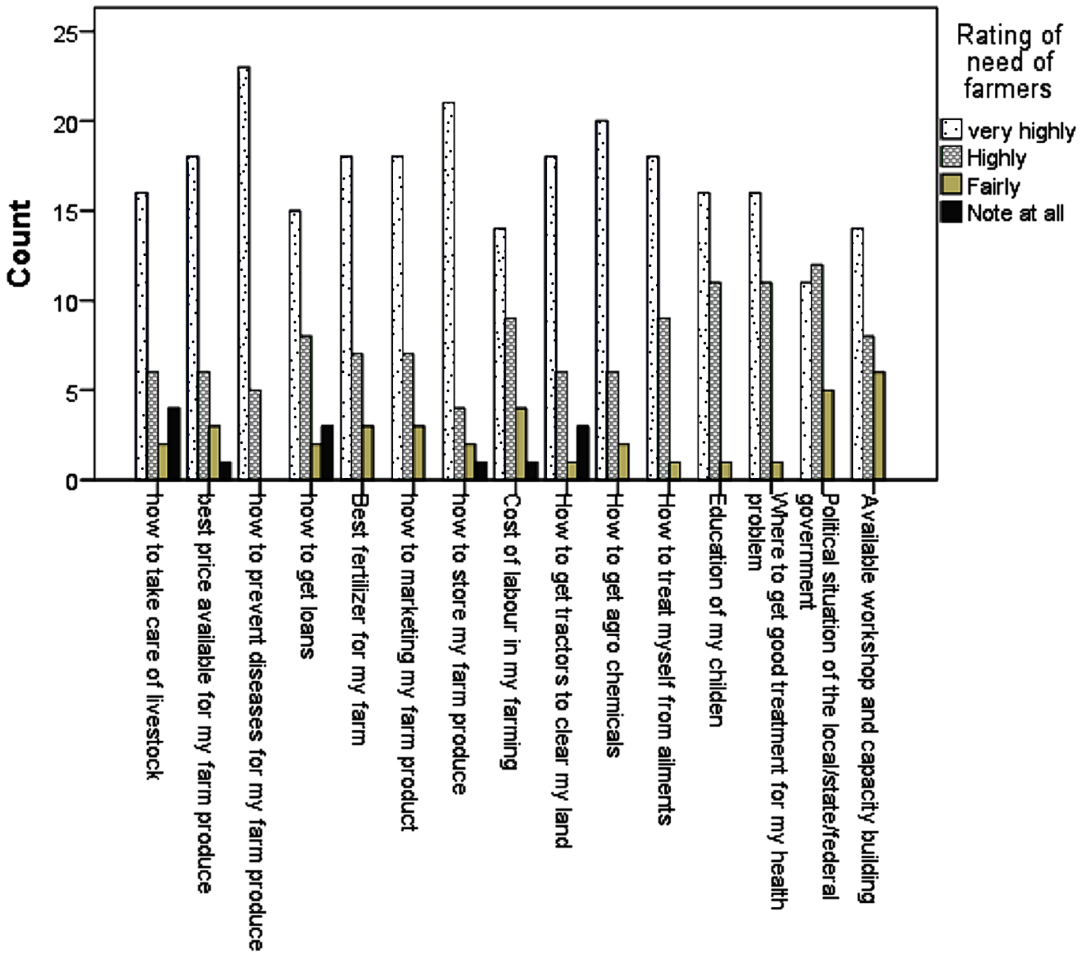
Figure 14.



of the respondents also agreed highly to it, 28.6% of the respondents also agreed fairly to it, while 42.9% of the respondents indicated that they have access to government extension workers. The study also tried to find out if conflict among various associations that exist in the community has ever been a hindrance to seeking information by the respondents, the findings in this case shows that 28.6% of the respondents indicated very highly that conflict among association of farmers can prevent information from getting to each other, 15.7% of the respondents agreed highly to it, 10.7% of the respondents agreed fairly to it, while 45% of the respondents did not agree at all. It could be observed that cumulatively, the conflict in association could be a hindrance to seeking and accessing information. However, despite all the identified problems, it is noticeable that about three of the variables does not constitute any hindrance to the process of accessing information to the respondents. For example, availability of network for mobile communication was not seen as a problem for getting information, only 25% of the respondents agreed very highly that lack of network for mobile communication is a challenge, while 10.7% of the respondents also agreed to it highly, 7.1% of the respondents agreed to it fairly, and 57.1% of the respondents did not agree to it at all. Similarly, body disability of any form was not accepted by the respondent as hindrance to seek information, from the analysis, 3.6% of the respondents indicated very highly that body

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Table 11. Medium of accessing information

	Rating of Medium of Accessing Information				Total
	Very Highly	Highly	Fairly	Not at All	
Cyber café	3.6%			96.4%	100.0%
Colleagues	57.1%	39.3%	3.6%		100.0%
Friends	60.7%	32.1%	7.1%		100.0%
Member	60.7%	28.6%	7.1%	3.6%	100.0%
Newspaper/magazine	28.6%		21.4%	50.0%	100.0%
Radio	57.1%	25.0%	17.9%		100.0%
Centre's in the town	17.9%	35.7%	10.7%	35.7%	100.0%
Television	42.9%	21.4%	17.9%	17.9%	100.0%
Library	10.7%	10.7%		78.6%	100.0%
seminar and workshop	25.9%	1.1%	8.5%	64.4%	100.0%
Extension office	34.5%	31.0%	31.0%	3.4%	100.0%
Community head	50.0%	32.1%	17.9%		100.0%
Religion	53.6%	39.3%	7.1%		100.0%
opinion leaders	39.3%	25.0%	28.6%	7.1%	100.0%
political leaders	28.6%	25.0%	42.9%	3.6%	100.0%
Total	38.1%	23.8%	15.5%	22.6%	100.0%

disability is a challenge, 10.7% of the respondents also agreed highly that it is a challenge, while 3.6% of the respondents agreed to it fairly. However, 82.1% did not agree at all that body disability hinders them from seeking information. The study also endeavored to find out if cultural difference among the farmers has been a hindrance to seek information, the respondents' response to this shows that 25% of the respondents indicated highly that cultural difference is a challenge faced by them in accessing information, 5.7% of the respondents also agreed highly, 15% of the respondents agreed fairly to it, however 54.3% of the respondents did not agree at all (Table 12 and Figure 16).

DISCUSSION OF FINDINGS

Information Needs of Respondents

Information on crops disease prevention, marketing agricultural products, agricultural loan and agro chemicals were the major information needs for farmers in the study area. This implies that farmers lack access to market information for their crops. This is consonance with Shepherd, (2000), who pointed out that information on, quantities traded, market prices and other marketing-related matters rarely reaches farmers in developing countries. Also, the study revealed that most farmers did not know where to get loans, similarly the study also indicated that the farmers need information on how to hire tractors to for land maintenance or purchase agricultural tools such as power tillers, which could be used to improve their agricultural productivity. Munyambonera et al., (2012) adds that availability and access to adequate,

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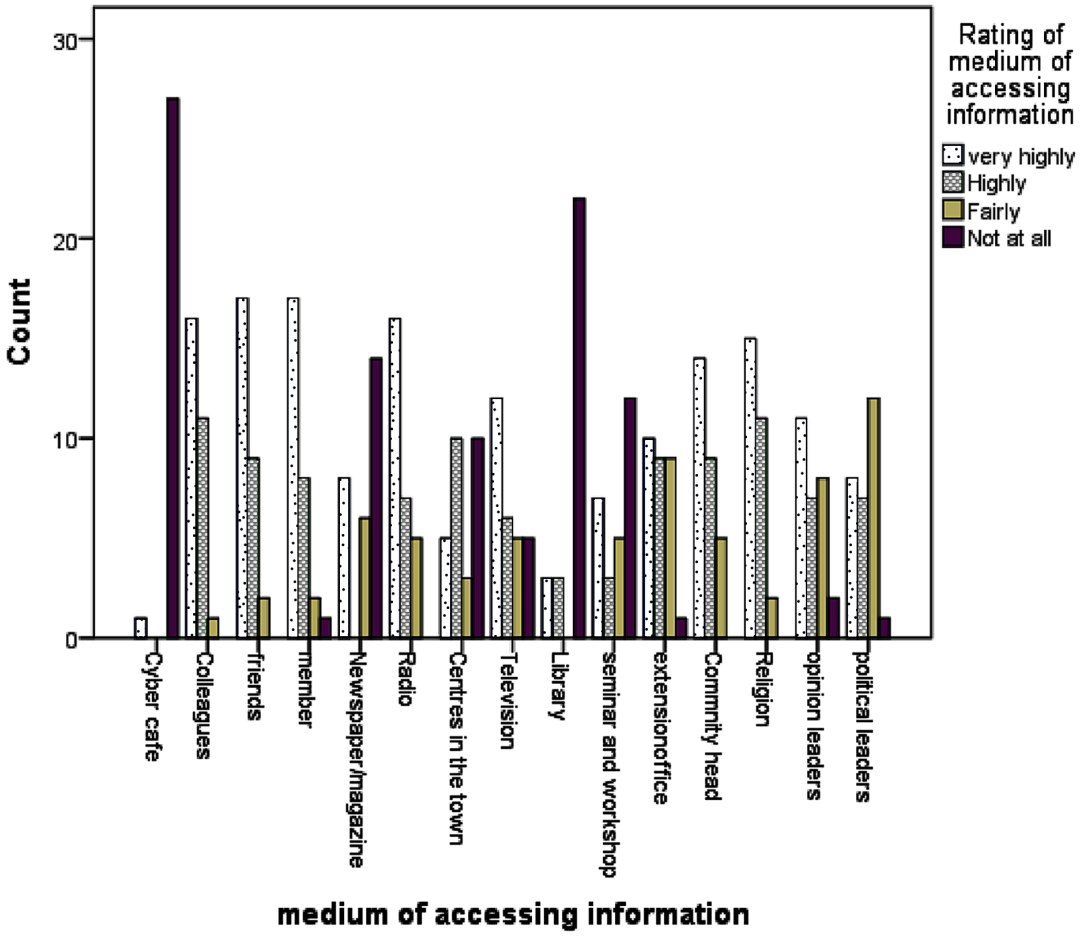
Figure 15.



timely and information on low cost credit from different institutional sources is of great importance especially to small and marginal farmers.

Medium of Accessing Information

Colleagues (co-farmers), personal experience, neighbors or friends and agricultural extension officers were the major sources of information used by the farmers in accessing agricultural information. The implication here is that most of the respondents relied on interpersonal sources in accessing agricultural information, probably because of their regularly availability and accessibility. Lwoga et al., (2011) for instance stressed that interpersonal sources such as friends, relatives and neighbours are all the time become the main providers of the agriculture information due to their credibility, reliability and most of all, they are trusted by the rural community. However, none of the respondents reported to use neither internet nor library and information centres in accessing agricultural information. This is probably because of low level of education, lack of electricity, lack of libraries or information centres in the rural areas, lack of of the role of internet in provision of agricultural information to farmers and lack of lack

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Table 12. Challenges/problems faced

Challenges/Problems Faced	Rating of the Challenges Faced				Total
	Very Highly	Highly	Fairly	Not at All	
Mobile communication	25.0%	10.7%	7.1%	57.1%	100.0%
Purchase credit	32.1%	10.7%	32.1%	25.0%	100.0%
Inability to use phone	39.3%	14.3%	32.1%	14.3%	100.0%
Body disability	3.6%	10.7%	3.6%	82.1%	100.0%
Extension workers	17.9%	10.7%	28.6%	42.9%	100.0%
Language barrier	32.1%	3.6%	35.7%	28.6%	100.0%
No electricity	39.3%	32.1%	25.0%	3.6%	100.0%
Inability to read and write	67.9%	25.0%	7.1%		100.0%
Limited time to seek for information	46.4%	32.1%	7.1%	14.3%	100.0%
Fear of going to urban areas	42.9%	25.0%	25.0%	7.1%	100.0%
Conflict among association member	28.6%	15.7%	10.7%	45.0%	100.0%
Lack of information center	35.7%	28.6%	17.9%	17.9%	100.0%
Unreliable source of information	35.7%	39.3%	17.9%	7.1%	100.0%
Lack of authentic transfer information	42.9%	25.0%	21.4%	10.7%	100.0%
Cultural difference	25.0%	5.7%	15.0%	54.3%	100.0%

of ICTs infrastructure in rural areas. Finding of this study are not surprising as they are in line with what have been reported previously by Benard (2011), Mtega and Benard (2013); Shaffril et al. (2010) and Samah et al. (2011). For instance, have established a few reasons why farmers are reluctant to use advance technology in accessing agricultural information such as internet, and among the reasons are do not know the benefits of the advance technology; they are illiterates: do not have skills or expertise in using the advance technology; lack of time spent on ICT and difficulties in using ICT. This therefore, calls for the government to create enabling environment for the farmers to use this modern technology so as they can access timely and current agricultural information.

Challenges Faced by Respondents in Accessing Agricultural Information

The majority of the respondents cited inability to read and write in English language in the study area was one the challenges facing farmers in accessing information. Through the oral interview with the key informants and personal observation via the researcher it was noted that there were no information services available in the area of the study such as village/ward libraries and the information centre in the community is only present but it is not utilized by the farmers. This is a common problem in most rural farmers. Therefore, agricultural extension workers should regard it as a challenge and provide farmers with access to current and relevant agricultural information. The findings further revealed the inadequate numbers of extension agents as major challenges constraining farmers from accessing information. For instance, in the study, the farmers indicated that lack or non-availability of extension officers is a challenge. In view of this, they do not have enough information to access from the agricultural extension

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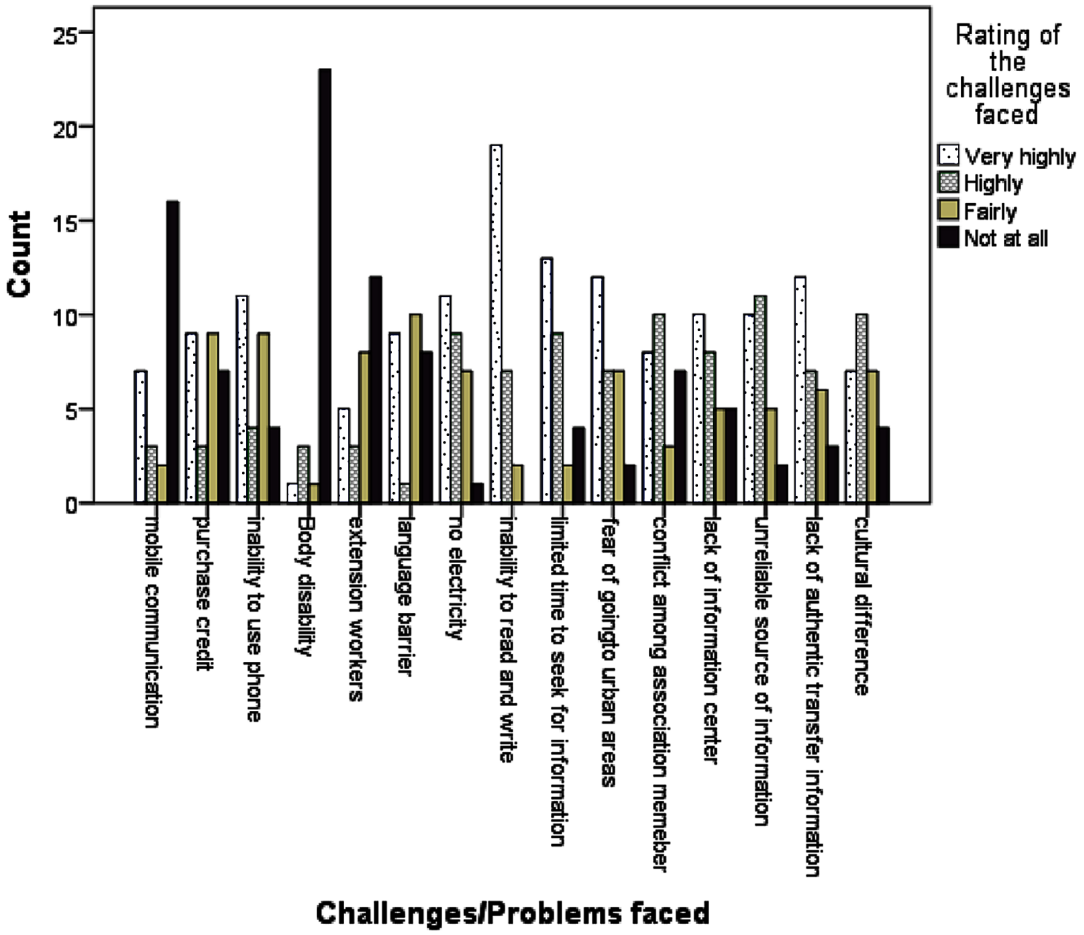
Figure 16.



officers. This also is in line with what have been found by Aina's (2006) findings, which revealed that the ratio of agricultural extension workers to the population in Africa is low. Similarly, inadequate funds were another challenge hindering farmers from accessing agricultural information as it was pointed by majority of the respondents. Due to financial problems, some of the farmers cannot afford to buy airtime, also, due to lack of electricity, the farmers are usually unable to charge their mobile phones to access and communicate information. Therefore, agricultural information sources and services where they exist should be widely published and promoted, not only to create awareness but also to promote and encourage usage by farmers.

CONCLUSION

According to Sarah et al (2012) in recent decades the value of information has increased considerably as the agricultural systems in developing countries become knowledge intensive. Therefore, the need to determine how farmers access information, the medium they use and the constraint that hinders their free

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access to required information is very important because like any other business farmers need concise, timely and comprehensive information to avoid loss of their farm produce, both on the farm and storage level, and also require appropriate environment to sell their produce for profit, all these and others are important factors to increase farmers productivity and consequently availability of food for citizens and sustenance of the nation. It is in this regard that this research is very important and findings can be of immense importance to guide research institute, state agricultural policy makers and international agencies who are also interested in the farming system in Nigeria.

RECOMMENDATIONS

It could be observed that from the age group, majority of farmers in laduba community are within the age range of 31-40, it is important that necessary incentives and encouragement is given to attract the youths of younger age to farming for availability of food for the nation.

It is noticeable that females form part of the farming population in Laduba, this is quite encouraging, for the population of the female to be improved, adequate access to information that will educate them and invoke their interest in farming is necessary.

The education status of farmers in in this study reveals that great percentage of them does not have formal education, only 14.3% of them had secondary education, this may hinder access to vital farming information from documentaries of national and international agricultural agencies. Hence, there is need for the farmers to be introduced to formal education through adult education programme on radio and television using the laduba information centre effectively.

From the study, the farmers significantly declared that information in agriculture is their major area of interest, therefore it is now important that all media that will assist the farmers to get concise, accurate and comprehensive information be made available to them. This may increase their interest in farming and consequently boost their economic level and consequently eradicate poverty among them and the nation in general.

Concerted effort should be made by government extension workers to provide the farmers information on how to prevent diseases on their crops on the field and also the best storage method for their farm produce, also they should be provided information on the best agro-chemicals to apply on their farm.

The information centre presently in the village should be improved for farmers to use it, human resource personnel that will promote its usage should be employed, the information center should have medium of disseminating information like radio and television and a well-stocked library could be developed in the centre, stocked with information materials to promote adult education programmes and enlightenment on different areas of farming. The documents acquired for these purpose should be in local languages and those written in simple understandable English language words.

The government should improve on the electricity in some of the rural areas including Laduba community and negotiate with operators of mobile communications, so that they can have subsidized airtime to communicate and receive information.

The group of extension workers like those from Kwara State Agricultural development project (ADP) and Nigerian Stored Products Research Institute (NSPRI) should interact effectively to give the farmers timely and necessary information they require and the extension workers should endeavor to sustain friendliness among the members of associations that exist in the community so that any conflict will not arise among them that will disrupt information sharing.

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REFERENCES

Adereti, F. O., Fapojuwo, O. F., & Onasanya, A. S. (2006). Information on utilization on cocoa production techniques by farmers in Oluyole Local Government Area of Oyo State, Nigeria. *European Journal of Soil Science*, *3*(1), 1–7.

Aina, L. O. (2006, August 20-24). Information Provision to Farmers in Africa: The Library- extension service linkage. *Proceedings of the World library and information congress, 72nd IFLA general conference and council '06*, Seoul, Korea. Retrieved from http://www.ifla.org/iv/ifla72/index.htm

Ajayi, O.O. (2002). African Response to the Information Communication Technology Revolution: A case study of the ICT development in Nigeria (ATPS Special Paper Series No 8).

Anwar, M. A. (2007). Research on information seeking and use in Pakistan: An assessment. *Pakistan Journal of Library and Information Science*, *8*, 15–32.

Aziagba, P. C., & Okede, G. W. (2011). information seeking behavior of cassava farmers in Upata clan, Ekpeye community of Rivers State, Nigeria.

Babu, S. C., Glendenning, C. J., Asenso-Okyere, K., & Govindarajan, S. K. (2012). Farmer's information needs and search behaviors. IFPRI Discussion paper 01165.

Borgman, C. L. (2000). *From Gutenberg to the global information infrastructure: access to information in the network world*. Cambridge, MA: MIT Press.

Brophy, P. (1993). Networking in British academic libraries. *British Journal of Academic Librarianship*, *8*(1), 49–60.

Butterworth, R. (2006, June 15). Information seeking and retrieval as a leisure activity. DL-CUBA 2006 - Workshop on digital libraries in the context of users' broaden activities, Chapel Hill, USA. *Proceedings of JCDL '06*. Retrieved from http://www.uclic.ucl.ac.uk/events/dl-cuba2006/papers/Butterworth.pdf

Dadzie, P. S. (2005). Electronic resources: Access and usage at Ashesi University College. *Campus-Wide Information Systems*, *22*(5), 1065–0741. Retrieved from http://www.emeraldinsight.com/Insight/ViewContentServlet doi:10.1108/10650740510632208

Devadason, F. J., & Pratap, P. L. (1997). Methodology for the identification of information needs and uses of users. *IFLA Journal*, *23*(1), 41–51. doi:10.1177/034003529702300109

Ellis, D. (1993). Modeling the information-seeking patterns of academic researchers: A grounded theory approach. *The Library Quarterly*, *63*(4), 469–486. doi:10.1086/602622

Ellis, D., Cox, D., & Hall, K. (1993). A Comparison of the Information Seeking Patterns of Researchers in the Physical and Social Sciences. *The Journal of Documentation*, *49*(4), 356–369.

Ellis, D., & Haugan, M. (1997). Modelling the Information Seeking Patterns of Engineers and Research Scientists in Industrial Environment. *The Journal of Documentation*, *53*(4), 384–403. doi:10.1108/EUM0000000007204

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Hayden, K.A. (1999). Information Seeking Models. Retrieved from http://www.ucalgary.ca/~ahayden/seeking.html

Järvelin, K., & Wilson, T. D. (2003). On conceptual models for information seeking and retrieval research. *Information Research*, 9(1). Retrieved from http://InformationR.net/ir/9-1/paper163.html

Kakai, J. M., Ikoja-Odongo, R., & Kigongo-Bukenya, I. M. N. (2004). A study of the information seeking behavior of undergraduate students of Makerere University, Uganda. *World Libraries*, 14(1). Retrieved from http://www.worlib.org/vol14no1/print/kakai_print.html

Krikelas, J. (1983). Information-seeking behaviour: Patterns and concepts. *Drexel Library Quarterly*, 19(2), 5-20, 78.

Kuhlthau, C. C. (1993). *Seeking meaning: a process approach to library and information services*. Norwood, NJ: Ablex Publishing.

Lwoga, E. T., Stilwell, C., & Ngulube, P. (2011). Access and use of agricultural information and knowledge in Tanzania. Retrieved from http://ir.muhas.ac.tz:8080/jspui/bitstream/123456789/1368/1/library_review_paper_lwoga_Stilwel_Ngulube.pdf

Meho, L. I., & Tibbo, H. R. (2003). Modeling the information-seeking behavior of social scientists: Ellis's study revisited. *Journal of the American Society for Information Science and Technology*, *54*(6), 570–587. doi:10.1002/asi.10244

Menzel, H. (1996). Information needs and uses. In C.A. Cuadra (Ed.), Annual Review of Information Science and Technology (ARIST) (Vol. 1, pp. 41-69). USA: Interscience Publishers.

Momoh, A. U, Osaheni, O & Oshioneb, F. (2015). Information seeking behavior of nurses in central hospitals in Delta State. *Pyrex Journal of Library and Information Science*, 1(3), 26.

Mtega, W., & And Benard, R. (2013). The state of rural information and communication services in Tanzania: A meta-analysis. *International Journal of Information and Communication Technology Research*, *3*(2), 64–73.

Munyambonera, E., Nampewo, D., Adong, A., & Mayanja, M. (2012). Access and Use of Credit in Uganda: Unlocking the Dilemma of Financing Small Holder Farmers. Retrieved from http://ageconsearch.umn.edu/bitstream/150229/2/policybrief25.pdf

Okunade, O. S. & Williams, J. O. (2014). *Agriculture in Nigeria: problems, consequences and the way forward*. Ilorin: Adewumi press.

Price, A. C. (2009). How to make a dollar out of fifteen cents: Tips for electronic collection development. *Collection Building*, *28*(1), 31–34. doi:10.1108/01604950910928493

Ray, K., & Day, J. (1998). Student attitudes towards electronic information resources. *Information Research*, 4(2). Retrieved from http://informationr.net/ir/4-2/paper54.html

Robinson, A. (2006). Open access: The view of a commercial publisher. *Journal of Thrombosis and Haemostasis*, *4*(7), 1454–1460. doi:10.1111/j.1538-7836.2006.02009.x PMID:16839337

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Saravan,, R., & Raja,, P., & Tayeng, S. (2009). Information input pattern and information need of Tribal Farmers in Arnuchal Pradesh, *Indian Journal of Extension Education*, *45*(1&2), 51-54

Shaffril, H. A. M., Samah, B. A., Hassan, M. A., & Silva, J. L. (2010). Socio-economic factors that impinge computer usage in administration works among village leaders in Malaysia. *Scientific Research and Essays*, *5*, 3623–3633.

L. Shanta Meitei & Th. Purnima Devi. (2009). Farmers information Needs in Rural Manipur: an assessment. *Annals of Library and information studies*, 56(2), 35-40

Shao, X., & Scherlen, A. (2007). Perceptions of open access publishing among academic journal editors in China. *Serials Review*, *33*(2), 114–121. doi:10.1080/00987913.2007.10765105

Sharma, P. S. K. (1990). *Universe of knowledge and research methodology*. Delhi: Ken Publications.

Shuling, W. (2007). Investigation and analysis of current use of electronic resources in university libraries. *Library Management*, *28*(1/2), 72–88. Retrieved from http://www.emeraldinsight.com/Insight/ViewContentServlet?Filename=Published/EmeraldFullTextArticle/Articles/0150280107.html doi:10.1108/01435120710723563

Solomon, P. (2002). Discovering information in context. *Annual Review of Information Service and Technology*, *36*(1), 229–264. doi:10.1002/aris.1440360106

Stigter, C. J. (2002). Opportunities to improve the use of seasonal climate forecasts. Bangkok, Thailand: Asian Disaster Preparedness Center (ADPC).

Swain, D. K., & Panda, K. C. (2009). Use of electronic resources in business school libraries of an Indian state: A study of librarians' opinion. *The Electronic Library*, *27*(1), 74–85. doi:10.1108/02640470910934605

Swain, D. K., & Panda, K. C. (2009). Use of electronic resources in business school libraries of an Indian state: A study. *Collection Building*, *28*(3), 108–116. doi:10.1108/01604950910971134

Swanson, B. (2008). Global review of good agricultural extension and advisory service systems. Food and Agricultural Organization, Rome.

Swanson, B., & Rajalahti, R. (2010). *Strengthening agricultural extension and advisory systems: procedures for accessing, transforming and evaluating extension systems. Agricultural and rural development discussion* (p. 45). Washington, DC: World Bank.

Tella, A., Tella, A., Ayeni, C. O., & Omoba, R. O. (2007). Self-Efficacy and Use of Electronic Information as Predictors of Academic Performance. *Electronic Journal of Academic and Special Librarianship*, 8(2). Retrieved from http://southernlibrarianship.icaap.org/content/v08n02/tella_a01.html

Thachill, G. (2008). Academic Libraries Redefined: Old Mission with a New Face. Scroll, 1(1).

Tologbonse, D., Fashola, O., & Obadiah, M. (2008). Policy Issues in Meeting Rice Farmers Agricultural Information Needs in Niger State. *Journal of Agricultural Extension*, *12*(2), 84–94.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Toner, L. (2008). Non-use of Library Services by Students in a UK Academic Library. *Evidence Based Library and Information Practice*, 3(3). Retrieved from http://ejournals.library.ualberta.ca/index.php/EBLIP/article/view/1330/1241

Tsakonas, G., & Papatheodorou, C. (2006). Analysing and evaluating usefulness and usability in electronic information services. *Journal of Information Science*, *32*(5), 400–419. doi:10.1177/0165551506065934

Weiler, A. (2005). Information-Seeking Behavior in Generation Y Students: Motivation, Critical Thinking, and Learning Theory. *Journal of Academic Librarianship*, *31*(1), 46–53. doi:10.1016/j.acalib.2004.09.009

Wilson, T. D. (1999). Models in information behavior research. *The Journal of Documentation*, *55*(3), 249–270. doi:10.1108/EUM0000000007145

Wilson, T. D. (2000). Recent trends in user studies: Action research and qualitative methods. *Information Research*, 5(3). Retrieved from http://informationr.net/ir/5-3/paper76.html

Zhang, Y. (2001). Scholarly use of internet-based electronic resources. *Journal of the American Society for Information Science*, *52*(8), 628–654. doi:10.1002/asi.1113

ADDITIONAL READING

Lenz, E. R. (1984). Information seeking: A component of client decisions and health behavior. *ANS. Advances in Nursing Science*, *6*(3), 59–72. doi:10.1097/00012272-198404000-00010 PMID:6426379

Okwu, O. J., & Umoru, B. I. (2009). A study of women farmers' agricultural information needs and accessibility: A case study of Apa Local Government Area of Benue St. Retrieved from http://www.academicjournals.org/AJAR

Saima Sadaf, Asif Javed, & Muhammad Luqman. (n. d.). Preferences of Rural Women for Agricultural Information Sources: A Case Study of District Faisalabad–Pakistan. *Journal of Agriculture & Social Sciences.* Retrieved from http://www.fspublishers.org

Sharma, A. K. (2007). Information Needs and Sharing Pattern among Rural Women: A Study. *IASLIC Bulletin*, *52*(3), 156–167.

KEY TERMS AND DEFINITIONS

Community: A group sharing a common understanding and often of the same language, manners, tradition and law.

Farming: The act of cultivating land for the purpose of planting desired agricultural crops for sustenance of life and profit making.

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Information: A processed data being searched for to use to enhance occupation and other things that sustains life.

Information Need: A piece of information, whether recorded or not, which an individual or a member of a group requires for effective functioning in their daily activities.

Information Seeking Behavior: An individual's way and manner of gathering and sourcing for information for personal use.

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Chapter 65
Congo Basin's Shrinking Watersheds:
Potential Consequences on Local Communities

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ABSTRACT

Rainfall time series data from three sites (Kinshasa, Luki, and Mabali) in the western Democratic Republic of Congo were analyzed using regression analysis; rainfall intensities decreased in all three sites. The Congo Basin waters will follow the equation $y = -20894x + 5483.16$; $R^2 = 0.7945$. The model suggests 18%-loss of the Congo Basin water volume and 7%-decrease for fish biomasses by 2025. Financial incomes generated by fishing will decrease by 11% by 2040 compared with 1998 levels. About 51% of women (N= 408,173) from the Lake Tumba Landscape fish; their revenues decreased by 11% between 2005 and 2010. If this trend continues, women's revenues will decrease by 59% by 2040. Decreased waters will severely impact women (e.g. increasing walking distances to clean waters). Increasing populations and decreasing waters will lead to immigrations to this region because water resources will remain available and highly likely ignite social conflicts over aquatic resources.

INTRODUCTION

Climate change is a scientifically established fact now (Walther et al., 2005), even though the magnitude of its multiple, diversified and multidimensional effects remain mostly in the domain of mathematical modeling. Discussions on the mitigation of climate change and adaptation processes (social, cultural and biological) remain at the core of scientific and political debates (Aiken et al. 1992; Fletcher, 1997; Fletcher, 2000; Hobbs & Knausenberger, 2003; Hughes, 1986; Inogwabini et al., 2006) because they are diversified and multidimensional, and will vary throughout the world (IPCC, 2007). The nature and the magnitude of these impacts have, however, yet to be described for different geographic environments

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and locations. This is even more important for the tropical region of Central Africa where documented evidence is scanty (Halpin, 1998; Inogwabini et al., 2006; Sonwa et al., 2009). Informed guesses and mathematical projections convey the message that climate change's effects in Central Africa may range from drier conditions in areas adjacent to as deserts (Sahara and Kalahari) where water occurs in shortage to high floods in coastal habitats directly adjacent to oceans due to increased water levels as a result of the melting of polar ice (Halpin, 1998).

Unfortunately, however, long-term field data that can document changes which highlight the effects of climate changes over the past years are difficult to find for Central Africa (Edwards & White 2000; Pimm, 2007; Sonwa et al., 2009). Lack of data fosters the use of surrogate data that can predict the effects of climate variation in Central Africa. One of those surrogates has been the linking of phenological data to weather patterns (Tutin & White, 1998), direct measurements of water levels (Colombant, 2005), using direct meteorological data and looking at their trends (Inogwabini et al., 2006). The use of long time series meteorological data as a proper detector of the effects of the climate change is fully justified by the fact that if climate change will affect water level, then drier conditions in the terrestrial Central Africa region are, logically, linked to water cycles, especially rainfall regimes over the continent. However, continuous time series data on rainfalls are difficult to find in Central Africa to document the trends and extents of felt changes (Halpin, 1998). Furthermore, where there are continuous long time series data, the analytical capabilities have made it difficult to determine understandable trends that crude data can convey. Even less available are data on effects of climate change on local economies, health, security and biodiversity (Sonwa et al., 2009; Stern, 2007).

MAIN FOCUS OF THE CHAPTER

This chapter presents three long term data from three locations in the western Democratic Republic of Congo (Figure 1), with the aim of presenting these long time series data in a single analytical framework and discussing patterns that emerge from that analysis in the context of global climate change. The chapter links trends in rainfall and surface area Congo Basin watershed and projects potential effects of these trends to the level of the central Africa region. Combining these projected effects with field data freshwater resources, the paper discusses inferred effects on climate changes on local populations.

STUDY SITES

Rainfall data were collected from (1) Mabali, (2) Kinshasa and (3) Luki. Mabali is located near the equatorial line (Inogwabini et al., 2006). Located in the *Cuvette Central*, weather patterns are believed to be stable (Bultot & Griffiths, 1972). The Cuvette Central is a lowland, flat and heavily flooded equatorial region. It is characterized by *terra firma* forest (forest whose floor remains dry for most of the year), *swampy forest*, and diverse types of savannahs inundated and terra firma (Evrard, 1968; Leonard, 1951 & 1952; White, 1983). The *Cuvette Central* is the lowest point within the Congo Basin and once constituted a water retention point during the late Miocene when many African inland basins were still *endorheic* (Roberts, 1975; Thieme et al., 2005). Kinshasa is a town of nearly 9,000,000 people (Aveling et al., 2003) and located south-west of the Mabali. Adjacent habitats to this mega city are essentially composed of wooded savannas on a sandy soil. Kinshasa is located at Pool Malebo, an open water sur-

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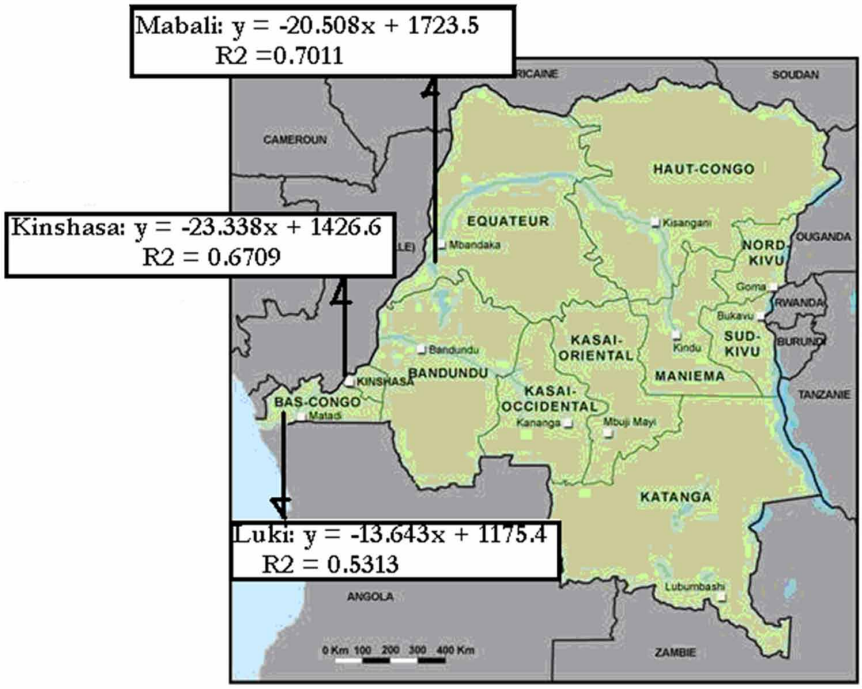
Figure 1. Locations from which weather data were collected



face leading to several multidirectional wind currents. These currents have an impact on rainfall regimes observed in Kinshasa.

Luki are located further south and closer to the Atlantic Ocean. With a population of 150, 4361 people (Iloweka, 2004), Luki is a forest island within a predominantly human landscape and degraded forests. Its position near the Atlantic Ocean implies that rainfall regime and other climatic events occurring in that region are potentially influenced by climatic events affecting the Atlantic Ocean.

The Congo Basin watershed covers 3,730,474 km^2, and is home to ~60 to 78 million people (Sonwa et al., 2009; WRI, 1998). About 62% (37 – 48 million people) of that population is still rural (Sonwa et al., 2009), even though the urban growth rate of the entire region is high and estimated at 5% per year (Atsimadja, 1992; WRI, 1998). This vast zone covers different habitat types, with tropical forest representing ~40% (14,920,190 km^2). The geography of the zone has an impressive biological diversity.

MATERIAL AND METHODS

Rainfall data from Mabali have been collected continuously from 1970 through 2004 (Inogwabini et al., 2006) while those from Luki were collected between 1958 and 2004. The data set from Kinshasa covers the period between 1971 and 2004. Total annual rainfall intensities (mm) of were plotted over time, i.e. 34 years for the Mabali data set, 46 years for Luki and 33 years for Kinshasa (Figure 1). To detect the trends in these data sets, the linear regression was used on annual rainfall intensities (mm). Those data, particularly on the Mabali Scientific Reserve, were published earlier (e.g. Inogwabini et al., 2006).

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Other data came mainly from the search of existing literature. Human population data were gathered from Atsimadja (1992), Aveling et al. (2003), CEFDHAC (2001), and Sonwa et al. (2009), WRI (1998), Trends in populations were derived using the model presented by De Saint Moulin (1991 & 2003). Data on fish stocks were also gathered from different sources. Fish biomasses and estimated financial incomes generated from fishing were drawn from Bene (2005), CEFDHAC (2001), Corsi (1984a, b), Colom et al. (2006). Leonard (1987), and Data on the decline in fish stocks were those used by Inogwabini & Lingopa (2006).

These data indicated that over a 34 year period reported by Inogwabini et al., (2006), the water depth of Lake Tumba decreased from 8 m down to 6 m, which is a 25% decrease over 34 years, leading to a rate of decrease of 0.0074%/year. This rate was used in combination with regional elevation data to produce the map depicting the future water situation in the Congo Basin watershed. Also, repeating a survey conducted by the Food Aid Organization (FAO) in 1998, Inogwabini & Lingopa (2006) reported a fish stock decrease of 4.5% for the fish stocks of Lake Tumba over a period of 17 years, which equals a decrease rate of 0.25%/year. As suggested by Huggett (1993) and Hulme et al. (2001), these rates, maintaining each of them as constants and assuming that they would apply to the whole basin, were used in linear regression models to project decrease in watersheds and fish stocks. The financial incomes generated by fish production provided by Bene (2005) were used to determine the per-ton cost of fish. Maintaining the price constant over years, I simply multiplied projected fish stocks per year to obtain trends in incomes. The rate of production was calculated to measure the trend in how many tons of fish will remain available to the increasing rural populations of the region over the next 60 years if current conditions remain constant. This important measure was defined as a simple ratio of projected tons of fish over projected total populations.

Data on effects of shrinking waters in the study region on women were those that came from the socioeconomic study carried out by Colom et al. (2006). These included the gender-sorted fish market data, assessment of felt environmental threat disentangled between women and men, traditional work division, etc. They were collected through a variety of methods, including structured interviews, focus groups, and literature reviews Colom et al. (2006). These data are presented in this chapter as simple means and where projected, they were assumed to progress constantly over years. Data on health came from official reports of the provinces and particular health facilities (MSPPE, 2010; SS, 2007). To confirm that these data reflected the reality on ground, I have checked trends with medical doctors that worked in the health divisions of Bikoro, Ntondo and Mbandaka.

RESULTS

The rainfall intensities decreased in all three sites over time for each sites following the regression equation $y = -20.508x + 1723.5$ ($R^2 = 0.7011$), $y = -13.643x + 1175.4$ ($R^2 = 0.5313$) and $y = -23.338x + 1426.6$ ($R^2 = 0.6709$) respectively for Mabali (Figures 1 and 2), Luki (Figure 1 and 3) and Kinshasa (Figure 1 and 4). The rainfall for Luki and mean rainfall for Kinshasa in 2004 represented only 59% and 61% of its levels 33 years earlier, in 1971 following the drought of 1970 when Luki received only 327.8 mm of rain. The situation has been even more dramatic for Mabali where the maximum rainfall represents > 25% of its levels in 1970 or 34 years earlier.

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If the rate of water loss in Lake Tumba is applied for the entire region and remains constant, watershed will decrease following the regression equation y = -20894x + 5E+07 (R^2 = 0.7945). This model indicates that by 2025, the Congo Basin watershed will have lost 18% of its total water mass as compared with its 1998 levels. The loss will deepen to -26.6% by 2040, -39% by 2065 and then around -43% by 2070. Equally, if the loss in the fish biomasses in Lake Tumba are applied to the whole region and remain constant over years, the fish stock will decrease by 7% between 1998 and 2025. This decrease will deepen down to -11% by 2040, -16% by 2058 and by -20% in 2075. The same proportions will be observed if fish prices in the markets are constant, decreasing from 47.8 million American dollars/year in 2005 (Bene, 2005) down to ~42.5 million American dollars/year (~11%) by 2040. At the same time, the human population will grow from 60 – 78 million people to 109.6 million (or an increase of 40.5%) in 2025, then to 141.18 million in 2040 (an increase of 81.0%), 179.08 million in 2058 (129.6%) and 214.89 million (175.5%) in 2075. Combining trends in fish resources and human growth, these changes imply that there will be a decrease of ~70.1% of both tons/person/year, which parallels the projected magnitude of loss of income from 2009 through 2075.

Figure 2. Rainfall trends in the Mabali Region between 1970 and 2004

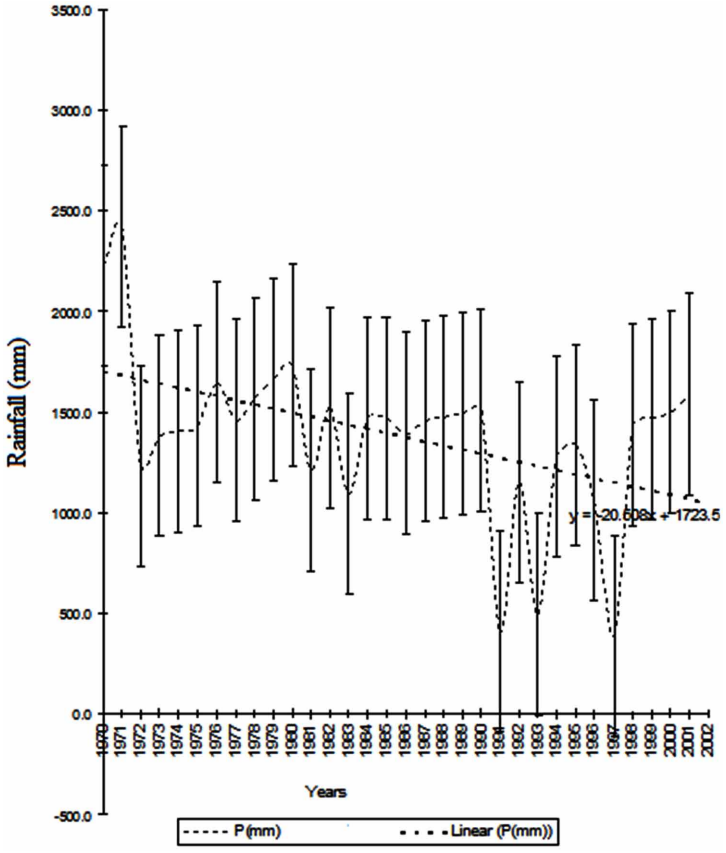

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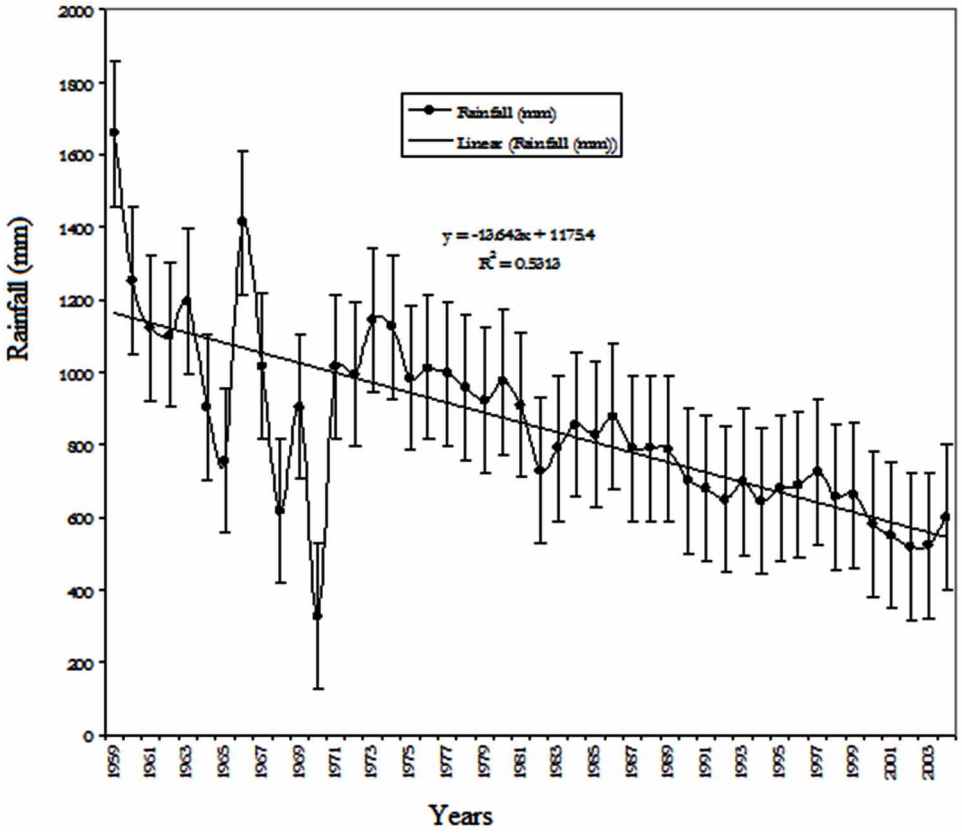
Figure 3. Rainfall trends in the Luki Region between 1958 and 2004



The 2005 socioeconomic data showed that 408,173 of ~1,012,000 all women (~51%) in the landscape were involved in fishing, and that each woman generated a mean annual income of ~2,100US$. This represented an overall income of 857,164,000 US$ annually; a significant % of the overall national budget for that year. In 2010, the fishing-generated financial income was estimated at ~ 1870 US$ per woman or a net decrease of 11%. If these trends are maintained constant, women generated income will decrease by 25% in 2020 and 59% in 2040 while the number depending on fishing for financial income will be 836,755 women, above the double of the women population in 2005.

Even though the region is a swamped zone, the data showed that more women (85%; N= 360) and girls (90%; N= 200) were involved in the activities of fetching water than men (25%; N = 140) and young boys (50%; N=140). The same socioeconomic data showed that that on average women walked ~ 6 km (round trip) to fetch drinkable water; this was done twice daily. This daily 12-km trip consumed 4 hours on average, representing 40% of a ten hour working day. Logically, three quarters of women reported that fetching water from long distances impeded their ability to conduct more lucrative activities such as commerce or even fishing, which are the most important economic activities in the region. More than three quarters of the interviewed women were afraid of fetching water from long distance sources because they feared being raped by former army soldiers. Interestingly, the same data set also showed reversed trends in girl education patterns; in areas where water sources were far away from the villages,

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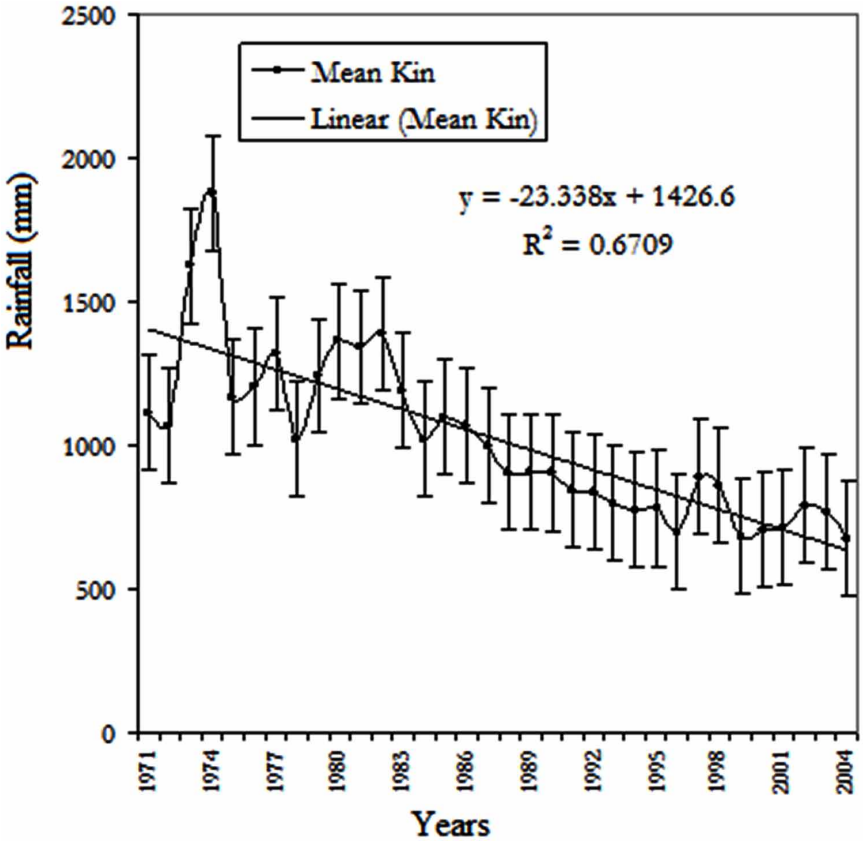
Figure 4. Rainfall trends in Kinshasa between 1971 and 2004



on average only 20% of girls had actually completed their secondary education while in towns where water sources are adjacent to houses, the figure increased to 45%.

Published reports (Secrétariat à la Santé 2007) from the study region indicated a global increase in diarrheas (globally 2.7% for the province of Equateur and 3% for that of Bandundu) and amoebic dysenteries (globally 8% for the province of Equateur and 7.2% for that of Bandundu) at the end of January through the end of February and from end of May through end of July. When looking at reports from Bikoro and Ntondo (near Lake Tumba) these figures are even higher for the same diseases. Diarrheas increase by 25% (Bikoro) and 30% (Ntondo) while amoebic dysenteries increase by 15% (Bikoro) and 24% (Ntondo). Health reports from Bikoro and Ntondo also show an increase in what they call skin itching (40% and 30% respectively for children under the age of 18); and 2007 health report from Ntondo also mentioned an increase in what they shyly called women specific genital ailments and infections by 23.6% during the same periods of the year. Periods from at the end of January through the end of February and from end of May through end of July are dry seasons when clean water is in shortage in the region.

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DISCUSSION

General Foresighted Effects

The three data sets on rain intensities (Figures 1, 2 & 3) clearly indicate that there has been 'continuous' drying up of the zone over the last decades. The mean rainfalls for Luki and for Kinshasa in 2004 represented only 59% and 61% of its levels 33 years earlier while a more dramatic change was depicted for Mabali with the maximum rainfall in 2004 representing only $\geq$ 25% of its levels in 1970. These inter-site variations would be logically expected, given the fact that weather patterns are functions of multiple parameters, including micro climates, which are ecosystem-dependent themselves (Salati, 1987). Conditions, ecological and climatic, in those three sites are widely different and therefore account for those differences. In-site changes are rather difficult to explain, even though they may easily be linkable to major human activities in some cases.

Luki is an island of forest within the Bakongo Region, which is the most logged region of the Congo (Iloweka, 2004). With an estimated human density of 237 persons/km^2 (Iloweka, 2004), the population struggles to make a living through agriculture and woodcutting, which are fostered in response to high demands for foodstuffs and the high consumption of wood (for energy and construction) in Kinshasa and the expanding towns of Matadi and Boma. Most of the demand is met by products coming directly from the adjacent Province of Bas-Congo. All these activities increased the deforestation rate and unbalancing of forest ecosystems, which may be feeding the climate changes. Even though there is a need to deepen our knowledge on the correlation between forest cover and rainfall regime in this region, it is fairly logical to infer, based on studies undertaken in other regions of the world (Eltahir & Bras, 1993 Gash & Nobre, 1996; Lettau et al.1979,), that changes in the rainfall in this region may be a consequence of deforestation, which is feeding into global climate change and its effects.

The situation appears of Kinshasa seems to be similar to that of Luki. Kinshasa, with a currently estimated population of 9 million people, has seen its immediate environment stripped of all natural forests and bush due to the demand for land needed to accommodate a rapidly increasing population. Forested areas that were left to maintain a healthy urban environment have been either invaded by houses or have seen their trees cut down to provide charcoal for energy. Such is also the case for Luki and even though this question calls for more detailed information to help establish clear causation links, it remains reasonable, based on studies done elsewhere (Eltahir & Bras, 1993; Gash & Nobre, 1996; Lettau et al., 1979), to hypothesize that changes observed in rainfall patterns in Kinshasa may be subsequent to decreasing vegetation cover both within the town itself and its immediately adjacent areas.

The 34-year data set from Mabali intrigues common wisdom and can be fully understood only in parallel with the overall climate change paradigm (Inogwabini et al., 2006). Mabali (Figure 1) is located 75km straight south of the Equator. Within this strip, climatic metrics are constant (Bultot & Griffiths, 1972; Evrard, 1968) there are constant temperatures, stable rainfall regimes and regular seasonal cycles. A first look at the data from Mabali questions the rationality of the data because the site appears to be in an ideal environment for a rainfall pattern to remain constant over years. This remains the question even when you consider the fact that Mabali is also surrounded by active logging activities and many forest clearings due to high human concentration around Lake Tumba because the extent of vegetation clearing are far from being of the same magnitude as in Luki and Kinshasa. Deconstructing the puzzle posed by the Mabali situation, Inogwabini et al. (2006), found that while the most acknowledged consequence of the climate change was global warming (Houghton et al., 1990), the Mabali long-term data indicated a

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local cooling phenomenon, which they attributed to longer dry seasons. Longer dry seasons mean less precipitation; therefore it is understandable that rainfall had decreased over the period covered by the study. Following Bultot & Griffiths (1972), Inogwabini et al. (2006), explained that in equatorial Africa dry seasons are cooler than normal temperatures due to over-evaporation, leading to persistent clouds. However, while tracking the explanations for longer dry seasons, they concluded that they could be logically explained only by inserting the global climate into the equation. Overall, decreased rainfall in the western Congo (in the three locations of Kinshasa, Luki and Mabali), regardless of reasons that may explain them, do agree with patterns in the other regions of Africa and have been documented previously (IRD, 2002; Mahe et al., 2001), albeit at localized scales.

In conclusion, these trends are clear and should ignite the will to establish causation links if they are to be managed appropriately. This is a call for appropriate research rather than depending on opportunistic data. There is also one precaution in trying to use these data sets and/or extrapolating them: decreased annual rainfall intensities may depict a phenomenon of a long term cyclical event whose frequencies may be difficult to decipher from such a short time-series data. Nevertheless, given the fact that human activities may have pushed natural environmental to the edges of irreversibility, the picture provided by these data series may convey an alarm signal given the fact that we may have gone beyond a certain resilience threshold. This is even more appealing when one considers that these climatic patterns agree with the overall picture of the Congo Basin and Africa, and may be attributable to the global climate change phenomenon (IRD, 2002; Inogwabini et al., 2006).

Previous studies (Hulme et al. 2001; Pearce & Turner, 1990; Sonwa et al., 2009; Stern, 2007) have described effects of climate changes to include economic aspects (decrease in financial incomes), health and sanitation (water quality and decrease in intake of fish proteins) and loss in biodiversity. Inogwabini et al. (2006) argued that the observed decrease in water depth of the Lake Tumba (from maximum depth of 8 m down to 6 m over 34 years) was essentially linked to the dramatic decline in rainfall. They also suggested that, apart from intensive fishing described by Inogwabini et al. (2009), observed decreases in fish stocks may also be linked to climatic conditions prevailing in the lake such as loss of reproduction sites, cooler temperatures and losses in some critical foods due to prolonged dry seasons, as fishes of the region adapted to different conditions and exhibit different requirements to reproduce and grow (Bailey, 1986; Banister, 1986; Chapman, 2001). They also indicated that if the weather change patterns they described remain constant, there would be numerous ecological consequences on forest ecosystems of the western Congo Basin (IRD, 2002; Inogwabini et al., 2006) in the long-term future. Evidence of such effects of climates on biodiversity have been described on several occasions (Fernández & Vrba, 2006; Lemoine & Böning-Gaese, 2003; Lemoine et al., 2007a & Lemoine et al., 2007b) and will likely occur in this region whose biodiversity is one of the most important on earth. To highlight the magnitude of the land affected by drying, a decrease in 18% of the size of the Congo watershed between 1998 and 2025 represents 673,968 km^2. This dried out area represents ~28% of the entire Democratic Republic of Congo and 23 times the size of Equatorial Guinea.

Beyond those consequences on biodiversity, the projected economic effects a drying watershed would also strike human economic activities, not only in terms of fish markets and protein intake but also in terms of agricultural productivity in the whole region. Increasing human populations will need more food and cultivatable land. Shortages in water will push people to find water sources for agriculture where this key resource will still is available, which is in the Central Congo Basin. That pattern would, most likely, lead to conflicts over water resources in the region. Lovett (2006) established that rainfall is one of the main determinants of ecological productivity, which in turn is the basis of agricultural economies.

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Shortages of rainfall will, therefore, undermine the rich cultural diversity as well by forcing people to migrate to regions that offer better agricultural production and sufficient water sources. The destruction of the resources that support traditional culture is, by any measure, the most dramatic effect of climate change in this region. Climate change would certainly precipitate dramatic, permanent shifts in local cultures. For example, all people in the Lake Tumba region prefer fish as their most important food item. Decreasing fish stocks will most likely push them to adopt new life styles and other techniques to extract natural resources to live on. The introduction of new techniques will affect community views, relationship to the environment and overall stability.

SPECIFIC EFFECTS OF WATER DECREASE ON WOMEN IN THE REGION

Decreasing water levels would likely increase in walking distances to clean water sources, which will ipso facto increase time consumed to fetch water, reduce girls' chances to attend formal education, decrease women's economic powers and expose them to gender-based violence.

While there might be other factors affecting gender-education patterns described in this study, increased walking distances to clean water sources, at least contributed to that picture and will very likely continue to reduce girls' chances to attend formal education unless major cultural and social changes happen. This finding conforms to the results reported from Ethiopia, Ghana, Tanzania (Komba, 1995) and India (UN-DESA, 2005) and other areas across Africa (YPOW, 2006). As reported in many studies (Inter-Agency Commission, 1990; IIon, 1992; Kinyanjui, 1993), literacy of women is an important key to improving health, nutrition and education in the family and to empowering women to participate in decision-making in society. Naturally, according to the *Childhood Engenderment Theories* (Chafetz, 2006), impeded access to formal education will keep future women under the yoke of inequality and reduce their self-esteem, perpetuating the current imbalanced power toward women (Chafetz & Haggan, 1996).

Socioeconomic data indicate that decreasing water levels will have more severe impact on women commercial activities than compared to the global effect. That the numbers of women will double provides a prelude of heighten conflicts over fishing points resulting from increased competition of fishing points. This, combined with reduced access to education caused by water shortage, will therefore further hinder women's economic powers, limiting the contribution of more than 50% of the population to contribute to economic returns expected by their societies and impact on means of achieving sustainable development and economic growth, which agrees with findings by Hanjra and Qureshi (2010) who projected that climate change effects will hinder the contribution of women to the global development. Reduced economic power means, again, lost self-esteem and will keep the current paradigms of social inequalities between men and women. Ironically, this will happen though women will see their workload increased by doubling walking distances to fetch water. Indeed, the estimated workload for fetching drinking water was a daily 12-km trip, consuming 40% of women working day. This was higher than the average time spent by women across rural Africa (Blackden & Wodon, 2006), which had been estimated at 26% (Water Aid, 2012).

Water Aid (2012) had suggested a cohort of effects of reduced water availability on women in developing countries, principally on their health and that of their families in general. Both structured interviews and focus groups with local communities were not able to document feeling of worsening human health conditions in the region, though 21% of interviewed people talked about health increasing costs. However, official health reports indicated that there was an increase in some diseases during dry seasons, a period

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when clean water is in shortage in the study region. Diarrheas, amoebic dysenteries, skin and itching in young people are water-borne diseases; and the fact that they increase during the period of clean water shortage indicate that should water decrease, the health conditions of the populations of this region would be affected directly. Diarrheas and amoebic dysenteries and other forms of diseases enumerated above have been reported to be directly linked to quality of water under other circumstances (Fewtrell et al. 2005; Gundry et al., 2004). Hence, the fact both structured interviews and focus groups with local communities were unable to document feeling of worsening human health conditions in the region may, most probably, be due to the sense of plenty of water and the fact that people had many other concerns that were priority to their livelihood than water-borne diseases. Of particular note here is that women specific genital ailments and infections increased by 23.6% during the dry seasons. Though there is no specific name on what these are, it would be sensible to think that decreasing water levels in the region would affect women's health conditions in a specific way. Aveling et al. (2003) and Inogwabini et al. (2009) documented the fact that people in the region of the study had no proper sewage treatment mechanisms and people have been used to dumping garbage into open water, which in turn they fetched for domestic needs. Decreasing water levels will reduce the potential that larger water masses have to dilute effects of dumped sewage and will, therefore, lead to unclean water, which will lead to unhygienic conditions.

It has been shown in the arid African regions (Manyanhaire et al., 2009), decreased water levels will reduce the spread of water-dependent human activities in a limited surface; limited spread zone for human activities alone will likely worsen health conditions. Major human settlements in areas of limited water supplies are always accompanied by worsening health conditions stemming from varied causes such as poor sewage and water treatment infrastructures, people sharing water sources with herds of cattle and other domestic animals. As indicated above, characteristics of this region are that there is no proper sewage treatment mechanisms, people dump garbage into open water, and defecate directly in open water (MSPPE, 2010). Decreasing water levels will reduce the potential that larger water masses have to dilute effects of dumped sewage and will, therefore, lead to unclean water. This will affect, in unforeseen degrees, both human populations and livestock who will be sharing the same water points.

It is worth repeating that in Central Africa, as most cultures, women and girls are primarily responsible for the use and management of water resources, sanitation and health at the household level (Seager et al., 2009; UN-DESA, 2005;); which facts will certainly expose them to gender-based violence. Water-driven conflicts would very likely results in similar impacts, including rape. An important result of this study is that women in this region already torn-apart by armed conflicts of different nature in the recent past have an acute perception of the risks of being raped while going for search of water.

Managing water at times of scarcity will bring women to the forefront of water-ignited conflicts. The recent history, with the Enyele Rebellion Movement on water pounds in the north-western part of the DRC provided proof to this situation (Guerra et al., 2010); decades-old suppressed conflict over fishing rights evolved into ethnic tussle for economic and political power in north-west. Some 200,000 refugees fled the fish-conflict violence since in 2009 (BBC, 2009) of whom 82% were women (IRIN, 2011). Unfortunately, the opportunity provided by the recent Conference of Parties to the Convention United Nations Framework Convention on Climate Change in Paris was not seized to discuss the implications of climate change on freshwater and its social consequences. The word water appears nowhere throughout the text of the Paris Agreement, the importance of water being inferred to only once in the preamble through the use of the word ocean, as a specific ecosystem. Without diminishing the value of other international mechanisms such as the International Water Management Institute and other conferences on the subject, this absence of water in the agreement shows how low the water issues are on the agenda of the global

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decision-making processes and, hence, lack of global perspectives on how to handle potential conflicts over freshwater sources. Of course, it could easily be argued that water is inferred through article 1 (1) of the Paris Agreement, which refers to the 1992 New York Convention which, in its article 4(e), calls parties to cooperate in preparing for adaptation to the impacts of climate change develop and elaborate appropriate and integrated plans for coastal zone management, water resources and agriculture, and for the protection and rehabilitation of areas, particularly in Africa, affected by drought and desertification, as well as floods. However, this inference is no so obvious and would demand a more refined practitioner of natural resources management to dig it out and make connections. It is suggested here that the best way to account for water and consequences of lack of its proper management is to factor freshwater in the development of the nationally determined contributions (Paris Agreement, article 3). But that will need a much more developed advocacy on behalf of the practitioners of natural resources management toward political decision-makers.

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REFERENCES

Aiken, J., Moore, G. F., & Holligan, P. M. (1992). Remote sensing of oceanic biology in relation to global climate change. *Journal of Phycology*, *28*(5), 579–590. doi:10.1111/j.0022-3646.1992.00579.x

Atsimadja, F. A. (1992). The changing geography of Central Africa. In G. P. Chapman & K. M. Baker (Eds.), *The changing geography of Africa and Middle East* (pp. 52–79). London: Routledge.

Aveling, C., Bofaya, B., Hall, J.S., Hart, J.A., Hart, T.B., Inogwabini, B.I., Plumptre, A. & Wilkie, D. (2003). *Democratic Republic of Congo – Environmental Analysis*. Wildlife Conservation Society for USAID Kinshasa.

Bailey, R. G. (1986). The Zaïre River system. In Davies & Walker (Eds.), The Ecology of River Systems. Junk Publishers. doi:10.1007/978-94-017-3290-1_6

BBC (British Broadcasting Company). (2013). *Democratic Republic of Congo Profile*. Available at http://www.bbc.co.uk/news/world-africa-13283212

Béné, C. (2005). The good, the bad and the ugly: Discourse, policy controversies, and the role of science in the politics of shrimp farming development. *Development Policy Review*, *23*(5), 585–614. doi:10.1111/j.1467-7679.2005.00304.x

Blackden, C. M., & Wodon, Q. (Eds.). (2006). *Gender, Time Use, and Poverty in Sub-Saharan Africa*. World Bank Working Paper 73.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Bultot, F., & Griffiths, J. P. (1972). The equatorial wet zone. In Griffiths (Ed.), Climates of Africa. Elsevier Publishing Company.

Chafetz, J. S. (2006). The varieties of gender theory in sociology. In J. S. Chafetz (Ed.), *Handbook of the sociology of gender* (pp. 3–23). New York: Springer. doi:10.1007/0-387-36218-5_1

Chafetz, J. S., & Haggan, J. (1996). The gender division of labor and family change in industrial societies: A theoretical accounting. *Journal of Comparative Family Studies*, *27*, 187–217.

Chapman, L. J. (2001). Fishes of African Rain Forests – diverse adaptations to environmental challenges. In Weber, White, Vedder & Naughton-Treves (Eds.), African Rain Forest, Ecology and Conservation: An interdisciplinary perspective. Yale University Press.

Colom, A., Bakanza, A., Mundeka, J., Hamza, T., & Ntumbandzondo, B. (2006). The socio-economic dimensions of the management of biological resources, in the Lac Télé – Lac TumbaLandscape, DRC Segment: A segment-wide baseline Socio-Economic study's Report. Submitted to the World Wide Fund for Nature DRC, Kinshasa Office, Democratic Republic of Congo.

Colombant, N. (2005). *Shrinking Lake Chad sparks tension, ingenuity*. Available at http://www.voanews.com /english/archive/2005-03

Conference on the Central African Moist Forest Ecosystems (CEFDHAC). (2001). *Regional Strategic Action Plan and biodiversity resources on the Congo basin ecosystems*. United Nations Development Program (UNDP), International Union for the Conservation of Nature (IUCN) and the Global Environment Facility (GEF).

Corsi, F. (1984a). *Développement des pêches dans le fleuve Zaïre. Rapport préparé pour le projet d'Assistance à l'Office National des Pêches et Amélioration de la Pêche Artisanale.* Rome: FAO.

Corsi, F. (1984b). *Zaïre: Développement et aménagement des pêches du lac Mai-Ndombe et ses affluents*. Technical report submitted to Food Aid Organization.

De Saint Moulin, L. (1991). Zaïre: Aperçu démographique – Résultats du recensement scientifique de la population en 1984. *Zaire-Afrique*, *255*, 227–261.

De Saint Moulin, L. (2003). La perception de la démocratie en République Démocratique du Congo. *Congo-Afrique*, *375*, 292–307.

Edwards, A., & White, L. J. T. (2000). Methods for recording the weather. In L. White & A. Edwards (Eds.), *Conservation research in the African rain forests: a technical handbook* (pp. 81–88). New York: Wildlife Conservation Society.

Eltahir, E., & Bras, R. (1993). On the response of the tropical atmosphere to large-scale deforestation. *Quarterly Journal of the Royal Meteorological Society*, *119*, 779–783.

Evrard. C. (1968). *Recherches écologiques sur le peuplement forestier des sols hydromorphes de la Cuvette Centrale congolaise*. Série scientifique Nº110/Office National de la recherché Scientifique et du Développement – Ministère Belge de l'Education Nationale et de la Culture.

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Fernández, M. H., & Vrba, E. S. (2006). Plio-Pleistocene climatic change in the Turkana Basin (East Africa): Evidence from large mammal faunas. *Journal of Human Evolution*, *50*(6), 595–626. doi:10.1016/j.jhevol.2005.11.004 PMID:16630645

Fewtrell, L., Kaufmann, R. B., Kay, D., Enanoria, W., Haller, L., & Colford, J. M. Jr. (2005). Water, sanitation, and hygiene interventions to reduce diarrhoea in less developed countries: A systematic review and meta-analysis. *The Lancet Infectious Diseases*, *5*(1), 42–52. doi:10.1016/S1473-3099(04)01253-8 PMID:15620560

Fletcher, S. R. (1997). *Global Climate Change Treaty: Negotiations and Related Issues. A CRS Report to Congress*. National Council for Science and the Environment & National Library for the Environment. Available at http://www.ncseonline.org/NLE/CRSreports/Climate

Fletcher, S. R. (2000). *Global Climate Change Treaty: The Kyoto Protocol. A CRS Report to Congress*. National Council for Science and the Environment & National Library for the Environment. Available at http://www.ncseonline.org/NLE/CRSreports/Climate

Gash, J. H. C., & Nobre, C. (Eds.). (1996). *Tropical Deforestation and Climate*. New York: John Wiley.

Guerra, R., Nakwafio, F., Kazadi, S., & Giuliano, M. (2010). *Pooled Fund 2010 Annual Report: Annex 10 - Pooled Fund First special allocation 2010.* Available at http://www.rdc-humanitaire.net/rdchbis/IMG/pdf/annex_10.pdf

Gundry, S., Wright, J., & Conroy, R. (2004). A systematic review of the health outcomes related to household water quality in developing countries. *Journal of Water and Health*, *2*, 1–13. PMID:15384725

Halpin, P. N. (1998). Global climate change and natural-area protection: Management responses and research direction. *Ecological Applications*, *7*(3), 828–843. doi:10.1890/1051-0761(1997)007[0828:GCCANA]2.0.CO;2

Hanjra, M. A., & Qureshi, M. E. (2010). Global Water Crisis and Future Food Security in an era of Climate Change. *Food Policy*, *35*(5), 365–377. doi:10.1016/j.foodpol.2010.05.006

Hobbs, M., & Knausenberger, W. (2003). *Burundi Environmental threats and opportunities assessment (ETOA), with emphasis on tropical forestry and biodiversity conservation*. Type-scripted Supplementary report to Integrated Strategic Plan for 2003-2005. USAID.

Houghton, J. T., Jenkins, G. J., & Ephraums, J. J. (1990). *Climate change: the IPPC scientific assessment*. Cambridge, UK: Cambridge University Press.

Huggett, R. J. (1993). *Modelling the human impact on nature – Systems analysis of environmental problems*. Oxford University Press.

Hughes, P. (1986). Ocean color: A key to climate change. *Weatherwise*, *39*(5), 267–270. doi:10.1080/00431672.1986.9929300

Hulme, M., Dohery, R. M., Ngara, T., New, M. G., & Lister, D. (2001). African Climate Change: 1900 – 2100. *Climate Research*, *17*, 145–168. doi:10.3354/cr017145

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Ilon, L.IIon. (1992). Fitting girls schooling into existing economic paradigms: Confronting the complexities. *International Journal of Educational Development*, *12*(2), 147–159. doi:10.1016/0738-0593(92)90036-L

Iloweka, E. M. (2004). The deforestation of rural areas in the Lower Congo Province. *Environmental Monitoring and Assessment*, *99*(1-3), 245–250. doi:10.100710661-004-4028-0 PMID:15641386

Inogwabini, B., & Lingopa, Z. (2006). Les Inventaires des Poissons dans le Lac Tumba, Congo et Ngiri – Paysage Lac Te'le´ – Lac Tumba, Segment RDC. Rapport Produit dans le Cadre du Programme CARPE. Type scripted report to the WWF DRC, Kinshasa (Democratic Republic of Congo).

Inogwabini, B. I., Dianda, M., & Lingopa, Z. (2009). The use breeding sites of *Tilapia congica* (Thys & van Audenaerde 1960) to delineate conservation sites in the Lake Tumba, Democratic Republic of Congo: Toward the conservation of the lake ecosystem. *African Journal of Ecology*, *48*, 800–806.

Inogwabini, B. I., Sandokan, B. M., & Ndunda, M. (2006). A dramatic decline in rainfall regime in the Congo basin: Evidence from a thirty-four data set from the Mabali Scientific Research Center, Democratic Republic of Congo. *International Journal of Climatology*, *31*, 278–286.

Inter-Agency Commission (UNDP, UNESCO, UNICEF, World Bank). (1990). *Final Report of the World Conference on Education for All: Meeting Basic Learning Needs*. United Nations.

IPCC (Intergovernmental Panel on Climate Change). (2007). *Climate Change 2007: Impacts, adaptation and vulnerability. Contribution to of Working Group II to the fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

IRD (Institut de Recherche pour le Développement). (2002). *Congo River Basin: geology and soil types influence drought. European Water Management News*. Available from: http://www.ewaonline.de

IRIN (Integrated Regional Information Networks). (2011). *DR-CONGO: Return delayed for 120,000 refugees.* Retrieved from http://www.irinnews.org/report/92712/drc-congo-return-delayed-for-120-000-refugees

Kinyanjui, K. (1993). Enhancing women's participation in the sciences bases curriculum: The case of Kenya. In J. K. Conway & S. C. Bourque (Eds.), *The politics of women's education. Perspective from Asia, Africa and Latin America*. Ann Arbor, MI: University of Michigan press.

Komba, D. (1995). Declining enrolment and quality of primary education in Mainland Tanzania. In C. Creighton & C. K. Omari (Eds.), *Gender, Family and Household in Tanzania*. Avebury.

Lemoine, N., Bauer, H.-G., Peintinger, M., & Böhning-Gaese, K. (2007). Effects of Climate and Land-Use Change on Species Abundance in a Central European Bird Community. *Conservation Biology*, *21*(2), 495–503. doi:10.1111/j.1523-1739.2006.00633.x PMID:17391199

Lemoine, N., & Böning-Gaese, K. (2003). Potential impact of global climate change on species richness of long-distance migrants. *Conservation Biology*, *17*(2), 577–586. doi:10.1046/j.1523-1739.2003.01389.x

Lemoine, N., Schaefer, H.-C., & Böhning-Gaese, K. (2007b). Species richness of migratory birds is influenced by global climate change. *Global Ecology and Biogeography*, *16*(1), 55–64. doi:10.1111/j.1466-8238.2006.00252.x

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Leonard, C. (1987). République du Zaïre - Publié par le Ministère de l'Economie et de l'Industrie. Imprimerie Pirotte, Liège. *Conjoncture Economique, 26*.

Leonard, J. (1951). Contribution a l'étude de la végétation des bains d'éléphants au Congo Belge. Le Rhynchosporeto-Cyperetum longibracteato. *Publication de la Société Royale de Botanique Belge.*, *84*, 13–27.

Leonard, J. (1952). Cynometreae et Amherstieae. In Flore du Congo Belge et du Ruanda-Burundi. INEAC.

Lettau, H., Lettau, K., & Molion, L. (1979). Amazonias hydrologic cycle and the role of atmospheric recycling in assessing deforestation effects. *Monthly Weather Review*, *107*(3), 227–238. doi:10.1175/1520-0493(1979)107<0227:AHCATR>2.0.CO;2

Lovett, J. C. (2006). Climate and Society. *African Journal of Ecology*, *44*(4), 421–422. doi:10.1111/j.1365-2028.2006.00708.x

Mahe, G., LHote, Y., Olivry, J. C., & Wolting, G. (2001). Trends and discontinuities in regional rainfall of West and Central Africa: 19511989. *Hydrological Sciences-Journal-des Sciences Hydrologiques*, *46*(2), 221–226. doi:10.1080/02626660109492817

Manyanhaire, I. O., Matewa, J. T., Svotwa, E., & Munhuwa, E. (2009). Water shortage Related problems following the closure of Mhangura copper mine in Mashonaland West Province of Zimbabwe. *Journal of Sustainable Development in Africa*, *11*, 239–252.

MSPPE (Ministère de la Santé Publique de la Province de l'Equateur). (2010). *Plan Provincial de la santé de l'Equateur*. CEMUBAC.

Pearce, D. W., & Turner, R. K. (1990). *Economics of Natural resources and the environment*. New York: Harvester Wheatsheaf.

Pimm, S. L. (2007). Africa: Still the Dark Continent. *Conservation Biology*, *21*(3), 567–569. doi:10.1111/j.1523-1739.2007.00697.x PMID:17531033

Roberts, T. R. (1975). Geographic distribution of African freshwater fishes. *Zoological Journal of the Linnean Society*, *57*(4), 249–319. doi:10.1111/j.1096-3642.1975.tb01893.x

Salati, E. (1987). The forest and the hydrological cycle. In R. E. Dickinson (Ed.), *The Geophysiology of Amazonia* (pp. 273–296). New York: Wiley.

Seager, J., Robinson, K., Van der Schaaf, C., & Gabizon, S. (2009). *Gender-Disaggregated Data on Water and Sanitation. Department for Economic and Social Affairs (UN-DESA) and UN-Water Decade Programme on Capacity Development*. New York: UNW-DPC.

Sonwa, D., Bele, Y., Somorin, O., Jum, C., & Nkem, J. (2009). Adaptation for forests and communities in the Congo Basin. *European Tropical Forest Research Network News*, *50*, 93–100.

SS (Secrétariat à la Santé). (2007). *République Démocratique du Congo: Annuaire des données sanitaires 2006*. Ministère de la Santé Publique de la République Démocratique du Congo, Kinshasa.

Stern, N. (2007). *Economics of climate change. The Stern Review*. Cambridge University Press. doi:10.1017/CBO9780511817434

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Thieme, M. L., Abell, R., Stiassny, M. L. J., Skelton, P., Lehner, B., Teugels, G. G., ... Olson, D. (Eds.). (2005). *Freshwater ecoregions of Africa and Madagascar: A conservation assessment*. Island Press.

Tutin, C. E. G., & White, L. J. T. (1998). Primates, phenology and frugivory: Present, past and future patterns in the Lopé Reserve, Gabon. In D. M. Newbery, H. H. T. Prins, & N. Brown (Eds.), *Dynamics of populations and Communities in the Tropics* (pp. 309–338). Oxford, UK: Blackwell Science.

UN-DESA (United Nations Department of Economic and Social Affairs). (2005). *A Gender Perspective on Water Resources and Sanitation.* Background paper NO 2. Commission on Sustainable Development Twelfth Session DESA/DSD/2005/2United Nations, New York.

Walther, G.-R., Hughes, L., Vitousek, P., & Stenseth, N. C. (2005). Consensus on climate change. *Trends in Ecology & Evolution*, *20*(12), 648–649. doi:10.1016/j.tree.2005.10.008 PMID:16701450

Water Aid. (2012). *Women's issues*. Retrieved from http://www.wateraid.org/documents/plugindocuments/women_and_wateraid_issue_sheet.pdf

White, F. (1983). The vegetation of Africa, a descriptive memoir to accompany the UNESCO/AETFAT/UNSO vegetation map of Africa. UNESCO. *Natural Resources Research*, *20*, 1–356.

YPOW (Young People of the World). (2006). *Water rights and wrongs - A Young People's Summary of the United Nations Human development Report 2006. Beyond scarcity: power, poverty and the global water crisis*. Available at http://www.gm.undp.org/Reports/report_youth_hdr.pdf

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Chapter 66
Nitrate, Total Ammonia, and Total Suspended Sediments Modeling for the Mobile River Watershed

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ABSTRACT

This paper presents details of a water quality model of the Mobile River watershed that estimates total suspended sediments at the outlet of the watershed. The model is capable of simulating Nitrate (NO_3), Total Ammonia (TAM), and Total Suspended Sediments (TSS) for extended periods of time at a daily temporal resolution (1970-1995). The Hydrological Simulation Program Fortran is used for modeling the hydrological, nitrogenous constituents, and sediment processes. Based on the nutrient simulation and exploration of the effects of two management practices (filter strips and stream bank stabilization and fencing) on nutrient removal, the resulting sediment model is used to implement the most efficient nutrient management practice and explore its effects on TSS concentrations in the Mobile River. Results show that the implementation of the management practice "stream bank stabilization and fencing" to agricultural lands in sub-watersheds that had intense agricultural activities produced the highest reductions of NO_3 concentration (up to 14.06%) and TAM concentrations (8.01%). Based on the nutrient simulation and identification of "stream bank stabilization and fencing" as the most efficient BMP for nutrient concentration reduction, the sediment model was used to explore its effects on TSS concentrations in the Mobile River. Implementing "stream bank stabilization and fencing" produced monthly median TSS concentration reductions ranging from 3.6% to 10.6% in the Mobile River.

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INTRODUCTION

The US Gulf Coast receives inputs of nutrients and sediments from intensive agricultural activities in upland watersheds (McPherson, et al., 2003). Seasonal hypoxia and high sediment load events have occurred in recent years. Continued land development and conversion of natural landscapes to urban development will exacerbate pollution (Vitousek et al., 1997; Wiener & Sassenrath, 2012). Moreover, nutrient and sediment contributions from upland watersheds where the main economic activity is agriculture play an important role (Harmel et al., 2007).

Nitrogenous constituents and sediments washed off by precipitation events from the croplands are loaded into streams (creeks, rivers) which take sediments and nutrients to coastal water bodies. Mobile Bay, an estuary located in the Alabama Gulf Coast, receives waters from one of the largest watershed in North America (Park et al., 2007): Mobile River Watershed. The estuary experiences regular hypoxic events during the summer (EPA, 2012). The Tombigbee watershed, one of the upland watersheds that drains into Mobile Bay via the Mobile River, has been identified as one of the sources of nutrient input due to its intensive agricultural activity (EPA, 2014). Increases in agricultural activities could potentially worsen the current situation. Alarcon & McAnally (2012) estimated that in a span of seventeen years some portions of the Tombigbee watershed underwent the following land-use/land-cover changes: 34% increase of agricultural lands, 263% increase of lands used for grazing or hunting animals (rangeland), and a 16% decrease of natural forest lands. With these significant changes in soil surface coverage, the transport of nutrient and sediments washed-off from this watershed to Mobile Bay and the Alabama Gulf Coast has increased proportionally. The increase of agricultural lands and agricultural intensification are anticipated to worsen the current situation (Matson et al., 1997; Harmel et al., 2006).

Conversion of forest land into crop or pasture can substantially increase the loss of sediments and nutrients from the land (Foley et al., 2005; Harmel et al., 2006). The rates of soil loss in particular will depend on management practices, especially the degree of tillage (no-tillage or conservation tillage versus conventional tillage) (Parajuli et al., 2013), and can also impact the loss of nutrients. While pastures may have reduced sediment losses, animal manures will increase the nutrient runoff from the field. A recent study at a small geographical scale (Kleinschmidt, 2005) postulated several management scenarios that may be used for reducing the effects of nutrient and sediment contamination to some of the Tombigbee streams. For cropland, filter strips, reduced tillage, stream bank stabilization and fencing, and terraces were identified as being the most useful in that order. For pasture land, stream bank stabilization and fencing, and terraces were the most useful.

The sources of nutrient and sediment loss in agricultural watersheds are mostly distributed in space (i.e., they are non-point sources). Non-point sources enhance the chances for complex physical and biochemical processes to occur during the transport of those contaminants through soil and water. Therefore, estimating the effects of nutrient and sediment wash-off from agricultural fields to streams and water bodies requires a complex quantitative approach. Watershed models are able to quantify those processes occurring either under natural conditions or due to anthropogenic activities. These models use mechanistic and empirical algorithms to calculate the hydrological processes within a watershed and also the migration of pollutants from point and non-point sources to water bodies. Previous research has shown the use of these types of models for quantification of processes in agricultural watersheds (Alarcon & Sassenrath, 2015). For the Mobile River watershed, an initial hydrological and nutrient model (Alarcon & Sassenrath, 2016) has been developed that covers all major streams in the watershed, including the

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Tombigbee River and the Alabama River watersheds. A sediment transport model for the entire watershed, however, has yet to be developed.

In this research, an existing nutrient model of the Mobile River watershed (Alarcon & Sassenrath, 2016) is improved by including modeling of total suspended sediments. The Better Assessment Science Integrating Point & Nonpoint Sources, BASINS GIS system (EPA, 2008) and the Hydrological Simulation Program Fortran, HSPF (Bicknell et al., 2001) are used to geo-process the input data and water quality modeling respectively. Through nutrient modeling, the optimum Best Management Practice (BMP) for nutrient removal is identified and, subsequently, this BPM's efficiency in terms of TSS removal is tested via simulation.

METHODS

Watershed Under Study

The Mobile River is a typical coastal river with mild slopes and meandering course. The river is seventy-two kilometers long and is the main contributor of fresh water to Mobile Bay. It carries waters coming from two important rivers: Tombigbee and Alabama rivers. The Upper and Lower Tombigbee rivers, which watersheds are located in northwest Alabama and northeast Mississippi, drain a catchment area of approximately 59000 square kilometers between both states. Fifty six percent of the watershed is in Mississippi and the rest (44%) lies in Alabama. The Alabama River catchment covers approximately 56000 square kilometers draining most of eastern Alabama, and portions of northwest Georgia and southeast Tennessee (Figure 1).

The Mobile River has an average annual stream flow of 1840 m3/s. The Mobile River watershed (Figure 1) covers approximately 115,000 km^2, extending into four southeastern states: Alabama, Mississippi, Georgia, and Tennessee. This drainage basin is the fourth-largest in the United States and the sixth-largest in North America. The river and its contributors have historically provided the principal navigational access for Alabama.

Physical Geography Characterization

The topographical characterization of the study area was performed using National Elevation Data (NED) (30-m horizontal, 1-m vertical), and USGS DEM (300-m horizontal 1-m vertical) topographical datasets. The NED dataset provides a seamless mosaic elevation data having as the primary initial data source the 7.5-minute elevation data for the conterminous United States (Lent & McKee, 2011). NED has a consistent projection (geographic), resolution (1 arc second, approximately 30 m), and metric elevation units (Deliman et al., 1999). The land-use/land-cover within the Mobile River watershed was characterized using the USGS GIRAS digital map. The USGS-GIRAS is a set of maps of land use and land cover for the conterminous U.S. delineated with a minimum mapping unit of 4 hectares and a maximum of 16 hectares (equivalent to 400 m spatial resolution), generated using the Geographic Information Retrieval and Analysis System (GIRAS) software. Today, they are widely known as the USGS GIRAS land use data sets (Alarcon & O'Hara, 2010).

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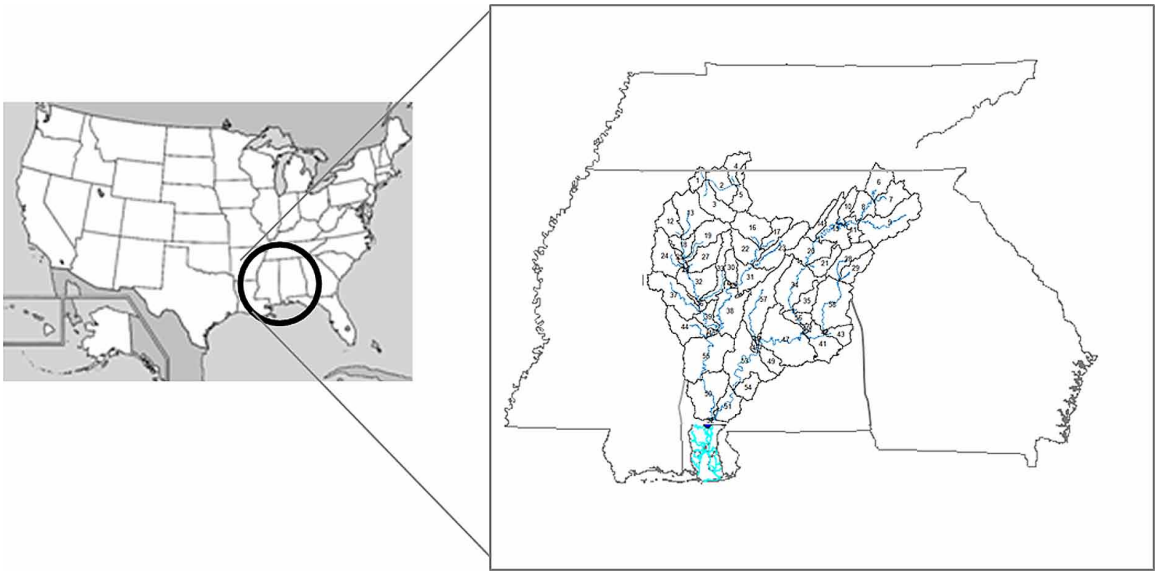
Figure 1. Mobile River watershed. The drainage basin (fourth-largest in the United States) drains streams located in Alabama, Mississippi, Georgia, and Tennessee.



Modeling Tool

Hydrological, nutrient and sediment modeling of the Mobile River watershed was carried out using the Hydrological Simulation Program Fortran (HSPF). The HSPF software is designed for modeling and simulating non-point-source and point-source watershed hydrology and water quality. Time-series of meteorological/water-quality data, land use and topographical data are used to estimate stream flow hydrographs and pollutant-graphs. The model simulates interception, soil moisture, surface runoff, interflow, base flow, snowpack depth and water content, snowmelt, evapo-transpiration, and ground-water recharge. Simulation results are provided as time-series of runoff, sediment load, and nutrient and pesticide concentrations, along with time-series of water quantity and quality, at any point in a watershed. Additional software (WDMUtil and GenScn) is used for data pre-processing and post-processing, and for statistical and graphical analysis of input and output data (Alarcon & O´Hara, 2010). The BASINS 4.1 GIS system (EPA, 2008) was used for downloading basic data and delineating the watershed included in this study. The creation of the initial HSPF model was done using the WinHSPF interface included in BASINS 4.1.

Figure 2 shows the delineation of the Mobile River watershed and corresponding HSPF model, based on the watershed delineation. Locations of water quality stations (from McPherson et al., 2003) in Tombigbee and Alabama rivers are shown in both: the delineated watershed and the schematic HSPF representation of the watershed. Notice that the HSPF model schematic mirrors the arrangement of sub-watersheds. Water quality simulations were performed for the most downstream sub-watershed encompassing Mobile River.

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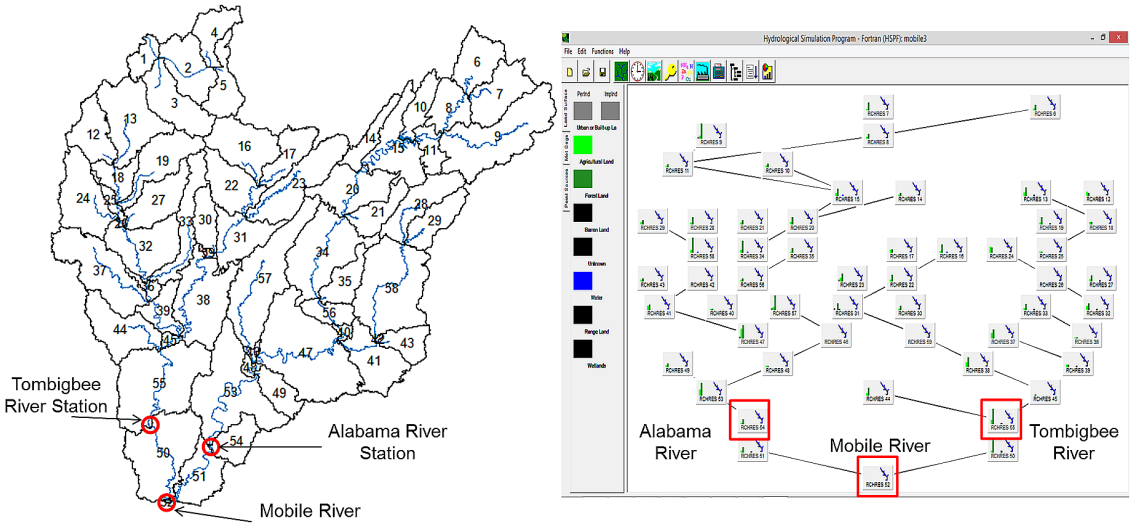
Figure 2. Delineated Mobile River watershed and corresponding HSPF model. Locations of water quality stations (from McPherson et al., 2003) in Tombigbee and Alabama rivers are shown. The corresponding HSPF watershed mode for Mobile River is also shown. Notice that the HSPF interface mirrors the arrangement of sub-watersheds. Water quality simulations were performed for the most downstream sub-watershed encompassing Mobile River.



Water Quality Management

Modeling and simulation in this research was performed in two phases. First, to identify the best management practice in terms of nutrient removal, two types of BMPs were tested for reduction of Nitrate (NO_3) and Total Ammonia (TAM). The BMPs considered in this first phase were filter strips, and stream bank stabilization and fencing (based on Kleinschmidt, 2005). In order to carry out this first computational exploration, a selection of sub-watersheds was performed to reduce computer processing time of water quality simulations.

Figure 3 shows agricultural lands in the Mobile River watershed area (left). It is evident that most of the agricultural activity in the area is concentrated in an agricultural belt that originates in northeastern Mississippi, crosses mid-southern Alabama, and ends in southwestern Georgia. Therefore, the sub-watersheds to which these agricultural lands belong (right hand side of Figure 3) were selected for implementing the BMPs and their corresponding removal efficiency. Three levels of implementation (in terms of percent of agricultural acreage) were simulated: 25%, 50%, and 75%. Those percentages of BMP were selected for allowing comparison of HSPF-simulated results with results reported in Kleinschmidt (2005). Figure 3 shows locations where comparison of simulated and measured/reported concentration values was performed: most downstream outlet of Mobile River, and water quality stations at Tombigbee and Alabama rivers.

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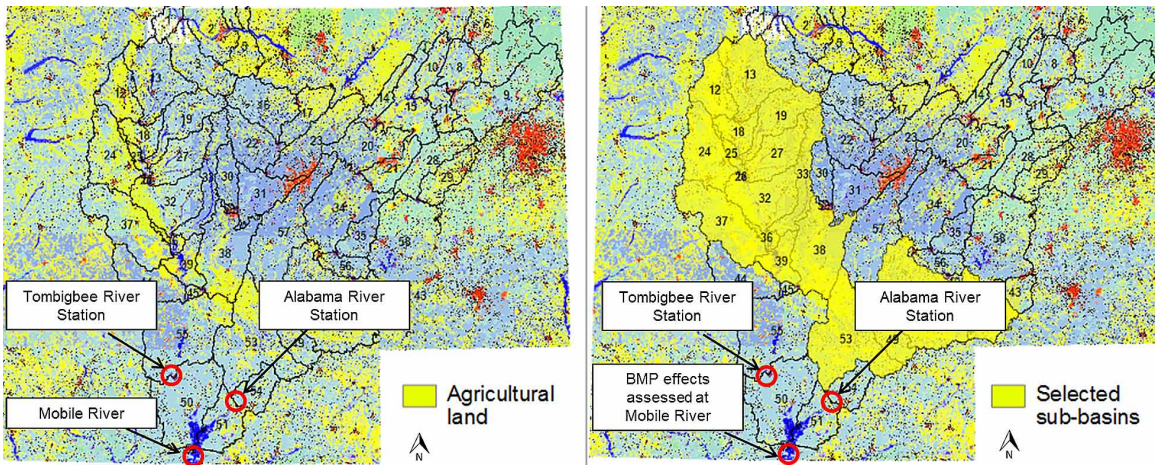
Figure 3. Distribution of agricultural lands in the Mobile River watershed and selected sub-basins for sediment and nutrient simulation. BMP effects were assessed at the Mobile River (watershed outlet).



The second phase of this research consisted on simulating a sediment management practice and assessing its effects in total suspended sediment concentrations in the Mobile River. The BMP for suspended sediments management was applied after the most efficient BMP for nutrient removal was identified. Therefore, the optimum BMP for nutrient removal was also assessed in its efficacy for TSS removal. The BMP was applied to the same sub-watersheds to which nutrient removal management practices were applied (i.e., sub-watersheds where agricultural activity was extensive).

RESULTS

Nutrient Modeling

Simulated nitrate concentrations from 1970 through 1995 are shown in Figure 4. Daily, monthly and annual mean concentration values achieved after the application of two types of BMPs: filter strips, and stream bank stabilization and fencing are shown. The charts show simulated results for application of those BPMs at 25%, 50% and 75% coverage of agricultural land areas.

As shown in Figure 4, most nitrate daily means range between 1 and 6 mg/L with seasonal peaks and minimums in summer and winter correspondingly. Monthly means follow the same seasonal pattern with concentration values ranging mostly between 1.3 and 5 mg/L. Daily and monthly means are mostly lower than the 10 mg/L criteria for nitrate in surface water bodies (EPA, 2016; Reilly et al., 1999). Spikes corresponding to summers of 1977, 1987 and 1988 coincide with low flow conditions reported by Alarcon et al. (2009). Annual mean concentrations range within 2.3 and 4.5 mg/L; 75% of the annual means are lower than 3 mg/L.

The assessment of the effects of the application of the BMPs at different percent coverages is shown in Table 1. Percent reductions in nitrate concentrations at Mobile River were calculated having as a baseline the model-estimated median concentration of nitrate when no BMP was applied.

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Figure 4. Nitrate concentrations in the Mobile River. Reduction in Nitrate concentrations after application of filter strips (left) and stream bank stabilization (right) are also shown.

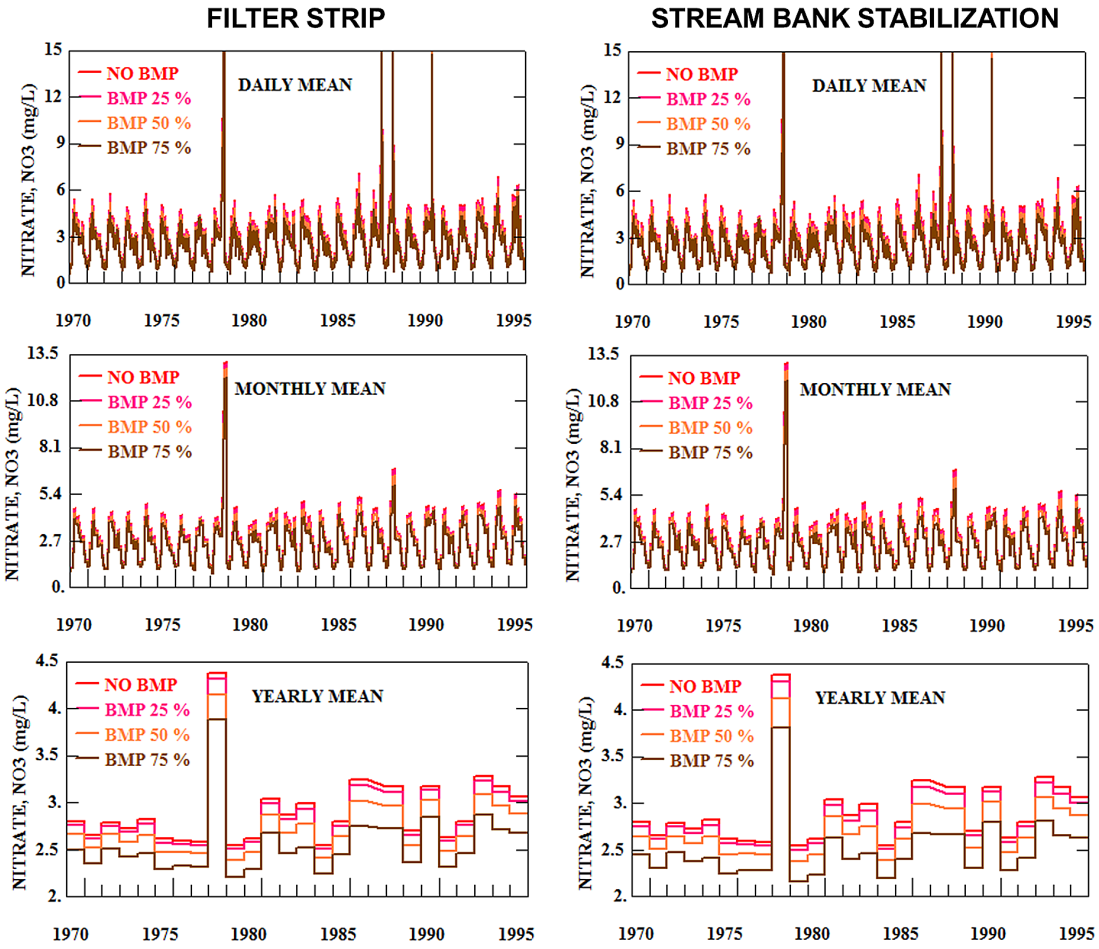

Table 1. Nitrate concentration reductions after implementation of a Filter Strip BMP or Stream Bank Stabilization and Fencing BMP to agricultural lands

NITRATE	Filter Strip		Stream Bank Stabilization	
	NO_3 mg/L	% NO_3 Reduction	NO_3 mg/L	% NO_3 Reduction
NO BMP	2.86	0.00	2.86	0.00
BMP 25%	2.82	1.48	2.81	1.82
BMP 50%	2.70	5.56	2.68	6.25
BMP 75%	2.52	12.24	2.46	14.06

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As shown in Table 1, stream bank stabilization and fencing is the BMP that shows better results in terms of nitrate concentration reductions in the Mobile River. Sequentially applying this BMP to 25%, 50% and 75% of agricultural acreage, produced NO_3 concentration reductions of 1.82%, 6.25%, and 14.06%, correspondingly.

Simulated total ammonia (TAM) concentrations for the simulation period 1970-1995 are shown in Figure 5. Simulated TAM monthly means range between 0.005 and 0.1 mg/L with summer peaks and winter lows as in the case of nitrate. Yearly mean concentration values cluster around 0.01 mg/L with the exception of 1978 when dry conditions were exacerbated by scarce precipitation (Alarcon et al., 2009). The figure also shows daily, monthly and annual mean concentrations for TAM after application of two BMPs (filter strip, and stream bank stabilization and fencing) are applied to increasing area coverages (25%, 50% and 75%). Table 2 compares the efficiency of those BMPs in terms of reduction of TAM concentrations in the most downstream point of the watershed. Stream bank stabilization is again shown to have a better efficacy in the reduction of TAM concentrations in the Mobile River.

Table 2 and Figure 5 show that stream bank stabilization and fencing is the BMP that is more efficient in terms of TAM concentration reductions in the Mobile River. Sequential application of this BMP produces 1.04%, 3.37%, and 8.01% reduction of TAM concentrations in the Mobile River, corresponding to 25%, 50% and 75% of this BMP application to agricultural lands.

Figure 5. Total Ammonia concentrations in the Mobile River. Reduction in TAM concentrations after application of filter strips (left) and stream bank stabilization (right) are also shown.

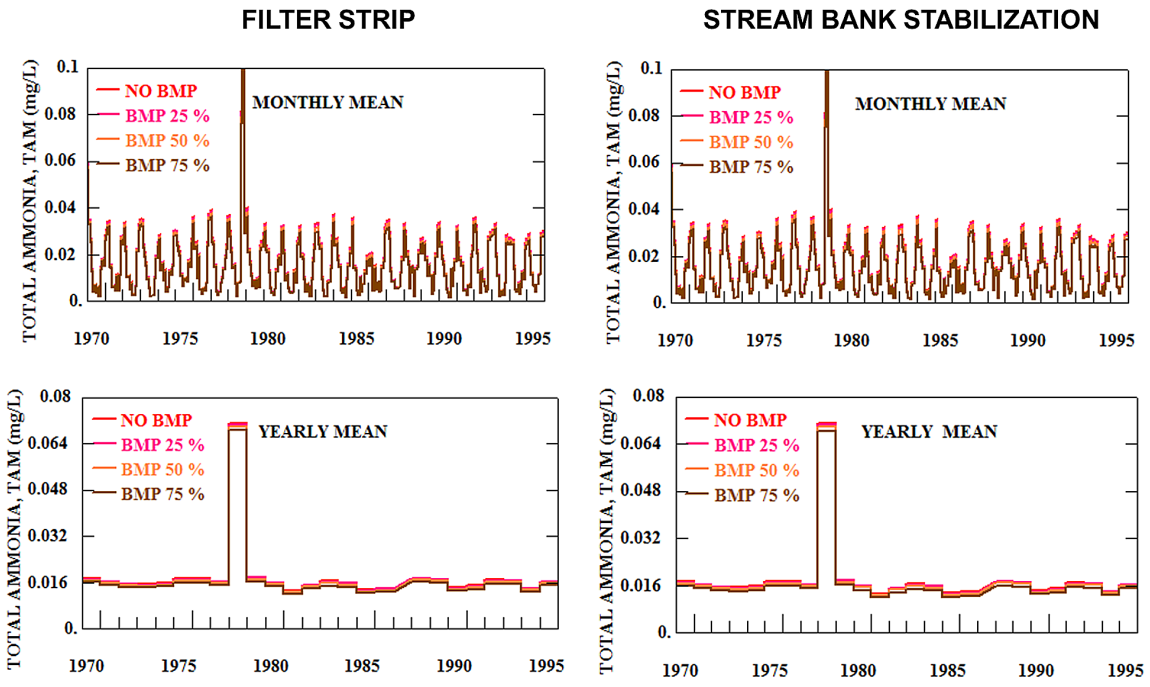

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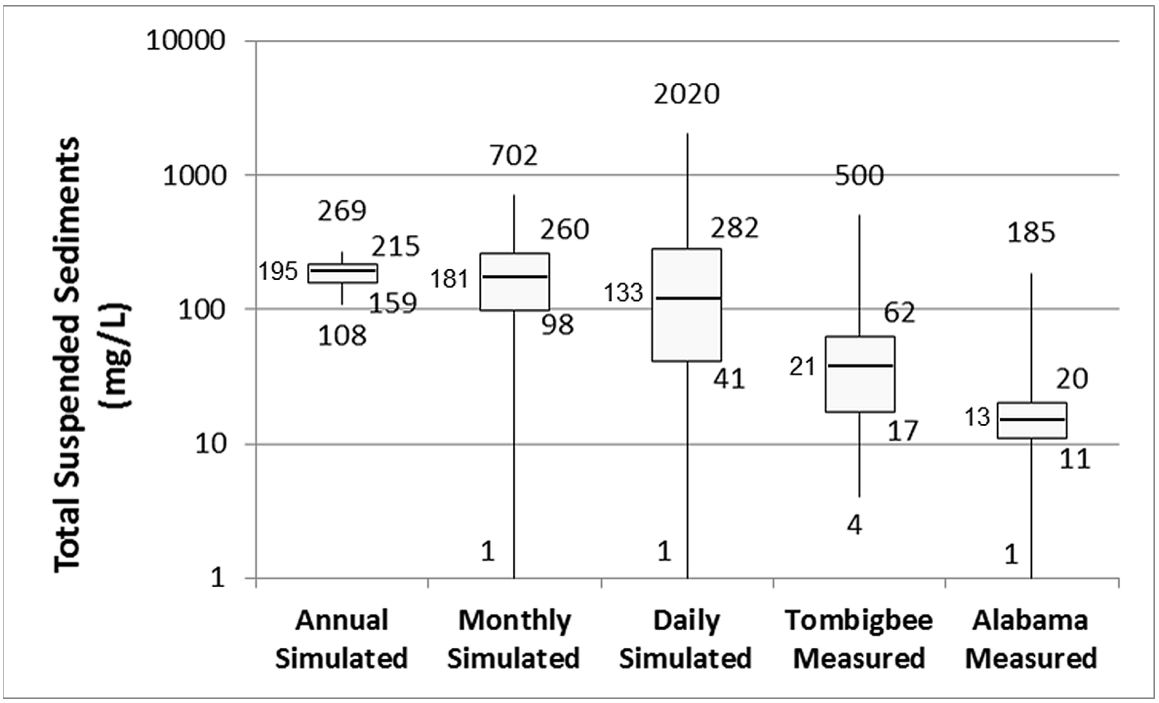
Table 2. TAM concentration reduction after implementation of a Filter Strip BMP or Stream Bank Stabilization and Fencing BMP to agricultural lands

TOTAL AMMONIA	Filter Strip		Stream Bank Stabilization	
	TAM mg/L	% TAM Reduction	TAM mg/L	% TAM Reduction
NO BMP	0.0240	0.00	0.0240	0.00
BMP 25%	0.0238	0.84	0.0237	1.04
BMP 50%	0.0230	3.16	0.0229	3.37
BMP 75%	0.0214	6.97	0.0212	8.01

Sediment Modeling

Since there were no water quality stations in the Mobile River it was not possible to proceed with a calibration of the model for total suspended sediments. However, McPherson et al. (2003) provide ranges of measured TSS concentrations at water quality stations located on the Tombigbee and Alabama rivers (shown in Figures 2 and 3). Those stations are located upstream from the Mobile River but their data could be used to assess the constancy of TSS estimations produced by the model. Figure 6 shows a comparison of TSS concentrations at the Mobile River against concentrations measured (McPherson et al., 2003) at Tombigbee and Alabama rivers. Minimum, first quartile, median, third quartile and maximum measured and simulated TSS concentrations are shown.

Figure 6. Comparison of total suspended solids (TSS) simulated and measured concentration. Measured concentrations at Tombigbee and Alabama Rivers were extracted from McPherson et al., 2003.



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As shown in Figure 6 median simulated TSS concentrations range between 133 to 195 mg/L while median concentrations measured at Tombigbee and Alabama rivers range between 13 and 21 mg/L. Measured concentrations at those rivers reach 500 and 185 mg/L, respectively, while simulated concentrations for Mobile River reach 269 to 2020 mg/L. Simulated concentrations seem to be higher than measured concentrations. This is because statistics for Mobile River were calculated using daily mean concentrations for the 1970-1995 simulation period (more than 9000 daily values), while statistics for measured data were calculated with less than 35 data records. Therefore, simulated data captured a higher number of extreme events and this fact has shifted median and quartile values towards higher concentrations. Also, since the watershed areas draining to those stations are roughly half of the total area that drains to Mobile River, it is expected for measured concentrations at those locations to be smaller than concentrations at Mobile River.

The previous section identified stream bank stabilization and fencing as the most efficient BMP in terms of nitrate and TAM concentration reduction. The sediment model was set up such that it would test how efficient this BMP would be to reduce TSS concentrations in Mobile River. Figure 7 shows daily, monthly and annual average concentrations for the 1970-1995 simulation period. Table 3 summarizes monthly median TSS concentration reductions after the BMP application.

The application of stream bank stabilization to agricultural lands within Mobile River watershed results in TSS concentration reductions in the Mobile River comparable in percentage to those achieved for nutrients. Sequentially applying the BMP to 25%, 50% and 75% of agricultural acreage reduces TSS concentrations by 3.6%, 7.1%, and 10.6%, respectively (Table 3).

Figure 7. Total suspended sediments (TSS) concentrations in the Mobile River. Reduction in TSS concentrations after application of stream bank stabilization to agricultural sub-watersheds.

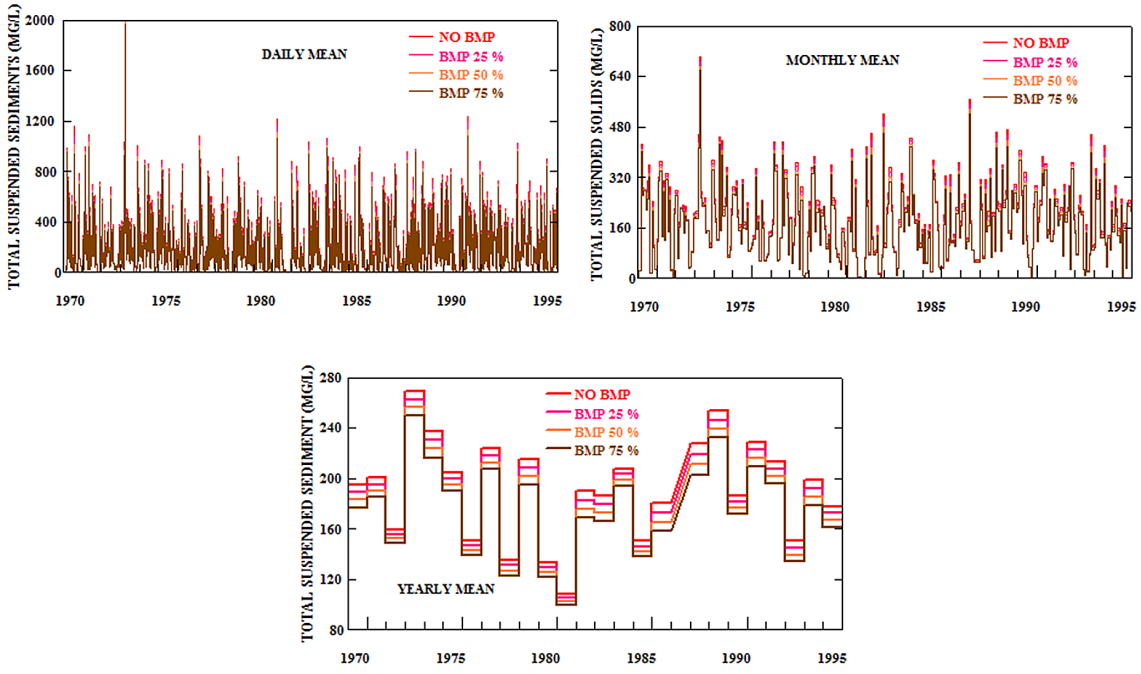

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Table 3. Total suspended sediment (TSS) concentration reduction after implementation of Stream Bank Stabilization and Fencing BMP to agricultural lands

TOTAL SUSPENDED SOLIDS	Stream Bank Stabilization and Fencing	
	TSS mg/L	% TSS Reduction
NO BMP	180.5	0
BMP 25%	172.5	3.6
BMP 50%	168	7.1
BMP 75%	161.5	10.6

CONCLUSION

The nutrient model for the Mobile River Watershed estimates nitrate daily mean concentrations ranging primarily between 1 and 6 mg/L, with seasonal peaks and minimums in summer and winter, correspondingly. Monthly NO_3 mean concentrations follow the same seasonal pattern with most values ranging between 1.3 and 5 mg/L. Daily and monthly means are lower than the 10 mg/L criteria for nitrate in surface water bodies. Peak concentrations (15.1 mg/L and 13.2 mg/L, respectively) corresponding to summers of 1977, 1987 and 1988 coincide with low flow conditions. Annual mean concentrations range within 2.3 and 4.5 mg/L, with 75% of the annual means lower than 3 mg/L. Simulated Total Ammonia concentrations are lower than NO_3 concentrations as would be expected in surface waters. Simulated TAM monthly means range between 0.005 and 0.1 mg/L with summer peaks and winter lows as in the case of nitrate. Yearly mean concentration values are approximately 0.01 mg/L with the exception of 1978 where low flow conditions occurred and yearly mean concentration reaches 0.07 mg/L.

Nutrient modeling and simulation of the application of two management practices (filter strips, stream bank stabilization and fencing) for nutrient removal in the Mobile River revealed that stream bank stabilization and fencing had greater impact on reducing nitrate and TAM concentrations than the application of filter strips to agricultural lands. The water quality model for the Mobile River Watershed developed in this research estimates that consecutive application of this BMP to 25%, 50% and 75% of agricultural lands within the watershed, reduces NO_3 concentrations by 1.82%, 6.25%, and 14.06%, respectively. Similarly, TAM concentrations are decreased by 1.04%, 3.37%, and 8.01%.

Based on the nutrient simulation and exploration of the effects of those two management practices (filter strips, stream bank stabilization and fencing) on nutrient removal, the sediment modeling portion of the water quality model was used to implement the most efficient nutrient management practice (streambank stabilization and fencing) and explore its effects on TSS concentrations in the Mobile River. Implementing stream bank stabilization and fencing produced monthly median TSS concentration reductions ranging from 3.6% to 10.6% in the Mobile River.

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REFERENCES

Alarcon, V. J., McAnally, W., Diaz-Ramirez, J., Martin, J., & Cartwright, J. (2009). A Hydrological Model of the Mobile River Watershed, Southeastern USA. In G. Maroulis & T. E. Simos (Eds.), *Computational Methods in Science and Engineering: Advances in Computational Science* (Vol. 1148, pp. 641–645). doi:10.1063/1.3225392

Alarcon, V. J., & McAnally, W. H. (2012). A Strategy for Estimating Nutrient Concentrations using Remote Sensing Datasets and Hydrological Modeling. *International Journal of Agricultural and Environmental Information Systems*, *3*(1), 1–13. doi:10.4018/jaeis.2012010101

Alarcon, V. J., & O'Hara, C. G. (2010). Scale-Dependency and Sensitivity of Hydrological Estimations to Land Use and Topography for a Coastal Watershed in Mississippi. In Computational Science and Its Applications, LNCS (Vol. 6016, pp. 491-500).

Alarcon, V. J., & Sassenrath, G. F. (2015). Sensitivity of Nutrient Estimations to Sediment Wash-off Using a Hydrological Model of Cherry Creek Watershed, Kansas. In Computational Science and Its Applications, LNCS (Vol. *9157*, 457–467. doi:10.1007/978-3-319-21470-2_33

Alarcon, V. J., & Sassenrath, G. F. (2016). Modeling and Simulating Nutrient Management Practices for the Mobile River Watershed. In Computational Science and Its Applications, *LNCS* (Vol. *9788*, pp. 33–43). doi:10.1007/978-3-319-42111-7_4

Bicknell, B. R., Brian, R., Imhoff, J. C., Kittle, J. L., Jr., Jobes, T. H., & Donigian, A. S., Jr. (2001). HSPF Version 12 User's Manual. National Exposure Research Laboratory. Office of Research and Development U.S. Environmental Protection Agency.

Deliman, P. N., Pack, W. J., & Nelson, E. J. 1999. *Integration of the Hydrology Simulation Program—FORTRAN (HSPF) Watershed Water Quality Model into the Watershed Modeling System (WMS)* (Technical Report W-99-2). US Army Corps of Engineers.

Reilly, J.F., Horne, A.J., & Miller, C.D. (1999, September). Nitrate removal from a drinking water supply with large free-surface constructed wetlands prior to groundwater recharge. *Ecological Engineering*, *14*(1-2), 33–47. doi:10.1016/S0925-8574(99)00018-X

EPA, Environmental Protection Agency. (2008). *BASINS: Better Assessment Science Integrating Point & Nonpoint Sources: A Powerful Tool for Managing Watersheds*. Retrieved from http://www.epa.gov/waterscience/BASINS/

EPA, Environmental Protection Agency. (2012). *National Coastal Condition Report IV*. Retrieved from http://www.epa.gov/sites/production/files/201410/documents/0_nccr_4_report_508_bookmarks.pdf

EPA, Environmental Protection Agency. (2014). *Alabama & Mobile Bay Basin Integrated Assessment of Watershed Health*. Retrieved from http://www.mobilebaynep.com/images/uploads/library

EPA, Environmental Protection Agency. (2016). *Table of Regulated Drinking Water Contaminants. Drinking Water Contaminants: Standards and Regulations*. Retrieved from http://www.epa.gov/your-drinking-water/table-regulated-drinking-water-contaminants

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Foley, J. A., DeFries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., ... Snyder, P. K. (2005). Global consequences of land use. *Science*, *309*(5734), 570–574. doi:10.1126cience.1111772 PMID:16040698

Harmel, D., Potter, S., Casebolt, P., Reckhow, K., Green, C., & Haney, R. (2006). Compilation of measured nutrient load data for agricultural land uses in the United States. *Journal of the American Water Resources Association*, *42*(5), 1163–1178. doi:10.1111/j.1752-1688.2006.tb05604.x

Kleinschmidt Co. (2005). *Tombigbee River Basin Management Plan. Alabama Department of Environmental Management*. Retrieved from http://www.adem.state.al.us/programs/water/nps/files/TombigbeeBMP.pdf

Lent, M., & McKee, L. (2011). *Guadalupe River Watershed Loading HSPF Model: Year 3 final progress report*. Richmond, CA: San Francisco Estuary Institute. Retrieved from http://www.sfei.org/sites/default/files/Guad_HSPF_Model__forSPLRev_17Feb2012.pdf

Matson, P. A., Parton, W. J., Power, A. G., & Swift, M. J. (1997). Agricultural intensification and ecosystem properties. *Science*, *277*(5325), 504–509. doi:10.1126cience.277.5325.504 PMID:20662149

McPherson, A. K., Moreland, R. S., & Atkins, J. B. (2003). Occurrence and Distribution of Nutrients, Suspended Sediment, and Pesticides in the Mobile River Basin, Alabama, Georgia, Mississippi, and Tennessee, 1999 – 2001 (Water-Resources Investigations Report 03 – 4203). United States Geological Survey.

Parajuli, P. B., Jayakody, P., Sassenrath, G. F., Ouyang, Y., & Pote, J. W. (2013). Assessing the impacts of crop-rotation and tillage on crop yields and sediment yield using a modeling approach. *Agricultural Water Management*, *119*, 32–41. doi:10.1016/j.agwat.2012.12.010

Park, K., Kim, C., & Schroeder, W. W. (2007). Temporal variability in summertime bottom hypoxia in shallow areas of Mobile Bay, Alabama. *Estuaries and Coasts*, *30*(1), 54–65. Retrieved from http://link.springer.com/article/10.1007%2FBF02782967 doi:10.1007/BF02782967

Vitousek, P. M., Mooney, H. A., Lubchenco, J., & Melillo, J. M. (1997). Human domination of Earths ecosystems. *Science*, *277*(5325), 494–499. doi:10.1126cience.277.5325.494

Wiener, J. D., & Sassenrath, G. F. (2012, June 27-29). Landscaping the long-term: Water system and irrigation re-visions for sustainability. *Proceedings of the AWRA 2012 Summer Specialty Conference*, Denver, CO.

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Chapter 67
Impact of Climate Change on Potato Production in India

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ABSTRACT

Potato is a temperate crop and higher day temperatures cause some areas to less suitable for potato production due to lower tuber yields and its quality. Tuber growth and yield can be severely reduced by temperature fluctuations outside 5-30 °C. The rate of warming in last 50 years is double than that for the last century. Increase in temperature and atmospheric CO2 are interlinked occurring simultaneously under future climate change and global warming scenarios. If CO2 is elevated to 550 ppm the temperature rise is likely to be 3 ºC with decline in potato production by 13.72% in the year 2050. The changing climate will affect the potato production adversely due to drought, salinity, frost, flooding, erratic unseasonal rains etc. It may reduce seed tuber production, impact storage facility and potato processing industries. Therefore, the quantification of regional vulnerability and impact assessment is very important for the development of early warning on disease forecasting systems, breeding of short duration and heat, drought, salinity tolerant and disease resistant cultivars.

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INTRODUCTION

The book chapter "Sustainable Potato Production and the Impact of Climate Change" deals with the possible impact of global warming and elevated CO_2 on Potato production. The results presented in this chapter are summarized findings of the research conducted in India; its agricultural universities and Indian council of Agricultural Research (ICAR). The level of atmospheric temperature and carbon dioxide raised under controlled conditions to some possible changes in near future to assess the impact on climate change on potato production. Findings of various researchers of India are compiled in the form of book chapter for easy understanding and in line of future work. Mitigation of impact of climate change on potato is discussed in global context.

BACKGROUND

The bottom-line conclusion of the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2001) is that the average global surface temperature will increase by between 1.4°C and 3°C above 1990 levels by 2100 for low emission scenarios and between 2.5°C and 5.8°C for higher emission scenarios of greenhouse gases and aerosols in the atmosphere. The effect of increased temperatures on potato production in specific areas will vary depending partly on the current temperature of that area. Temperatures above 30 °C can have several negative impacts on potato production like: slowing tuber growth and initiation, less partitioning of starch to the tubers, physiological damage to tubers (e.g. brown spots), shortened/non-existent tuber dormancy, making tubers sprout too early. These effects can reduce crop yield and the number and weight of tubers. As a result, areas where current temperatures are near the limits of potatoes' temperature range will likely suffer large reductions in potato crop yields in the future.

Potato farming is the most important economic activity in some parts of India. Uttar Pradesh, Punjab and West Bengal are the major potato producing states. There is direct effect of global warming and serious risk to future crop production and food security in the country. At high altitudes, global warming will probably lead to changes in the time of planting, the planting of late-maturing cultivars, and a shift of the location of potato production. In many of these regions in India, changes in potato yield are likely to be relatively small in initial stage but expected to trigger in coming era of global warming. Shifting planting time or location is less feasible at lower altitudes, and in these regions global warming could have a strong negative effect on potato production. It is likely that the currently observed trend of global warming, which has been 0.6 ºC + 0.2 since 1900, will continue and that the average global temperature will increase by between 1.4 and 5.8 ºC over the period 1990 to 2100. It is shown that heat-tolerant potato cultivars could be used to mitigate effects of global warming in (sub) tropical regions. Climate change is now an acknowledged fact and reality. The evidence gathered world over using state-of-the-art technology by various national and international agencies is irrefutable. Human activities like rapid industrialization, intensive agriculture, and indiscriminate use of fertilizers, deforestation and increasing use of fossil fuels during past 150 years are the major contributing factors for climate change. The continued effect of these activities resulted in increasing emission of CO_2 and other greenhouse gases (GHG) leading to global warming as a '*greenhouse effect*' due to entrapment of back radiation from earth by these gases. The increase in temperature due to global warming is 0.76 ºC since 1850. The rate of warming in last 50 years is double than that for the last century. The rate of warming is increasing. The 20th century's last two decades were the hottest in 400 years and possibly the warmest for several millennia, according

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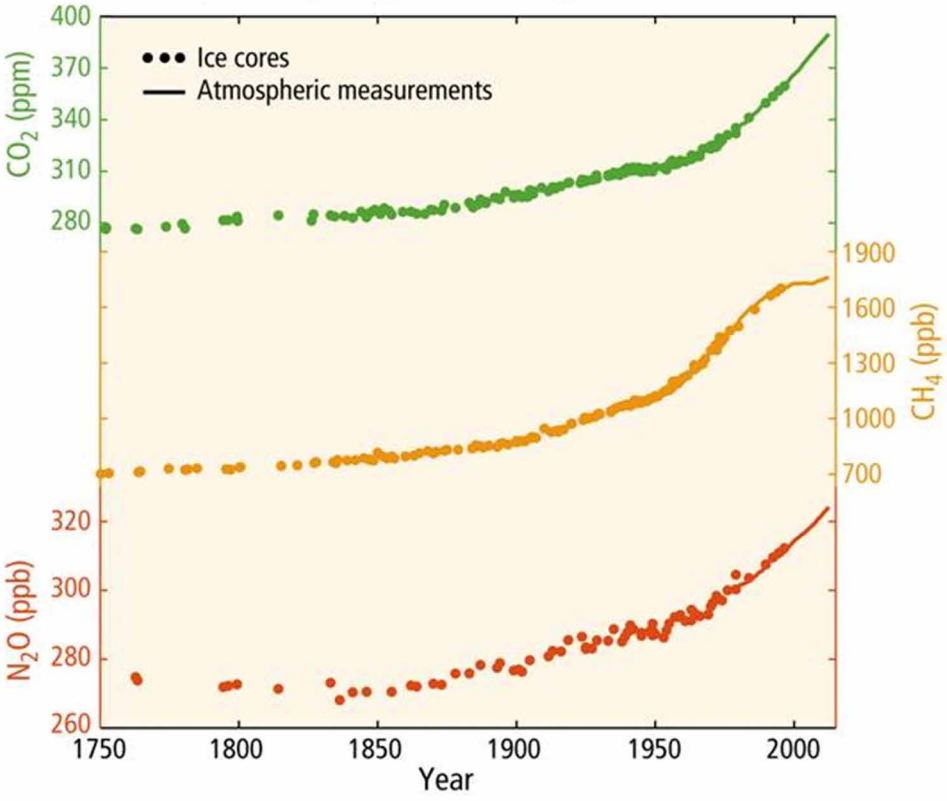
to a number of climate studies. And the United Nations' Intergovernmental Panel on Climate Change (IPCC) reports that 11 of the past 12 years are among the dozen warmest since 1850. The CO_2 concentration is projected to double from the current level of 360 ppm in the atmosphere. Global warming is occurring along with shifting pattern of rainfall and increasing incident of extreme weather events like floods, droughts and frosting. Concentration of greenhouse gases on time scale is presented in Figure 1.

Global annual average surface temperature in 2015 is looking set to reach 1°C above the pre-industrial average (as represented by the 1850-1900 reference period) for the first time, according to the HadCRUT4 dataset produced by the Met Office and the Climatic Research Unit at the University of East Anglia (Figure 2). This is based on the current January to September 2015 temperature anomaly, and is also expected to hold when the final full-year anomaly is calculated. The warmth of 2015 represents an important marker because it means we are reaching halfway to 2°C for the first time. In 2010, parties to the United Nations Framework Convention on Climate Change (UNFCCC) agreed warming should be limited to below 2°C to avoid dangerous climate change.

The growth of potato in India has been phenomenal since 1950 with increase in area production and productivity by 6, 15 and 3 times, respectively. Globally India stands at 4th and 3rd position now with respect to acreage and production, respectively. The crop is mainly confined to Indo-Gangetic plains in

Figure 1. Observed changes in atmospheric greenhouse gas concentrations. Atmospheric concentrations of carbon dioxide (CO2, green), methane (CH4, orange), and nitrous oxide (N2O, red). Data from ice cores (symbols) and direct atmospheric measurements (lines) are overlaid
Source: (IPCC 2014).



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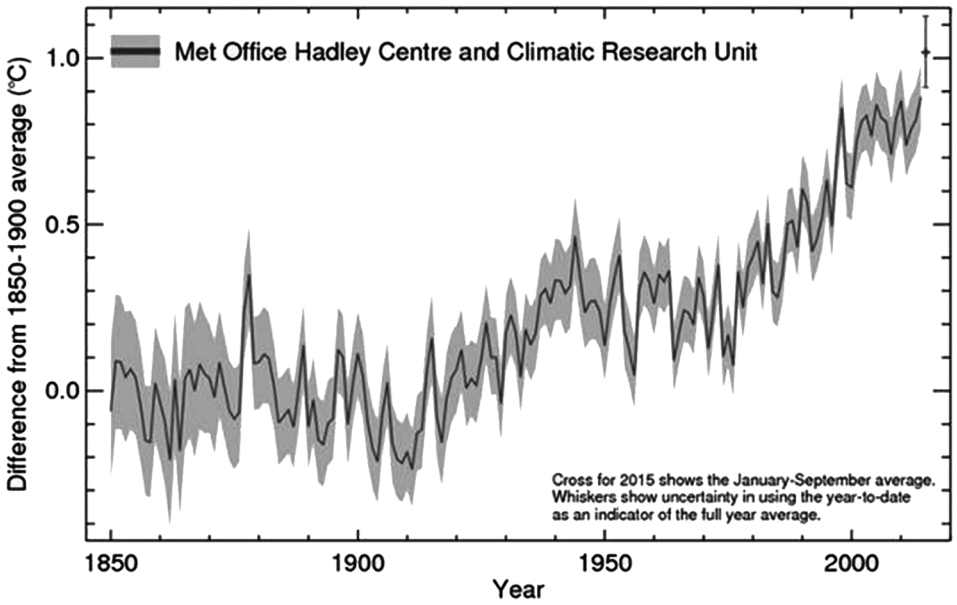
mild and cool winters in India. The autumn/winter planted crop in northern plains of India comprising the states of Uttar Pradesh, West Bengal, Bihar, Punjab and Haryana contributes 84% of total potato production in India. Here, the crop is grown totally under irrigated conditions. It is also grown in small scattered areas as rainfed crop in hills during summers and as rainy (*kharif*) and winter seasons crop in plateau region. However, the climate change and global warming will have a profound effect on potato growth story in India impacting every aspect of not only production and profitability, but seed multiplication, storage, marketing and processing of this perishable vegetatively propagated crop. Under the impact of future scenarios of climate change, the growth projections of potato in India might be arrested or even reversed, unless effective adaptation measures are evolved for timely application.

IMPACT ANALYSIS

Increase in temperature and atmospheric CO_2 are interlinked occurring simultaneously under future climate change and global warming scenarios. Effect of their interaction on potato would be more relevant and of greater economic significance compared to their usually counteracting direct effects on crop growth, yield and quality. Potato is mostly grown in north India during winters usually receiving few scattered rains. Under future scenarios the global warming is projected to be more pronounced over land areas with maximum temperature increase over northern India. The winter and post monsoon seasons are likely to be more affected by warming. Therefore, potato in addition to direct effects on growth and yield may be subjected to indirect effects of warming. These are increasing drought due to reduction in precipitation accentuating salinity and unpredictable extreme events of erratic unseasonal rains, flooding and frosting *etc*.

Figure 2. Observed global mean temperature difference from the 1850-1900 mean (°C) from HadCRUT4
Source: Morice et al 2012.



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Effect of Elevated CO_2 and Temperature

Productivity

Effect of Elevated CO2 and Rise in Temperature on Potato Production in India

All India estimates of potato production were made by INFOCROP-POTATO simulation model (Singh, 2005, 2008) without adaptations and assuming that area under the crop remains constant at current levels (1.2 m ha) in future climate scenarios (Table 1). Results showed that the potato production will increase by 11.12% at elevated CO_2 of 550 ppm and 1 ºC rise ºin temperature. However, the future climate scenarios for India indicates that at elevated CO_2 of 550 ppm the temperature rise is likely to be 3 ºC (IPCC, 2007), with decline in production by 13.72% in the year 2050. The 1 ºC rise in temperature is likely to be associated with only 400 ppm of CO_2 to be assumed in the year 2020 (IPCC, 2007), with a decline in potato production by 3.16% (Table 1).

Direct Effect of Elevated CO2

The effect of elevated CO_2 concentration in controlled experiments conducted in OTC (Open top chambers), FACE (Free air carbon enrichment) and growth chambers overwhelmingly suggests positive effect on growth and yield with only few negative influences.

The CO_2 concentration and assimilation are positively correlated. Doubling the CO_2 concentration from ambient level of 360 ppm to 720 ppm increased the total biomass by 27 to 66% (Collins, 1976; Heagle *et al*., 2003; Olivo *et al*., 2002; Donnelly *et al*., 2001; Miglietta *et al*., 1998; Van de Geijn & Dijkstra, 1995). The tuber yield increased from 32 to 85% (Collins, 1976; Wheeler *et al*., 1991; Heagle *et al*., 2003; Craigon *et al*., 2002; Olivo *et al*., 2002; Donnelly *et al*., 2001; Miglietta *et al*., 1998; Finnan *et al*., 2002). The increase in tuber yield is estimated to be approximately 10% for every 100 ppm increase in CO_2 concentration (Miglietta *et al*., 1998). These positive effects are attributed to increased photosynthesis from 10 to 40% (Collins, 1976; Katny *et al*., 2005; Olivo *et al*., 2002; Vandermeiren *et al*., 2002; Schapendonk *et al*., 2000). The increase in photosynthesis was most marked in young leaves (Katny *et al*., 2005; Vandermeiren *et al*., 2002). This is attributed to phenomenon of photosynthetic acclimation later in the growing season particularly in old leaves (Vandermeiren *et al*., 2002; Schapendonk *et al*., 2000; Lawson *et al*., 2001). Varietal differences in response to elevated CO_2 concentration exists (Olivo *et al*., 2002). Number of tubers remained unaffected under elevated $CO_{2,}$ but mean tuber weight

Table 1. Change (%) in potato production in India from current levels as affected by elevated CO2 and rise in temperature without adaptations

Atmospheric CO_2 conc. (ppm)	Rise in temperature (ºC)					
	Nil (current)	1 (2020)	2	3 (2050)	4	5 (2090)
369 (current)	0.0	-6.27	-17.09	-28.10	-42.55	-60.55
400 (2020)	3.40	-3.16	-14.57	-25.54	-58.63	-58.63
550 (2050)	18.65	11.12	-1.25	-13.72	-30.25	-49.94

(Values in parentheses are likely years for associated CO_2 levels and temperature rise) Source: (Singh, 2009)

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increased mainly through increase in number of cells in tubers without influencing the cell volume (Collins, 1976; Chen and Setter, 2003; Donnelly *et al*., 2001). However, an increase in tuber number has been also observed (Miglietta *et al*., 1998; Craigon *et al*., 2002).

Elevated CO_2 concentration reduces evapotranspiration (ET) resulting in water saving to the extent of 12 to 14%(Magliulo *et al*., 2003; Olivo *et al*., 2002). Elevated CO_2 concentration advances the tuber initiation and flowering (Miglietta *et al*., 1998) but hastens senescence of leaves (Miglietta *et al*., 1998; Vaccari *et al*., 2001). The few negative effects of elevated CO_2 concentration include reduction in chlorophyll content in leaves particularly during later growing season after tuber initiation (Bindi *et al*., 2002; Lawson *et al*., 2001).

Direct Effect of Temperature

Growth and development is affected at high temperatures encountered in the tropics. No potato crop growth is possible below 2 ºC and above 30 ºC (Van Keulen & Stol, 1995). The minimum (0-7 ºC), optimum (16-25 ºC) and maximum (40 ºC) temperatures for net photosynthesis are reported (Kooman & Haverkort, 1995). Potato requires cool night temperature to induce tuberization (Burt, 1964; Ku *et al*., 1977; Cutter, 1992). Although photosynthesis in potato is suppressed by high temperature (Ku *et al*., 1977), it is not as sensitive to temperature as tuberization and partitioning of photosynthates to tuber (Reynolds *et al*., 1990; Midmore & Prange, 1992). The radiation use efficiency (RUE) is suppressed under high temperatures (Allen & Scott, 1992). High temperature reduces tuber number and size (Ewing, 1997).

High temperature brings about marked morphological changes like etiolated growth with smaller size of compound leaves and leaflets reducing the LAI (Ewing, 1997; Fleisher *et al*., 2006) in addition to reduction in tuber number and size (Peet & Wolfe, 2000; Khan *et al*., 2003). However, long day conditions and high temperature prevailing in spring season in Punjab state in plains of India favoured growth of foliage at the cost of tubers and improved processing quality of tubers (Marwaha & Sandhu, 2002).

Potato requires cool night temperature to induce tuberization, which is inhibited by even moderately high temperatures (Ku *et al*., 1977; Ewing, 1997). Tuber initiation was most affected by high temperature (Ghosh *et al*., 2000). High temperature reduces the gross photosynthetic rate (Fleisher *et al*., 2006). Although photosynthesis in potato is suppressed by high temperature (Ku *et al*., 1977), it is not as sensitive to temperature as tuberization and partitioning of photosynthates to tuber (Reynolds *et al*., 1990; Midmore and Prange, 1992). Therefore, even moderately high temperature drastically reduces tuber yield without much affecting the photosynthesis and total biomass production (Peet & Wolfe, 2000).

Interaction Effect of Temperature and CO_2

Potato tuber yield of plants exposed to high temperatures (35 ºC) were extremely low regardless of CO_2 treatment, while in a non-temperature stress treatment (25 ºC) doubling CO_2 increased tuber yield significantly by 71.5% (Peet & Wolfe, 2000). In another study potato was grown for 35 days under CO_2 concentrations (500, 1,000, 1,500 and 2,000 micromoles mol-1) at both 16 ºC and 20 ºC air temperature. The mean starch concentration increased with increasing CO_2 concentration at both 16 ºC and 20 ºC and was consistently higher at 16 ºC than at 20 ºC (Cao & Tibbitts, 1997). The SLW (g.m-2) was positively related to the foliar starch concentration on the basis of leaf area or dry weight (Cao & Tibbitts, 1997).

The CO_2 enrichment does not appear to compensate for the detrimental effects of higher temperature on tuber yield, while the quality of potato is likely to be impacted severely in terms of marketable grade of tubers and internal disorders.

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Quality

Elevated CO_2 increased the amount of dry matter and starch with decrease in glycoalkaloid and nitrates improving the quality of tubers (Vorne *et al*., 2002; Schapendonk *et al*., 2000; Donnelly *et al*., 2001). Nearly all the nutrient elements tend to decrease in tubersunder elevated CO_2 (Cao and Tibbitts, 1997; Fangmeier *et al*., 2002) and the citric acid content decreases causing a higher risk of discoloration after cooking (Vorne *et al*., 2002).

High temperature is associated with tuber disorder of internal necrosis (Sterrett *et al*., 1991). In a pot experiment in naturally lit glass house and phytotron, the high temperature (30 ºC) decreased the total dry matter and tuber yield and degraded quality by reducing specific gravity of tubers (Ghosh *et al*., 2000). Nitrate reductase (NR) activity was also decreased by high temperature. The inhibition of tuber yield was due to limited translocation of carbohydrates from leaves to tubers following the reduction of NR activity and carbohydrate expense for dark respiration (Ghosh *et al*., 2000). It can also affect tuber quality by causing 'heat sprouting' which is premature growth of stolons from immature tubers (Wolfe *et al*., 1983; Struik *et al*., 1989) and internal necrosis (Sterrett *et al*., 1991). Potato processing requires large size tubers with high dry matter. Warming may reduce proportion of marketable and processing grade tubers for table and processing purposes, though dry matter may increase.

Indirect Effects of Climate Change and Global Warming

Draught

Optimal water supply is essential for potato, because of its shallow root system. The potato plant generally roots rather shallowly 40-50 cm (Beukema & Van der Zaag, 1990). Potato is extremely sensitive to drought particularly at tuber initiation with substantial loss in tuber yield. Dry matter partitioning to root, shoot, leaf and stem as a function of development stage (DS) and the root:shoot ratio is affected by drought stress. Drought, while reducing dry matter production increases the root:shoot ratio indicating a shift in the balance of growth in favour of roots. Roots of plants grown in drought conditions also tend to be thinner. Both responses enable drought plants to exploit the available soil moisture more effectively (Vos, 1995). Tuber initiation and maturity under drought stress conditions is hastened (Beukema & Van der Zaag, 1990).

1. **Salinity:** Potato is highly sensitive to salinity and irrigation with saline waters with even moderate residual sodium carbonate (RSC) values (Singh & Trehan, 1993).
2. **Frost:** Potato is extremely sensitive to frost. Complete loss of foliage is reported below 2 ºC of ambient temperatures for 2-3 consecutive nights. More than 4-5 hrs. duration of temperature below 1 ºC may result in foliage loss of 50% in even one night exposure. However, yield losses depend on crop growth stage at occurrence of frost. Frosting late in the season from 80-90 days after planting (DAP) results in yield loss of 10-15%, while that at 50-60 DAP may cause yield loss of 30-50%.
3. **Flooding:** Flooding for even short period of 2-3 days during active vegetative phase affects growth and yield. Flooding before emergence severely affects emergence due to rotting of seed tubers and soil crust formation, while that near harvesting results in rotting and rupture of tuber lenticels affecting physical appearance and marketable quality.

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4. **Erratic Unseasonal Rains:** Rains of even 10-15 mm during planting or immediately after planting affects emergence due to soil crust formation and delays planting operation with consequent loss in yield. Rains during active vegetative phase may promote incidence of late blight disease.
5. **Seed Tuber Production:** In vegetatively propagated potato crop, the disease free quality seed tubers as planting material has special and added significance. Tuber as seed material is the carrier of a host of fungal, bacterial and viral diseases, responsible for rapid and drastic reduction in yield in successive generations of clonal multiplication. Most importantly the seed tubers alone accounts for half of the cost of inputs in potato cultivation and the profitability of the cropping enterprise to a large extent depends on quality of seed used. Viral diseases transmitted by aphid and other vectors are mainly responsible for rapid degeneration of planting materials in potato crop. The technology of '*seed plot technique*' was developed on the sole premise of growing seed tubers in relatively aphid free periods in plains during winters and termination of vines by dehaulming before aphid population crosses a threshold to minimize infection of viral diseases. The appearance of potato peach aphid (*Myzus persicae*) is reported to advance by two weeks for every 1°C rise in mean temperature and population build up is positively correlated with maximum temperature and minimum relative humidity (Biswas *et al*. 2004; Dias *et al*., 1980). Thus, under the impact of climate change and global warming the earlier appearance and increase in aphid population is likely to limit the aphid free period to the detriment of seed tuber quality and quantity, which will ultimately affect potato production in India. In many regions warming may abolish seed tuber production altogether, while in others it will involve extra cost on chemicals and pesticides treatment with increased cost of seed resulting in decline in profitability.
6. **Storage:** The harvesting of potato in plains of India coincides with onset of hot summer season. Cold storage of tubers is recommended by the end of February to prevent heavy weight loss and rotting. It is cold stored up to the end of October till withdrawal for human consumption and planting is accomplished. In certain regions relatively cooler climate permits on farm storage of tubers for short period for 80-90 days in improvised country stores, heaps and pits with acceptable losses. However, warming during the period from March to June may preclude this practice with increased cost of storage in the cold stores. On the other hand earlier cold storage than the recommended by the end of February and prolonged storage beyond October till weather is favourable for planting, might become necessary under global warming scenarios. This will increase the operational cost and energy use in cold stores with implied increase in cost of cold storage and enhanced market price of potato for table and seed purpose. More number of strategically located cold stores near production and consumption centers would be needed to maintain the supply chain during hot summer months from March to October under global warming.
7. **Potato Processing Industry:** The potato tubers stored in cold stores at 4 ºC is not suitable for processing purposes due to increase in reducing sugar content imparting undesirable attributes in various processed products. Potato tubers kept in low temperature stores at 10 ºC or in on farm country stores are utilized for processing. However, tubers kept in these low temperature and country stores suffer from sprouting and weight loss once the dormancy is broken rendering it relatively unfit for processing. Global warming will reduce the 'time window' of availability of potato suitable for processing and will result in enhanced cost of chemical treatment of tubers to prevent sprouting. This has implication for viability of potato processing industry for supply of raw material for extended periods to be economical.

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Regional Vulnerability to Climate Change in India

The entire Indo-Gangetic plains, where irrigated potato is mainly grown is vulnerable. However, the state of West Bengal with highest productivity and second largest potato producing state in India appears highly vulnerable. Winters are mild in West Bengal and 'window' of suitable growing period is small, any rise in temperature will severely impact productivity with associated problems of storage and post harvest handling of produce in warmer conditions. Other vulnerable states are Bihar and Uttar Pradesh, which contributes maximum in total potato production. The states of Punjab, Haryana, and adjoining areas in northern Rajasthan and western Uttar Pradesh, where winters are relatively severe experiencing occasional frost might benefit from global warming to certain extent. The rainfed crop in plateau regions and other areas in south India would be most vulnerable due to warming and associated drought conditions.

Observations on Aberrant Weather and Extreme Events

- Rains in winter season received at planting affects emergence and delays planting with reduction in tuber yield.
- Heavy showers during the crops season resulting in flooding affects tuber yield.
- Heavy rains at the time of harvesting induce rottage in field and in temporary heaps of harvested potato in the field.
- Overcast sky and rains early in the crop season invariably increases the attack of late blight disease with severe reduction in yield.
- Early frosting received in last fortnight of December and first week of January damages the crop in North-Western plains and western UP.
- Relatively warmer winters in the year 2008 reduced tuber yield in West Bengal, UP and Bihar.

Adaptation Measures for Climate Change and Global Warming

- Use of crop residue mulches for some time after planting.
- Using drip irrigation in place of furrow and basin methods.
- Alter cultural management in potato based cropping systems.
- Conservation tillage and on farm crop residue management.
- Improvement and augmentation of cold storage facilities and air conditioned transportation from producing to consumption centers.
- Subsidizing additional cost of pests and water management.
- Insurance against weather for the cash crop of potato with high cost of cultivation.
- Strengthen education, research and development in warm climate production technology for ware and seed potato crop.

Mitigation Measures to Reduce Emission of CO_2/ghg and Carbon Sequestration Potential of the Crop

Potato being a short duration annual crop with readily decomposable crop residues has very limited carbon sequestration potential. Other mitigation measures are as follows.

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- Resource conservation techniques
- Organic farming

FUTURE STRATEGIES FOR RESEARCH

- Quantification of regional vulnerability and impact assessment.
- Development of early warning disease forecasting systems.
- Breeding short duration and heat tolerant cultivars. Mining biodiversity to heat tolerance on priority.
- Breeding drought, salinity tolerant and disease resistant cultivars.
- Advance planning for possible relocation and identification of new areas for potato cultivation.
- Improved agronomic management for water and fertilizer use efficiency.
- Development of agro-techniques for warm weather cultivation and potato based cropping systems.

CONCLUSION

Potato a native of temperate region grown under long day conditions in mild and cool summer season in Europe and America was introduced and adapted to tropical short day conditions in India during the last century. The growth of potato in India has been phenomenal since 1950 with increase in area production and productivity by 6, 15 and 3 times, respectively. The crop is mainly confined to Indo-Gangetic plains in mild and cool winters in India. The autumn/winter planted crop in northern plains of India comprising the states of Uttar Pradesh, West Bengal, Bihar, Punjab and Haryana contributes 84% of total potato production in India, where the crop is grown totally under irrigated conditions. Growth and development is affected at high temperatures encountered in the tropics. No potato crop growth is possible below 2 ºC and above 30 ºC. The minimum (0-7 ºC), optimum (16-25 ºC) and maximum (40 ºC) temperatures for net photosynthesis are reported. Potato requires cool night temperature to induce tuberization. Although photosynthesis in potato is suppressed by high temperature, it is not as sensitive to temperature as tuberization and partitioning of photosynthates to tubers.

The climate change and global warming will have a profound effect on potato growth story in India impacting every aspect of not only production and profitability, but seed multiplication, storage, marketing and processing of this perishable vegetatively propagated crop. Under the impact of future scenarios of climate change the growth projections of potato in India might be arrested or even reversed, unless effective adaptation measures are evolved for timely application and implementation. Increase in temperature and atmospheric CO_2 are interlinked occurring simultaneously under future climate change and global warming scenarios. Effect of their interaction on potato would be more relevant and of greater economic significance compared to their usually counteracting direct effects on crop growth, yield and quality. It is estimated that due to global warming potato production in India may decline by 3.16 and 13.72% from current levels by the year 2020 and 2050, respectively. The potato production will be directly affected by climate change, while there would be several indirect effects on various facets of supply, storage, utilization and acreage of the crop in future climate scenarios.

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REFERENCES

Allen, E. J., & Scott, R. K. (1992). Principles of agronomy and their application in the potato Industry. In P. M. Harris (Ed.), *The potato crop. The scientific basis for improvement* (pp. 816–881). London: Chapman and Hall. doi:10.1007/978-94-011-2340-2_17

Beukema, H. P., & Van der Zaag, D. E. (1990). *Introduction to potato production*. Wageningen: Pudoc.

Bindi, M., Hacour, A., Vandermeiren, K., Craigon, J., Ojanpera, K., Selldén, G., ... Fibbi, L. (2002). Chlorophyll concentration of potatoes grown under elevated carbon dioxide and/or ozone concentrations. *European Journal of Agronomy*, *17*(4), 319–335. doi:10.1016/S1161-0301(02)00069-2

Biswas, M. K., De, B. K., Nath, P. S., & Mohasin, M. (2004). Influence of different weather factors on the population build up of vectors of potato virus. *Annals of Plant Protection Sciences*, *12*(2), 352–355.

Burt, R. L. (1964). Influence of short periods of low temperature on tuber initiation in the potato. *European Potato Journal*, *7*(4), 197–208. doi:10.1007/BF02368251

Cao, W., & Tibbitts, T. W. (1997). Starch concentration and impact on specific leaf weight and element concentrations in potato leaves under varied carbon dioxide and temperature. *Journal of Plant Nutrition*, *20*(7-8), 871–881. doi:10.1080/01904169709365302 PMID:11541213

Chen, C. T., & Setter, T. L. (2003). Response of potato tuber cell division and growth to shade and elevated CO_2. *Annals of Botany*, *91*(3), 373–381. doi:10.1093/aob/mcg031 PMID:12547690

Collins, W. B. (1976). Effect of carbon dioxide enrichment on growth of the potato plant. *HortScience*, *11*, 467–469.

Craigon, J., Fangmeier, A., Jones, M., Donnelly, A., Bindi, M., De Temmerman, L., ... Ojanpera, K. (2002). Growth and marketable-yield responses of potato to increased CO2 and ozone. *European Journal of Agronomy*, *17*(4), 273–289. doi:10.1016/S1161-0301(02)00066-7

Cutter, E. G. (1992). Structure and development of the potato plant. In P. M. Harris (Ed.), *The potato crop. The scientific basis for improvement* (pp. 65–161). London: Chapman and Hall. doi:10.1007/978-94-011-2340-2_3

de Souza, D. J., Yuki, V. A., Costa, A. S., & Teixeeira, P. R. M. (1980). Study of the spread of virus diseases in a warm climate as compared to a cold climate, with a view to obtaining seed potatoes with a low rate of virus diseases. *Summa Phytopathologica*, *14*, 58–59.

Donnelly, A., Craigon, J., Black, C. R., Colls, J. J., & Landon, G. (2001). Elevated CO_2 increases biomass and tuber yield in potato even at high ozone concentrations. *The New Phytologist*, *149*(2), 265–274. doi:10.1046/j.1469-8137.2001.00015.x

Donnelly, A., Lawson, T., Craigon, J., Black, C. R., Colls, J. J., & Landon, G. (2001). Effects of elevated CO_2 and O_3 on tuber quality in potato (*Solanum tuberosum* L.). *Agriculture, Ecosystems & Environment*, *87*(3), 273–285. doi:10.1016/S0167-8809(01)00144-X

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Ewing, E. E. (1997). Potato. In H. C. Wien (Ed.), *The Physiology of Vegetable crops* (pp. 295–344). Wallingford, UK: CAB International.

Fangmeier, A., De Temmerman, L., Black, C., Persson, K., & Vorne, V. (2002). Effects of elevated CO_2 and/or ozone on nutrient concentrations and nutrient uptake of potatoes. *European Journal of Agronomy*, *17*(4), 353–368. doi:10.1016/S1161-0301(02)00071-0

Finnan, J. M., Donnelly, A., Burke, J. I., & Jones, M. B. (2002). The effects of elevated concentrations of carbon dioxide and ozone on potato (*Solanum tuberosum* L.) yield. *Agriculture, Ecosystems & Environment*, *88*(1), 11–22. doi:10.1016/S0167-8809(01)00158-X

Fleisher, D. H., Timlin, D. J. & Reddy, V. R. (2006). Temperature influence on potato leaf and branch distribution and on canopy photosynthetic rate. *Agronomy Journal, 98,* 1442-1452.

Ghosh, S. C., Asanuma, K., Kusutani, A., & Toyota, M. (2000). Effect of temperature at different growth stages on nonstructural carbohydrate, nitrate reductase activity and yield of potato (*Solanum tuberosum*). [Japan]. *Environment Control in Biology*, *38*, 197–206. doi:10.2525/ecb1963.38.197

Heagle, A. S., Miller, J. E., & Pursley, W. A. (2003). Growth and yield responses of potato to mixtures of carbon dioxide and ozone. *Journal of Environmental Quality*, *32*(5), 1603–1610. doi:10.2134/jeq2003.1603 PMID:14535300

IPCC. (2001). *Third assessment report of the Intergovernmental Panel on climate change*. WMO, UNEP.

IPCC. (2007). *Fourth assessment report of the Intergovernmental Panel on climate change*. WMO, UNEP.

IPCC. (2014). Climate Change 2014: Synthesis Report. In R. K. Pachauri & L. A. Meyer (Eds.), *Contribution of Working Groups I*. Geneva, Switzerland: II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

Katny, M. A. C., Hoffmann, T. G., Schrier, A. A., Fangmeier, A., & Jager, H. J. (2005). Increase of photosynthesis and starch in potato under elevated CO2 is dependent on leaf age. *Journal of Plant Physiology*, *162*(4), 429–438. doi:10.1016/j.jplph.2004.07.005 PMID:15900885

Khan, I. A., Deadman, M. L., Al Nabhani, H. S., & Al Habsi, K. A. (2003). Interactions between temperature and yield components in exotic potato cultivars grown in Oman. *Acta Horticulturae*, *619*(619), 353–359. doi:10.17660/ActaHortic.2003.619.41

Kooman, P. L., & Haverkort, A. J. (1995). Modelling development and growth of the potato crop influenced by temperature and daylength: Lintul-Potato. In A. J. Haverkort & D. K. L. MacKerron (Eds.), *Potato ecology and modelling of crops under conditions limiting growth* (pp. 41–60). Dordrecht: Kluwer Academic Publishers. doi:10.1007/978-94-011-0051-9_3

Ku, G., Edwards, E., & Tanner, C. B. (1977). Effects of light, carbon dioxide and temperature on photosynthesis, oxygen inhibition of photosynthesis and transpiration in *Solanum tuberosum. Plant Physiology*, *59*(5), 868–872. doi:10.1104/pp.59.5.868 PMID:16659958

Lawson, T., Craigon, J., Tulloch, A. M., Black, C. R., Colls, J. J., & Landon, G. (2001). Photosynthetic responses to elevated CO2 and O3 in field-grown potato (*Solanum tuberosum*). *Journal of Plant Physiology*, *158*(3), 309–323. doi:10.1078/0176-1617-00105

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Magliulo, V., Bindi, M., & Rana, G. (2003). Water use of irrigated potato (*Solanum tuberosum* L.) grown under free air carbon dioxide enrichment in central Italy. *Agriculture, Ecosystems & Environment*, *97*(1-3), 65–80. doi:10.1016/S0167-8809(03)00135-X

Marwaha, R. S., & Sandhu, S. K. (2002). Yield, growth components and processing quality of potatoes as influenced by crop maturity under short and long days. *Advances in Horticultural Sciences*, *16*, 47–52.

Midmore, D. J., & Prange, R. K. (1992). Growth responses of two *Solanum* species to contrasting temperatures and irradiance levels: Relations to photosynthesis, dark respiration and chlorophyll fluorescence. *Annals of Botany*, *69*, 13–20.

Miglietta, F., Magliulo, V., Bindi, M., Cerio, L., Vaccari, F. P., Loduca, V., & Peressotti, A. (1998). Free air CO2 enrichment of potato (*Solanum tuberosum* L.), development, growth and yield. *Global Change Biology*, *4*(2), 163–172. doi:10.1046/j.1365-2486.1998.00120.x

Olivo, N., Martinez, C. A., & Oliva, M. A. (2002). The photosynthetic response to elevated CO2 in high altitude potato species (*Solanum curtilobum*). *Photosynthetica*, *40*(2), 309–313. doi:10.1023/A:1021370429699

Peet, M. M., & Wolfe, D. W. (2000). Crop ecosystem responses to climate change: Vegetable crops. In K. R. Reddy & H. F. Hodges (Eds.), *Climate Change & Global Crop Production* (pp. 213–243). CAB International. doi:10.1079/9780851994390.0213

Reynolds, M. P., Ewing, E. E., & Owens, T. G. (1990). Photosynthesis at high temperature in tuber bearing *Solanum species. Plant Physiology*, *93*(2), 791–797. doi:10.1104/pp.93.2.791 PMID:16667538

Schapendonk, A. H. C. M., Oijen van, N., Dijkstra, P., Pot, C. S., Jordi, W. J. R. M., & Stoopen, G. M. (2000). Effects of elevated CO_2 concentration on photosynthetic acclimation and productivity of two potato cultivars grown in open-top chambers. *Australian Journal of Plant Physiology*, *27*, 1119–1130.

Singh, J. P., Govindakrishnan, P. M., Lal, S. S., & Aggarwal, P. K. (2005). Increasing the efficiency of agronomy experiments in potato using INFOCROP-POTATO model. *Potato Research*, *48*(3-4), 131–152. doi:10.1007/BF02742372

Singh, J. P., Govindakrishnan, P. M., Lal, S. S., & Aggarwal, P. K. (2008). Infocrop-Potato a Model for Simulating Growth and Yield of Potato in the Sub-Tropics. Central Potato Research Institute, Shimla.

Singh, J. P., Lal, S. S., & Pandey, S. K. (2009). Effect of climate change on potato production in India. Central Potato Research Institute, Shimla, Newsletter, 40, 17-18.

Singh, J. P., & Trehan, S. P. (1993). *A case study of soil and irrigation water related constraints in potato crop production: Cause and correction*. National Seminar on 'Developments in Soil Science, 58th Annual convention, Dehradun.

Sterrett, S. B., Lee, G. S., Henninger, M. R., & Lentner, M. (1991). Predictive model for onset and development of internal heat necrosis of 'Atlantic' potato. *Journal of the American Society for Horticultural Science*, *116*, 701–705.

Struik, P. C., Geertsema, J., & Custers, C. H. M. G. (1989). Effects of shoot, root and stolon temperatureon the development of potato plant. III. Development of tubers. *Potato Research*, *32*, 151–158. doi:10.1007/BF02358227

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Vaccari, F. P., Miglietta, F., Giuntoli, A., Magliulo, V., Cerio, L., & Bindi, M. (2001). Free air CO2 enrichment of potato (*Solanum tuberosum* L.). Photosynthetic capacity of leaves. *Italian Journal of Agronomy*, *5*, 3–10.

Van de Geijn, S. C., & Dijkstra, P. (1995). Physiological effects of changes in atmospheric carbon dioxide concentration and temperature on growth and water relations of crop plants. In A. J. Haverkort & D. K. L. MacKerron (Eds.), *Potato ecology and modelling of crops under conditions limiting growth* (pp. 89–100). Dordrecht: Kluwer Academic Publishers. doi:10.1007/978-94-011-0051-9_6

Van Keulen, H., & Stol, W. (1995). Agro-ecological zonation for potato production. In A. J. Haverkort & D. K. L. MacKerron (Eds.), *Potato Ecology and Modelling of Crops under Conditions Limiting Growth* (pp. 357–372). Dordrecht: Kluwer Academic Publishers. doi:10.1007/978-94-011-0051-9_23

Vandermeiren, K., Black, C., Lawson, T., Casanova, M. A., & Ojanpera, K. (2002). Photosynthetic and stomatal responses of potatoes grown under elevated CO2 and/or O3 - results from the European CHIP-programme. *European Journal of Agronomy*, *17*(4), 337–352. doi:10.1016/S1161-0301(02)00070-9

Vorne, V., Ojanpera, K., De Temmerman, L., Bindi, M., Högy, P., Jones, M. B., ... Persson, K. (2002). Effects of elevated carbon dioxide and ozone on potato tuber quality in the European multiple-site experiment CHIP-project. *European Journal of Agronomy*, *17*(4), 369–381. doi:10.1016/S1161-0301(02)00072-2

Vos, J. (1995). Nitrogen and the growth of potato crops. In A. J. Haverkort & D. K. L. MacKerron (Eds.), *Potato ecology and modelling of crops under conditions limiting growth* (pp. 115–128). Dordrecht: Kluwer Academic Publishers. doi:10.1007/978-94-011-0051-9_8

Wheeler, R. M., Tibbitts, T. W., & Fitzpatrick, A. H. (1991). Carbon dioxide effects on potato growth under different photoperiods and irradiance. *Crop Science*, *31*(5), 1209–1213. doi:10.2135/cropsci1991.0011183X003100050026x PMID:11537629

Wolfe, D. W., Fereres, E., & Voss, R. E. (1983). Growth and yield response of two potato cultivars to various levels of applied water. *Irrigation Science*, *3*(4), 211–222. doi:10.1007/BF00272837

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Chapter 68
Rift Valley Fever and the Changing Environment:
A Case Study in East Africa

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ABSTRACT

Rift Valley fever is a severe disease affecting both humans and animals. The Rift Valley fever virus can be transmitted by body fluids, and the most common way for humans to get infected is from animals. The virus is also vector-borne and can be transmitted by many species of mosquitoes. As with other vector-borne diseases, the epidemiology may vary in response to environmental changes. Here the effects of climate and land use changes on Rift Valley fever, as well as on other vector-borne diseases, are discussed. The effect of irrigation in East Africa on inter-epidemic transmission of RVF is discussed in greater detail, followed by recommendations for future research and actions.

INTRODUCTION

The last century has seen a period of ecological change, unprecedented in recent times, with dramatic reductions in pristine habitats, ecosystem services and biodiversity along with equally dramatic increases in numbers of people and of domestic animals. Most land use practices change the environment and are due to human influence, often related to feeding the growing population, such as increased irrigation

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and land deforestation to allow crop cultivation. Environmental change is ubiquitous, and new diseases continue to emerge, while concerns about the impact of environmental change on human health grow. However, while it seems intuitive that degradation of ecosystems will increase the risk of disease, detailed knowledge on how specific environmental changes in a given context affect disease transmission is often lacking. As a consequence, decision makers may inadvertently increase health risks.

This chapter uses the example of Rift Valley fever (RVF) to explore relations between disease dynamics and environmental change. Two main drivers, climate and land use changes, can be identified. We focus on irrigation as a type of land use change. In addition, RVF is characterized, describing the knowns and unknowns about its epidemiology and recapitulating the history and impact of RVF outbreaks in east Africa. Next we discuss relations between RVF and climate and land use change. Findings from an ongoing study, which shows that an irrigated area can support endemic transmission of RVF, without any signs of outbreaks, are also presented and the relevance of this is discussed.

IMPORTANCE AND DRIVERS OF EMERGING DISEASE

Emerging infectious diseases in both animals and humans cause major economic and health burdens in every part of the world. On average, a new human disease appears every four months and around 75% of emerging diseases are zoonotic (Jones et al., 2008). Most originate from wildlife, and the study of disease emergence has a strong focus on wildlife. However, economically important emerging diseases often involve domestic animals. For example, between 1997 and 2009, six major emerging diseases have together cost at least 80 billion USD: the Nipah virus outbreak in Malaysia, West Nile fever in the USA, severe acute respiratory syndrome (SARS, starting in Asia), highly pathogenic avian influenza (HPAI, starting in Asia), bovine spongiform encephalopathy (BSE, starting in the UK) and RVF in East Africa (World Bank, 2012). In all of these, livestock or animals farmed for human consumption provided either a reservoir or a bridge to transmit the disease to people. Later outbreaks of emerging infectious diseases, such as Middle East respiratory syndrome (MERS) and the Ebola outbreak in West Africa, were also caused by viruses with an animal reservoir; in the case of MERS livestock (camels) are an amplifying host, and in the case of Ebola a livestock interface has been suspected (Atherstone, Smith, Ochungo, Roesel, & Grace, 2015; Wong et al., 2015; Yuen, 2015).

The burden of infectious diseases is not uniform, and in low-income countries a high proportion of disease stems from zoonotic diseases and diseases recently emerged from animals (Grace, Gilbert, Randolph, & Kang'ethe, 2012). In Africa, diseases affect poor people disproportionally and further contribute to their poverty in a vicious circle. In particular, zoonotic diseases have the potential to harm both the livelihoods and health of those depending on livestock. Africa is also the continent where more than half of all outbreaks of emerging infectious diseases verified by WHO between 1996 and 2009 occurred, and where the time lags between outbreak detection and public alerts are the longest (Chan et al., 2010).

Moreover, demographic growth is predicted to remain high in Africa, with the continent's population predicted to reach 4 billion in 2100 (from 1 billion in 2014) (Gerland et al., 2014). This rapid population growth is likely to drive equally rapid changes in ecosystems, including crop expansion into marginal areas, irrigation, deforestation, urban sprawl, road building, mining and bush meat harvesting (Grace & Bett, 2014). Depending on how these changes affect the number of susceptible animals and humans, their risks of exposure and the infectiousness of the infected individuals, they may either increase or decrease disease incidence (Lindahl & Grace, 2015). Land-use change often drives disease and has been

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estimated to be responsible for more than 20% of disease emergence on the island continent of Australia (McFarlane, Sleigh, & McMichael, 2013). In addition, the risks of land use associated diseases are often exacerbated by change and variation in climate changes and the poor adaptive capabilities of communities.

Influence of Environmental Change on Arthropods and Arthropod-Borne Diseases

The dependence of arthropod vectors on the surrounding environment makes them susceptible to change. Arthropods are exothermic, and thus their life cycles, as well as possible pathogen replication within them, are strongly affected by temperature (Khasnis & Nettleman, 2005; Kramer & Ebel, 2003). Vectors are also dependent on suitable habitats for breeding, determined by factors such as soil, land cover and use, temperature, moisture, rainfall patterns and vegetation. When climate changes, the consequence may be that a vector changes its potential distribution and seasonal pattern of activity (Githeko, Lindsay, Confalonieri, & Patz, 2000; Patz, Campbell-Lendrum, Holloway, & Foley, 2005; Russell, 1998). Climate change may also result in changes in precipitation with varying effects on vectors (Githeko et al., 2000). For example, drastically increased precipitation may flush out larval habitats (Impoinvil et al., 2011; Khasnis & Nettleman, 2005; Murty, Rao, & Arunachalam, 2010), but the long term effect might be establishment of more breeding grounds.

The Effect of Climate and Indirect Consequences

Climate changes have direct and indirect impacts on vector-borne disease transmission. Changes in temperature can change vector competence, and thus cause mosquito species (that are minor or insignificant vectors) to become more important (Mellor & Leake, 2000; Tabachnick, 2013). Whether or not, and how efficiently, an arthropod can act as a vector depends on many factors. Temperature affects the longevity of the vector and the rate of virus multiplication within it (Kramer & Ebel, 2003; Tabachnick, 2013). In addition, humidity and wind could influence the longevity and dispersal of the vector, and precipitation may determine the spatial distribution and suitability of breeding grounds.

So how will vector-borne diseases be affected when climate changes? The complex nature of vector-borne disease transmission makes predictions difficult. It is important to understand the impact of climate change on environmental factors that may influence vector dynamics (Tabachnick, 2010), such as changes in land use, population movements and interactions. Increased temperatures may increase the need for irrigation or dams, thus creating vector habitats, and movement and interactions between humans and different animal species bring new vectors into contact with new hosts. The transmission from the vectors depends on the vector capacity (Cohuet, Harris, Robert, & Fontenille, 2010), defined as the number of potentially infective bites an individual is exposed to during one day from one particular vector species (Black & Moore, 2005).

Extrinsic and intrinsic factors needed to be estimated for the calculation of vector capacity:

- The probability that a vector feeds on a specific host, which depends on the feeding frequency and the proportion of meals taken from that host.
- The vector density in relation to the host density.
- The probability that the vector survives each day.

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- The vector competence, which is the proportion of vectors taking an infected meal that become infected and can transmit the infection to another host.
- The duration of the vector's life after the incubation period of the pathogen in the vector.

It is clearly an over-simplification, therefore, to equate increase in vector-borne transmission with increase in temperature. Temperature affects the intrinsic factors of the arthropods, such as development rate and longevity (and thus vector abundance), pathogen incubation period within the vector (extrinsic incubation period (EIP)), behaviour and reproduction. Increased temperatures speed processes up within the arthropods and thus decrease both the incubation period in the vectors and their longevity (Kramer & Ebel, 2003; Tabachnick, 2013). In general, all factors contributing to increased vector abundance, shorter incubation periods, and increased vector survival are likely to increase the disease transmission. However, factors contributing to an increased host density and proportion of suitable hosts could also result in increased disease transmission, and these factors may also be dependent on environmental changes, such as increased droughts making farmers keep more goats instead of relying on crop production.

The indirect effects of climate change on ecosystems are thus also important. Decreased surface water availability may cause large numbers of potential hosts to aggregate closer to the water sources which could intensify transmission, and reduced availability of water bodies could negatively impact the predators that feed on mosquito larvae (Epstein, 2001). In addition, even when an increase in disease incidence is observed after climate change, there are many possible confounding factors such as droughts reducing crop yield and impacting the nutritional status of a community, interrupted infrastructure, which may for example make vaccination campaigns or health care impossible, or decreased social and health services. All these events may contribute to the subsequent increase in disease incidence (Lindahl & Grace, 2015).

Due to these complexities, there are uncertainties as to how different vector-borne diseases may be affected by different aspects of climate change. Each vector-pathogen system has a different range of tolerated temperatures, with optimal transmission occurring within a tighter range (Mellor & Leake, 2000). Since minimum temperatures are predicted to change more than maximum temperatures, it has been suggested that the effects on vector-borne disease transmission are more likely to go from suboptimal to more optimal, than from optimal to temperatures higher than those ideal for transmission (Ostfeld, 2009). As an example, the lower temperature allowing malaria transmission is estimated to be around 14-18°C, whereas the upper limit is around 35-40°C. When changes occur, it is likely to affect disease transmission in borderline regions more than in areas of core suitability (Githeko, Lindsay et al. 2000), although temperature changes that could make transmission more optimal in the local setting are likely to have an impact. Cold temperatures affect the duration of the mosquito's breeding season and some species are able to continue breeding at lower temperatures (Mogi, 1996). Increases in temperature could lead to a life span shorter than the incubation period, or higher mosquito mortality, therefore, limiting disease transmission. However, the capacity of mosquitoes to find suitable microhabitats to avoid heat is an efficient adaptation strategy.

However, it is not certain that the increased potential for disease transmission caused by climate change will be observable. If the transmission of vector-borne diseases is already high, it may not be possible to observe small changes in transmission rates, and this could be the case especially in tropical low-income countries (Reiter, 2001). The opposite scenario may occur in developed countries, where socioeconomic factors may prohibit increased spread of diseases, in spite of climate becoming more permissive. Mosquitoes capable of transmitting malaria are present as far north as Scandinavia, but be-

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cause of improved living standards and healthcare, malaria disappeared from Europe in the 20th century (Hulden & Hulden, 2009), and is unlikely to return.

The Effect of Land Use Changes

Climate changes, though an important contributor to mosquito habitat suitability, is not the only factor responsible for distribution changes of vector-borne diseases. Indeed, most of the new introductions of invasive mosquito species have not been related directly to climate change (Gubler et al., 2001). Globalization, increased travels and trade provide excellent means for transportation of adult mosquitoes, as well as their eggs. In spite of these risks, travels and trade are highly promoted and unlikely to be reduced (Lindahl & Grace, 2015).

Vectors have different requirements for their breeding grounds, and these are often, but not always, dependent on meteorological factors. One of the major vectors for RVF in West Africa, *Aedes vexans*, breeds in seasonal ponds, which vary in size with the rainfall, since the mosquito eggs also require a period of draught before the rains in order to hatch (Vignolles et al., 2009). Some of the factors influencing the availability of suitable breeding grounds are, however, affected by anthropogenic activities, such as irrigation, agricultural intensification, urbanization, and deforestation. In addition, climate and land use changes interact with each other as well as other drivers. For example, climate induced deterioration of agricultural conditions may increase the rural-urban migration; it may initiate schemes for irrigation, or cause people to switch agricultural practices. Furthermore, large-scale changes in land use such as deforestation may contribute to climate change.

Irrigation may be an especially potent driver of vector-borne disease in Africa given current forecasts for large-scale expansion. Irrigation has been associated with a plethora of diseases including malaria, schistosomiasis, and RVF (Keiser et al., 2005; Steinmann, Keiser, Bos, Tanner, & Utzinger, 2006). Africa has an enormous potential for irrigation: just 4% of the total cultivated area is irrigated compared to 37% in Asia and 14% in Latin America (You, 2008). It is expected that heavy investments in irrigation are likely to occur over the coming decades and smallholder irrigation could cover 30-40 million ha, benefitting 400 million people (Keiser et al., 2005; Xie, You, Wielgosz, & Ringler, 2014). However, it is possible that this may expose them to additional health risks.

RIFT VALLEY FEVER: AN EMERGING DISEASE

Rift Valley fever (RVF) was identified in the 1930s in the Rift Valley region in Kenya, although probable outbreaks could be traced as far back as 1912 (Daubney, Hudson, & Garnham, 1931; Davies, 2010; Findlay, 1932). Analyses of the viral genome suggests that the original emergence of the virus, proposed to have evolved rather recently, might be due to early land use changes in the shape of colonial agricultural development with introduction of large scale ruminant farming (Pepin, Bouloy, Bird, Kemp, & Paweska, 2010).

The virus was not known to be zoonotic until human cases were described in the 1951 South African outbreak (Davies, 2010), and the full zoonotic potential was realized only in 1977 when an outbreak in Egypt resulted in about 600 human deaths, among some 200,000 human cases (Nanyingi et al., 2015; Soumaré et al., 2012). Rift Valley fever is considered one of the emerging infectious diseases that is having the most severe impacts in the African continent, and is present in most of sub-Saharan Africa,

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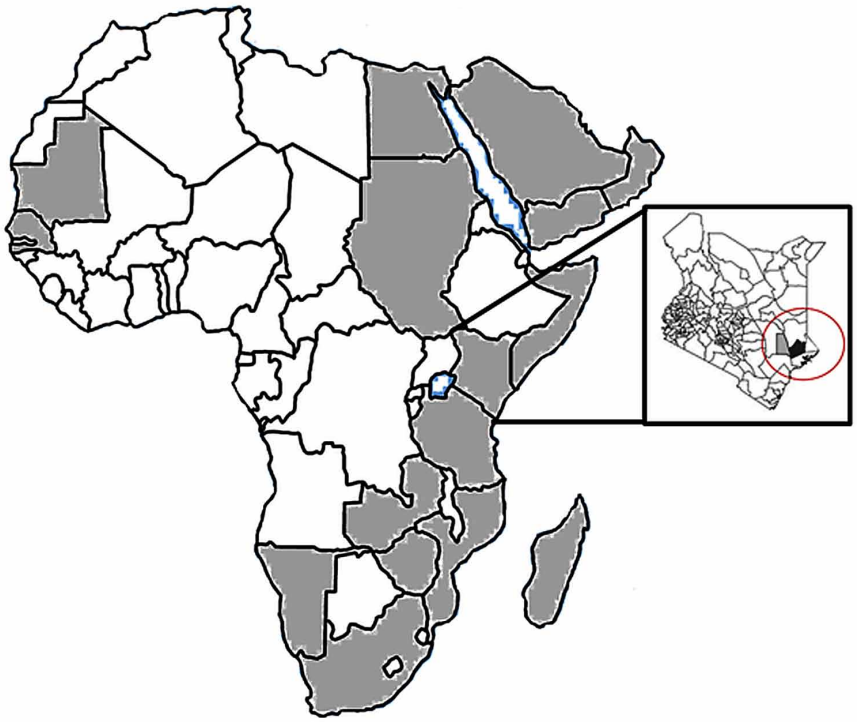
Figure 1. Map over the countries in Africa which have experienced extensive outbreaks of Rift Valley fever (grey); the insert of Kenya shows the study areas for the case study on Rift Valley fever, with dark grey for the pastoral areas in Ijara district, and light grey for the areas close to the irrigation scheme in Tana River district.
Swanepoel & Coetzer, 2004.



with extensive outbreaks occurring in Kenya, Tanzania, Madagascar, Mauretania, Senegal, Namibia, Mozambique, South Africa, Zimbabwe, Zambia and Sudan (Figure 1), but additional countries have also experienced small outbreaks, or there has been evidence of virus circulation (Nanyingi et al., 2015; Swanepoel & Coetzer, 2004). With outbreaks extending outside sub-Saharan Africa and occurring as far north as Egypt and the Arabian Peninsula, it is feared that the virus has the potential to spread into Europe and to other parts of the world (Chevalier, Pépin, Plée, & Lancelot, 2010; Moutailler, Krida, Schaffner, Vazeille, & Failloux, 2008; Turell, Sardelis, O'Guinn, & Dohm, 2002; Turell et al., 2008). Within Africa, RVF strains seem to be circulating over large distances, with samples in Madagascar shown to be similar to both North and East African strains and to the strains causing outbreaks in the Arabian Peninsula (Sall et al., 1998; Shoemaker et al., 2002). Phylogenetic studies suggest that RVF virus has been introduced into West Africa from other parts of Africa on five different occasions (Soumaré et al., 2012). Trade and transport of infected animals has been suggested to be one of the mechanisms that allowed virus dispersal.

The RVF virus belongs to the *Bunyaviridae* family, in the genus Phlebovirus. This is a large viral family with more than 300 disease-causing viruses which have tripartite single-stranded RNA. Although the viruses often are transmitted by vectors such as mosquitoes or ticks, they may also be transmitted directly by body fluids, especially fetal materials that may carry high loads of virus. The RVF virus can

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be transmitted by numerous mosquitoes from at least 6 genera and over 30 species (Pepin et al., 2010; Walter & Barr, 2011). However, even though many mosquitoes may harbour the virus, they may not all be important for the disease epidemiology, and different vectors are important in different parts of Africa. In East Africa, it is believed that the primary vectors maintaining the virus and starting outbreaks are floodwater breeding *Aedes* species, whereas secondary vectors fuelling the outbreak are likely to be *Culex* species (Anyamba et al., 2010; Sang et al., 2010; Vilaly et al., 2013).

The virus has a predilection for the liver but spreads to many parts of the body after a host is infected (Pepin, Bouloy, Bird, Kemp, & Paweska, 2010). Clinical cases in humans are usually characterized by hemorrhagic fever and encephalitis, whereas animals abort or have hemorrhages and necrotic hepatitis (Elliott, 1997). Case fatality in young livestock can be high, and although it is difficult to assess accurately how many humans were actually infected in an outbreak, as many as 47% of confirmed and probable cases may succumb to the disease (Mohamed et al., 2010). In addition, the virus frequently causes abortion storms (Pepin et al., 2010). In the earlier outbreaks, it was reported that indigenous livestock were unaffected (Davies & Martin, 2006); however, breed has not been reported as one of the risk factors for animal infection, summarized by recent reviews (Nanyingi et al., 2015; Nicholas, Jacobsen, & Waters, 2014). Moreover, if indigenous breeds are as likely as exotic breeds to be infected, but not to develop disease, seroprevalence studies are unable to detect such a trait.

Although much research has been conducted on RVF and its vectors, some uncertainties remain, especially as to how the virus is maintained during the periods between epidemics, which have been occurring every 5-15 years in East Africa. The vectors for RVF are divided into primary and secondary vectors, where the primary vectors are involved in the initial transmission of the virus to host animals, and the secondary vectors play a larger role later in the outbreak by propagating it. *Aedes* mosquitoes are believed to be most important for disease transmission, especially those breeding in flood water. In East Africa, these mosquitoes breed in depressions termed dambos, where the eggs diapause during the dry periods, and hatch during subsequent flooding that follows prolonged rain (Logan et al., 1991). Transovarial transmission has been shown in many mosquito species, and adult reared from larvae collected in naturally flooded dambos have been shown to contain the virus (Linthicum, Davies, Kairo, & Bailey, 1985). It is therefore believed that the virus may survive in the eggs for years while waiting to hatch, and that this could explain how the virus persists during the inter-epidemic periods. It is also possible that immature stages of mosquitoes can be infected by virus present in the breeding habitats, and it has been shown that larvae of *Culex pipiens*, *Aedes mcintoshi* and *A. circumluteolus* can become infected experimentally and subsequently transfer the virus when feeding as adults (Turell, Linthicum, & Beaman, 1990).

Another explanation is that wildlife reservoirs maintain the virus in an endemic sylvatic cycle. A number of studies have shown that wild animals naturally seroconvert to RVF (Britch et al., 2013; Evans et al., 2008; Olive, Goodman, & Reynes, 2012). Sudden increases in rainfall could lead to more mosquitoes hatching, and the increased number of vectors cause spillover onto livestock and humans. Secondary vectors, such as other *Culex* species also multiply after the rains, which promotes the outbreak. It is even possible that the virus is maintained by a low level circulation among domestic animals.

The epidemiology of RVF is further complicated because body fluids of infected animals (including fetal membranes) are infectious and this is the main cause of infection in humans, although they may still get infected from mosquitoes (Anyamba et al., 2009). Therefore, certain occupation groups such as herders, farmers, slaughterhouse workers and veterinarians are at greater risk of infection. Similar contacts may occur during care or slaughtering of infected animals or possibly from ingestion of raw milk.

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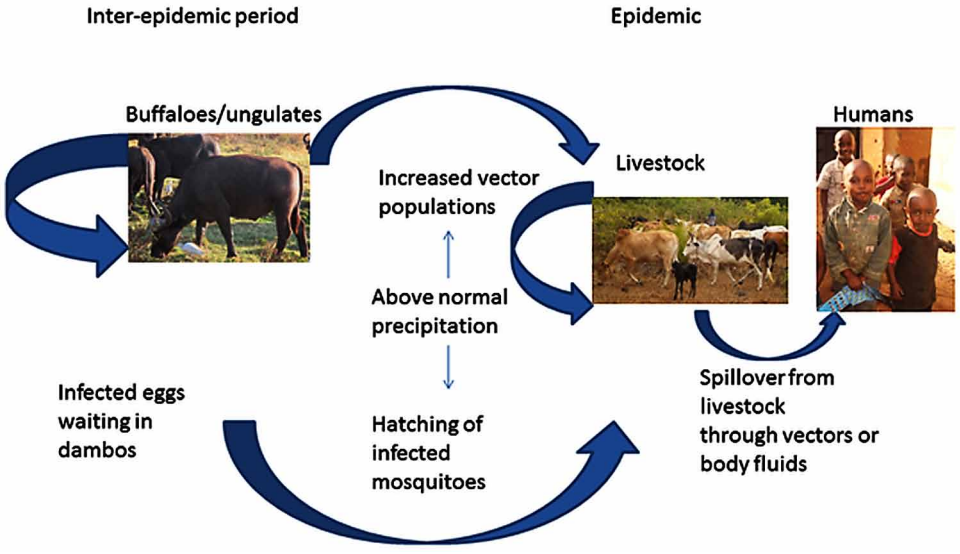
Whereas RVF is mostly known for the severe outbreaks, it is believed to be endemic and circulating between the outbreaks. Molecular epidemiological estimates suggest that the virus may not only persist but also expand undetected during these periods (Pepin et al., 2010). Possible ways in which RVF could be maintained during epidemiological cycles are shown in Figure 2.

Rift Valley Fever Outbreaks in East Africa and Their Impacts

Whereas RVF outbreaks have been associated with semi-arid or irrigated areas in West and North Africa, outbreaks in East Africa often occur in plateau grasslands (Martin et al., 2008). In 1997, Kenya experienced heavy rains, and this was followed by an outbreak of RVF, which may have infected as many as 27 000 humans (Woods et al., 2002). In this outbreak, the main risk factors for human infections were sheltering animals in the home and contact with sheep blood or body fluids. Farmers reported losing up to 70% of their sheep and goats, and as much as 95% of young lambs (Woods et al., 2002). The next major outbreak started in 2006 in Kenya and 2007 in Tanzania, continuing with Somalia and Sudan. While the Tanzania outbreak had a total number 511 suspected cases, it is unknown how many were really infected and it is believed that only severe cases were detected (Mohamed et al., 2010). For the outbreak in Sudan, up to 75,000 humans may have been exposed (Hassan, Ahlm, Sang, & Evander, 2011). It was estimated that more than 900 people died in the outbreak in the four countries affected (Nanyingi et al., 2015). Based on interviews, it was estimated that more than 400,000 livestock died in Kenya during the outbreak, with large economic consequences (Rich & Wanyoike, 2010). Also in Tanzania the economic consequences were severe, with exports of cattle decreased by more than 50% (Sindato, Karimuribo, & Mboera, 2012).

Livestock production is crucial for the livelihood in the arid and semi-arid areas of East Africa, where many are pastoralists, and an outbreak of a severe infectious disease such as RVF can be devastating for the individual livestock holders; however, it will also have an impact on national economy (Anyamba,

Figure 2. Epidemiology of Rift Valley fever



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Linthicum, & Tucker, 2001). After the 2006-2007 outbreak in Kenya, pastoralists ranked RVF as the disease with the highest impact on livestock-derived livelihoods (Jost et al., 2010). This outbreak was estimated to have caused large economic losses to the region. The World Bank (2012) estimated that the entire outbreak in East Africa caused losses of 30 million USD, similar to estimates by Rich and Wanyoike (2010).

Rift Valley Fever, Climate, and Land Use Change

RVF epidemics occur when environmental, ecological and climatic factors are conducive. Many studies have demonstrated the association with excessive rainfall, the El Nino Southern Oscillation (ENSO), changes in normalized difference vegetation index (NDVI) and presence of water bodies (Métras et al., 2011; Tourre, Lacaux, Vignolles, & Lafaye, 2009; Anyamba, Linthicum, & Tucker, 2001). However, the association with weather, which is very clear in East Africa where outbreaks occur after periods of above normal rainfall (in intervals of around 5-15 years) (Anyamba, Linthicum, & Tucker, 2001; Davies, Linthicum, & James, 1985), is not as evident in West Africa (Chevalier, Rocque, & Baldet, 2004).

There have been several attempts to model how climate change impacts RVF; either using knowledge-driven spatial models, or mathematical dynamic transmission models (Métras et al., 2011). The results of some models are being made available online, such as the model by the healthy future project and University of Liverpool (http://www.healthyfutures.eu/ (Morper-Busch, Kienberger, & Hagenlocher, 2015)). The modelling commonly takes into account mosquito vectorial capacity with biting frequencies and life cycle dependent on temperature, and breeding dependent on precipitation. However, there is a need to incorporate other environmental factors, such as land use, human and animal densities, water storage and irrigation, in such models so as to predict RVF transmission more accurately. Although climate is a very important driver of vector dynamics, more factors may be of importance and we lack a complete understanding of the life cycles of the vectors (Tabachnick, 2010). The consequences of this may be suboptimal prediction models and inaccurate decisions taken in the face of outbreaks.

Methods including remote-sensing have also proved very beneficial for studying spatial dynamics of RVF, and the influence of climate and environmental changes, and through this it has been possible to link the dynamics of *Aedes vexans* with rainfall and changes in water bodies (Tourre et al., 2009). Work in West Africa also shows the possibility of including these techniques in creating risk maps and early warning systems (Vignolles, Tourre, Mora, Imanache, & Lafaye, 2010).

Land use changes may have similar effects to climate change, by providing increased mosquito breeding grounds, and changing the availability and movements of different hosts. Increased water storage and utilization along rivers, as well as development of dams and irrigation systems, enlarge the areas that could be suitable for mosquito development, which can increase the risk of RVF transmission. A few outbreaks have been associated with anthropogenic changes to water bodies, such as the 2000-2001 outbreak in Yemen (Abdo-Salem et al., 2006), and the 1987 epidemic in the Senegal River basin (Thonnon et al., 1999). However, it must also be remembered that the purpose of providing a community with irrigation or water reservoirs often is to improve the livelihood of the inhabitants, which may lead to socioeconomic improvements, including increased living standards, improved nutritional status and access to health care and prophylactic measures. These socioeconomic factors may reduce the exposure of humans to pathogens, and make them more resistant to disease, which is likely to reduce the risks of disease spread (Lindahl & Grace, 2015). In addition, agriculture increase, following irrigation, makes

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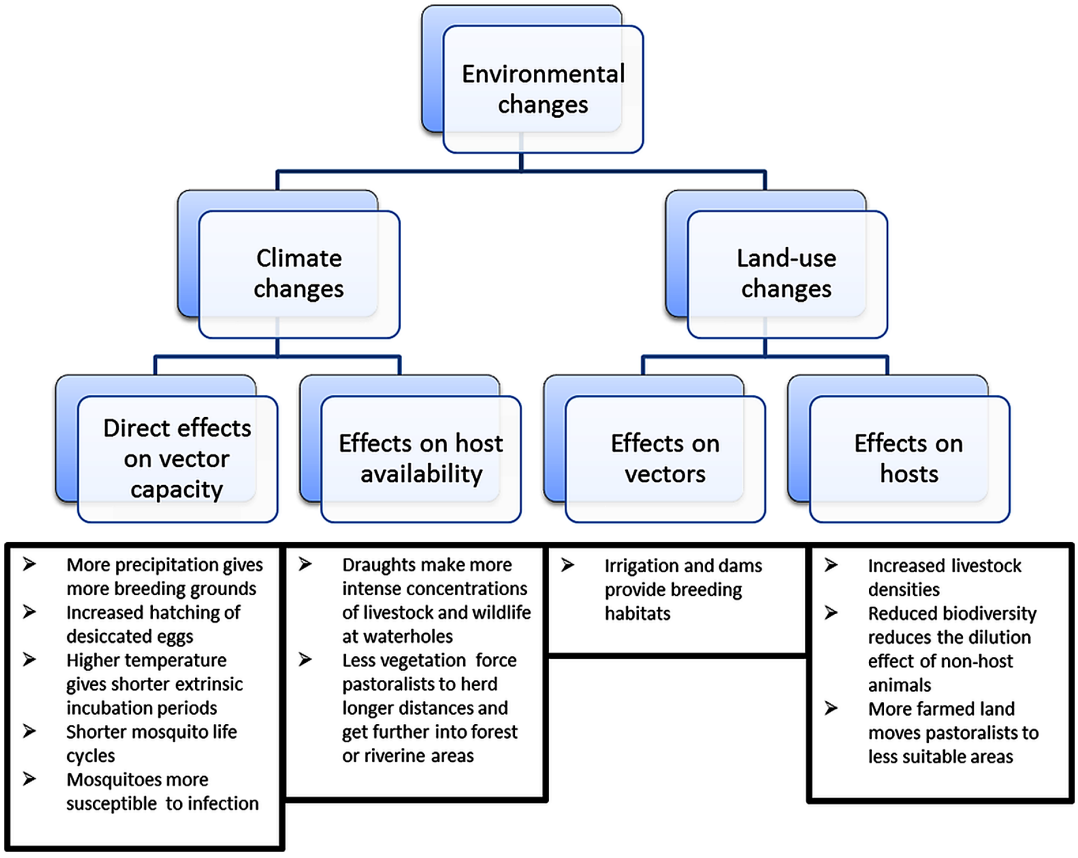
the communities more resilient to the devastating effect of a Rift Valley fever outbreak in cattle, by providing more diversified means of income and food sources (Figure 3).

Circulation of RVF Virus in Irrigated Areas During the Inter-Epidemic Period: A Case Study From Kenya

Kenya has considerable potential to increase irrigation (You, Xie, Wood-Sichra, Guo, & Wang, 2014) and there are many ongoing and planned irrigation schemes. The Northeast part of Kenya has been the focus of the last outbreaks of RVF, and the first case in the 2006 outbreak was detected in Garissa (Sang et al., 2010). The land bordering the Tana River is semi-arid with increasing irrigation. This area, including Garissa, and Tana River counties, is a hot spot for RVF outbreaks (Martin et al., 2008), and is also high in biodiversity with many endangered species threatened by land use change (Medley, 1993, 2009). Figure 1 is showing the location of the study areas within Kenya.

In this case study conducted in 2013-14, the aim was to study the circulation of RVF in an irrigated area by investigating seroprevalence of RVF in humans and animals; perform an entomological survey and interview actors in the animal value chains.

Figure 3. How environmental changes can affect Rift valley fever transmission



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Serum samples from humans, aged 5-90 years old, were collected in villages both from irrigated and non-irrigated, pastoral areas. In total, 303 people were sampled within the irrigation schemes in Bura and Hola in Tana River County, and 728 in the pastoral areas in Ijara district in Garissa County. Serum was tested using a commercial competitive enzyme-linked immunosorbent assay (ELISA) (Biological Diagnostic Supplies Limited, UK) according to manufacturer's instruction, but with a modified conjugate dilution (1:12 000) and adjusted incubation time. The original protocol was modified after consultation with the manufacturer to allow controls to fall within the fixed range before analyses. This ELISA does not differentiate IgG and IgM antibodies (Kortekaas et al., 2013), and therefore it is not possible to tell if infections causing the seropositivity are old or new. Overall 21.5% (95% confidence interval 19-24%) were seropositive, with no significant difference between the areas. Significantly more adults (over 18 years) were seropositive ($p<0.001$), and significantly more men than female ($p=0.04$).

Ruminants (sheep, goats, and cattle) were sampled in randomly selected villages within the two irrigation schemes located in Hola and Bura, in Tana River County. A total of 1997 animals were sampled, and tested with the same ELISA as the human samples. The overall seroprevalence was 25.6% (95% confidence interval 23.7-27.6%), with no difference between the two irrigation schemes, nor between the seroprevalences in goats, sheep and cattle. Juveniles had a significantly ($p<0.001$) lower seroprevalence rates than adults, 12.3% compared to 30.2%. The seroprevalence among adult ruminants may be confounded by previous vaccination campaigns in sheep and goats, campaigns were known to have taken place but there were no records of animals vaccinated. However, similar prevalence pattern was observed in unvaccinated cows: 36.4% in adults, significantly higher than in calves (19.1%, $p<0.001$). The last outbreak of RVF occurred in 2006-2007, therefore, juveniles could not have been infected during the outbreak. The level of prevalence detected is supportive of local endemic transmission (Table 1).

In the same study, entomological surveys were implemented with Kenyan Medical Research Institute (KEMRI) as has been described previously (Sang et al., 2010). Preliminary observations demonstrate that irrigated farms (specifically drainage canals) support the development of the primary vectors of RVF, mainly *Aedes mcintoshi* and *Aedes ochraceus*. These mosquitoes are believed to develop in floodwater after periods of prolonged heavy rainfall (Linthicum, Davies, Bailey, & Kairo, 1984) and it has been shown that they are infected with RVF in the same area (Sang et al., 2010). The irrigated areas had significantly higher numbers of both primary (*Aedes* spp) and secondary (*Culex* spp) vectors (Sang et al. unpublished data). This emerging evidence shows that irrigated fields can mimic breeding conditions established in flooded areas and there is a need to integrate vector management activities with irrigation, especially in areas that are conducive for RVF transmission.

Table 1. Rift Valley fever seroprevalence in humans and ruminants in Northeastern Kenya

	Humans	**Ruminants**
Overall seropositivity	21.48%	25.59%
Young*	3.71%	12.31%
Adults	30.69%	30.22%
Male	24.88%	14.81%
Female	19.22%	28.80%

*Young ruminants include weaners and younger animals. Young humans include people <18 years.

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Interviews and focus groups discussions among livestock value chain actors in Tana River during the same time showed that knowledge about RVF was high in some groups, such as animal traders and slaughterhouse workers, where 88 and 90% respectively knew about the disease, whereas only 40% of milk traders knew about it. Out of 43 interviewed value chain actors, only two said they would report dead livestock to veterinarian, whereas nine reported that they would slaughter the animal. It was also common to slaughter sick animals, and the main reason for this was meat consumption (49%) (Nyokabi, 2015).

There was a higher seroprevalence rate in female animals, which may warrant further studies. Since RVF may cause reproductive failures and abortions in females, and aborted materials contain high viral loads (Pepin et al., 2010), this might indicate that the females are infected through contact with this infected material and not only through mosquito bites. This also indicates that even endemic RVF transmission could have economic impacts, and this might go undetected in an environment where there are many other pathogens causing abortions and reproductive failure. In humans, men are more exposed to infections. A higher prevalence in male herders has been observed in previous studies, and risk factors shown to increase the risk of seropositivity include contact with livestock, handling sick animals, fetal materials, or activities connected to slaughtering (Nanyingi et al., 2015).

It was observed that seroconversions must have occurred in the inter-epidemic period, since some positive animals were too young to have been infected in the last known outbreak 2006-07. Seroconversion in livestock during inter-epidemic periods has been observed before. Infected vectors have been encountered during inter-epidemic periods in Kenya, as well as seroconversions in both wildlife and livestock (Linthicum et al., 1985). This has also been found in other countries; in a recent study in Tanzania, 8% of the small ruminants were seropositive, including animals borne after the last outbreak (Wensman et al., 2015). Awareness is often decreasing in inter-epidemic periods (Martin et al., 2008), although we found varying levels of awareness among different risk categories.

Overall, this study showed that an irrigated area can have an endemic transmission of RVF, without any sign of outbreaks, but that seroprevalence is not necessarily higher in these areas compared to non-irrigated ones, in spite of significantly higher number of mosquitoes. This indicates that although it may be evident that irrigation increases the abundance of vectors, other factors also play a role in determining if infection will occur. Higher number of vectors are however likely to contribute to increased risk of outbreaks, but would need to be studied more intently during an epidemic period. Future work should include looking into how factors such as irrigation, agricultural and pastoral behaviour changes, animal and human densities, and socioeconomic parameters, including education and living standards impact on RVF disease transmission and outbreak occurrence.

SOLUTIONS AND RECOMMENDATIONS

As shown, both climate and land use changes can affect the epidemiology of RVF. The case of irrigation is particularly relevant in sub-Saharan Africa, which has low levels of irrigation and high levels of population growth, and many believe large investments in irrigation are necessary for sufficient food supply. Irrigation schemes are often constructed in dry/hot areas where rates of vector development are likely to be rapid, if water sources provide suitable breeding sites. This increased risk should be considered and monitored when designing new irrigation schemes or planning new dams. In addition, the effect of climate change on the introduction of new vectors and pathogens should also be considered in order to use the most suitable technologies and be prepared for public health consequences.

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There is no single optimal solution for dealing with the risk of RVF outbreaks. Depending on the risks in the region, vaccination campaigns before predicted outbreaks may be the most cost efficient option, but require good forecasting models, and for policy makers to be well informed about the disease. In addition, it is important that stakeholders and policy makers are informed about the risks of RVF transmission between epidemics and RVF emergence. Other strategies include better diagnostics, case management and farming practices to reduce RVF outbreak risks.

Importantly, there is a lack of reliable guidelines, tools or procedures to steer emergency response measures in the event of an outbreak. In the past, the losses associated with outbreaks have in part been a result of insufficient capacity offered by decision makers, who lacked accurate information about efficient preventive and response measures. More recently, there have been promising developments in planning for RVF control in East Africa. These include:

- **Risk Maps and Early Warning Systems:** Known disease hotspots have been geo-referenced and analysed together with detailed data on precipitation, rainfall, soil types, land use and vegetation to produce RVF risk maps (Martin et al., 2008; Sindato et al., 2014). These maps can be used to target surveillance efforts, and also in trade negotiations. This could put an end to the blanket trade bans and their disastrous effects on people's livelihoods. The maps have also been combined with socio-economic variables, which define vulnerability in order to determine how best to respond to an outbreak in local communities.
- **Contingency Plans and Standard Methods and Procedures:** These are key to mounting early, effective action in the face of an emergency. These are pre-prepared plans and operational protocols to create uniformity in animal disease detection, diagnostic and control procedure across a region. The Government of Kenya produced and endorsed a contingency plan for RVF in 2010 which was updated in 2014. In addition, a standards methods and procedures manual has been produced by AU-IBAR (2014).
- **Decision Support Tool:** Policy makers face a dilemma in responding to RVF. Too early response and they may cause unnecessary panic. Too late and impacts will be more severe. A decision support tool has been developed comprising a list of the sequence of events related to increasing and decreasing the risk of an RVF epizootic and the appropriate actions that should match these events (Consultative Group for RVF Decision Support, 2010).
- **Vaccination Guidance:** This is often lacking among policy makers. Model-based analyses can offer guidance on preventative action by indicating the proportion of animals that need to be vaccinated to prevent spread. In addition, model-based analyses demonstrate that vaccinating strategically over a five-year period could reduce the thresholds needed to stop an epidemic. Such periodic vaccinations could be done annually or biannually, depending on logistical/economic considerations and the type of vaccine available.
- **Impact Assessment Tools:** A system dynamics model that combines biological and socio-economic processes involved in Rift Valley fever transmission has been developed as an integrated framework for evaluating the impacts of the disease along livestock value chains in north eastern Kenya.
- **Disease Scenarios:** These are plausible stories, not projections, and illustrate what might happen, based on given assumptions in the chosen settings. They can be used to identify and discuss a range of possible futures and used to create action to build resilience. Scenarios have been developed for RVF along with some other emerging diseases in Africa (http://www.diseasescenarios.

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org/scenarios.html), and others have looked at how agriculture and disease risks in general will develop in different future scenarios (Oborn et al., 2013).

FUTURE RESEARCH DIRECTIONS

As mentioned above, there is a lack of evidence regarding RVF epidemiology and factors that maintain RVF between outbreaks. Such knowledge is necessary for efficient future interventions. Future research should focus on filling the gaps identified here and reported in the literature:

- The importance of different vectors, including their vector competencies, their breeding requirements and the risks of transovarial transmission.
- The inter-epidemic transmission, including the role of wildlife and domestic animals, and the risks for humans.
- The role of socioeconomic factors in improving resilience of vulnerable populations during outbreaks.
- The impacts of land use change and climate change on disease epidemiology.

CONCLUSION

It is difficult to predict exactly how environmental changes will affect the incidence of vector-borne diseases, and it must be remembered that other changes, not directly influencing the vectors directly, may play very substantial roles. RVF as a disease may be directly influenced by environmental and climatic changes, and increasing irrigation may be one cause of increased vector populations. However, this may not be directly translated into higher prevalence of disease, and it is important to further study the other factors that may contribute to this. In order to increase the preparedness for RVF outbreaks, it is important to bridge the knowledge gaps and to improve surveillance systems and decisions support tools that can aid stake holders.

Whereas social insecurity, political unrest and poverty may drive the emergence of disease, improved housing, education, nutrition and health care services will render people less exposed to mosquito bites and more resistant to disease. Increased irrigation and agricultural outputs may help in achieving this. Improving socio-economic conditions is therefore likely to increase people's resilience to the negative effects of environmental change with regard to vector-borne diseases.

REFERENCES

Abdo-Salem, S., Gerbier, G., Bonnet, P., Al-Qadasi, M., Tran, A., Thiry, E., ... Roger, F. (2006). Descriptive and spatial epidemiology of Rift valley fever outbreak in Yemen 2000-2001. *Annals of the New York Academy of Sciences*, *1081*(1), 240–242. doi:10.1196/annals.1373.028 PMID:17135517

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Anyamba, A., Chretien, J.-P., Small, J., Tucker, C. J., Formenty, P. B., & Richardson, J. H., … Linthicum, K. J. (2009). Prediction of a Rift Valley fever outbreak. *Proceedings of the National Academy of Sciences of the United States of America*, 106(3), 955–9. 10.1073/pnas.0806490106

Anyamba, A., Linthicum, K. J., Small, J., Britch, S. C., Pak, E., de La Rocque, S., ... Swanepoel, R. (2010). Prediction, assessment of the Rift Valley fever activity in East and Southern Africa 2006-2008 and possible vector control strategies. *The American Journal of Tropical Medicine and Hygiene*, *83*(2 Suppl.), 43–51. doi:10.4269/ajtmh.2010.09-0289 PMID:20682905

Anyamba, A., Linthicum, K. J., & Tucker, C. J. (2001). Climate-disease connections: Rift Valley fever in Kenya. *Cadernos de Saude Publica*, *17*, S133–S140. doi:10.1590/S0102-311X2001000700022 PMID:11426274

Atherstone, C., Smith, E., Ochungo, P., Roesel, K., & Grace, D. (2015). Assessing the Potential Role of Pigs in the Epidemiology of Ebola Virus in Uganda. *Transboundary and Emerging Diseases*, n/a. doi:10.1111/tbed.12394 PMID:26310206

AU-IBAR. (2014). Standard Methods and Procedures (SMPs) for Control of Rift Valley Fever (RVF) in the Greater Horn of Africa. Nairobi.

Black, W. C. I. V., & Moore, C. G. (2005). Population biology as a tool to study vector-borne diseases. In W. C. Marquardt, B. C. Kondratieff, C. G. Moore, J. E. Freier, H. H. Hagedorn, W. C. I. V Black, … S. Higgs (Eds.), Biology of disease vectors (2nd ed., pp. 187–206). San Diego: Elsevier Academic Press.

Britch, S. C., Binepal, Y. S., Ruder, M. G., Kariithi, H. M., Linthicum, K. J., Anyamba, A., ... Wilson, W. C. (2013). Rift Valley fever risk map model and seroprevalence in selected wild ungulates and camels from Kenya. *PLoS ONE*, *8*(6), e66626. doi:10.1371/journal.pone.0066626 PMID:23840512

Chan, E. H., Brewer, T. F., Madoff, L. C., Pollack, M. P., Sonricker, A. L., & Keller, M., … Brownstein, J. S. (2010). Global capacity for emerging infectious disease detection. *Proceedings of the National Academy of Sciences* (Vol. 107, pp. 21701–21706). 10.1073/pnas.1006219107

Chevalier, V., Pépin, M., Plée, L., & Lancelot, R. (2010). Rift Valley fever--a threat for Europe? *Euro Surveillance: Bulletin Européen Sur Les Maladies Transmissibles. European Communicable Disease Bulletin, 15*.

Cohuet, A., Harris, C., Robert, V., & Fontenille, D. (2010). Evolutionary forces on Anopheles: What makes a malaria vector? *Trends in Parasitology*, *26*(3), 130–136. doi:10.1016/j.pt.2009.12.001 PMID:20056485

Consultative Group for RVF Decision Support. (2010). Decision-support tool for prevention and control of Rift Valley fever epizootics in the Greater Horn of Africa. *The American Journal of Tropical Medicine and Hygiene*, *83*(2 Suppl.), 75–85. PMID:20682910

Daubney, R., Hudson, J. R., & Garnham, P. C. (1931). Enzootic hepatitis or rift valley fever. An undescribed virus disease of sheep cattle and man from east africa. *The Journal of Pathology and Bacteriology*, *34*(4), 545–579. doi:10.1002/path.1700340418

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Davies, F. G. (2010). The historical and recent impact of Rift Valley fever in Africa. *The American Journal of Tropical Medicine and Hygiene*, *83*(2 Suppl.), 73–74. doi:10.4269/ajtmh.2010.83s2a02 PMID:20682909

Davies, F. G., & Martin, V. (2006). Recognizing Rift Valley Fever. *Veterinaria Italiana*, *42*(1), 31–53. PMID:20429078

Elliott, R. M. (1997). Emerging viruses: The Bunyaviridae. *Molecular Medicine (Cambridge, Mass.)*, 3. PMID:9323708

Epstein, P. (2001). West Nile virus and the climate. *Journal of Urban Health*, *78*(2), 367–371. doi:10.1093/jurban/78.2.367 PMID:11419587

Evans, A., Gakuya, F., Paweska, J. T., Rostal, M., Akoolo, L., Van Vuren, P. J., ... Feikin, D. R. (2008). Prevalence of antibodies against Rift Valley fever virus in Kenyan wildlife. *Epidemiology and Infection*, *136*(09), 1261–1269. doi:10.1017/S0950268807009806 PMID:17988425

Findlay, G. M. (1932). Rift valley fever or enzootic hepatitis. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, *25*(4), 229–IN11. doi:10.1016/S0035-9203(32)90042-X

Gerland, P., Raftery, A. E., ev ikova, H., Li, N., Gu, D., Spoorenberg, T., ... Wilmoth, J. (2014). World population stabilization unlikely this century. *Science*, *346*(6206), 234–237. doi:10.1126cience.1257469 PMID:25301627

Githeko, A. K., Lindsay, S. W., Confalonieri, U. E., & Patz, J. A. (2000). Climate change and vector-borne diseases: A regional analysis. *Bulletin of the World Health Organization*, *78*, 1136–1147. PMID:11019462

Grace, D., & Bett, B. (2014). Zoonotic diseases and their drivers in Africa. In C. D. Butler (Ed.), *Climate Change and Global Health* (pp. 228–236). Boston: CABI. Retrieved from https://books.google.com/books?hl=en&lr=&id=qVDNBAAAQBAJ&pgis=1 doi:10.1079/9781780642659.0228

Grace, D., Gilbert, J., Randolph, T., & Kang'ethe, E. (2012). The multiple burdens of zoonotic disease and an Ecohealth approach to their assessment. *Tropical Animal Health and Production*, *44*(S1), S67–S73. doi:10.100711250-012-0209-y PMID:22886445

Gubler, D. J., Reiter, P., Ebi, K. L., Yap, W., Nasci, R., & Patz, J. A. (2001). Climate variability and change in the United States: Potential impacts on vector- and rodent-borne diseases. *Environmental Health Perspectives*, *109*, 223–233. doi:10.2307/3435012 PMID:11359689

Hassan, O. A., Ahlm, C., Sang, R., & Evander, M. (2011). The 2007 Rift Valley fever outbreak in Sudan. *PLoS Neglected Tropical Diseases*, *5*(9), e1229. doi:10.1371/journal.pntd.0001229 PMID:21980543

Hulden, L., & Hulden, L. (2009). The decline of malaria in Finland--the impact of the vector and social variables. *Malaria Journal*, *8*(1), 94. doi:10.1186/1475-2875-8-94 PMID:19422702

Impoinvil, D. E., Solomon, T., Schluter, W. W., Rayamajhi, A., Bichha, R. P., Shakya, G., ... Baylis, M. (2011). The Spatial Heterogeneity between Japanese Encephalitis Incidence Distribution and Environmental Variables in Nepal. *PLoS ONE*, 6(7). PMID:21811573

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Jones, K. E., Patel, N. G., Levy, M. A., Storeygard, A., Balk, D., Gittleman, J. L., & Daszak, P. (2008). Global trends in emerging infectious diseases. *Nature*, *451*(7181), 990–993. doi:10.1038/nature06536 PMID:18288193

Jost, C. C., Nzietchueng, S., Kihu, S., Bett, B., Njogu, G., Swai, E. S., & Mariner, J. C. (2010). Epidemiological assessment of the Rift Valley fever outbreak in Kenya and Tanzania in 2006 and 2007. *The American Journal of Tropical Medicine and Hygiene*, *83*(2 Suppl.), 65–72. doi:10.4269/ajtmh.2010.09-0290 PMID:20682908

Keiser, J., De Castro, M. C., Maltese, M. F., Bos, R., Tanner, M., Singer, B. H., & Utzinger, J. (2005). Effect of irrigation and large dams on the burden of malaria on a global and regional scale. *The American Journal of Tropical Medicine and Hygiene*, *72*(4), 392–406. PMID:15827275

Khasnis, A. A., & Nettleman, M. D. (2005). Global warming and infectious disease. *Archives of Medical Research*, *36*(6), 689–696. doi:10.1016/j.arcmed.2005.03.041 PMID:16216650

Kortekaas, J., Kant, J., Vloet, R., Cêtre-Sossah, C., Marianneau, P., Lacote, S., ... Brun, A. (2013). European ring trial to evaluate ELISAs for the diagnosis of infection with Rift Valley fever virus. *Journal of Virological Methods*, *187*(1), 177–181. doi:10.1016/j.jviromet.2012.09.016 PMID:23022325

Kramer, L. D., & Ebel, G. D. (2003). Dynamics of flavivirus infection in mosquitoes. In T. J. Chambers & T. P. Monath (Eds.), *Flaviviruses: Pathogenesis and Immunity* (Vol. 60, pp. 187–232). San Diego: Academic Press Inc.

Lindahl, J. F., & Grace, D. (2015). The consequences of human actions on risks for infectious diseases: a review. *Infection Ecology & Epidemiology, 5*.

Linthicum, J. J., Davies, F. G., Bailey, C. L., & Kairo, A. (1984). Mosquito species encountered in a flooded grassland dambo in Kenya. *Mosquito News*, *44*(2), 228–232.

Linthicum, K. J., Davies, F. G., Kairo, A., & Bailey, C. L. (1985). Rift Valley fever virus (family Bunyaviridae, genus Phlebovirus). Isolations from Diptera collected during an inter-epizootic period in Kenya. *The Journal of Hygiene*, *95*(1), 197–209. doi:10.1017/S0022172400062434 PMID:2862206

Logan, T. M., Linthicum, K. J., Thande, P. C., Wagateh, J. N., Nelson, G. O., & Roberts, C. R. (1991). Egg hatching of Aedes mosquitoes during successive floodings in a Rift Valley fever endemic area in Kenya. *Journal of the American Mosquito Control Association*, *7*(1), 109–112. PMID:2045800

Martin, V., Chevalier, V., Ceccato, P. N., Anyamba, A., Simone, L., De, & Lubroth, J., … Domenech, J. (. (2008). The impact of climate change on the epidemiology and control of Rift Valley fever. *Revue Scientifique et Technique (International Office of Epizootics)*, *27*(2), 413–426. doi:10.20506/rst.27.2.1802 PMID:18819669

McFarlane, R. A., Sleigh, A. C., & McMichael, A. J. (2013). Land-Use Change and Emerging Infectious Disease on an Island Continent. *International Journal of Environmental Research and Public Health*, *10*(7), 2699–2719. doi:10.3390/ijerph10072699 PMID:23812027

Medley, K. E. (1993). Primate Conservation along the Tana River, Kenya: An Examination of the Forest Habitat. *Conservation Biology*, *7*(1), 109–121. doi:10.1046/j.1523-1739.1993.07010109.x

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Medley, K. E. (2009). Patterns of forest diversity along the Tana River, Kenya. *Journal of Tropical Ecology*, *8*(04), 353. doi:10.1017/S0266467400006684

Mellor, P. S., & Leake, C. J. (2000). Climatic and geographic influences on arboviral infections and vectors. *Revue Scientifique Et Technique De L Office International Des Epizooties, 19*, 41–54.

Métras, R., Collins, L. M., White, R. G., Alonso, S., Chevalier, V., Thuranira-McKeever, C., & Pfeiffer, D. U. (2011). Rift Valley fever epidemiology, surveillance, and control: What have models contributed? *Vector Borne and Zoonotic Diseases (Larchmont, N.Y.)*, *11*(6), 761–771. doi:10.1089/vbz.2010.0200 PMID:21548763

Mogi, M. (1996). Overwintering strategies of mosquitoes (Diptera: Culicidae) on warmer islands may predict impact of global warming on Kyushu, Japan. *Journal of Medical Entomology*, *33*(3), 438–444. doi:10.1093/jmedent/33.3.438 PMID:8667392

Mohamed, M., Mosha, F., Mghamba, J., Zaki, S. R., Shieh, W.-J., Paweska, J., ... Njenga, M. K. (2010). Epidemiologic and clinical aspects of a Rift Valley fever outbreak in humans in Tanzania, 2007. *The American Journal of Tropical Medicine and Hygiene*, *83*(2 Suppl.), 22–27. doi:10.4269/ajtmh.2010.09-0318 PMID:20682902

Morper-Busch, L., Kienberger, S., & Hagenlocher, M. (2015). Healthy Futures Atlas: An Open-source WebGIS to Support Infectious Disease Intervention Planning in Eastern Africa. *Journal for Geographic Information Science*, 1, 460–463.

Moutailler, S., Krida, G., Schaffner, F., Vazeille, M., & Failloux, A.-B. (2008). Potential vectors of Rift Valley fever virus in the Mediterranean region. *Vector Borne and Zoonotic Diseases (Larchmont, N.Y.)*, *8*(6), 749–753. doi:10.1089/vbz.2008.0009 PMID:18620510

Murty, U. S., Rao, M. S., & Arunachalam, N. (2010). The effects of climatic factors on the distribution and abundance of Japanese encephalitis vectors in Kurnool district of Andhra Pradesh, India. *Journal of Vector Borne Diseases*, *47*, 26–32. PMID:20231770

Nanyingi, M. O., Munyua, P., Kiama, S. G., Muchemi, G. M., Thumbi, S. M., Bitek, A. O., … Njenga, M. K. (2015). A systematic review of Rift Valley Fever epidemiology 1931–2014. *Infection Ecology & Epidemiology, 5*.

Nicholas, D. E., Jacobsen, K. H., & Waters, N. M. (2014). Risk factors associated with human Rift Valley fever infection: Systematic review and meta-analysis. *Tropical Medicine & International Health : TM & IH*, *19*(12), 1420–1429. doi:10.1111/tmi.12385 PMID:25252137

Nyokabi, S. (2015). *Biosecurity Measures in Meat and Milk Value Chains: A Study in Bura sub-county, Kenya*. Germany: Hohenheim University.

Oborn, I., Bengtsson, J., Hedenus, F., Rydhmer, L., Stenström, M., Vrede, K., ... Magnusson, U. (2013). Scenario development as a basis for formulating a research program on future agriculture: A methodological approach. *Ambio*, *42*(7), 823–839. doi:10.100713280-013-0417-3 PMID:23836311

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Olive, M.-M., Goodman, S. M., & Reynes, J.-M. (2012). The role of wild mammals in the maintenance of Rift Valley fever virus. *Journal of Wildlife Diseases*, *48*(2), 241–266. doi:10.7589/0090-3558-48.2.241 PMID:22493102

Ostfeld, R. S. (2009). Climate change and the distribution and intensity of infectious diseases. *Ecology*, *90*(4), 903–905. doi:10.1890/08-0659.1 PMID:19449683

Patz, J. A., Campbell-Lendrum, D., Holloway, T., & Foley, J. A. (2005). Impact of regional climate change on human health. *Nature*, *438*(7066), 310–317. doi:10.1038/nature04188 PMID:16292302

Pepin, M., Bouloy, M., Bird, B. H., Kemp, A., & Paweska, J. (2010). Rift Valley fever virus (Bunyaviridae: Phlebovirus): an update on pathogenesis, molecular epidemiology, vectors, diagnostics and prevention. *Veterinary Research*, *41*(6), 61. doi:10.1051/vetres/2010033 PMID:21188836

Reiter, P. (2001). Climate change and mosquito-borne disease. *Environmental Health Perspectives*, *109*(S1), 141–161. doi:10.1289/ehp.01109s1141 PMID:11250812

Rich, K. M., & Wanyoike, F. (2010). An assessment of the regional and national socio-economic impacts of the 2007 Rift Valley fever outbreak in Kenya. *The American Journal of Tropical Medicine and Hygiene*, *83*(2 Suppl.), 52–57. doi:10.4269/ajtmh.2010.09-0291 PMID:20682906

Russell, R. C. (1998). Mosquito-borne arboviruses in Australia: The current scene and implications of climate change for human health. *International Journal for Parasitology*, *28*(6), 955–969. doi:10.1016/S0020-7519(98)00053-8 PMID:9673874

Sall, A., Zanotto, P. de A., Vialat, P., Sene, O., Bouloy, M., Sall, A. A., ... Sene, O. K. (1596–1597). M. B. (1998). Origin of 1997-98 Rift Valley fever outbreak in East Africa. *Lancet*, *352*(9140).

Sang, R., Kioko, E., Lutomiah, J., Warigia, M., Ochieng, C., O'Guinn, M., ... Richardson, J. (2010). Rift Valley fever virus epidemic in Kenya, 2006/2007: The entomologic investigations. *The American Journal of Tropical Medicine and Hygiene*, *83*(2 Suppl.), 28–37. doi:10.4269/ajtmh.2010.09-0319 PMID:20682903

Shoemaker, T., Boulianne, C., Vincent, M. J., Pezzanite, L., Al-Qahtani, M. M., Al-Mazrou, Y., ... Ksiazek, T. G. (2002). Genetic analysis of viruses associated with emergence of Rift Valley fever in Saudi Arabia and Yemen, 2000-01. *Emerging Infectious Diseases*, 8(12). PMID:12498657

Sindato, C., Karimuribo, E., & Mboera, E. G. (2012). The epidemiology and socio-economic impact of Rift Valley fever epidemics in Tanzania: A review. *The Onderstepoort Journal of Veterinary Research*, *79*(2), E1. doi:10.4102/ojvr.v79i2.467

Sindato, C., Karimuribo, E. D., Pfeiffer, D. U., Mboera, L. E. G., Kivaria, F., Dautu, G., ... Paweska, J. T. (2014). Spatial and temporal pattern of Rift Valley fever outbreaks in Tanzania; 1930 to 2007. *PLoS ONE*, *9*(2), e88897. doi:10.1371/journal.pone.0088897 PMID:24586433

Soumaré, P. O. L., Freire, C. C. M., Faye, O., Diallo, M., de Oliveira, J. V. C., Zanotto, P. M. A., & Sall, A. A. (2012). Phylogeography of Rift Valley Fever virus in Africa reveals multiple introductions in Senegal and Mauritania. *PLoS ONE*, *7*(4), e35216. doi:10.1371/journal.pone.0035216 PMID:22539961

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Steinmann, P., Keiser, J., Bos, R., Tanner, M., & Utzinger, J. (2006). Schistosomiasis and water resources development: Systematic review, meta-analysis, and estimates of people at risk. *The Lancet Infectious Diseases*, *6*(7), 411–425. doi:10.1016/S1473-3099(06)70521-7 PMID:16790382

Swanepoel, R., & Coetzer, J. A. W. (2004). Rift Valley fever. In J. A. W. Coetzer & R. C. Tustin (Eds.), *Infectious Diseases of Livestock* (2nd ed., pp. 1037–1070). Cape Town: Oxford University Press.

Tabachnick, W. J. (2010). Challenges in predicting climate and environmental effects on vector-borne disease episystems in a changing world. *The Journal of Experimental Biology*, *213*(6), 946–954.

Tabachnick, W. J. (2013). Nature, nurture and evolution of intra-species variation in mosquito arbovirus transmission competence. *International Journal of Environmental Research and Public Health*, *10*(1), 249–277. doi:10.3390/ijerph10010249 PMID:23343982

Thonnon, J., Picquet, M., Thiongane, Y., Lo, M., Sylla, R., & Vercruysse, J. (1999). Rift valley fever surveillance in the lower Senegal river basin: Update 10 years after the epidemic. *Tropical Medicine & International Health*, *4*(8), 580–585. doi:10.1046/j.1365-3156.1999.00437.x PMID:10499082

Tourre, Y. M., Lacaux, J.-P., Vignolles, C., & Lafaye, M. (2009). Climate impacts on environmental risks evaluated from space: a conceptual approach to the case of Rift Valley Fever in Senegal. *Global Health Action, 2*.

Turell, M. J., Dohm, D. J., Mores, C. N., Terracina, L., Wallette, D. L. Jr, Hribar, L. J., ... Blow, J. A. (2008). Potential for North American Mosquitoes to Transmit Rift Valley Fever Virus 1. *Journal of the American Mosquito Control Association*, *24*(4), 502–507. doi:10.2987/08-5791.1 PMID:19181056

Turell, M. J., Linthicum, K. J., & Beaman, J. R. (1990). Transmission of Rift Valley fever virus by adult mosquitoes after ingestion of virus as larvae. *The American Journal of Tropical Medicine and Hygiene*, *43*(6), 677–680. PMID:2267972

Turell, M. J., Sardelis, M. R., O'Guinn, M. L., & Dohm, D. J. (2002). Potential vectors of West Nile virus in North America. In *Japanese Encephalitis and West Nile Viruses* (Vol. 267, pp. 241–252). Berlin: Springer-Verlag Berlin. doi:10.1007/978-3-642-59403-8_12

Vignolles, C., Lacaux, J.-P., Tourre, Y. M., Bigeard, G., Ndione, J.-A., & Lafaye, M. (2009). Rift Valley fever in a zone potentially occupied by Aedes vexans in Senegal: Dynamics and risk mapping. *Geospatial Health*, *3*(2), 211–220. doi:10.4081/gh.2009.221 PMID:19440963

Vignolles, C., Tourre, Y. M., Mora, O., Imanache, L., & Lafaye, M. (2010). TerraSAR-X high-resolution radar remote sensing: An operational warning system for Rift Valley fever risk. *Geospatial Health*, *5*(1), 23–31. doi:10.4081/gh.2010.184 PMID:21080318

Vilaly, A. E. E., Arora, M., Butterworth, M. K., Vilaly, M. A. M. E., Jarnagin, W., & Comrie, A. C. (2013). Climate, environment and disease: The case of Rift Valley fever. *Progress in Physical Geography*, *37*(2), 259–269. doi:10.1177/0309133313478315

Walter, C. T., & Barr, J. N. (2011). Recent advances in the molecular and cellular biology of bunyaviruses. *The Journal of General Virology*, *92*(Pt 11), 2467–2484. doi:10.1099/vir.0.035105-0 PMID:21865443

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Wensman, J. J., Lindahl, J., Wachtmeister, N., Torsson, E., Gwakisa, P., Kasanga, C., & Misinzo, G. (2015). A study of Rift Valley fever virus in Morogoro and Arusha regions of Tanzania - serology and farmers' perceptions. *Infection Ecology & Epidemiology*, *5*(0), 30025. doi:10.3402/iee.v5.30025 PMID:26584830

Wong, G., Liu, W., Liu, Y., Zhou, B., Bi, Y., & Gao, G. F. (2015). MERS, SARS, and Ebola: The Role of Super-Spreaders in Infectious Disease. *Cell Host & Microbe*, *18*(4), 398–401. PMID:26468744

Woods, C. W., Karpati, A. M., Grein, T., McCarthy, N., Gaturuku, P., Muchiri, E., ... Swanepoel, R. (2002). An outbreak of Rift Valley fever in northeastern Kenya, 1997-98. *Emerging Infectious Diseases*, 8(12). PMID:11897064

World Bank. (2012). *People, pathogens, and our planet. Volume 2: the economics of one health*. Washington, DC. Retrieved from http://documents.worldbank.org/curated/en/2012/06/16360943/people-pathogens-planet-economics-one-health

Xie, H., You, L., Wielgosz, B., & Ringler, C. (2014). Estimating the potential for expanding smallholder irrigation in Sub-Saharan Africa. *Agricultural Water Management*, *131*, 183–193. doi:10.1016/j.agwat.2013.08.011

You, L., Xie, H., Wood-Sichra, U., Guo, Z., & Wang, L. (2014). Irrigation potential and investment return in Kenya. *Food Policy*, *47*, 34–45. doi:10.1016/j.foodpol.2014.04.006

You, L. Z. (2008). Africa: Irrigation investment Needs in Sub-Saharan Africa. Retrieved from https://openknowledge.worldbank.org/handle/10986/7870

Yuen, K. Y. (2015). From SARS to MERS and Ebola. *Journal of Microbiology, Immunology, and Infection*, *48*(2), S3. doi:10.1016/j.jmii.2015.02.002

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Chapter 69
Impact of Overpopulation on Land Use Pattern

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ABSTRACT

Overpopulation does not depend only on the size or density of the population, but on the ratio of population to available sustainable resources. It also depends on how resources are managed and distributed throughout the population. Overpopulation is one of the hazards and serious problem, which creates a great obstacle in the way of national development. It is estimated that growth in human population affect the global land use pattern available for agriculture, forest land cover, nearby area of different type of water bodies. The rapid increase of human population is putting extraordinary pressure on our natural resources available e.g. land, water, ecosystem services etc. The purpose of this chapter is to highlight the various environmental implications of overpopulation and rural-urban migration which in turns affect the land use pattern of world. Deforestation and loss of ecosystems that sustain global atmospheric oxygen and carbon dioxide balance is also another implication.

INTRODUCTION

In past few years, cities grow due to the rapid increase in world population and the migration of people from villages to cities. In the developing countries, the population growth has been more unstable& some cities are facing unplanned and uncontrolled settlements (e.g. slums) at the densely populated areas. Human beings have maximum population on earth although it decreases with high death rate due to illnesses, infections, famines; accidents and war but comparatively fertility rates should be high for species survival. Many factors affect the rate of change of population. As number of individual increases, the problems related to it are also increased. The main reasons that affect growth of population are the natality, mortality, immigration and migration. The natality is the ratio between births and individuals in given population and time. The mortality is the ratio of number of deaths to individuals present in given area and time. Migration is the number of people enters in or out of an area. The rate of change of population size is affected by these factors in a particular region. Overpopulation has been initiated

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due to the increase in birth rates and the decrease in death rates in present time due to better medical facilities and progresses in the field of medicine. Movement of people to developed countries for better job opportunities, war, and natural disasters like hurricanes, cyclones, earthquakes etc. There is great pressure on the natural resources (water, land) due to overpopulation. Among all the natural resources, Land is the most important one. All agriculture, animal and forestry productions depend on the land productivity. The entire land ecosystem, which composed of soil, water and plant, and soil biodiversity, is used to fulfil the community demand for food, energy, water requirement. The unmanageable use of land is the main reason for destruction of our environment. For the sustainable development of an area, regular monitoring of land cover/ land use changes is essential. Overpopulation, consumption, overuse, wastage and misuse of resources have strained the earth's carrying capacity. The demands that put pressure on our environment are also alter the future of sustainability on earth. Regular monitoring of urban land cover/ land use changes is necessary for sustainable development of an area. In India, increase in population size due to unplanned activities which leads to urbanization that reduces the agricultural land. This is also having serious impacts on the resources base of the region. The development of urban area takes place either in radial way nearby a developed city or linearly along the highways. Life of Indians depends on agriculture and similar activities in rural areas. As per Indian census during 2011, the population of country is 1,210,193,422 (Provisional Census, 2011). The Indian populations increased with a decadal growth of 17.64%. In this chapter, the impacts of increased population on land use types and availability of land for agriculture, industry, construction of dams, water bodies etc. and in turn their impact on environment will be discussed.

Population

Population is defined as the total individuals of a species in a given geographical area. While populations of a species acquire different areas are called sister populations in a geographical area, the population is further divisible into subgroups called demes. The population present in an area are capable of interbreeding among themselves. The chances of interbreeding are more between individuals of same deme than between different demes of that population which is further reduced between populations of sister populations. An individual usually interact with their closest neighbors, but if at some other point in the life cycle widespread movements occurs such as a dispersal stage, the deme is much larger than such neighbor interactions. The description of a population requires three parameters numbers and kinds of the species in an area or space and time. On Earth, various biotic interaction and effect of abiotic factors population can be dispersed:

1. Random dispersion.
2. Uniform or regular dispersion.
3. Clumped dispersion.

This dispersal of biotic community also occurs on the basis of availability of food and abiotic parts of environment interact with the biotic community. Habit of food and interaction between food chain also helps the population to survive in any area which is termed as food web; the individuals get more options of food than traditional way in its habitat.

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Overpopulation

Overpopulation, an unwanted condition where the ever increasing human population exist affects the carrying capacity of Earth. Overpopulation is the difference between natality and mortality in populations. Environmental degradation occurs not only due to population growth but also on other impacts that contribute to environmental degradation. The results of such population growth for developing countries like India span three areas;

- Changes in land use,
- Disposal of harmful waste to the environment and
- Depletion of natural resources.

As growth of population occurs, this extended growth begins to alter our environment. This concept draws upon the idea that every individual has certain basic needs. As natural resources are used, wastes are generated and disposed of. Thus, the misuse of resources, generation of waste and environmental damage relies on that society's lifestyles and pattern of consumption. Population growth is determined by number of individuals added to the population by birth (natality) and immigration from other area and subtracted by the population decreases by death rate (mortality) and emigration to other area. It increases the size of population and population lost by deaths (mortality) and emigration, reduces the population size.

Population growth = (Natality + Immigration) - (Mortality + Emigration)

Human population size increases due to the following reasons:

- Change in population size: As discussed above growth of population is affected by the entry and exit of the people in given area.
- Population movement (emigration, immigration): Both these factors affect growth of population.
- Circumstances origin of a country that lead people to emigrate- As we all know people of particular area move in and out due the following reasons:
    - No job opportunities.
    - Poverty.
    - War.
    - Environmental disasters (flood, drought, famine, earthquake, etc.)
- Offers that attract people:
    - Economic opportunity (jobs, industries)
    - Political freedom.
    - More availability of resources (availability of better food, habitat, etc.)

As per Indian census 2011, the density of Indian population has increased from 325 persons per square kilometers in 2001 to 382 persons/square kilometers. It may occur by rural to urban migration. Environmental stress, biodiversity loss, change in climate and pressure on natural resources strongly distress the population of any area and various survey shows that the population of all countries in total is already overpopulated. But population of human are still increasing. World population counted 6.8 billion in

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2009, and are predictable to climb to 9.2 billion in 2050. According to Prospects of World Population, this growth will take place in the developing countries (United Nations, Department of Economic and Social Affairs, Population Division (2015). The ease of use of sustainable resources which is placing competitive stress on the basic resources support to biodiversity and reduces the way of life, do not affect the population growth. Overpopulation influences land use patterns with consumption behaviors and productive activities of people. "Consumption by human had far exceeded resources available for every individual on land and requires 1/3 of land more to complete their needs than mother earth provides (United Nations, 1992)."

Population Development and Environmental Exploitation

Below are listed a number of the effects of population development and environmental exploitation by human populations.

1. Loss of crop lands, forest lands, wetlands for industrial expansion and extraction of minerals use.
2. Fragmenting diversity and wildlife habitats.
3. Increasing impermeable surfaces means more flooding.
4. More resources extraction, manufacturing and consumption.
5. Destruction of habitat due to change of temperature and adaptation in food chain.
6. Extinction of different flora and fauna of different area and some species become endangered due to loss of habitat and disturbance in their food chain and environmental benefits like availability of medicinal plants, fire wood, sandal wood, etc.
    a. Economic loss.
    b. Health impacts.
    c. Social disruption.
7. Change in global climate leads to increase the temperature of earth which in turn leads to polar ice melting, rise in sea level, ice cap melting, decrease in biodiversity, change in temperature of earth, etc.
8. Burning of fossil fuel leads to air pollution and overexploitation of available resources.

Table 1. World Population Change in last few decades

Major Areas	Population (Millions)			
	1950	1975	2005	2011
World	2519	4074	6465	6987
More Developed Regions	813	1047	1211	1242
Less Developed Regions.	1707	3027	5253	5745
Africa	224	416	906	1051
Asia	1396	2395	3905	4216
Europe	547	676	728	740
Latin America and the Caribbean	167	322	561	596
Northern America	172	243	331	346
Oceania	13	21	33	37

Source: (World Population Data Sheet, 2011)

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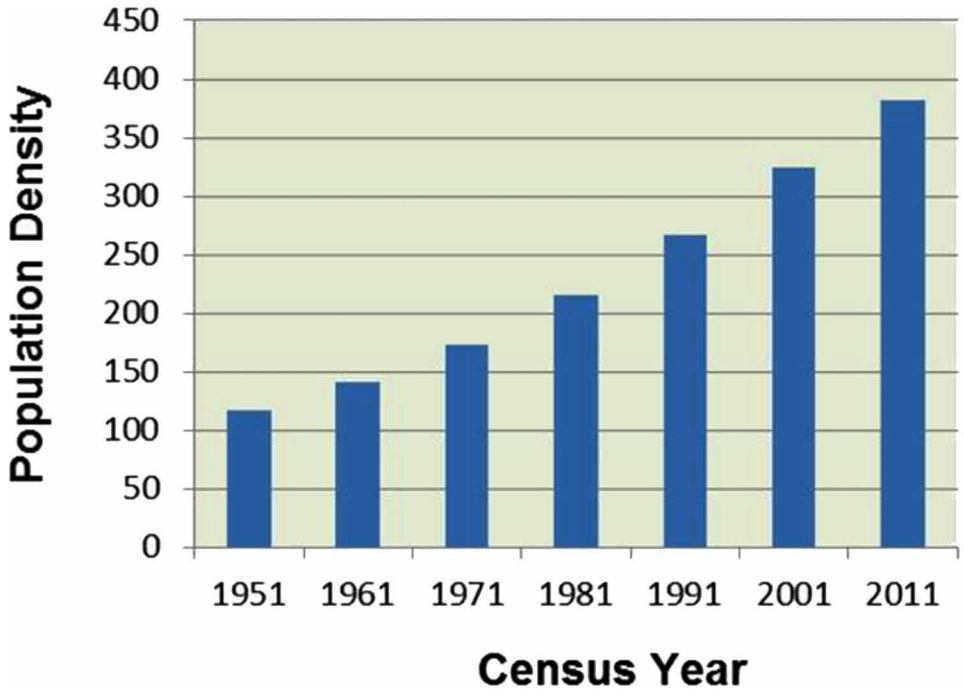
Figure 1. Population change in India during 1951-2011
Source: Indian Population Census (2011)



LAND USE AND OVERPOPULATION EFFECT ON LAND USE PATTERN

Use of land for different purposes of an area at a given time and space is land use. Land is used under different land use pattern like agricultural land, forest, fallow land etc. (Freeman, 1968). It is also used as cultivation of crops, building of houses, roads, railways, industries, grazing of animals, etc. The percentage of land used for various purposes differs from one region to another. The land use pattern is regulated by interaction of abiotic factors, such as relief, soil climatic conditions, minerals resources, etc. and the human density of population and the technological and social requirement of the people. Almost all human activities related to food, shelter and clothing takes place on land. Land use is categorized by, actions, the measures and contributions of people in a certain land cover type to cultivate change or maintain it. The availability of land on earth is limited. There is conflict over access and rights of these natural resources. It has also resulted in tough competition between the agriculture and other sectors over usage of land. Moreover, land also suffers from various problems such as soil erosion, degradation and deforestation. Worldwide changes to forests, farmlands, resources of water and air need to determine to provide, water, food, fiber and shelter for individuals present on earth. World's plantations, croplands, pastures and increase in urban area, associated with large increases in natural resources and fertilizer consumption, along with considerable biodiversity loss. Population increases in developing countries has produced stress on land, fragmentation of land holding, fisheries, forests, change in temperatures, biodiversity loss etc. Global warming due to increasing consumption of fossil fuels could have harmful impacts on the populous coastal regions in countries(developing). We face the challenge to make balance between instant needs of human and conserving the capability of the biosphere to provide goods and

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services for future. Practices for the food production, land use pattern change, over utilization of natural resources, development of urban area, industrial development, and change in methods of utilization are few reasons which make more complex relationship between population and land use.

Land on the basis of land use pattern are broadly categorized in following form:

1. Agricultural lands
2. Forests
3. Non- agricultural use of land
4. Barren and uncultivated lands
5. Permanent Pasture and other Grazing Land
6. Miscellaneous cash crops and groves
7. Cultivable wasteland
8. Fallow lands, other than current fallows
9. Current fallows
10. Roads, Dams, streams, lakes, building different infrastructure like schools, colleges, hospitals, government buildings, etc.

The global land area is 13.2 billion ha. Of this, 12% (1.6 billion ha) is currently in use for cultivation, 28% (3.7 billion ha) include in forest, and 35% (4.6 billion ha) includes grasslands and forest ecosystems and about 22% of land covered by low income countries (Fischer et al., 2010). As the population grows, the land use pattern also changes. There is transition of land use types to other type of land.

India is with a total geographical area of 328.37 million hectares of which 305.27 million hectares the reporting area. In the total geographic area, land covered by forest in absolute as well as relative terms has significantly increased from 14.2% to 22.80%. Area not available for cultivation has declined over the years indicating the spread of farm land while the pace of growth in land put in non-agricultural uses has outpaced the rate of growth in area available for cultivation.

Agriculture Land

The agricultural area is the sum of permanent crops, arable, permanent meadows and pastures land. Human is dependent on the nature for its needs. Agricultural lands provide open space and support habitat of wildlife, while the similarity between farmland to natural areas encounters management techniques that reduce the adverse effects of farming on sensitive areas. Agriculture has caused the greatest land transformations seen across the globe. The rapidly increasing population coupled with non-agricultural area uses available land will further shrink to very low level. The available land for agriculture also used for many purposes other than crop production like for establishment of animal husbandry to fulfil the need of milk and milk products of growing population (Ramankutty et al., 2006). Agricultural practices are also many types at different places for e.g. subsistence and commercial agriculture and both of these agriculture types further are of different types i.e. nomadic and shifting types in which people cultivate food crops for their livelihood only. Shifting cultivation is also called slash and burn agriculture i.e. clearance of forest or burn it for agricultural use. When the soil's fertility is lost, the land is neglected and the cultivators move to other available land. The method of cultivation is traditional and unscientific which reduce fertility power of land. Out of the total geographical area of India, 329 million hectares, area available for sowing is only 141 million hectares (i.e., 41%) (Table 2). the total cultivated

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Table 2. Land Use Pattern in India during 1951-2008

Classification	Lands in Million Hectares						
	1950-51	1960-61	1970-71	1980-81	1990-91	2000-01	2007-08
Geographical area	328.37	328.37	328.37	328.37	328.37	328.37	328.37
Reporting Area for land use	284.32	298.46	303.75	304.16	304.86	305.18	305.67
Net sown area	118.75	133.20	140.86	140.29	143	141.36	140.86
Forest	40.48	54.05	63.81	67.46	67.81	69.53	69.63
Not Available for Cultivation	47.52	50.75	44.61	39.55	40.48	41.48	43.22
(a)Area under non- agri use	9.36	14.84	16.48	19.66	21.09	22.97	26.17
(b)Barren & uncultivable land	38.16	35.91	28.16	19.66	19.39	17.59	17.29
Other uncultivated land excl. fallow land	49.45	37.64	35.13	32.31	30.22	27.74	26.82
(a)Pasture & other graining land	6.68	13.97	13.26	11.99	11.4	10.67	10.39
(b)Miscellaneous tree crops	19.83	4.46	4.37	3.58	3.82	3.44	3.31
(c)Cultivable waste land	22.94	19.21	17.50	16.74	15.00	13.63	13.12
Fallow lands	28.12	22.82	19.33	24.55	23.36	25.07	25.15
(a)Fallow land other than current fallow	17.45	11.18	8.73	9.72	9.66	10.29	10.34
(b)Current fallow	10.68	11.64	10.60	14.83	13.70	14.78	14.81

Source: (Indian Agricultural Statistics Research Institute, Data Book-2011, New Delhi)

land is 173 million hectares and net area sown is 141 million hectares and 37 million hectares of land used again and again. Population growth is also likely to promote agricultural intensification, shifting cultivation etc. Transformation of agricultural land into non-agricultural to support industries, housing, transport, irrigation, recreational facilities etc. It has been expected that during 1950-51 to 2009-10, the percentage of land not used for agricultural purposes over different area has change from 3.3 to 8.6%. Non-agricultural area has grown to 2.57 million ha i.e. by 11% (1999-2000 to 2009-10), Due to large demand for infrastructure, more and more fertile land is being diverted. (Statistical abstract of India, 2010)

Forest

Forest provided human being with employment and monetary income. The large-scale dependence exerts pressure on forests, leading to their unsustainable exploitation and eventual degradation. Unregulated exploitation of forest is a major cause of forest degradation and also for environmental pollution. Forests are exposed to overexploitation, encroachments, illegal cut down and so on, leading to their degradation. In 2007, the forest cover of world was observed under 4 billion ha, with the Asia-Pacific region accounting for around 20% (approx. 758 million ha) of area covered by forests (FAO, 2009). Global forest area tends to decline. The most considerable issues related to population distribution, pollution, and transport planning, infrastructure development and environment is reduction in forest land which reflect by following environmental problems.

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Deforestation

The Amazon basin is the regions that have lost the largest area to deforestation, and where deforestation has the greatest impact on biodiversity and biomass loss (Houghton et al., 1991, Laurance, 1998, Lambin et al., 2003), but farming and pastures made by modification in agricultural land affect the environment of biomes. Agricultural lands deteriorate by different modern farming techniques or by slash-and-burn cultivation. When flora of forest area is transformed into grassland and burned, its production is lost in about three years. This causes deforestation of large areas, mostly in tropical regions. One of the reasons for deforestation is the use of wood as fuel for cooking and heating. Ghana lost almost a third of its dense forest due to this reason in between 1938 to 1980 (FAO, 1986b). The loss of primary forest is also caused by the building of roads and the expansion of residential areas in some areas. The changes in agricultural practices like shifting cultivation etc. are also increases desertification. Excess use of ground water by increasing population results in lower down ground water table leads to decrease in moisture of soil.

Destroying Diversity and Wildlife Habitats

Population increase alters the habitat of the migratory birds coming from different parts of the world. More people will demand more building sites, roads, schools, businesses, shopping, and enjoyable services by using resources from the national forests. In various parts of the world, wild animals are hunted for various purposes like meat, skin, horns, etc. This disturbs the ecological balance of the environment. Many birds have become extinct and many others are on the way of extinction. Our forests are treasure troves of biological diversity. They harbor millions of species of animals. Our wildlife suffers severely due to deforestation and urbanization. Many animals have become extinct because they have lost their natural habitation. Hence, there is greater need for the preservation of wildlife. The 2012 update of International Union for Conservation of Nature and Natural Resources (IUCN) and the Red List of Threatened Species shows that of the 63,837 species examined worldwide, 19,817 are threatened to extinction. It is found that 41% of amphibian species are threatened, as well as 33% of reef building corals and 25% of mammals (IUCN, 2013). If present trends continue, scientists warn, nearly half of all biodiversity will be vanished, because of acidifying oceans, climate change, invasive species, habitat loss, pollution and overexploitation of natural resources and increased human population. Overpopulation has changed some universal circumstances and parameters such as:

- Annual absorption of 42% terrestrial net primary productivity,
- 30% net primary productivity of marine,
- 50%fresh water,
- 40% land devoted to human food production and
- 50% land mass converted for human use. (Chadha et al., 2004).

Rainforests enclosed 14% land surface of the Earth, now they cover 6% of bare and researcher estimates that the last remain rainforests could be used up in, >40 years and indeed by the end of the century at the current rate of deforestation(FAO, 2011).Nearly 30% of the ocean's reefs since1980,due to mainly warming temperatures, acidifying oceans and pollution have disappeared, including 1/2 of the reefs in the Caribbean and 90% of Philippines' coral reefs, and experts observed that Australian Great

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Barrier Reef may be vanished by the year 2050 and coral reefs could be gone by the end of the century completely(FAO, 2011b).

Desertification

It appears an absolute evil, while an irrigation area faces the problem of salinization, while reversible, may be a greater loss than the washing off topsoil in a marginal area. "The reasons behind the destruction of ecosystems under the combined pressure of adverse climate & cultivation are desertification" (FAO, 1986). The area under irrigation faces the problems of water logging and salinization. According to FAO (1994), from total 240 million hectares currently irrigated land, about 30% are severely affected by salinity and another 60 – 80%isinfluenced to some degree. The largest irrigated areas affected by salinity are28% of the USA, 23% of China, 2% of Pakistan and 11% of India (Umale, 1993). India has observed huge increase in large projects from large dams and thermal power projects to massive industrial complexes and huge mines. About 92% regions in arid Rajasthan are affected by desertification (slightly 30%, moderately 41% and severely 21%). Area affected by desertification in the neighboring arid Gujarat is near about 93%. (ICARDA, 2006)

Non-Agricultural Use of Land

Population growth in world is now increases and its impact on land use trend is quite disturbing and shocking. The changes in land use posed pressure on land properties due to rising population. The problematic features are in the form of:

- Land used for non-agricultural purposes,
- Increase in fallow land,
- Decrease in area used for tree crops and
- Groves comes under categories miscellaneous.

Area under non-agricultural use is increasing rapidly but not at the cost of agricultural area. The effect of an increase in population density on change in cropping intensity is not significant statistically. Forest transition or more generally, ecological conversion arises as an economy change to non- farming production, agriculture emphases in the lands used for production, and agriculture at margin is abandoned, favouring the recovery of forests and other natural ecosystems. Although it is not as much of important as related to deforestation and much less observed by the general public and the scientific community, practices of ecosystem reclamation can be observed in many Latin American areas.

Barren and Uncultivated Lands

These areas include areas of bedrock coverage, path of desert, rock glaciers scraps, residues from volcanic eruption and other accumulations of rock without vegetative cover. Other types of barren and uncultivated lands include:

- Dry salt area,
- Beaches,

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- Sandbanks,
- Stripe mines, and
- Pebbles pits.

Mining of minerals sites displays such kind of problem in land use. As the top layers of the soil become harder to use site for other purposes, so that the land become barren land. Mining process increase as the demand increases which in turn increases wasted or infertile land. In this type of situation, an interaction of natural processes and human activities cause the land not to properly sustain its ecosystem services.

Permanent Pasture and Other Grazing Land

All grazing land like village common grazing land, permanent meadows/pasture or not included in this category. Population growth also affects the land used for grazing, as the animal's dependent on the grazing move from one place to another for fodder. Nomadic population take their animals with them and grow fodder for them nearby utilize available land or clear the forest area.

Miscellaneous Cash Crops and Groves

Land under dead trees, thatching grasses, bamboo, bushes and other groves for fuel, etc. which excluded under 'Orchards' are included in this category. As this area is not included in net area sown categories, cash crops are also grown in these areas for commercial purposes now a day. People alter practices of such land for their benefits.

Cultivable Wasteland

The land is not used for cultivation or left free past 4-5 years included in this category and left for succession for some reason or the other. Such lands are covered by the wild grasses or shrubs which have no economic value. They may be accessible or inaccessible or may lie in separate area. Agricultural lands, forests, grassland, sand metropolitan areas are part of the dry lands. A key role in biophysical practices by reflection and absorption of solar radiation and conserving the balance of atmospheric constituents is maintained by dry lands. The grain and livestock, fruity plants and micro-organisms, the habitat that supports many vegetable species of world is provided by them. Dryland regions faces occurrence of prolonged periods of drought because of high variation in both rainfall and intensities (FAO, 2004) as to affect the water and moisture balance and adversely affect services provided by ecosystem and the resident populations. Expansion of cropland area in these regions can fail owing to overexpansion of unsuitable technologies for production into the drylands environment. Increased population pressures and human expansion into drier areas during long wet periods leave an increasing in population vulnerable to drought. As the population grow rapidly in drylands due to improvements in health conditions and other factors has placed remarkable stress on the natural-resource base. The destruction of the fragile dryland ecosystem has also led to their impoverishment. An example of dryland agriculture in the Asia-Pacific region areas is land degradation defined as the productivity loss of the land (FAO, 2000).

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Fallow Lands, Other Than Current Fallows

Fallow land and the cropland which are not seeded in one season; it may or may not be ploughed. For the control of weeds and pests, these lands are chemically treat or cultivated or left as it is. Crop rotation method is used to restore fallow lands. All land which was used for farming but currently is waste Landis placed in this category. There is need to decrease the extent and frequency of these lands in order to increase agricultural production. All these problems can be overcome by the use of fertilizers, providing irrigation facilities, crop rotation and several other similar modern farm techniques.

Current Fallow Lands

Current fallow lands are those lands which are leave as waste in current year but used for crop production in previous year.

Roads, Dams, Streams, Lakes, Buildings and Different Infrastructure Like Schools, Colleges, Hospitals, Government Buildings Etc.

Much type of renewable materials is derived from biomass. Sometimes lands available for different primary demands like food crops, fibre crops or as source of energy is also used at some time. As population grow and its needs increases, pressure on productive land and the water will certainly also increase, raise the problem of competition.

Roads

In order to further strengthen the network of road & making it more efficient to fulfil traffic rules; the key emphasis is on development of road network, building of roads, bye passes, bridges and road over bridges. A programme for improvement of roads widening, establishment, reconstruction, constructing of cement concrete pavements and blocks, premix carpet, building of cross hygiene and construction of pipes and retaining walls etc. need to be taken. Increases in human population and thickness often take place without sufficient investment in transport infrastructure. This raises time spent on driving vehicles, intervals and public transport systems faces the problem of overcrowd. Overloaded transport systems result in many adverse effects. The ratio of population in cities in developing countries has increased to nearly double since 1960 (from > 22%to < 40%), while in more developed regions the urban share has grown from 61%to 76%. The total length of roads in India increased more than 11 times during 1951 to 2011 i.e. 60 years. It has been increased from 3.99 lakh kilometer on March 31,1951, to 46.90 lakh kilometers as on March 31, 2011 (Ministry of Road Transport & Highways of India, 2012).

Rural – Urban Development

Urbanization is estimated to continue well into the next century. By 2030, it is expected that nearly 5 billion (61%) of 8.1 billion people of the world will stay in cities (FAO, 2000). The modern trend toward urbanization presumably brings with it, and is accelerated by, the economic advantages of division of labor, specialization of knowledge, skills and abilities, and multiplication of goods and services. As these advantages are realized, the requirement of moving persons, goods and ideas among establishments in-

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creases. Mobility becomes an index of progress and some of the limitations upon growth. India shares this global trend toward urbanization. Population growth of urban has gone beyond the development of:

- Basic services,
- Household services,
- Sewerage and solid waste disposal,
- Increasing waste generation at home,
- Water supply,
- Offices and industries, together with unplanned waste disposal facilities which consequence increased environmental deterioration.

There is increasing air pollution by automobiles. Ecology and health affected by this polluted environment. Poverty continues in metropolitan and peri-urban areas; awareness about the glaring inequities in close urban setting may lead to social unrest. Instead of harmful impact of urbanization on global warming, acid rain and ozone depletion, it has serious influence on the available arable land and subsequently leading to deforestation in maximum part of world. It is contended that decrease resources risks like water table lower down, soil nutrients declining etc. are also higher in the cities because of huge demand of food, water and fuel and disposal of municipal and other wastes are not only logistically difficult, however also a resource-consuming exercise. Although the efficiency of present agriculture and the connected reduce cost of foods are positive for consumers, farmers with small lands, mainly individuals on marginal lands, are frequently affected by large-scale agriculture. This is stimulating rural–urban migration. The modernization of agriculture and rural–urban migration increases the shift in the mode of production of food and the abandonment of agriculture at marginal land and land available for grazing that favour restoration of ecosystem with spontaneous processes and by enabling the construction of secure areas or conservation policies (Izquierdo and Grau, 2008; Grau and Aide, 2007; Aide and Grau, 2004; Mather, 2001; Mather and Needle, 1998).

REASONS BEHIND LAND DEGRADATION

As the demand of food and services provided by ecosystem increases, the production and cultivation of services also increases. The carrying capacity and land use pattern to provide services and goods ecosystem in given time for its beneficiaries is also reduced. The ecosystem services also exploit for the cost-effective growth and develop the livelihood of growing population. The farming system is largely subsistence based and not necessarily market-oriented. So, the land degradation is "the reduction or complete loss of the fertility of the soils for sustainable use."(FAO, 1980) These modifications occur due to soil erosion or by use excessive chemical in the fields. Here are few reasons of deterioration of land to overcome the scarcity of food and other ecosystem services:

Chemical Reduction

Chemical reduction may consist in:

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The reduction of inorganic nutrients (mainly nitrogen, phosphorus and potassium) or organic matter like humus or fertile soil

For demand of irrigation, the river and stream water is used in certain regions of world. In some regions, nutrients concentration declined by water erosion: "several nutrients are percolated during the heavy rainfalls, in the humid tropics particularly on isolated land", in addition, these nutrients "can be exhausted due to cultivation of similar crops repeatedly in same area for many years" (FAO, 1983). Reduction is rigorous in the areas where "a poor or less fertile soil is used for agriculture, without the use of fertilizer or organic manure" (ISRIC/UNEP, 1991).

Salinization

The concentration of salts in the soil may changes due to:

Poor organisation of irrigation practices. Schemes high salt concentration of water used for irrigation or ignorance of drainage system of soil can increase the risk of soil salinization, especially at the regions with high evaporation rates e.g. in arid areas.

1. Sometimes salty water of sea mixed with groundwater by percolation and fresh water bodies generally used for irrigation;
2. Rapid loss of water due to evaporation in soils irrigated with salty water or saline water (ISRIC/UNEP, 1991).

The Decrease of soil fertility and the yield of crop are the damaging effect of Salinization. (FAO, 1994)

Acidification

Due to growth of population, industries are also growing now a day. These industries disposed excess of effluent in the nearby areas or in water bodies increases the acidity of land. Disproportionate use of acidifying fertilizer or drainage in specific types of soil is another reason of acidification. This type of soil is not good for agriculture or cultivable purposes so used for some other purposes like infrastructure of buildings, etc.

Pollution

As the number of individuals is increasing production of waste like solid, liquid and gaseous form. The growth of industries (waste addition, disproportionate use of pesticides, oil spills etc.) in different areas also pollutes the land and water bodies and it can strongly reduce the agricultural potential of lands. Soil pollution from heavy metals by inappropriate disposal of industrial discharges, along with the excessive use of pesticides and lack of management of municipal and domestic wastes, is becoming a key concern. Some commercial fertilizers also have high concentration of heavy metals that have negative impact on the environment. The indiscriminate use of agrochemicals (fertilizers and pesticides) is often responsible for land degradation. Soil texture, infiltration and permeability characteristics are affected adversely to a considerable extent due to excessive grazing, fire and unmanageable practices of cultivation in land.

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Global Climate Change

India's urban population (1996) of about 240 million is one of the largest in the world. Increase in urban population is based on natural growth and migration from rural areas. The urban environmental issues arise from failure to provide the basic needs to urban population. Barely 50% of urban population have access to safe water supply and sanitation facilities. Intensification of agricultural is causing depletion of groundwater and serious soil degradation in some of the most agricultural intensive and significant areas of the planet. Land use for agriculture, urbanization and infrastructure (e.g. roads) continues to cause loss of habitat for much of the world's biodiversity. The terrestrial ecosystems as well as the world's marine ecosystems are being degraded and also intensive exploitation of marine flora, fauna, water, air & soil pollutions and chemical changes in ocean such as acidification, etc., is done regularly. The stress of increasing population on energy resources during the past decade has increased the concentration of atmospheric carbon dioxide. All this factors alter the whole earth environment and affect the biodiversity and global climate. The 21st Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP21) will be held in Paris in December 2015 with the objective to achieve, for the first time, a universal and binding agreement to efficiently combat climate change and stimulate and accelerate the transition towards resilient and low-carbon societies and economies. The anticipated new climate-related agreement in Paris in Dec.2015 is expected to result in more requirements, such as the reporting in the form of "intended nationally determined contributions (INDCs) i.e. towards achieving stabilization of GHG concentrations in the atmosphere (Kononov, 2015).

CONCLUSION

As we all know, the needs of every individual is dependent on the environment. For this we modify our environment and extract or destroy the resources. Land use pattern also changes with last few years of time period as the population increase. If these land use practices are well planned and sustainable, the problems related to land can be solved. Wasteland can be restored with afforestation and scientific techniques.

- By giving education, awareness to youngsters or teenager would create the required consciousness among them that small families are more efficient. It helps to enable them to attain considerable decline in the size of family, achieve their reproductive goals and improve quality of life.
- Agroforestry joins shrubs and trees with farming and forestry practices to produce more diverse profitable, healthy, fruitful, and conservation land use systems, to fulfil the needs of growing population. Itis mandatory to use the available agriculture land for great yield and better production of food. With two or more interacting plant species in a given area, it creates a more complex habitat that can support a wider variety of fauna and biodiversity. Apart from all these benefits, it is also reducing poverty by enhancing the production of timber, wood and other products for consumption and sale, contributing food security, cleaner water through reduced nutrient and soil runoff and also maintain ecological balance. But it uses more soil nutrient and need more attention for production. The Government of India initiated programme for agroforestry as a combined sustainable land management system on June 2, 1992. It announced the National Conservation Plan in order to tackle multidimensional agricultural problems facing the nation today.

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- The forest conserves the quality and quantity soil and water in many ways, leaves and branches decrease wind strength, after the absorbing solar radiation, decreases the surface area for evaporation. The canopy growth and the decomposition of plant organic matter like leaves, branches and fruits, etc., by soil fauna and microbes, modify soil quality and components, affect the water penetration and drainage and also increase the fertility of the soil. This process is cost affecting and meet the need of growing population. Water cycle and ecological system are conserved by increase in vegetation cover.
- A healthy ecosystem can mitigate change. With time, the composition of species may change but the ecosystem will still function to withstand life. New species moving into the environment, by increase or decrease in number of existing species, or by evolution over time may alter the ecological condition of the area. Natural resources are usually recycled within an ecosystem and progression can help the population to adapt the concern environment without collapse of the system. The more the biodiversity, more easily the system is able to adjust to changes.

REFERENCES

Agricultural subsidies: U.S. Assistance Programs. (2007). U.S. Assistance Programs in the United States, the Federal Government first Assisted Agriculture.

Aide, T. M., & Grau, H. R. (2004). Globalization, migration, and Latin American ecosystems. *Science*, *305*(5692), 1915–1916. doi:10.1126cience.1103179 PMID:15448256

Brown & Jacobson. (1987). The Future of Urbanization: facing the Ecological and Economic Constraints. Worldwatch Paper No. 77.

Central Statistical Organization. (2004). *Statistical Abstract of India*. New Delhi: CSO.

Central Statistical Organization. (2010). *Statistical Abstract of India*. New Delhi: CSO.

Chadha, G. K., Sen, S., & Sharma, H. R. (2004). State of Indian Farmer: A Millennium Study: Land Resources (vol. 2). Academic Foundation.

Collins, J. (1987). Labour scarcity and ecological change. In P. Little & M. Horowitz (Eds.), *Lands at risk in the third world: local level perspectives* (pp. 19–37). Boulder, CO: Westview Press.

Cruz, M. C. J. (1994). Population pressure and land degradation in developing countries. In *Population, environment and development* (pp. 135–147). New York: United Nations.

Dyson, T. (2004). India's Population – The Future. In T. Dyson, R. Cassen, & L. Visaria (Eds.), *Twenty First Century India Population, Economy, Human Development, and the Environment*. New Delhi, India: Oxford University Press.

FAO. (1980). Natural resources and the human environment for food and agriculture. Environment Paper No 1. Rome: FAO.

FAO. (1983). Keeping the land alive. Soil erosion - its causes and cures. Soils Bulletin No 50. Rome: FAO.

FAO. (1984). *Land, food and people*. Rome: FAO.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

FAO. (1986a). *African agriculture: the next 25 years*. Rome: FAO.

FAO. (1986b). *Atlas of African Agriculture*. Rome: FAO.

FAO. (1992). *Protect and produce* (Revised edition). Rome: FAO.

FAO. (1993a). *Key aspects of strategies for the sustainable development of dry lands*. Rome: FAO.

FAO. (1993b). *Sustainable development of dry lands and combating desertification*. Rome: FAO.

FAO. (1994). Water policies and agriculture. Rome: FAO.

FAO. (2004a). Decentralization and Rural property taxation. FAO Land Tenure Studies 7. Rome: FAO.

FAO. (2004b). *Water charging in irrigated agriculture. An analysis of international experience*. Rome, FAO.

FAO. (2006). *Global forest resources assessment 2005: Progress towards sustainable forest management. FAO Forestry Pater 147*. Rome: Food and Agriculture Organization of the United Nations.

FAO. (2009). *FAO STAT Data*. Rome: FAO.

FAO. (2010). Global forest resources assessment 2010. FAO Forestry Paper 163. Rome: FAO.

FAO. (2011a). State of the world's forests 2011. Rome: FAO.

FAO. (2011b). *Climate change, water and food security. FAO Water Reports 36*. Rome: FAO.

Fischer, G., Hizsnyik, E., Prieler, S., & Wiberg, D. (2010). *Scarcity and abundance of land resources: competing uses and the shrinking land resource base*. SOLAW Background Thematic Report TR02. Rome: FAO.

Forest Survey of India. (2003). *State of Forest Report*. Dehra Dun: FSI, India.

Freeman, T. W. (1968). *Geography and Planning, Hutchinson*. London: University Library.

Grau, H. R., & Aide, T. M. (2007). Are rural–urban migration and sustainable development compatible in mountain systems? *Mountain Research and Development*, *27*(2), 119–123. doi:10.1659/mrd.0906

Houghton, R. A., Leftwowitz, D. S., & Skole, D. C. (1991). Changes in the landscape of Latin America between 1850 and 1985: I. Progressive loss of forests. *Forest Ecology and Management*, *38*(3-4), 143–172. doi:10.1016/0378-1127(91)90140-Q

Indian Agricultural Statistics Research Institute. (2011). *Data Book*. New Delhi: Author.

International Center for Agricultural Research in the Dry Areas (ICARDA). (2006). Desertification and its Control in India. Author.

ISRIC. (1988). Guidelines for general assessment of the status of human- induced soil degradation. Working Paper and Preprint 88/4, ISRIC Wageningen.

ISSS. (1987). *Proceeding on the Second International Workshop on a Global Soils and Terrain Digital Database*. SOTER report 2. ISSS Wageningen.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Iyengar, S. (2003). Environmental Damage to land Resources Need to Improve Land Use Data Base. *Economic and Political Weekly*, 3596–3604.

Izquierdo, A., & Grau, H. R. (2008). Land use and demographic trends across Eco regions of NW Argentina. *Journal of Environmental Management*.

Kononov, S. (2015). United Nations Framework Convention on Climate Change: Key Findings. Academic Press.

Lal, R. (1994). *Method and Guidelines for assessing sustainable use of soil and water resources in the tropics. SMSS Technical Monograph 21*. Ohio State University.

Lambin. (2003). *Land Change Science: Observing, Monitoring and Understanding, Trajectories of Change on the Earth's Surface*. London: Springer.

Laurance, G. W., Ferreira, L. V., Rankin-de Merona, J. M., & Laurance, S. G. (1998). Rain forest fragmentation and the Dynamics of Amazonian Tree Communities, Australia. *Ecology*, *79*(6), 2032–2040. doi:10.1890/0012-9658(1998)079[2032:RFFATD]2.0.CO;2

Mather, A. S. (1992). The forest transition. *Area*, *24*, 367–379.

Mather, A. S. (2001). The Transition from Deforestation to Reforestation in Europe. In A. Angelsen & D. Kaimowitz (Eds.), *Agricultural technologies and tropical deforestation* (pp. 35–52). Wallingford, UK: CABI Publishing. doi:10.1079/9780851994512.0035

Mather, A. S., & Needle, C. L. (1998). The forest transition: Theoretical basis. *Area*, *30*(2), 117–124. doi:10.1111/j.1475-4762.1998.tb00055.x

Ministry of Environment and Forest. (1999). National Forestry Action Programme: India, Vol. I: Status of Forestry in India. New Delhi: MoEF, Government of India.

Ministry of Environment and Forest. (2002). Interim country report-India for United Nations Forum on Forest (UNFF-II). New Delhi: MoEF, Government of India.

Ministry of Home Affairs. (2011). Indian Population Census, 2011. Office of the Registrar General & Census Commissioner, India.

Ministry of Road Transport and Highways. (2012). *Basic road statistics of India 2008-09, 2009-10 & 2010-11*. Transport Research Wing. New Delhi: Author.

National Report on Implementation of the United Nations Convention to Combat Desertification. (2006). Ministry of Environment & Forests.

Planning Commission. (2002). Tenth Five-year Plan 2002-2007: *Dimensions and Strategies (vol. 1)*. New Delhi: Planning Commission, Government of India.

Planning Commission. (2002). Tenth Five-year Plan 2002-2007: *Sectoral Policies and Programmes (vol. 2)*. New Delhi: Planning Commission, Government of India.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Ramankutty, N., Graumlich, L., Achard, F., & Alves, D. (2006). Global land-cover change: recent progress, remaining challenges. In E. F. Lambin & H. J. Geist (Eds.), *Land-Use and Land-Cover Change: Local Processes and Global Impacts* (pp. 9–39). Berlin: Springer-Verlag. doi:10.1007/3-540-32202-7_2

Richards, J. F. (1986). *World Environmental History and Economic Development in Sustainable Development of the Biosphere* (W. C. Clark & R. E. Munn, Eds.). Laxenburg, Austria: International Institute for Applied Systems Analysis.

UNDP. (2000). *Human Development Report, United Nations Development Programme*. New York: Oxford University Press.

UNEP. (1992). *The world environment 1972-1992. Two decades of challenge* (M. K. Tolba & ... , Eds.). London: Chapman & Hall.

United Nations. (1977). New York: Round-up, Plan of Action and Resolutions of UNCOD.

United Nations. (1992). *The United Nations programme of action from Rio*. New York: UN.

United Nations. (2001a). Population, Environment and Development: The Concise Report. New York: UN.

United Nations. (2001b). *World population prospects: The 2000 revision, highlights*. ESA/P/WP. UN.

United Nations, Department of Economic and Social Affairs, Population Division. (2015). *World Population Prospects: The 2015 Revision, Key Findings and Advance Tables*. Working Paper No. ESA/P/WP.241. Author.

WHO. (1992). *Our Planet, Our Earth, Report of the WHO Commission on Health and Environment*. Geneva: World Health Organization.

WHO. (1997). Health and Environment in Sustainable Development: Five Years after Earth Summit. Geneva: WHO.

World Bank. (2007). *Agriculture for development World Development Report 2008*. Washington, DC: World Bank.

World Population Data Sheet. (2011). Washington, DC: Population Reference Bureau.

World Population Prospects. (2003). The 1998 Revision. United Nations; 1998. World Urbanization Prospects: The revision. New York, NY: United Nations.

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Section 6
Managerial Impact

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Chapter 70
Characterization and Management Concerns of Water Resources Around Pallikaranai Marsh, South Chennai

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ABSTRACT

Pallikaranai is one of the last remaining natural wetlands of Chennai. This marsh collects floodwater and increases groundwater levels in the region. The present study characterizes the water sources available around Pallikaranai Marsh. Groundwater was found to be the main source of water in the study area, extracted through domestic wells as well as commercially through a large number of agricultural wells. Direct surface water extraction from wetlands by private tankers was also observed in some areas. Acute water shortage and inefficient water supply by the government has led to thriving of tanker market in this area. Shrinking of the marsh and surrounding water bodies owing to construction, dumping of waste and encroachment accompanied by over-extraction of groundwater is driving this area towards extreme water crisis especially in event of climate change. Conservation of wetlands and evolving norms for sustainable water extraction of groundwater especially by commercial entities is recommended.

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BACKGROUND

Hydrological cycle forms an essential part of climate system (Askew, 1987) and change in climate is associated with changes in a number of components of hydrological cycle like altered precipitation pattern, intensity, etc. (Trenberth, 2011). Wetlands perform essential hydrological functions and are known to act as a sponge- 'soaking up water during wet periods and releasing it during dry periods'- signifying their importance as buffers against extreme climate change events that affect water availability (Bullock & Acreman, 2003; Maltby & Acreman, 2011). Some of the most important ecosystem services provided by wetlands are water supply and regulation, groundwater recharge and maintaining high water table, surface water storage, and removal of sediments, nutrients and other contaminants to improve water quality (Juliano & Simonovic, 1999; Zedler & Kercher, 2005). Apart from hydrological services, wetlands regulate global climate change through sequestration and long term storage of carbon dioxide from the atmosphere (Mitsch et al., 2013). Wetlands, mangroves and reefs also protect the coastal and inland communities from tropical storms and cyclones in events of extreme climate change (Turner, Oppenheimer, & Wilcove, 2009).

India sustains 16% of the world population with only 4% of the world's water resources (UNICEF, FAO and SaciWATERs, 2013). It is predicted that in future, the relative proportion of water used for irrigation will drop, whereas domestic and industrial use will increase. According to the National Water Policy, highest priority has been given to drinking water followed by irrigation, hydropower, ecology, etc. (Michael, 2009). However, with the rapid growth and expansion of metro cities, providing safe drinking water is one of the biggest challenges that the country faces today (Srinivasan, 2008).

Chennai, located on the east coast, is a water scarce city that has the lowest per capita availability of water amongst the four metro cities in India (Ruet, Saravanan, & Zerah, 2002). Although Chennai receives an average annual rainfall of 1200-1300 mm, only 5% of this actually seeps into the ground in urban areas (Janakarajan, Butterworth, Moriarty, & Batchelor, 2007). Traditionally a network of tanks (traditional rainwater storage reservoirs), ponds, temple tanks and wells formed the primary source of water in Chennai (Agarwal & Narain, 1997). Later due to increased inward migration and population pressure, these surface water sources had to be supplemented by groundwater pumped from wells in peri-urban areas (Janakarajan et al., 2007).

Chennai Metropolitan has 4 distinct systems of water supply-

1. Metro Water Board supply,
2. Municipal supply in towns adjoining Chennai city,
3. Domestic shallow wells or tube-wells, and
4. Private market including tanker trucks and retail distribution of bottled water (Anand, 2001).

Chennai Metropolitan Water Supply and Sewerage Board (also called 'Metro Water Board' or CMWSSB) obtains water from three interconnected rain-fed reservoirs, well fields and two inter basin projects (Srinivasan, 2008).

Despite the new projects, Chennai's reservoir storage capacity, mostly controlled by external agencies, remains very low (Srinivasan, 2015). As the gap between supply and demand is increasing by the day, the city is facing problems of low water supply, waste water management; fall in water table, salt water intrusion and flooding (Narain, Anand, & Banerjee, 2013).

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One important source of water in Chennai Metropolitan is a large number of wetlands located in and around the city. Care Earth's assessment of the wetlands of Greater Chennai, based on a study of Survey of India topo-sheets of 1971 and composite imageries for the period 2009-11, revealed that Greater Chennai has 474 wetlands organized as complexes (Care Earth Trust, 2012). These wetland complexes perform critical ecosystem services like providing fresh water and recharging groundwater aquifers. However it is estimated that more than half of these wetlands have been converted for various uses, encroached upon or used as dumping sites (Gupta & Nair, 2011).

Adding to the water woes is the changing climate which is one of the major factors that threatens water security (Schewe et al., 2014). The freshwater resources have been projected to be strongly affected by climate change (Bates, Kundzewicz, Wu, & Palutikof, 2008). The impact of climate change is expected to be more severe in developing countries and IPCC has predicted increased water stress in India (Mertz, Halsnæs, Olesen, & Rasmussen, 2009). Climate change can affect water resources in terms of changes in precipitation and runoff patterns, rise in sea level and subsequent altered land use and water demands (Frederick & Major, 1997). Projected impact of climate change on water resources suggest that water supply may either increase or decrease in water stressed countries in the near future. This can be accompanied by water quality degradation, increase in salt water intrusion into coastal aquifer, and an increase in flood and drought frequency (Erwin, 2009). Extreme and intense rainfall events associated with climate change resulting in increased runoff will not alleviate water stress but would rather lead to enhanced flooding if the excess water is not stored (Arnell, 2004).

Pallikaranai Marsh

Historically, a large part of South Chennai was a floodplain comprising of Pallikaranai Marsh, smaller satellite wetlands and tracts of pasture land (Vencatesan, 2007). Pallikaranai, one of the last remaining natural wetlands in the city collects flood water and increases ground water levels in this landscape (Care Earth, 2002, 2005; Drescher et al., 2007; Joshi & Kale, 2013). As Chennai is bound by Bay of Bengal in east and Andhra Pradesh in north, much of the recent expansion of the city has been towards south covering areas like Velachery, Madipakkam, Thoraipakkam, Pallikaranai, etc. swallowing several agricultural villages and wetlands. These areas constitute the peri-urban region of Chennai city. These transitional areas around the city not only provide land and water resources for urban expansion but also serve as a sink for urban wastes (Narain, 2010). Further, these areas in Chennai have been witnessing population escalation as well as rise in water demand (Appasamy, 1995). The recent expansion of the city with a spurt in Information Technology industry, residential complexes and large number of informal settlements has resulted in problems of encroachment of the land and wetlands, pollution and unsustainable groundwater abstraction. This has led to fall in water table, flooding, water contamination, salinity intrusion, health problems, etc. The present study focuses on characterizing and assessing the current status of the water resources located around Pallikaranai Marsh in South Chennai. This study was supported and funded by the Tamil Nadu Forest Department.

ASSESSMENT OF WATER RESOURCES

The study was conducted around Pallikaranai Marsh (12.949371°N latitude and 80.218184°E longitude) in Chennai Metropolitan Area. Pallikaranai is largely a freshwater marsh located nearly 20 km South of

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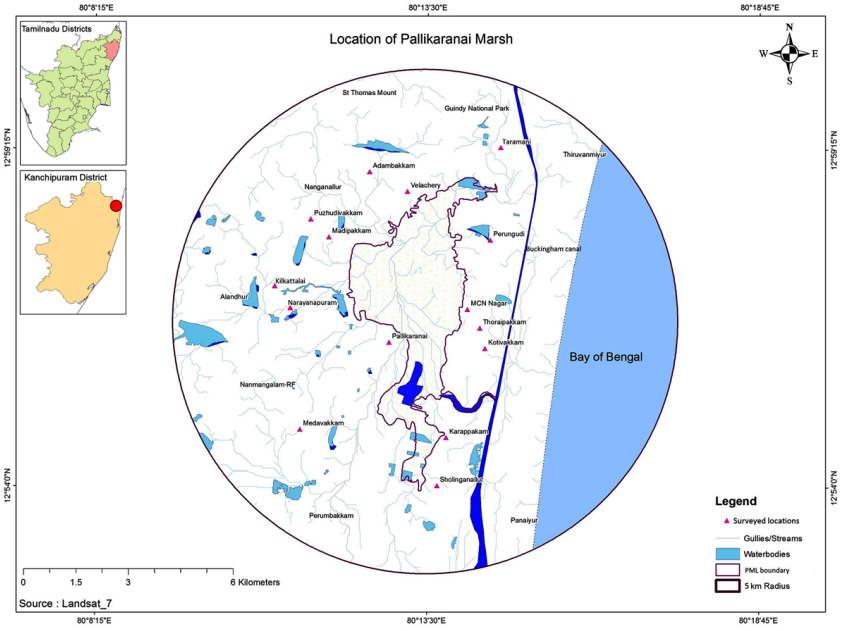
Chennai city. It drains an area of about 250 km^2 through two outlets - Okkium Maduvu and Kovalam creek and falls into Bay of Bengal (Vencatesan, Daniels, Jayaseelan, & Karthick, 2014). Over the years, the size of the marsh has reduced from 6000 ha in 1900s to the present 593 ha. Pallikaranai is one of the 94 wetlands identified under National Wetland Conservation and Management Programme of the Government of India.

A large part of South Chennai was historically a floodplain comprising of the Pallikaranai Marsh, smaller satellite wetlands and tracts of pasture land and forests. These small wetlands formed an important source of irrigation for the area. Presently, the occurrence of the freshwater aquifer running parallel to the coast has significantly contributed to the expansion of the city in this direction (Vencatesan et al., 2014). Over the past 50 years large parts of the marsh have been reclaimed into terrestrial habitats and converted to residential colonies. The assessment of water resources was carried out within 5 km radius from the centre of the marsh mainly covering residential areas of Perungudi, Thoraipakkam, Karapakkam, Velachery, Medavakkam, Madipakkam-Puzhudivakkam and Pallikaranai (Figure 1).

Systematic field surveys were carried out from January 2013-2014, in addition to the ongoing longitudinal surveys of Care Earth Trust on Pallikaranai Marsh for the past 13 years. The survey focused on the 5 km radius area from the center of the marsh to assess and characterize the water resources. Surveys were undertaken by walking along the highway roads, inside the colony streets and barren fields. Total area of 37.608 km^2 was covered within 5 km radius. Water sources were identified in the field and categorized on the basis of the nature of the source as surface and groundwater. These sources have been further classified as Primary and Secondary source. 'Primary source' defines the direct source of water for the consumer while 'Secondary source' are the sources that supply water to the consumer via a supply chain and storage structure. In this case the municipal water tanks and village tanks have been classified as secondary sources as they are filled by water tankers which draw water from groundwater sources.

Figure 1. Map showing the study area within the 5 km radius of Pallikaranai Marsh



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Another secondary source is packaged drinking water plants which process groundwater to be supplied as water cans, packets, etc. to the consumer. However the actual number of groundwater sources has not been accounted for these two observations. All the shops selling water in the form of packets/cans/bottles have been classified as 'small scale water source' in the 'Others' secondary source category as the source (whether ground or surface) for these packaged units could not be ascertained in the present study. Accordingly, water sources are categorized as wetlands (including lakes), small ponds (relatively smaller water bodies), temple tanks, well sources (private dug well and agricultural wells), manmade water tanks (village tanks), and municipal water tanks (Sintex tanks erected by the government). The geographical position of source (latitude and longitude) was marked using GARMIN GPS. To quantify the fresh water usage around Pallikaranai Marsh, data was obtained by interviewing people at lorry tanker filling stations. Data collected included the number of water tankers being filled every day, cost of filling water tanker at filling stations and cost of delivery at final point.

On the basis of field survey, eleven water resources were identified around Pallikaranai Marsh. Table 1 classifies the water sources around Pallikaranai Marsh providing details about their location and their use. The important water sources in the region are described in the following section.

Table 1. Classification of water sources present around Pallikaranai Marsh, their number in each direction and use

Source	Primary Source	Secondary Source	No. of Sources in Each Direction Around Pallikaranai Marsh					% of Source	Use
			East	West	North	South	Total		
GW	Hand Pump				2		2	0.6	Domestic
		Manmade water tank (village tank)	16	15	5	8	44	14.2	Domestic
		Municipal water tank	33	20	52	16	121	39	Domestic
		Packaged drinking water plant	1	1			2	0.6	Drinking, cooking
	Pump set (Bore well)		2			1	3	1.0	Domestic
	Well (domestic)			5		1	6	1.9	Domestic
	Well (Agricultural or Private well)			19	1	10	30	9.7	Commercial (tanker)
SW	Small pond		1	6	4	2	13	4.2	Bathing, washing
	Temple pond			2	2		4	1.3	Bathing
	Wetlands		6	10	8	5	29	9.4	Domestic/cleaning vehicles, livestock
		Surface water pumping		1			1	0.3	Commercial extraction by private tankers
Others		Small scale water source	9	21	20	6	56	18.1	Drinking

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Groundwater

Groundwater is the dominant source of water in the study area available to the consumers through municipal water tanks and manmade/village tanks. Municipal tanks supply water to large slum areas located on the northern side of the Pallikaranai Marsh whereas private residential buildings, apartments and industries depend mainly on pump sets and private water tankers. More than hundred municipal water tanks were observed in all the areas around the marsh. Water supply to these tanks is under the control of CMWSSB. Maximum number of municipal tanks was observed on northern side of the marsh in areas like Velachery, Perungudi and Taramani followed by Thoraipakkam, and MCN Nagar located on the eastern side of the marsh. These tanks are filled by water tankers which extract water from agricultural and private wells present around Pallikaranai Marsh. Apart from this, nearly forty man-made water tanks/village tanks were observed mainly on eastern and western side, in Thoraipakkam, Kilkattalai, Puzhudivakkam and Madipakkam areas. These are tanks constructed in each village filled by groundwater extracted using pump sets. The water from these tanks is supplied through an underground pipeline system to the households.

Wells are one of the most important water sources in the area used for extraction of freshwater. About thirty agricultural wells located mainly on the western side of the marsh in Madipakkam, Kilkattalai and Narayanapuram were observed to be used for commercial extraction of water by both private and municipal tankers. The availability of well sources is higher in the west and south as some years back these areas were completely under agriculture, and the farming activities depended on seasonal wetlands and agricultural wells. However, as a result of commercial water extraction, farming activities in the area have almost discontinued. The area has given way to residential houses, commercial buildings and educational institutions. It was observed that these dug wells still have a remarkable storage of water possibly because of the presence of water bodies nearby and inflow of groundwater. Apart from this, the seasonal rainfall also safeguards these wells. As a household survey for water supply was not conducted, the extent of use of domestic wells could not be completely ascertained in the present study.

Surface Water

Nearly 30 wetlands, 4 temple ponds and 13 small ponds were observed around Pallikaranai Marsh. The wetlands are mainly concentrated in the western and northern side of the Marsh. The seasonally filled wetlands around the marsh include Lakes of Velachery, Adambakkam, Perungudi, Kilkattalai, Muvarasapattu, Madipakkam, Puzhudivakkam, Nesavallar Nagar and Narayanapuram. These water bodies are used to a small extent for domestic purposes like washing, bathing, cleaning of vehicles, by livestock, etc. Few tankers were also observed pumping surface water from Kilkattalai Lake nearly 3 km away from Pallikaranai Marsh. Narayanapuram Lake in the west has three open wells which supply fresh water to surrounding areas through underground pipeline system. The water in the lake was relatively clean and is used by local people for bathing, washing and fishing. However signs of pollution were also observed in different parts of this lake.

The number of small ponds is higher along the western side of the marsh. These water bodies are seasonally filled and provide fresh water, fodder, fuel, and fishery resources for local people. As a cultural tradition in Tamil Nadu, old temples generally house ponds in the vicinity, and 4 temple ponds (temple tank) were observed in the entire 5 km radius of the study site which serve as a vital habitat for aquatic flora and fauna, though not used for domestic purposes.

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Tanker Market

The water vending by private tankers depends on groundwater drawn from agricultural and private wells situated in areas like Perungudi, Madipakkam, Medavakkam, Velachery and Thoraipakkam. Every day, on average 700-800 tankers are filled at source (Figure 2). The tankers with an average capacity of 9,000 liters per vehicle provide water every day to the low-income areas which are not connected with the piped supply system. These tankers transfer water to storage tanks made of concrete or plastic (Sintex tanks) installed by the CMWSSB. The cost of water tanker filling is ₹150-190 (USD 2-3) but the cost of delivery is ₹700-800 (USD 10-12), nearly 3-4 times the filling cost. The delivery cost varies depending upon the season and distance to the delivery point. The main consumers of water provided by tankers include domestic households, industries, hotels, academic institutions and offices across the city.

Two water processing plants were observed in the vicinity of the marsh in Medavakkam area. In addition, more than fifty shops selling packaged drinking water were recorded around the marsh. Though the actual source of this water supply could not be ascertained in the present study, the water processing plants generally draw groundwater.

Figure 3 shows the various sources of water available around Pallikaranai Marsh.

MAJOR CONCERNS

The expansion of Chennai city has led to growth of peri-urban areas. As a consequence, the water bodies in peri-urban areas are in the process of being reclaimed to build urban infrastructure in addition to extraction of water for supply to both urban and peri-urban areas (Narain et al., 2013). Flooding and

Figure 2. A long queue of water tankers at the periphery of Pallikaranai Marsh

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Figure 3. Various sources of water around Pallikaranai Marsh, A. Piped water supply through village tanks, B. Tanker water supply, C. Wetlands, and D. Domestic wells

over-extraction of groundwater are known to affect the water security of urban and peri-urban areas (Janakarajan, 2009). The area around Pallikaranai Marsh which was originally a low lying floodplain is now a composite of industrial, residential, institutional and commercial establishments, and remnant natural habitats. In this peri-urban area, the water security is governed by the analogous processes of urbanization and climate change (Narain, 2010). On the basis of the present study, the following possible causes of water stress in the study area have been identified.

Over-Extraction of Groundwater

Chennai experiences acute water scarcity especially during low rainfall years. During these times groundwater plays an essential role in meeting the water demand (Janakarajan, Zehra, & Llorente, 2006). Growth of the city in the absence of adequate supply infrastructure has resulted in unsustainable extraction of groundwater (Srinivasan, Seto, Emerson, & Gorelick, 2013). The present study showed that nearly thirty agricultural wells located mainly on the western side of the marsh were used for extraction of groundwater by both private and municipal tankers. In addition to over-extraction, the increase in impervious surface owing to rapid urbanization has reduced the area for groundwater recharge. The impacts of groundwater depletion can be varied, the most direct and important being the loss of base-flow. This can further result in drying up of wells, increased cost of pumping and well infrastructure, salt-water intrusion, reduction in biodiversity, etc. (Ponce, 2006). Rapid urbanization together with disappearance of traditional network of tanks and ponds has resulted in over-exploitation of groundwater resources in Chennai. Chennai city during the past two decades has depended heavily on private and agricultural wells for water supply impacting groundwater table, changing the land-use pattern and affecting the livelihood of the farm-

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ers (Ruet, Gambiez, & Lacour, 2007). According to Janakarajan et al. (2007) nearly 80% of Chennai groundwater has already depleted and further exploitation may result in enhanced sea water intrusion.

Degradation of Wetlands

Wetlands provide various ecosystem services of value to the society like preventing floods, filtering nutrients and pollutants thereby improving water quality, groundwater buffering, and serving as an important habitat for flora and fauna (Gren, Folke, Turner, & Batemen, 1994). Coastal cities similar to Chennai are one of the most rapidly urbanizing places and rapid urbanization affects the hydrology, geomorphology and ecology leading to drastic changes in the urban wetlands (Ehrenfeld, 2000). More than half of the wetlands in Chennai have already been converted to other uses (Chandramohan & Bharthi, 2009). A large part of South Chennai where the present study was conducted was historically a floodplain comprising of Pallikaranai Marsh and other smaller satellite wetlands. In our survey 29 large and 13 small water bodies were identified around the Pallikaranai Marsh. The historical images of Pallikaranai Marsh and surrounding areas show that a large number of water bodies drained into the marsh mainly during seasonal rains creating an effective drainage system (Care Earth, 2002 & 2005). However, over the years, in addition to Pallikaranai Marsh, the surrounding water bodies including Adambakkam, Kilkattalai, Narayanapuram Lake, Velachery Lake and other similar wetlands have shrunk drastically. This is attributed to rapid urban development, road laying and encroachment resulting in blocking of water channels in addition to draining of domestic sewage into the marsh. An inner ring road laid at the center of the Adambakkam Lake has completely separated it from the marsh while the Thoraipakkam radial road constructed in the center of the Kilkattalai Lake has divided the lake into two parts altering the water flow. As these wetlands belonging to a single system of water bodies, aid in crucial groundwater percolation, their disappearance will significantly impact water sustainability in this region (Chandramohan & Bharthi, 2009). Further, a large number of studies have shown that degradation of wetlands often results in loss of water retention and enhanced risk of flooding (Brody, Highfield, Ryu, & Spanel-Weber, 2007).

Informal and Unregulated Water Market

According to Janakarajan (2013) piped water supply accounts for only one fifth of the total water demand in Chennai while Ruet et al. (2002), state that at least 60% of water used in Chennai comes from sources other than public system. The limitations in groundwater availability and unreliable piped supply have led to an increase in demand for water tanker supply. This private water market is largely informal as it is not monitored by a regulatory agency in terms of quantity of water extracted, quality as well the economic value of water in the system. This informal commercial water sector consists of bulk suppliers like tankers and small scale suppliers including cans, bottles, sachets, etc. (Venkatachalam, 2012). Present study showed that an average of 700-800 private tankers extract groundwater from agricultural and private wells around Pallikaranai Marsh. Tanker water is nearly 3 to 50 times more expensive than municipal piped water supply (Srinivasan, Gorelick, & Goulder, 2010). Further these informal tanker markets have led to drastic decline in groundwater in peri-urban areas affecting agriculture and livelihood of farmers (Londhe et al., 2004). In order to regulate groundwater extraction and illegal transportation of water the Chennai Metropolitan Area Ground Water (Regulation) Act was enacted in 1987, foreseeing the registration of existing wells, regulations for sinking new wells, issuing licenses to extract water

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for non-domestic use and issue of licenses for transportation through goods vehicle (Ruet et al., 2002). However this Act is grossly violated as both private companies and Metro Water Board are responsible for overexploitation of groundwater in many peri-urban areas apart from the private lorry and tankers that are operating in the Metropolitan Area without proper licenses (Janakarajan et al., 2006). In addition to water tankers, more than fifty shops were found to sell packaged drinking water in the study area. These small scale suppliers provide value added service in terms of treated water thereby setting up a strong consumer base and involving large money transactions. Studies have shown that informal water market serves both the high and low income groups in Chennai ensuring good quality water supply (Venkatachalam, 2012).

Anticipated Water Stress Due to Climate Change

Extreme and frequent weather events as a result of climate change are expected to alter the quantity as well as quality of available water resources in the future (Bahri, 2012). Water availability is the most critical and direct impacts of climate change in urban and peri-urban areas. As the population rises in these regions, the water demand goes up while the water becomes limiting as rainfall patterns and groundwater levels change (UN-Habitat, 2011). It has been projected that climate change will affect water supply primarily through flood damage and increased water treatment costs. On the other hand, prolonged periods of drought will affect surface water supply and enhance the vulnerability of groundwater systems (Bahri, 2012). It has been predicted that in India, climate change would affect water resources in terms of decline of the glaciers in the Himalayas, increase in both drought-like situations and flood events, change in groundwater quality and groundwater recharge, and increased saline intrusion of coastal and island aquifers due to rising sea levels (INCCA Report, 2010). In Chennai, a city located on the east coast, the future climate hazards include cyclones and floods resulting in drinking water shortage (Tanner, Mitchell, Polack, & Guenther, 2009). Further studies project occurrence of more extreme temperatures as well as rainfall events on the east coast of India (Dash & Hunt, 2007). An increase of flood risk has been observed across the last two decades over the eastern coast (Guhathakurta, Sreejith, & Menon, 2011).

Climate change affects precipitation variability, resulting in frequent floods and drought (Miller, Rhodes, & MacDonnell, 1997). These two major possible scenarios arising due to climate change affecting water resource availability are discussed below.

Flooding

Just as the government delegations from various countries including India were committing to limiting climate change at COP21, Paris; catastrophic flooding affected hundreds of people causing loss of life and property in and around Chennai. Even though such events are unpredictable and cannot be directly linked to climate change, climate change with its generally warmer sea water causes increase in number of storms and flooding, indicating that El Niño has a part to play in the sequence of extreme weather events (Gross, 2016). Climate change can affect the intensity and frequency of floods as a result of extreme rainfall events and such events are projected to become more frequent over a large number of regions (Bates et al., 2008). In addition to this, urbanization increases impervious surfaces and loss of natural drainage resulting in floods. Chennai receives an average annual rainfall of 1300 mm, most of which falls during North-East monsoon in the months of October through December (Figure 4). Meteorological data analyses shows that though there is a year-to-year variability, there are been no significant

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upwards or downwards trend during the last 200 years. However, heavy precipitation events in the last few decades - 1985, 1996, 1998, 2005, 2008, 2010 and 2015 have resulted in catastrophic floods in Chennai ((Walsh, Glaser, & Militzer, 1999; Gupta & Nair, 2010). Pallikaranai Marsh in southern Chennai is an important area for the storage of storm water runoff from the surrounding areas, allowing the overflow to drain into the sea. Historically the seasonally flooded marsh was used for supporting agriculture as evidenced by the absence of dug out wells in the landscape until the last five decades. While agriculture declined over the years, the marsh continued to collect the overrun of the surrounding wetlands in south Chennai. The reason for rise in floods especially around the marsh is not only because of heavy rainfall events but also due to extensive urbanization of the surrounding areas which poses a physical obstruction to runoff to the marsh. Lack of adequate storm water drainage, garbage dumping in the marsh and encroachment of the wetlands also compound the problem. As a result, the natural drainage is highly obliterated leading to frequent floods in the area. Figure 5 shows one of the flooding events in an area surrounding Pallikaranai Marsh. A favorable microclimate and assured water availability has made the area prime spot for large scale real estate development. This however is adding to the water stress in the region. Figure 6 shows change in the extent of the Pallikaranai Marsh for the time period between 1970 and 2010. Degradation of the marsh over the years has severely curtailed its water holding capacity and studies have shown that events of above normal precipitation would cause flooding of the residential and commercial spaces within this landscape (Apfelbacher, 2008; Glaser et al., 2008; Vencatesan et al., 2014). More than 5,550 hectares of wetlands in the area has been developed into commercial real estate. Large scale encroachment of the wetlands around the marsh has also resulted in increased incidents of flooding. The density of habitation is maximum on the northern and north-western portions of the marsh which are impacted intensively during flooding (Vencatesan et al., 2014). Recent heavy rains in Chennai resulted in disastrous flood largely attributed to ignoring hydrological concerns during urban planning.

Figure 4. Monthly rainfall pattern in Chennai over a period of 5 years. Source of data: Customized Rainfall Information System (CRIS), Hydromet Division, India Meteorological Department

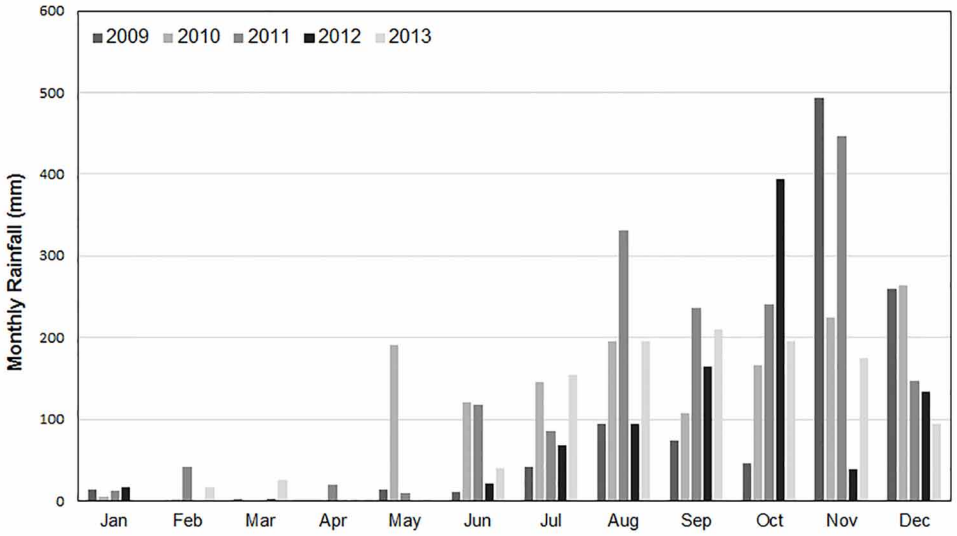

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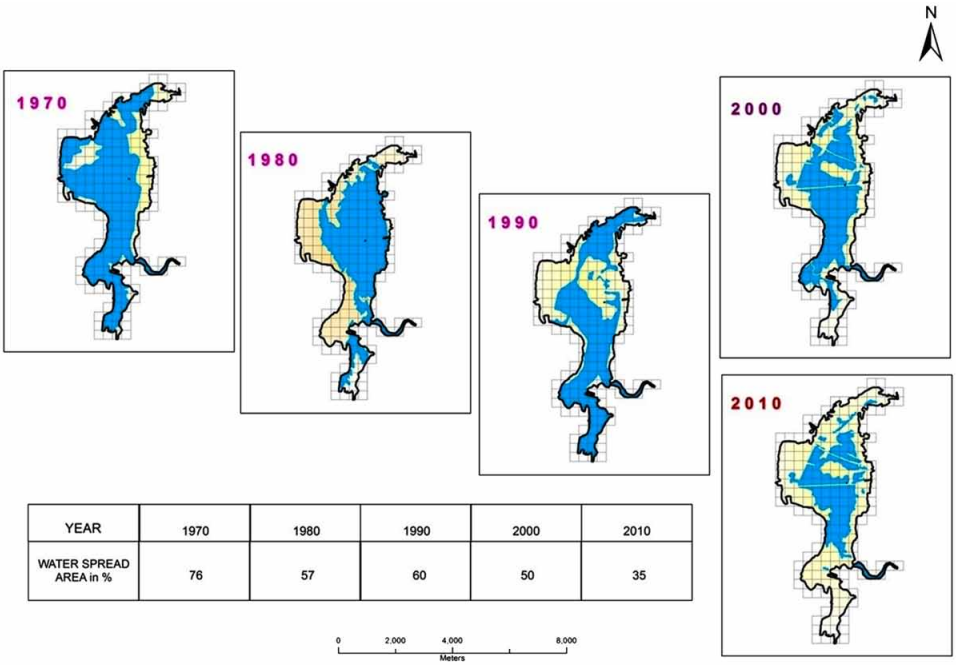
Figure 5. A flooding event in south Chennai

Figure 6. Maps showing water spread area in Pallikaranai Marsh (1970-2010) (Source: Vencatesan et al., 2014)



YEAR	1970	1980	1990	2000	2010
WATER SPREAD AREA in %	76	57	60	50	35

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Wetlands are known to play a significant role in modifying the hydrological cycle and either reduce or delay floods (Bullock & Acreman, 2003). Nearly 80% of the studies suggest that floodplain wetlands reduce flooding by reducing both the magnitude and frequency of peak flow events (Acreman & Holden, 2013). Wetlands reduce the amount and speed of rainwater runoff and improve surface water quality in urban areas (Jha, Bloch, & Lamond, 2012). Alteration of wetlands is known to reduce the natural water retention and enhance flooding risk (Brody et al., 2007). Flooding can also contaminate water supplies in addition to rendering areas inhabitable and imposing additional costs on storm water drainage (Bahri, 2012). Worldwide, encroachment into of low lying areas closer to the water bodies has increased the damage potential due to floods. Further, globally, an increase in the number of inland flooding together with a rise in economic losses has been reported (Kron & Berz, 2007; Kundzewicz et al., 2014). Wetland restoration and conservation in Hubei Province, China and New Orleans, USA helped withstand storm surges and reduced the volume of rainwater runoff in these urban cities, resulting in improved resilience to flooding (Renaud, Sudmeier-Rieux, & Estrella, 2013). Further, a study by Walters & Babbar-Sebens (2016) in Midwestern United States, showed that presence of wetlands provided steady peak flow reductions across all climate change scenarios.

Drought

Decreased precipitation, enhanced evapotranspiration and reduced soil moisture have been defined as the main causes for drought. Climate change is predicted to impact water availability by altering both the frequency and severity of droughts (McDonald et al., 2011). According to IPCC Assessment Report (2007), the areas affected by drought are predicted to expand in addition to rising sea levels in the coastal areas. Growing demand from the expanding population and excessive withdrawals can thereby aggravate the problem of drought. Increase in vulnerability of shallow groundwater systems is also projected in case of extended dry periods (Bahri, 2012). The importance of groundwater as a perennial source of freshwater is projected to increase under more frequent and intense extreme climate events like drought. Wetlands have been reported to play an important role in groundwater recharge through both rain-fed discharge and focused recharge (Taylor et al., 2013).

A study by Dash and Hunt (2007) has shown that the maximum and minimum temperature have been increasing by 0.6°C and 0.4°C respectively on the eastern coast of India. Chennai city lying in this region faces acute water scarcity especially during low rainfall years. During such period groundwater plays an essential role in meeting the water demand and the south Chennai aquifer is an important source of groundwater during drought years. A study by Seifelislam (2013), analyzing the effective recharge amount over the period from 2001 to 2013 showed that there has been a decrease in the groundwater level of the aquifer recharged by Pallikaranai Marsh. The reduced recharge capacity is mainly attributed to decrease in the recharge area owing to large-sale construction.

Study by van der Kamp and Hayashi (1998) has shown that the wetlands in the semi-arid northern Prairie region are important sites of groundwater recharge. Their study also showed that drainage of wetland lowers the water table in the vicinity of the wetland thereby reducing the yield of surrounding shallow wells. Various other studies have recorded that the recharge rates of wetlands vary from 1 to 45 mm per year (Hayashi, van der Kamp, & Rudolph, 1998). Study by Acharya and Barbier (2000) showed that the Hadejia-Nguru wetlands in northern Nigeria formed by floodwaters of the region help in recharging of the aquifers which are used for domestic consumption and irrigation during the dry season.

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Another study in Okavango delta in northern Botswana showed that 80 to 90% of seasonal floodwater recharges the groundwater (McCarthy, 2006).

Events of low rainfall, drying up of reservoirs and reduced groundwater recharge makes Chennai highly vulnerable to multiyear drought (Srinivasan et al., 2013). The south Chennai aquifer is important, especially during the drought years for meeting the water requirements. However it is speculated that increasing urbanization of the area will lead to over-extraction of groundwater resulting in sea water intrusion.

CONCLUSION

Although climate change scenarios predict high risk to wetlands, intact wetlands would play a key role in climate change adaptation. Wetlands act as sinks for organic carbon in addition to storing water to buffer runoff and recharging groundwater table, thereby, positively impacting water availability (Junk et al., 2013). The water sources identified in the present study can suffice the supply of water to the area but not without proper maintenance and restoration. It was found that wells around the marsh retained water supply even during peak summer months owing to groundwater recharge by Pallikaranai and surrounding wetlands. The marsh also plays an effective role in collecting floodwaters and overflows from nearby wetlands in the surrounding area. Therefore Pallikaranai Marsh together with the surrounding wetlands is vital to Chennai city as a means of adapting to climate change. Hence it is imperative to maintain and restore these wetlands and tanks for ensuring sustainable supply of water to surrounding areas. It is suggested that institutions like CAP (Conservation Authority of Pallikaranai Marsh), CMWSSB, Central Groundwater Board, Tamil Nadu Pollution Control Board, etc. should undertake steps to conserve these wetlands, preventing further construction, reclamation, pollution and road laying. Further, in view of the rampant violation of the Groundwater Act, an attempt should be made to regularize the informal tanker market. Protocols for extraction of groundwater especially by commercial entities should be in place and unsustainable extraction of water from bore wells inside the wetlands should also be monitored. These few steps would be in line to facilitate the transformation of Chennai from water starved to a water sustainable city.

REFERENCES

Acharya, G., & Barbier, E. B. (2000). Valuing groundwater recharge through agricultural production in the Hadejia-Nguru wetlands in northern Nigeria. *Agricultural Economics*, *22*(3), 247–259. doi:10.1111/j.1574-0862.2000.tb00073.x

Acreman, M., & Holden, J. (2013). How wetlands affect floods. *Wetlands*, *33*(5), 773–786. doi:10.100713157-013-0473-2

Agarwal, A., & Narain, S. (1997). *Dying Wisdom. Rise, Fall and Potential of India's Traditional Water Harvesting System.* Faridabad, India: Thomson Press Ltd.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Anand, P. B. (2001). *Water scarcity in Chennai, India: Institutions, entitlements and aspects of inequality in access*. WIDER Discussion Papers // World Institute for Development Economics (UNU-WIDER), No. 2001/140. Retrieved February 15, 2015, from http://hdl.handle.net/10419/53004

Apfelbacher, J. (2008). *Land Use/Cover Change in the Context of Global Change around the Pallikaranai Marshland*. (Unpublished bachelor's thesis). Department of Physical Geography, University of Freiburg, Germany.

Appasamy, P. (1995). *Water allocation and management in Madras. Report funded by Overseas Development Institute*. Chennai: Madras Institute of Development Studies.

Arnell, N. W. (2004). Climate change and global water resources: SRES emissions and socio-economic scenarios. *Global Environmental Change*, *14*(1), 31–52. doi:10.1016/j.gloenvcha.2003.10.006

Askew, A. J. (1987). Climate change and water resources. In S. I. Solomon, M. Beran, & W. Hogg (Eds.), *The influence of climate change and climatic variability on the hydrologic regime and water resources* (Vol. 168, pp. 421–340). Wallingford, UK: IAHS Publishers.

Bahri, A. (2012). Integrated urban water management. *Global Water Partnership Technical Committee Background Papers*, (16). Retrieved February 13, 2015, from http://www.gwp.org/Global/The%20Challenge/Resource%20material/GWP_TEC16.pdf

Bates, B., Kundzewicz, Z. W., Wu, S., & Palutikof, J. P. (Eds.). (2008). *Climate change and water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva*. Geneva, Switzerland: IPCC.

Brody, S. D., Highfield, W. E., Ryu, H. C., & Spanel-Weber, L. (2007). Examining the relationship between wetland alteration and watershed flooding in Texas and Florida. *Natural Hazards*, *40*(2), 413–428. doi:10.100711069-006-9003-3

Bullock, A., & Acreman, M. (2003). The role of wetlands in the hydrological cycle. *Hydrology and Earth System Sciences Discussions*, *7*(3), 358–389. doi:10.5194/hess-7-358-2003

Care Earth. (2002). Conservation of Urban Wetlands- Pallikaranai Marsh, A Baseline study. Report supported by Tamil Nadu Pollution Control Board.

Care Earth. (2005). Current Status of the Pallikaranai Marsh and Recommendations for Protection and Restoration. Report submitted to the Tamil Nadu Pollution Control Board.

Care Earth Trust. (2012). *Identification of wetlands for protection, restoration and conservation in Greater Chennai. Report submitted to the Chennai Metropolitan Development Authority*. Chennai, India: Government of Tamil Nadu.

Chandramohan, B. P., & Bharati, D. (2009). Role of Public Governance in the Conservation of Urban Wetland System: A Study of Pallikaranai Marsh. In *Proceedings of the Indian Society for Ecological Economics (INSEE), 5th Biennial Conference, Ahmedabad, India. Customized Rainfall Information System (CRIS)*. Hydromet Division, India Meteorological Department. Retrieved February 16, 2015 from http://hydro.imd.gov.in/

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Dash, S. K., & Hunt, J. C. R. (2007). Variability of climate change in India. *Current Science*, *93*(6), 782–788.

Drescher, A., Glaser, R., Pfeiffer, C., Vencatesan, J., Schliermann-Kraus, E., Glaser, S., & Dostal, P. (2007). *Risk assessment of extreme precipitation in the coastal areas of Chennai as an element of catastrophe prevention. In 8. Forum DKKV/CEDIM: Disaster Reduction in Climate Change 15./16.10.2007*. Germany: Karlsruhe University.

Ehrenfeld, J. G. (2000). Evaluating wetlands within an urban context. *Ecological Engineering*, *15*(3), 253–265. doi:10.1016/S0925-8574(00)00080-X

Erwin, K. L. (2009). Wetlands and global climate change: The role of wetland restoration in a changing world. *Wetlands Ecology and Management*, *17*(1), 71–84. doi:10.100711273-008-9119-1

Frederick, K. D., & Major, D. C. (1997). Climate change and water resources. *Climatic Change*, *37*(1), 7–23. doi:10.1023/A:1005336924908

Glaser, S., Glaser, R., Drescher, A., Pfeiffer, C., Schliermann-Kraus, E., Lechner, M., & Vencatesan, J. (2008). *Geo-communication for risk assessment and catastrophe prevention of flood events in the coastal areas of Chennai*. iEMSs 2008: International Congress on Environmental Modelling and Software Integrating Sciences and Information Technology for Environmental Assessment and Decision Making 4th Biennial Meeting of iEMSs. Retrieved from http://www.iemss.org/iemss2008/index.php?n=Main. Proceedings

Gren, M., Folke, C., Turner, K., & Batemen, I. (1994). Primary and secondary values of wetland ecosystems. *Environmental and Resource Economics*, *4*(1), 55–74. doi:10.1007/BF00691932

Gross, M. (2016). World under water. *Current Biology*, *26*(2), R47–R50. doi:10.1016/j.cub.2016.01.001 PMID:27213204

Guhathakurta, P., Sreejith, O. P., & Menon, P. A. (2011). Impact of climate change on extreme rainfall events and flood risk in India. *Journal of Earth System Science*, *120*(3), 359–373. doi:10.100712040-011-0082-5

Gupta, A. K., & Nair, S. S. (2010). Flood risk and context of land-uses: Chennai city case. *Journal of Geography and Regional Planning*, *3*(12), 365–372. Available online at http://www.academicjournals.org/JGRP

Gupta, A. K., & Nair, S. S. (2011). Urban floods in Bangalore and Chennai: Risk management challenges and lessons for sustainable urban ecology. *Current Science (Bangalore)*, *100*(11), 1638–1645.

Hayashi, M., van der Kamp, G., & Rudolph, D. L. (1998). Water and solute transfer between a prairie wetland and adjacent uplands, 1. Water balance. *Journal of Hydrology (Amsterdam)*, *207*(1), 42–55. doi:10.1016/S0022-1694(98)00098-5

INCCA Report, .Indian Network for Climate Change Assessment. (2010). *Climate Change and India: A 4x4 Assessment A Sectoral and Regional Analysis for 2030s*. Ministry of Environment & Forests, Government of India.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

IPCC (Intergovernmental Panel on Climate Change). (2007). *Synthesis Report.* Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland: IPCC.

Janakarajan, S. (2009). Urbanization and peri-urbanization: Aggressive competition and unresolved conflicts. The case of Chennai city in India. *South Asian Water Studies*, *1*(1), 51–76.

Janakarajan, S. (2013). *Optimising Local Water Resources and Availability in Urban and Peri-urban Chennai* [PDF document]. Retrieved from cseindia.org/userfiles/Janakarajan.pdf

Janakarajan, S., Butterworth, J., Moriarty, P., & Batchelor, C. (2007). Strengthened city marginalised peri-urban villages: stakeholder dialogues for inclusive urbanisation in Chennai, India. In J. Butterworth, R. Ducrot, N. Faysse, & S. Janakarajan (Eds.), *Peri-urban water conflicts: Supporting dialogue and negotiation* (pp. 51–75). Delft, Netherlands: IRC International Water and Sanitation Centre.

Janakarajan, S., Zehra, M. H., & Llorente, M. (2006). *Urban Water Conflicts in Indian Cities: Man-made Scarcity as a Critical Factor*. MIDS Working Paper No.196. Chennai, India: Madras Institute of Development Studies.

Jha, A. K., Bloch, R., & Lamond, J. (Eds.). (2012). *Cities and flooding: a guide to integrated urban flood risk management for the 21st century*. World Bank Publications. Retrieved from http://hdl.handle.net/10986/2241

Joshi, V. U., & Kale, V. S. (2013). Environmental Conflicts in Coastal Metropolitan Cities in India: Case Studies of Mumbai and Chennai Metropolitan Regions. In A. Z. Khan, L. X. Quynh, E. Corijn & F. Canters (Eds.), *Environmental Conflicts in Coastal Urban Areas: Towards a Strategic Assessment Framework for Sustainable Development*. Retrieved from http://digilab-epub.uniroma1.it/index.php/SECOA/article/download/103/92

Juliano, K., & Simonovic, S. P. (1999). *The impact of wetlands on flood control in the Red River Valley of Manitoba.* University of Manitoba. Retrieved February 10, 2015, from http://www.ijc.org/rel/pdf/wetlandsman.pdf

Junk, W. J., An, S., Finlayson, C. M., Gopal, B., Květ, J., Mitchell, S. A., ... Robarts, R. D. (2013). Current state of knowledge regarding the worlds wetlands and their future under global climate change: A synthesis. *Aquatic Sciences*, *75*(1), 151–167. doi:10.100700027-012-0278-z

Kron, W., & Berz, G. (2007). Flood disasters and climate change: trends and options—a (re-)insurer's view. In J. L. Lozán, H. Grabl, P. Hupfer, L. Menzel, & C. D. Schönwiese (Eds.), *Global change: enough water for all?* (pp. 268–273). University of Hamburg, Hamburg.

Kundzewicz, Z. W., Kanae, S., Seneviratne, S. I., Handmer, J., Nicholls, N., Peduzzi, P., ... Muir-Wood, R. (2014). Flood risk and climate change: Global and regional perspectives. *Hydrological Sciences Journal*, *59*(1), 1–28. doi:10.1080/02626667.2013.857411

Londhe, A., Talati, J., Singh, L. K., Vilayasseril, M., Dhaunta, S., Rawlley, B., . . . Mathew, R. P. (2004). *Urban-hinterland water transactions: a scoping study of six class I Indian cities.* IWMI Tata Water Policy Programme Working Paper.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Maltby, E., & Acreman, M. C. (2011). Ecosystem services of wetlands: Pathfinder for a new paradigm. *Hydrological Sciences Journal*, *56*(8), 1341–1359. doi:10.1080/02626667.2011.631014

McCarthy, T. S. (2006). Groundwater in the wetlands of the Okavango Delta, Botswana, and its contribution to the structure and function of the ecosystem. *Journal of Hydrology (Amsterdam)*, *320*(3), 264–282. doi:10.1016/j.jhydrol.2005.07.045

McDonald, R. I., Green, P., Balk, D., Fekete, B. M., Revenga, C., Todd, M., & Montgomery, M. (2011). Urban growth, climate change, and freshwater availability. *Proceedings of the National Academy of Sciences of the United States of America*, *108*(15), 6312–6317. doi:10.1073/pnas.1011615108 PMID:21444797

Mertz, O., Halsnæs, K., Olesen, J. E., & Rasmussen, K. (2009). Adaptation to climate change in developing countries. *Environmental Management*, *43*(5), 743–752. doi:10.100700267-008-9259-3 PMID:19184576

Michael, A. M. (2009). *Irrigation: theory and practice*. New Delhi, India: Vikas Publishing House Pvt Ltd.

Miller, K. A., Rhodes, S. L., & MacDonnell, L. J. (1997). Water allocation in a changing climate: Institutions and adaptation. *Climatic Change*, *35*(2), 157–177. doi:10.1023/A:1005300529862

Mitsch, W. J., Bernal, B., Nahlik, A. M., Mander, Ü., Zhang, L., Anderson, C. J., ... Brix, H. (2013). Wetlands, carbon, and climate change. *Landscape Ecology*, *28*(4), 583–597. doi:10.100710980-012-9758-8

Narain, V. (2010). *Peri urban water security in a context of urbanization and climate change: A review of concepts and relationships*. Peri Urban Water Security Discussion Paper Series, Paper No. 1, SaciWATERs. Retrieved February 16, 2015, from http://saciwaters.org/periurban/newsletter/pdfs/discussion_papper_1.pdf

Narain, V., Anand, P., & Banerjee, P. (2013). *Periurbanization in India: A review of the literature and evidence*. Report for the project – Rural to Urban Transitions and the Peri-urban Interface. SaciWATERs. India. Retrieved February 16, 2015, from https://saciwaters.org/east-west-center/pdf/status-paper.pdf

Ponce, V. M. (2006). *Groundwater Utilization and Sustainability*. Retrieved February 9, 2015, from Lecture Notes Online Web site: http://groundwater.sdsu.edu/

Renaud, F. G., Sudmeier-Rieux, K., & Estrella, M. (Eds.). (2013). *The role of ecosystems in disaster risk reduction*. Tokyo, Japan: United Nations University Press.

Ruet, J., Gambiez, M., & Lacour, E. (2007). Private appropriation of resource: Impact of peri-urban farmers selling water to Chennai Metropolitan Water Board. *Cities (London, England)*, *24*(2), 110–121. doi:10.1016/j.cities.2006.10.001

Ruet, J., Saravanan, V. S., & Zérah, M. H. (2002). *The Water and Sanitation Scenario in Indian Metropolitan Cities: Resource and Management in Delhi, Calcutta, Chennai, Mumbai.* CSH Occasional Paper No.6. New Delhi: Centre de Sciences Humaines.

Schewe, J., Heinke, J., Gerten, D., Haddeland, I., Arnell, N. W., Clark, D. B., ... Kabat, P. (2014). Multimodel assessment of water scarcity under climate change. *Proceedings of the National Academy of Sciences of the United States of America*, *111*(9), 3245–3250. doi:10.1073/pnas.1222460110 PMID:24344289

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Seifelislam, A. (2013). *A rapid assessment of the impact of wetland's degradation on groundwater resources in the fast growing city Chennai. (Unpublished Internship-Report for the European Program Chance2Sustain)*. Pondicherry, India: French Institute of Pondicherry.

Srinivasan, V. (2008*). An integrated framework for analysis of water supply strategies in a developing city: Chennai, India* (Doctoral dissertation). Available from ProQuest Dissertations and Theses database. (UMI No. 3332994)

Srinivasan, V. (2015). Reimagining the past–use of counterfactual trajectories in socio-hydrological modelling: The case of Chennai, India. *Hydrology and Earth System Sciences*, *19*(2), 785–801. doi:10.5194/hess-19-785-2015

Srinivasan, V., Gorelick, S. M., & Goulder, L. (2010). Factors determining informal tanker water markets in Chennai, India. *Water International*, *35*(3), 254–269. doi:10.1080/02508060.2010.487931

Srinivasan, V., Seto, K. C., Emerson, R., & Gorelick, S. M. (2013). The impact of urbanization on water vulnerability: A coupled human–environment system approach for Chennai, India. *Global Environmental Change*, *23*(1), 229–239. doi:10.1016/j.gloenvcha.2012.10.002

Tanner, T., Mitchell, T., Polack, E., & Guenther, B. (2009). Urban governance for adaptation: assessing climate change resilience in Ten Asian Cities. *IDS Working Papers*, (315), 01-47.

Taylor, R. G., Scanlon, B., Döll, P., Rodell, M., Van Beek, R., Wada, Y., ... Konikow, L. (2013). Ground water and climate change. *Nature Climate Change*, *3*(4), 322–329. doi:10.1038/nclimate1744

Trenberth, K. E. (2011). Changes in precipitation with climate change. *Climate Research*, *47*(1), 123–138. doi:10.3354/cr00953

Turner, W. R., Oppenheimer, M., & Wilcove, D. S. (2009). A force to fight global warming. *Nature*, *462*(7271), 278–279. doi:10.1038/462278a PMID:19924191

UN-Habitat. (2011). *Cities and climate change: global report on human settlements 2011*. London: Earthscan.

UNICEF, FAO, & SaciWATERs. (2013). *Water in India: Situation and Prospects, 11*. Retrieved February 9, 2015, from www.unicef.org/india/Final_Report.pdf

van der Kamp, G., & Hayashi, M. (1998). The groundwater recharge function of small wetlands in the semi-arid northern prairies. *Great Plains Research: A Journal of Natural and Social Sciences*. Retrieved February 16, 2015, from http://digitalcommons.unl.edu/greatplainsresearch/366

Vencatesan, J. (2007). Protecting wetlands. *Current Science-Bangalore*, *93*(3), 288–290.

Vencatesan, J., Daniels, R. J. R., Jayaseelan, S. S., & Karthick, M. N. (2014). *Comprehensive Management Plan for Pallikaranai Marsh. Technical Report submitted to the Conservation Authority for Pallikaranai Marsh*. Tamil Nadu Forest Department.

Venkatachalam, L. (2012). *Role of Informal Water Markets in Urban Water Supply: A Household Survey Based Case Study of Chennai City*. Working Paper, Institute for Water Policy, National University of Singapore.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Walsh, R. P. D., Glaser, R., & Militzer, S. (1999). The climate of Madras during the eighteenth century. *International Journal of Climatology*, *19*(9), 1025–1047. doi:10.1002/(SICI)1097-0088(199907)19:9<1025::AID-JOC402>3.0.CO;2-F

Walters, K. M., & Babbar-Sebens, M. (2016). Using climate change scenarios to evaluate future effectiveness of potential wetlands in mitigating high flows in a Midwestern US watershed. *Ecological Engineering*, *89*, 80–102. doi:10.1016/j.ecoleng.2016.01.014

Zedler, J. B., & Kercher, S. (2005). Wetland resources: Status, trends, ecosystem services, and restorability. *Annual Review of Environment and Resources*, *30*(1), 39–74. doi:10.1146/annurev.energy.30.050504.144248

KEY TERMS AND DEFINITIONS

Aquifer: An underground layer of rock saturated with water through which water can be extracted.

Ecosystem Services: These are services provided by a particular ecosystem for the benefit of human beings.

Floodplain: It is a low lying area near a stream or river which is at a risk of flooding.

GW: Groundwater.

Marsh: Marsh is a type of wetland which is either frequently or continually inundated, dominated by emergent vegetation. It can range from freshwater to brackish to saltwater.

Peri-Urban Areas: Areas around urban centres having both urban and rural characteristics.

SW: Surface water.

Urbanization: It is the increase in population in urban areas resulting in social, economic and environmental transformations.

Wetland: Land which is either temporarily or permanently saturated with water, characterized by unique soil properties and vegetation.

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Chapter 71
Managerial Reactions to Ambiguous Environmental Changes:
Attention, Reasoning, and Erratic Decisions

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ABSTRACT

Managers in organizations are typically faced with changing and ambiguous signals in their operating environment. Based on interpretation of these signals, managers react with appropriate strategies. This chapter presents critical organizational issues in decision making process and its outcomes, including the manager's selective attention, interpretation, and reasoning of uncertain operating environment. In particular, the chapter first discusses why individual managers in the same organization who are faced with same environmental changes may differently interpret threat and opportunity aspects of these changes. Second, the chapter links outcomes of such interpretation to investigate different types of organizational actions. Third, the chapter drives into a greater depth to explore how the manager's experience and characteristics of the environment affect forms of reasoning in interpretation process and performance of subsequent organizational actions.

1. INTRODUCTION

Organizations are required to adapt to environmental changes to survive and prosper. The adaptations are largely influenced by how managers interpret these environmental changes (Daft & Weick, 1984; Thomas, Clark, & Gioia, 1993). Managers in organizations are typically faced with challenges of interpreting changing and ambiguous signals in their operating environment. Based on their interpretation, managers formulate and implement appropriate strategies in response to these signals (Dutton, Fahey, & Narayanan, 1983). The effectiveness of these strategies on organizational performance is thus largely

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determined by the extent to which the strategies are fit with the environment (Miles & Snow, 1978). Because signals in the environment are often complex and ambiguous, managers appear to simply categorize them into a salient form of either threats or opportunities (Dutton & Jackson, 1987). The importance of these categorizations lies in their link to strategic decision making process and subsequent organizational actions (Dutton & Jackson, 1987; Thomas et al., 1993). In addition to perceptions of the environment, actions of an organization are also influenced by its characteristics such as strategic orientations and resource slack (Chattopadhyay, Glick, & Huber, 2001).

Going more deeply into the decision making process, strategic decisions and organizational actions are often the result of the manager's attention, interpretation, and analogical reasoning (Dutton et al., 1983; Ocasio, 1997). Attention and interpretation are so intertwined that there is no meaningful distinction between them (Cho & Hambrick, 2006). Managerial attention to environmental changes strongly influences how firms behave (Ocasio, 1997). Attention refers to noticing and interpreting of various stimuli in the environment (Ocasio, 1997). Analogical reasoning is relevant when the present new situation that requires interpretation has both similarities and dissimilarities vis-à-vis the manager's prior experience. It builds on the manager's past experience in a similar circumstance to draw inferences about the present new and partially-known situation (Miller & Lin, 2015). In particular, managers focus on and respond to only certain aspects of their environment (Ocasio, 1997). Thereafter, they try to map their past similar experience onto the present partially-known situation to identify an appropriate analogy as a plausible inference for subsequent organizational actions.

High quality decision making and organizational actions via such attention and analogical reasoning processes are usually obtainable in stable and consistent environments (March, 1982). However, in reality, organizations seldom experience such environments as they usually have to adapt to ambiguous environmental changes. Strategic decision making, particularly in rapidly changing environments, can thus be highly unpredictable and, in response to these changes, is at times inconsistent. This inconsistency, at times even with limited new information, is simply because managers make erratic decisions (Mitchell, Shepherd, & Sharfman, 2011). These erratic decisions are influenced by cognitive and environmental factors.

This chapter presents critical organizational issues in the strategic decision making process and outcomes with respect to the manager's attention, interpretation, and reasoning of ambiguous environmental changes. In particular, we first discuss why managers in the same organization who are faced with same environmental changes may interpret threat and opportunity aspects of these changes differently, taking into account structural distance of the changes, perception of organizational capability, and domain-specific experience (Barreto & Patient, 2013). Second, we link outcomes of such interpretation to investigate organizational actions in terms of externally versus internally directed actions, taking into account organizational characteristics such as strategic orientation and resource slack (Chattopadhyay et al., 2001). Third, we drive into a greater depth to investigate how the manager's experience and environmental signals in terms of hostility and dynamism affect forms of reasoning in interpretation process and performance of subsequent organizational actions (Miller & Lin, 2015; Mitchell et al., 2011).

2. THEORETICAL BACKGROUND

According to attention-based view, firms can be viewed as systems of structurally distributed attention of individuals (Ocasio, 1997). Organizational behaviors are thus determined by how attention of decision

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makers in the organization is channeled and distributed. In particular, strategic choices of these decision makers depend on issues and answers that they focus their attention on. Such attention is associated with biased interpretation where individual managers in an organization assign varying weights to contrasting aspects of the same stimuli (Cho & Hambrick, 2006). Therefore, individual managers in an organization may have different interpretations on the same stimuli. This interpretation is context-specific and it depends on characteristics of the stimuli and the individual who direct attention (Ocasio, 1997).

Managers interpret exogenous ambiguous signals by paying attention to their salient aspects in terms of an opportunity versus a threat (Dutton & Jackson, 1987; Ocasio, 1997). Which of these two salient aspects (e.g., threat and opportunity) of environmental signals individual managers are likely to pay more attention to depends on their attentional drivers (Ocasio, 1997). These drivers include social, economic, cultural, and cognitive factors that influence allocation of time, effort, and attentional focus of individual managers in an organization.

Based on strategic issue diagnosis theory (Dutton et al., 1983), individual managers' political interests and cause-effect beliefs can interact with characteristics of the environmental change to influence the interpretation. Managers are likely to pay more attention to particular aspects of such change when the change poses a potential threat to their political interests in terms of status, power, and control of resources. Cause-effect beliefs are understandings of effects of external environment and strategic inputs on organizational performance. Managers also use such beliefs to make sense of environmental changes and to selectively focus on certain aspects of these changes.

The assessment of future events, according to construal level theory, depends on individual considerations of desirability and feasibility of their outcomes (Liberman & Trope, 1998). Desirability refers to the degree of attraction or aversion that an individual attributes to outcomes of an event. Feasibility refers to the degree of ease with which an individual can reach outcomes of an event. For a given environmental change, a manager's political interests will therefore crate a more positive attitude toward that change when expected outcomes of that change satisfy those interests (Barreto & Patient, 2013). Likewise, a manager's cause-effect beliefs will therefore create a more positive belief toward that change when reaching expected outcomes of that change is feasible based on such beliefs (Barreto & Patient, 2013). Therefore, managers with political interests and cause-effects beliefs that create more positive attitudes and beliefs about an environmental change are likely to perceive opportunity aspects more salient while those with more of such negative attitudes and beliefs are likely to perceive threat aspects more salient (Barreto & Patient, 2013).

These perceived threats and opportunities are associated with urgency, difficulty, and high stakes (Dutton & Jackson, 1987). Threats are involved with an unfavorable circumstance where losses are likely and one has little control, and opportunities are associated with a favorable circumstance where gains are likely and one has a reasonable amount of control. To predict organizational responses to environmental threats and opportunities, the threat rigidity hypothesis (Staw, Sandelands, & Dutton, 1981) suggests that organizations appear to exhibit rigidity to act on something new, when faced with economic adversity or threats because of constraints in terms of information, control, and resources. Managers faced with threats are likely to perceive that they have little control over the circumstance that potentially yields a negative outcome. Threat perceptions can also heighten concerns about organizational efficiency. To mitigate such negative perceptions, managers are likely to respond to these threats by acting in less risky domains internal to organizations where they have a greater amount of control.

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Prospect theory (Kahneman & Tversky, 1979), however, appears to contradict the explanation of such organizational responses. Actual decision making of individuals is not always rational as individuals are likely to frame decision alternatives as either gains or losses. However, their perception of losses from these alternatives tends to be more pronounced than gains. Importantly, individuals are likely to be risk averse when faced with gains and be risk seeking when faced with losses. In particular, managers in favorable or opportunity situations feel that they have more to lose than to gain, and thus are likely to be risk-averse. On the contrary, managers in unfavorable or threat circumstances feel that they have little to lose and thus are likely to be risk-seeking.

3. MANAGERIAL ATTENTION AND INTERPRETATION

Managers in organizations are usually overwhelmed with information that goes beyond their capability to attend to and to process all at once. They are faced with ongoing challenges of interpreting such information, which is changing in nature and coming from both inside and outside of their organization. Importantly, managers are able to attend to, interpret, and respond to only certain aspects of information in their organizational environment (Ocasio, 1997). Based on individual biases, they often assign varying weights to and interpret contradictory aspects of the same environmental signal. Managerial attention to a particular organizational issue is thus associated with context-specific and biased interpretation (Cho & Hambrick, 2006).

Environmental information is often ambiguous, containing both threat and opportunity aspects (Dutton & Jackson, 1987). Whether managers are more likely to attend to threat or opportunity aspects of the environment depends largely on social, economic, cultural, and cognitive factors. Particularly, these factors influence the extent to which managers allocate time, effort, and attentional focus to each of these two environmental aspects (Dutton & Jackson, 1987; Ocasio, 1997).

To understand why managers in the same organization who are faced with same environmental signals may interpret threat and opportunity aspects differently, we need to know characteristics of the focal organization and its environment. Such selective attention is influenced by individual managers' assessments of desirability and feasibility (Barreto & Patient, 2013; Liberman & Trope, 1998). The attentional drivers that capture variation in desirability and feasibility are structural distance of environmental signals and perception of organizational capability respectively.

3.1 Structural Distance From Environmental Change

Managers pay different levels of attention to aspects of an organization's environment because of their structural position within the organization (Ocasio, 1997). Different structural positions are associated with varying interests of stakeholders involved in these positions. Managers are therefore likely to give more weight to certain aspects of environmental changes at the expense of other aspects. Whether managers within a firm would assign more weight to threat aspects than to opportunity aspects of an environmental change or vice versa depends on the distance between their structural position and the locus of direct impact from that change (Barreto & Patient, 2013).

In the presence of an ambiguous environmental change, managers in a structurally shorter distance from the change are more likely to interpret such change as threat while those in a structurally longer distance from that change are more likely to interpret it as opportunity (Barreto & Patient, 2013). In

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particular, when the distance is short, managers are likely to perceive that their interests are at a greater risk and possible losses are more salient. Therefore, they tend to focus more on what they currently have rather than look for what they could have in the future (Samuelson & Zeckhauser, 1988). When the distance is long, however, managers have more latitude to prepare and to draw on what they could have in the longer term to counter with such changes.

3.2 Perception of Organizational Capability

Firm resources and capabilities can direct managers to differently interpret aspects of an environmental change (Ocasio, 1997). Managers, however, have different perceptions of their organizational capability even if they belong to an organization that holds same resources and capabilities. This perceived capability is essentially determined by the extent to which each manager perceives their firm as holding the resources and capabilities that can sufficiently address requirements from the environmental changes (Dutton & Duncan, 1987).

In the presence of an ambiguous environmental change, managers with higher levels of perceived organizational capability are more likely to interpret such change as opportunity while those with lower levels of perceived organizational capability are more likely to interpret that change as threat (Barreto & Patient, 2013). In particular, when the perceived capability is high, managers are likely to form more positive early beliefs toward congruent opportunity aspects of the change. When the perceived capability is low, managers are likely to form more negative early beliefs toward incongruent threat aspects of that change.

Managers who possess greater and better-organized knowledge in a specific domain are likely to have more confidence in their beliefs related to that domain (Fischer & Budescu, 2005). Such domain-specific knowledge can indirectly affect the manager's attention toward threat and opportunity aspects of a given related environmental change. In particular, domain-specific knowledge tends to strengthen the positive effect of perceived capability on opportunity interpretation and also strengthen its negative effect on threat interpretation of an environmental change (Barreto & Patient, 2013).

These attentional drivers (e.g., structural distance from environmental change and perception of organizational capability) exert their pressure on managerial interpretation of environment in a hierarchical manner depending on the importance of events (Hubner, Steinhauser, & Lehle, 2010). Events are classified as superordinate when they are more central and essential and subordinate when they are peripheral and less essential to an organization (Barreto & Patient, 2013). Structural distance from environmental change is therefore superordinate because it directly affects the manager's interests, whereas perception of organizational capability is subordinate because it reflects the manager's beliefs about the firm's ability to address and handle the changes.

Accordingly, variations in the structural distance from environmental change have a priority and dominant effect on the interpretation of the change regardless of variations in the perceived capability (Barreto & Patient, 2013). In particular, a long structural distance to environmental changes tends to strengthen the manager's attention toward the opportunity aspects and weaken the attention toward the threat aspects regardless of the level of perceived capability. A high level of perceived capability may strengthen the manager's attention toward the opportunity aspects and weaken the attention toward the threat aspects only when the distance from the environmental changes is structurally short.

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4. ORGANIZATIONAL ACTIONS AND MANAGERIAL INTERPRETATION

The simple categorizations of environmental information into either threat or opportunity aspects allow organizations to further process and respond to strategic issues related to environmental changes (Chattopadhyay et al., 2001; Dutton & Jackson, 1987). Because both threat and opportunity aspects of the environment are associated with urgency, difficulty, and high stakes, they are likely to evoke some organizational actions (Dutton & Jackson, 1987).

Organizational actions toward such environmental changes are broadly classified into whether they are directed externally or internally (Cook, Shortell, Conrad, & Morrisey, 1983; D'Aveni & MacMillan, 1990). Externally directed organizational actions are aimed at modifying the environment. Managers are often required to operate in new business domains where they have less control. These actions are generally riskier and more difficult to implement and control (Dutton & Jackson, 1987). On the contrary, internally directed organizational actions are aimed at adapting an organization to environmental changes. Managers are often required to operate in existing largely known business domains where they have a relatively larger amount of control. These actions are generally less risky and easier to implement and control (Cook et al., 1983; Dutton & Jackson, 1987).

4.1 Reduction or Enhancement of Control vs. Loss or Gain Situations

Organizational actions in response to either threat or opportunity interpretation are subject to characteristics of environmental events. These events are largely categorized as reduction or enhancement of control versus loss or gain situations (Chattopadhyay et al., 2001). In the events that are directly related to the reduction or enhancement of control, managers who interpret their environment as threats are likely to perceive that they have little control over the situation. This perception intensifies concerns about the organization's efficiency (Staw et al., 1981).

To mitigate such perceived control-reducing threats, managers are likely to respond to associated strategic issues in domains internal to their organization over which they have a greater amount of organizational control (Chattopadhyay et al., 2001; Thomas et al., 1993). This organizational response is usually done by initiating internally directed risk-averse actions (Dutton & Jackson, 1987). On the contrary, managers who interpret their environment as opportunities are likely to perceive that they have a greater sense of control over the situation with potential gains (Dutton & Jackson, 1987). Managers faced with such control-enhancing opportunities are likely to initiate externally directed actions, which might otherwise be perceived as too risky (Dutton & Jackson, 1987; Thomas et al., 1993).

In the events that are directly related to the loss or gain of tangible resources, mangers in favorable situations are likely to be risk-averse because they feel that they have more to lose than to gain from these situations (Kahneman & Tversky, 1979). On the contrary, managers who are in unfavorable circumstances are likely to be risk-seeking because they feel that they have less to lose than to gain from these situations. Thus, managers who interpret their environment as threats are likely to respond to associated strategic issues with externally directed risk-seeking actions (Chattopadhyay et al., 2001), while those who interpret their environment as opportunities are likely to respond with internally directed risk-averse actions (Fiegenbaum & Thomas, 1988; Wiseman & Gomez-Mejia, 1998).

The effects of threat and opportunity interpretation on externally or internally directed organizational actions are contingent upon organizational characteristics in terms of strategic orientation such as product-market development versus domain defense and organizational resource slack (Chattopadhyay

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et al., 2001). In particular, variations in an organization's adoption of such strategic orientation and use of resource slack are also shaped by the manager's perceptions of strategic issues in the environment.

4.2 Strategic Orientation

Organizations that focus on developing new products or markets are likely to pursue externally directed actions while those that emphasize on domain defense are likely to pursue internally directed actions (Chattopadhyay et al., 2001). The effectiveness of the former largely depends on the extent to which the organization can control or modify the external environment, whereas that of the latter relies on the extent to which the organization can increase its efficiency through standardization of internal organizational processes (Miles & Snow, 1978).

When faced with control-reducing threats, managers are likely to respond to the associated strategic issues with well-known and familiar organizational actions (Staw et al., 1981). However, for organizations that emphasize a product-market development, managers tend to pursue externally directed actions such as expanding in new markets or introducing new products to mitigate such control-reducing threats (Chattopadhyay et al., 2001). When faced with control-enhancing opportunities, managers are likely to go beyond their usual routines regardless of their organization's strategic orientation (Staw et al., 1981). Organizations that emphasize product-market development may, therefore, be even more likely to pursue such externally directed actions.

The effects of likely gain and loss situations are likely to be independent of organizational context such as strategic orientations (Fiegenbaum & Thomas, 1988; Kahneman & Tversky, 1979). In particular, managers who are faced with threats of likely losses are more likely to engage in externally directed risk-seeking actions. Such externally directed actions may be reinforced when the organization pursues product-market development strategy. Lacking such strategic orientation, the likelihood of externally directed actions may be reduced. Managers who are faced with opportunities of likely gains are likely to engage in internally directed risk-averse actions. Such internally directed actions are likely to be reinforced when the organization pursues domain defense strategy.

4.3 Organizational Resource Slack

Organizations holding more resource slack have greater flexibility to implement strategic actions in response to strategic issues in their environment (Cyert & March, 1963). Resource slack allows organizations to relax their internal control and to be more involved in externally directed actions that are otherwise considered highly uncertain and risky. When holding lower levels of resource slack, organizations are thus likely to pursue internally directed less risky actions, which require lower levels of resource slack.

When faced with control-reducing threats, organizations that possess higher levels of resource slack are likely to focus even more on internal processes to gain even more control over the situation by initiating internally directed actions (Chattopadhyay et al., 2001; Staw et al., 1981). Resource slack also provides the cushion for organizations to be able to spend time waiting until such threats are gone away or are at a manageable level (Dutton & Duncan, 1987). Without sufficient resource slack, organizations may be more sensitive to changing environment because of lacking resources to buffer the associated threats (D'Aveni & MacMillan, 1990). These organizations may have to engage in more externally directed problemistic search actions to adapt to the environment and survive from the threats (Cyert & March, 1963; Dutton & Duncan, 1987).

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Opportunities often lead organizations to depart from their usual actions (Dutton & Jackson, 1987). With higher levels of resource slack, organizations may relax internal control and engage more in externally directed actions because resource slack buffers them from uncertainty and risk associated with these actions (Nohria & Gulati, 1996). In response to control-enhancing opportunities, organizations with higher levels of resource slack may therefore be more motivated to engage in even more risky externally directed actions to explore and exploit such opportunities in their environment. Without sufficient resource slack, organizations may engage in internally directed actions, which are mainly aimed at politically commanding a share of scarce resources to exploit such opportunities in the environment (Cyert & March, 1963).

When faced with likely loss situations, organizations are likely to take externally directed risky actions because they feel that they have less to lose than to gain from these situations (Kahneman & Tversky, 1979). With higher levels of resource slack, organizations may have even more latitude to pursue such risky actions (Chattopadhyay et al., 2001; Wiseman & Gomez-Mejia, 1998). Without sufficient resource slack, organizations are thus likely to pursue internally directed actions, which are less costly and less risky, aiming at tightening control in their existing business domains and improving efficiency (Cook et al., 1983).

When faced with likely gain situations, organizations are likely to be risk-averse and pursue internally directed actions because such opportunities are typically associated with a degree of uncertainty and risk (Kahneman & Tversky, 1979). Organizations are likely to feel that they have more to lose than to gain from these situations. Particularly, organizations with higher levels of resource slack may choose to forgo such external opportunities because the availability of resource slack allows them to sit back and afford to be risk-averse. Organizations without sufficient resource slack however may instead choose to take greater risk associated with externally directed actions and problemistic search to acquire additional resources (Cyert & March, 1963).

These organizational actions are the outcome of the manager's analogical reasoning processes (Miller & Lin, 2015). Along these processes, to facilitate organizational learning and effective actions, managers scan the environment to selectively collect relevant data and then interpret to give meaning to these data (Daft & Weick, 1984). Such interpretation transforms a variety of information associated with aspects of the environmental changes into an integrated and holistic understanding.

5. ANALOGICAL REASONING AND ERRATIC DECISIONS

The analogical reasoning processes of managers require that characteristics of the current situation be compared with those of past organized knowledge to arrive at classifications of the situation based on the degree to which they are matched (Dutton & Jackson, 1987; Markman & Moreau, 2001). This inference yields hypotheses that guide current organizational actions to exploit perceived opportunities or to mitigate threats in the changing environment (Dutton et al., 1983). The accuracy of such inference therefore critically influences strategic actions and organizational performance. Excessive optimism or pessimism about the organization's prospects may lead to inappropriate strategic actions and poor organizational performance.

Analogical reasoning has different forms including satisficing match, best available match, and exact match (Miller & Lin, 2015). The reasoning processes are involved with specifying possible analogies from past memories, comparing these analogies to the current problems, selecting an analogy, and deriv-

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ing inferences (Markman & Moreau, 2001). In dynamic environments, best available match and exact match as opposed to satisficing match are likely to improve the accuracy of interpretation over time (Miller & Lin, 2015). Past distant experiences through satisficing match may be useful in early periods when the complexity of environment is low. However, organizations should try to unlearn past distant experiences in favor of investing heavily in the learning of more recent dynamic environments through best available match or exact match.

For new entrants, investing heavily for learning in dynamic environments may lead to poor organizational outcomes in the short run. However, over time, they can attain better organizational performance derived from accumulated knowledge and experience in coping with dynamism in the environment (Miller & Lin, 2015). Decision makers with limited experience in their complex operating environment should employ the best of what they know, rather than wait for what they should ideally know to address the problems.

While in the short run, applying well known past experiences can reduce volatility of organizational outcomes relative to heavily investing for learning in the dynamic environment, this lower risk alternative also comes at the expense of organizational performance in the long run (Miller & Lin, 2015). Therefore, organizations in dynamic environments are required to tradeoff between their operating performance and risk when deploying past experiences and investing in learning to address problems in the short and long term, respectively.

5.1 Metacognition

The quality of analogical reasoning is associated with ability of managers to understand their own thinking. This ability is determined by the manager's metacognition. Metacognition refers to the ability to understand a given situation in relation to one's own cognitions (Haynie, Shepherd, Mosakowski, & Earley, 2010). A manager's inconsistent judgments for the same circumstance are erratic decisions which are the result of erroneous beliefs of one's own cognitions and lack of awareness in one's own decision-making processes. A person has a metacognitive experience if that person feels a particular task is difficult to understand and then draws on past experience to inform decision frameworks for present new, but related situations (Haynie et al., 2010). Therefore, managers with more metacognitive experiences are likely to better apply their previous decision-making processes to address the current decision tasks, thereby improving quality of their decision making.

Managers tend to use metacognitive experiences when the situations are complex and thus require careful consideration (Flavell, 1979). By using metacognitive experiences to address the current decision tasks, managers can verify the usefulness of their decision-making processes, thereby allowing them to improve quality of their thinking processes (Flavell, 1979). The use of metacognitive experiences, over time, allows managers to accumulate important knowledge and gain better control of their decision-making processes, thereby reducing the likelihood of making erratic decisions (Mitchell et al., 2011).

Managers possessing more metacognitive experiences are thus less likely to make erratic strategic decisions. Because thinking processes of individual managers are embedded in the broader external environment, quality of their judgments will rely not only on their metacognitive experiences and ability to understand their own thinking and decision making, but also on their perception of the environmental context.

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5.2 Hostile and Dynamic Environment

The extent to which managers make erratic strategic decisions is influenced by their perceived experience in hostile and dynamic environments (Dutton & Duncan, 1987). In hostile environments, decision makers may not be able to sufficiently carry out cognitive processes to arrive at a stable decision (Staal, Bolton, Yaroush, & Bourne, 2008). Managers may not be able to take sufficient past, present, and future alternatives into consideration. In particular, such a threatening environment worsens information processing ability of decision makers, thus leading to inconsistent decision outcomes (Staal et al., 2008). Managers are therefore likely to make more erratic strategic decisions in an environment with greater hostility (Mitchell et al., 2011).

Dynamic environments are highly unstable and unpredictable (Dutton & Duncan, 1987). In these environments, managers hardly comprehend the relationship between means and ends of the situation, so they are required to concurrently draw on multiple cognitive processes at a given time (Gilbert & Osborne, 1989). Managers may thus be less aware of their own inconsistencies between current and previously established preferences in decision making processes (March, 1982; Ocasio, 1997). In an environment with greater dynamism, managers are thus likely to make more erratic strategic decisions.

In an environment that is characterized by both hostility and dynamism, managers are likely to perceive a higher risk of failure and a greater uncertainty about sources of such failure. They tend to be anxious about highly uncertain threats (Freeman & Freeman, 2008). Because available data about environmental threats are not sufficient, managers are likely to utilize minimal data in their decision making processes (Freeman & Freeman, 2008). Such decision making processes are thus unlikely to yield thoroughly thoughtful and logical decision alternatives. The erratic strategic decisions due to hostile environments are thus likely to be more pronounced with a combination of high environmental dynamism.

6. DISCUSSION AND CONCLUSION

Managers play the critical role in diagnosis of strategic issues in their company's operating environment. This diagnosis is conducted through their attention and interpretation of organizational data and stimuli and their analogical reasoning (Barreto & Patient, 2013; Chattopadhyay et al., 2001; Miller & Lin, 2015). Because individual managers are different in their attention to opportunity versus threat aspects of the environment, managers within the same organization and environment may also differ in their interpretation of these two environmental aspects (Barreto & Patient, 2013). Such attention is shaped by individual managers' divergent desirability and feasibility considerations (Barreto & Patient, 2013; Miller & Lin, 2015). In particular, the results of such interpretation processes in terms of threat and opportunity are contingent upon structural distance of the manager from the environmental signals, perception of organizational capability, and characteristics of the organizational environment.

Organizational actions are largely influenced by such threat or opportunity interpretation. However, threat aspects of the environment are likely to be more pronounced than opportunity aspects in managerial decision making (Chattopadhyay et al., 2001). In particular, control-reducing threats lead to more conservative internally directed actions whereas likely losses lead to riskier externally directed actions. When faced with a control-reducing threat, managers are likely to act in domains in which their organization has the greatest control including implementation of well-known strategies (Staw et al., 1981). However, they will be risk-seeking when their organization is faced with a loss prospect (Kahneman &

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Tversky, 1979). Organizational actions in response to control-enhancing and likely gain opportunities are however rather equivocal (Chattopadhyay et al., 2001). When faced with opportunities, organizations may focus more on developing and exploiting new ideas and technologies rather than taking any actions in response to control-enhancing or likely gain opportunities (Dutton & Jackson, 1987).

Organizations are likely to pursue externally directed riskier actions when they are faced with external events that threaten their distinctive resources and capabilities. When managers place greater emphasis on product-market development instead of domain defense, organizational actions are likely to be externally rather than internally directed because their capabilities lie in gaining control over the external environment through building new products and markets (Chattopadhyay et al., 2001). These externally directed actions are likely to be more salient to deal with control-reducing threats which lower their control over the external environment.

Because threat aspects of the environment are likely to be more pronounced than opportunity aspects in managerial decision making, organizational resource slack appears to provide managers the resources necessary to respond to control-reducing threats and likely losses (Chattopadhyay et al., 2001). In particular, organizations with more resource slack are likely to respond to control-reducing threats with internally directed actions while respond to threats of likely losses with externally directed actions. Organizational resource slack however may not always influence organizational actions to respond to control-enhancing and likely gain opportunities. In such case, organizations may use resource slack to implement actions that are independent of the outcome of managerial interpretation.

In dynamic environments, managerial interpretations as discussed above are likely to be more accurate when organizations pursue analogical reasoning in the form of best available or exact match rather than satisficing match (Miller & Lin, 2015). While these forms of reasoning may worsen performance of organizational actions in the short run, they promote experiential learning and, over time, improve accuracy of the reasoning and thus organizational performance in the long run (Miller & Lin, 2015). Experiential learning is indeed fundamental to the accuracy of reasoning and interpretation of environmental signals. Therefore, organizations should unlearn past distant experiences, which often mislead them to pursue a satisficing form of reasoning for the sake of short-term organizational performance.

When environmental unpredictability is not very high, organizations should pursue reasoning in the form of best available match rather than exact match (Miller & Lin, 2015). In such circumstance, managers should deploy the best of what they know instead of waiting for all of what they should ideally know. Managers may pursue satisficing match only in early periods with low environmental volatility (Miller & Lin, 2015). In particular, satisficing form of reasoning, while stabilizing organizational performance in the short run relative to reasoning in the form of best available and exact match, comes at the expense to organizational performance in the long run.

Strategic decision making processes are critical to organizational outcomes. However, these processes are often inconsistent and thus erratic. Erratic decisions are engendered from the manager's lacking of metacognitive experiences in the decision domains and in the characteristics of environment (Mitchell et al., 2011). Such metacognitive experiences decrease the extent to which managers make erratic strategic decisions.

Environmental hostility increases the extent to which managers make erratic strategic decisions. However, in dynamic environments, managers may, over time, invest in learning to accumulate experience in these environments to the extent that such experience reduces erratic strategic decisions (Zollo & Winter, 2002). Environmental dynamism may thus provide organizations with learning opportunities that potentially mitigate such adverse effects of environmental hostility (Mitchell et al., 2011). In environ-

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ments with greater hostility, managers may thus be able to reduce erratic strategic decisions when they have accumulated more experience through investing in learning from dynamic environments (Mitchell et al., 2011). However, without such learning opportunity (e.g., in low levels of environmental dynamism), the hostility aspects of environment are likely to exert a more salient negative effect on organizational decision making processes.

Managers should be aware that individuals in an organization may be unconsciously biased in strategic decision making. Managers may be able to reduce the biases by seeking more ideas from outside of their own organizations. Organizations often rely on their past experiences and apply these to current strategic decision making. Such local search may paralyze efforts of individuals and organizations to explore and develop new solutions for long-term performance. While recognizing the importance of past experience, managers should increase the number of alternatives, and utilize them to complement decision making.

However, managers should also be cautious that investing in new and unfamiliar alternatives may turn out to be not useable, excessively delaying responses and causing significant costs. In an uncertain organizational environment, managers should not forgo such opportunities but consider strengthening their capabilities by implementing experiments. Experiments allow an organization to learn and gain experience that potentially becomes alternatives and guidelines for encountering new challenges in the future.

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REFERENCES

Barreto, I., & Patient, D. L. (2013). Toward a theory of intraorganizational attention based on desirability and feasibility factors. *Strategic Management Journal*, *34*(6), 687–703. doi:10.1002mj.2029

Chattopadhyay, P., Glick, W. H., & Huber, G. P. (2001). Organizational actions in response to threats and opportunities. *Academy of Management Journal*, *44*(5), 937–955. doi:10.2307/3069439

Cho, T. S., & Hambrick, D. C. (2006). Attention as the mediator between top management team characteristics and strategic change: The case of airline deregulation. *Organization Science*, *17*(4), 453–469. doi:10.1287/orsc.1060.0192

Cook, K., Shortell, S., Conrad, B., & Morrisey, M. (1983). A theory of organizational response to regulation: The case of hospitals. *Academy of Management Review*, *8*(2), 193–205. PMID:10263058

Cyert, R., & March, J. (1963). *A Behavioral Theory of the Firm*. Englewood Cliffs, NJ: Prentice-Hall.

D'Aveni, R., & MacMillan, I. (1990). Crisis and the content of managerial communications: A study of the focus of attention of top managers in surviving and failing firms. *Administrative Science Quarterly*, *35*(4), 634–657. doi:10.2307/2393512

Daft, R. L., & Weick, K. E. (1984). Toward a model of organizations as interpretation systems. *Academy of Management Review*, *9*(2), 284–295.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Dutton, J., & Jackson, S. (1987). Categorizing strategic issues: Links to organizational action. *Academy of Management Review*, *12*(1), 76–90.

Dutton, J. E., & Duncan, R. B. (1987). The creation of momentum for change through the process of strategic issue diagnosis. *Strategic Management Journal*, *8*(3), 279–295. doi:10.1002mj.4250080306

Dutton, J. E., Fahey, L., & Narayanan, V. K. (1983). Toward understanding strategic issue diagnosis. *Strategic Management Journal*, *4*(4), 307–323. doi:10.1002mj.4250040403

Fiegenbaum, A., & Thomas, H. (1988). Attitudes towards risk and the risk-return paradox: Prospect theory explanations. *Academy of Management Journal*, *31*(1), 85–106. doi:10.2307/256499

Fischer, I., & Budescu, D. V. (2005). When do those who know more also know more about how much they know? The development of confidence and performance in categorical decision tasks. *Organizational Behavior and Human Decision Processes*, *98*(1), 39–53. doi:10.1016/j.obhdp.2005.04.003

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive-developmental inquiry. *The American Psychologist*, *34*(10), 906–911. doi:10.1037/0003-066X.34.10.906

Freeman, D., & Freeman, J. (2008). *Paranoia: The Twenty-First Century Fear*. Oxford, UK: Oxford University Press.

Gilbert, D. T., & Osborne, R. E. (1989). Thinking backward: Some curable and incurable consequences of cognitive busyness. *Journal of Personality and Social Psychology*, *57*(6), 940–949. doi:10.1037/0022-3514.57.6.940

Haynie, J. M., Shepherd, D., Mosakowski, E., & Earley, P. C. (2010). A situated metacognitive model of the entrepreneurial mindset. *Journal of Business Venturing*, *25*(2), 217–229. doi:10.1016/j.jbusvent.2008.10.001

Hubner, R., Steinhauser, M., & Lehle, C. (2010). A dual-stage two-phase model of selective attention. *Psychological Review*, *117*(3), 759–784. doi:10.1037/a0019471 PMID:20658852

Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica*, *47*(2), 263–291. doi:10.2307/1914185

Liberman, N., & Trope, Y. (1998). The role of feasibility and desirability considerations in near and distant future decisions: A test of temporal construal theory. *Journal of Personality and Social Psychology*, *75*(1), 5–18. doi:10.1037/0022-3514.75.1.5 PMID:11195890

March, J. G. (1982). Theories of choice and making decisions. *Society*, *20*(1), 29–39. doi:10.1007/BF02694989

Markman, A. B., & Moreau, C. P. (2001). Analogy and analogical comparison in choice. In D. Gentner, K. J. Holyoak, & B. N. Kokinov (Eds.), *The Analogical Mind: Perspectives from Cognitive Science*. Cambridge, MA: MIT Press.

Miles, R. E., & Snow, C. C. (1978). *Organizational Strategy, Structure, and Process*. New York: McGraw-Hill.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Miller, K. D., & Lin, S. J. (2015). Analogical reasoning for diagnosing strategic issues in dynamic and complex environments. *Strategic Management Journal*, *36*(13), 2000–2020. doi:10.1002mj.2335

Mitchell, J. R., Shepherd, D. A., & Sharfman, M. P. (2011). Erratic strategic decisions: When and why managers are inconsistent in strategic decision making. *Strategic Management Journal*, *32*(7), 683–704. doi:10.1002mj.905

Nohria, N., & Gulati, R. (1996). Is slack good or bad for innovation? *Academy of Management Journal*, *39*(5), 1245–1264. doi:10.2307/256998

Ocasio, W. (1997). Towards an attention-based view of the firm. *Strategic Management Journal*, *18*(S1), 187–206. doi:10.1002/(SICI)1097-0266(199707)18:1+<187::AID-SMJ936>3.3.CO;2-B

Samuelson, W., & Zeckhauser, R. (1988). Status quo bias in decision making. *Journal of Risk and Uncertainty*, *1*(1), 7–59. doi:10.1007/BF00055564

Staal, M. A., Bolton, A. E., Yaroush, R. A., & Bourne, L. E. Jr. (2008). Cognitive performance and resilience to stress. In B. J. Lukey & V. Tepe (Eds.), *Biobehavioral Resilience to Stress*. Boca Raton, FL: CRC Press.

Staw, B., Sandelands, L., & Dutton, J. (1981). Threat rigidity effects in organizational behavior: A multilevel analysis. *Administrative Science Quarterly*, *26*(4), 501–524. doi:10.2307/2392337

Thomas, J., Clark, S., & Gioia, D. (1993). Strategic sensemaking and organizational performance: Linkages among scanning, interpretation, action, and outcomes. *Academy of Management Journal*, *36*(2), 239–270. doi:10.2307/256522 PMID:10125120

Wiseman, R., & Gomez-Mejia, L. (1998). A behavioral agency model of managerial risk taking. *Academy of Management Review*, *23*(1), 133–153.

Zollo, M., & Winter, S. G. (2002). Deliberate learning and the evolution of dynamic capabilities. *Organization Science*, *13*(3), 339–351. doi:10.1287/orsc.13.3.339.2780

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Chapter 72
Assessing the Readiness of Farmers Towards Cold Chain Management: Evidences From India

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ABSTRACT

The purpose of the paper is to gain an insight into the current status of farmers' awareness and practices towards maintaining the postharvest cold chain. The related hypotheses are developed and tested. The major findings include- marginalized and small farms, literacy and poor awareness level are the main causes for the backwardness of Indian farmers. Also, lack of funds forces farmers to ignore the use of cold storage. Further, multi-intermediaries and fluctuating consumer prices result farmers in not getting fair share of the consumer rupee. One of the major challenges in front of fresh food industry in India is to reduce postharvest losses across the chain through increasing awareness level of famers towards cold chain, building market information systems to assist farmers in decision-making and improving food safety and quality of farm produce available in the market.

INTRODUCTION

Given that most food, pharmaceutical, and chemical products get degraded by inappropriate exposure to temperature, humidity, light and certain contaminants (Smith, 2005), a consistent management of controlled environment all along the supply chain is a key in maintaining the quality of perishable products till the final delivery point. A 'Cold Chain' is a physical process that dominates the supply chain of perishable products. The cold chain includes a series of equipment and processes used to protect the perishables, by keeping them chilled and frozen, starting from the source of origin to the destination

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of consumption (Salin & Nayga, 2003). The perishable products can be categorized into two types viz, living products and non-living products. The living Products include fruits, vegetables, live seafood, flowers etc., where respiration is an on-going process, which uses up stored energy or food reserves by emitting heat and water vapors (Dahlenburg, 2001). Here, temperature is an imperative constraint, and the impact of non-optimal temperatures result into the loss of quality in form of earlier ageing and natural senescence. Too high temperature results in loss of quality, rapid deterioration and microbial spoilage whereas, in contrast, too low temperature shows early death, chilling injury, freezing destructions and death (Shewfelt et al., 2014; Ames, 2006).

Perishable products begin to loose quality as soon as they are harvested. Proper postharvest handling of fresh produce before and during their storage period is essential for maintaining the quality and increasing the shelf life of these produce. These fresh produce can become contaminated with human pathogens or spoilage bacteria at any point in the supply chain, i.e. from cultivation to consumption (James et al., 2008). As the consumption of fresh produce has increased significantly in the last decade (Rediers et al, 2009), with occurrence of series of food poisoning and related diseases, global consumers nowadays are more concerned about the safety of their food (Griffith, 2006). Cost reduction and quality improvement at the upstream side of the distribution center became the strategic attention points (Lemeilleur and Codron, 2011, Buurma & Saranark, 2006). The main sources of postharvest contamination are temperature abuse at farm level (Brackett, 1992), harvesting equipment, transport containers, processing equipment, and human handling (Beuchat & Ryu, 1997). Strict temperature control throughout the supply chain can minimize the risk of food-borne illnesses because cold storage drastically reduces the growth rate of most human pathogens (Ukuku & Sapers, 2007).

The sourcing of perishable products play an important role for food related business. It is a key factor for the production costs as well as for the quality of the food products, the social, sensorial or food safety aspects (Aidoo, 1993). Thus, it is important for any organization to have reliable sources. A farmer can be a reliable source if equipped with proper knowledge and skills. In a developing country like India, there is a need to strengthen the farmer link, which is a critical link of the cold chain.

A farmer plays an important role in cold chain. The farmer can be a reliable source if equipped with proper knowledge and skills. There is a need to strengthen the farmer link, which is a critical link of the cold chain. In this research, we intend to find the readiness of Indian farmers towards the cold chain practices. The main objective of the research is to gain an insight into the current status of farmers' awareness and practices towards maintaining the postharvest cold chain. For this, one sector from each living and non-living category of perishables is chosen. The sectors, Fruits and Vegetables (FV) and Milk and Milk Products (MMP) are chosen from the living products' and non-living products' categories respectively. The FV and MMP sectors include product handling at temperatures of -20^{o}C to +10^{o}C and that range covers handling temperatures of most of the perishable items.

LITERATURE REVIEW

Researchers (Tanksale & Jha, 2015; Narula, 2011; Allais & Letang, 2009; Ferna Andez-Trujillo et al., 2000; Srivastava, 2006; Jain, 2007; Singh, 2007) enumerated number of problems faced at farmers' end like, no transparency in pricing at farmer end, lack of awareness about the use of IT for being better informed, improper handling, loading and unloading of perishables, fragmented production, leading to fragmented chains, etc. One of the underlying reasons for such paradoxes is the lack of knowledge,

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skills and unawareness about the market information (Jarimopas et al., 2008). Small farmers are poverty stricken, illiterate and dependent on monsoon in India (Shukla & Jharkharia 2013; Sridhar & Ballabh, 2007). Poor market orientation and low value addition capacity, gives them low margins leading to low risk-taking abilities. Thus, small farmers enter a vicious circle and find it difficult to break. A little bargaining power and a heavy dependence on their farm produce for basic needs, add to their woes and they end up becoming victims to the exploitative market intermediaries who deny them a fair share of the consumer rupee (Sridhar & Ballabh, 2007).

India is world's largest producer of milk and second highest producer of fruits and (Planning Commission, 2013). But, unfortunately not a single Indian dairy company has featured in the list of global top 20. Also, around 30 to 40 percent of total production of fresh fruits and vegetables is wasted every year in India. One of the main reasons is inadequate knowledge, skills and awareness in the farmers about the postharvest losses. Most perishables are required to be cooled to a suitable temperature as early as possible after harvest. This is called pre-cooling. A delay of few hours between harvest and cooling can have significant effects on the degradation rate of many perishable products. Pre-cooling reduces their metabolic activity, reduces the growth of microorganisms and prevents other changes such as wilting, before the produce is placed in cold storage. It also reduces the load on the cold store refrigeration system.

Within this context, although India has been the world's largest milk producer since 1995, unfortunately not a single Indian dairy company featured in the list of global top 20 dairy companies (Banerjee, 2007). Moreover, estimates says around 30 percent to 40 percent of the total production of fresh fruits and vegetables, is wasted in India, which is tantamount to the total production of the United Kingdom (Khan, 2005). In most developed countries like the USA and the UK postharvest losses are below 15% of the production. Post-harvest losses (including storage) in Somalia are estimated at 20-30% of the production. If we glance upon the African countries; In Kenya post-harvest losses were estimated at 10-23%, in Malawi 6-14%, in Rwanda 10-20%, in Tanzania 20-60%, Uganda 4-17% and in Zambia 9-21%. For Sorghum post-harvest losses were estimated at 0-37% in Nigeria, 6-20% in Sudan, 0-10% in Zambia and 25% in Zimbabwe. In Ghana post-harvest losses were estimated at 20% (Manzini, 2014; Kader, 2008; Delken, 2008).

Most of the farmers are ignorant about the use of cooling activities, its usefulness and availability. The cold chain facilities usually do not reached them due to either poor extension services or high cost. Meenke (2006) attributed the reasons to the non-utilization of cold chain facilities as high cost of cold store space, cost of transportation and uncertainty of receiving proper return of the preserved value. Farmers are mostly ignorant of right stage of harvesting, proper cleaning, grading and packing of the produce, which results in low price for their produce (Sun & Zheng, 2006; Sridhar & Ballabh, 2006, Pai & Sastry, 1989). Sridhar & Ballabh (2006) emphasized that regulation and red tape is the key limitation why farmers are not getting a fair portion of consumer's money. Other hurdles are like inadequate support from government and a high unit refrigeration costs. Although Indian government has announced many subsidies to cold storage set up yet, many feel that it receives inadequate support from government. These observations lead to the formulation of hypotheses 1 and 2.

H1: Post harvest losses between farm and cold storage are positively influenced by (a) In adequate pre-cooling facilities, (b) Insufficient knowledge among farmers, (c) High cost of product refrigeration and (d) Inadequate support from government.

H2: There is a significant difference of perception between FV and MMP sector at farm level, regarding pre-cooling practices.

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Related to Value of Perishable Produce: Procurement to Consumption

Perishable products begin to lose the value as soon as they are harvested (Bogataj et al., 2005). Proper post-harvest handling of fresh produce before and during their storage period is extremely essential for maintaining the quality and increasing the shelf life of these produce (Rediers et al., 2009). The main sources of these losses are temperature abuse at farm level (Brackett, 1992; Rosset et al., 2004), harvesting equipment, transport containers, processing equipment, and human handling (Beuchat & Ryu, 1997).

At farm level there are so many causes for losses in the value of product food chain like, microbiological, mechanical and physiological factors. To ensure that foods have a uniformly high quality for sale in the fresh market sector, it is necessary to clean, sort and grade the crop before cooling and cold storage. A few hours of delay between harvest and cooling can have measurable effects on the deterioration rate of many perishable products.

Temperature homogeneity in most cold storages is directly governed by the airflow patterns in the system (Duiven & Binard, 2002). Refrigeration systems with non-uniform airflow implicated as a major cause of temperature variability. For sensitive products, this level of temperature variability may have significant food quality and safety implications (Smale et al., 2006). The inefficient utilization of storage space within cold rooms has been identified and quantified accurately, whilst the quality control task has been recognized as the most time-consuming task and a critical cause for hindering product flow (Manikas & Terry, 2009, Joshi, et al. 2010). Zhang et al. (2003) stated that one of the particular attributes of the logistics systems for chilled and frozen goods is the maintenance of product quality, which is dependent on the duration of delivery time and variation of temperature in the cold chain. An effective logistics system not only delivers food products freshly and safely, but also on time, which is an important concern of customers (James et al., 2008). Tarantilis and Kiranoudis (2001) acknowledged that since long managing the perishability of foods is a difficult problem in distribution management. In context of developing countries it is observed that lack of adequate infrastructure (Salin & Nayga, 2003) along with high cost for installation and operation are the biggest bottleneck for strong and efficient cold chain. Operating costs for these cold chain facilities are about double as compared to developed countries (Joshi et al., 2009). These observations lead to the formulation of hypotheses 3 and 4.

H3: Loss in the product value with time is positively influenced by (a) Inadequate handling skills, (b) Improper use of cold storage, (c) Inadequate refrigerated transportation, and (d) High cost of cold chain facilities.

H4: There is a significant difference of perception between FV and MMP sector in assigning importance to quality and safety measures between farm and consumer.

METHODOLOGY

To address the issues related to cold chain practices of Indian industries and stakeholders, a questionnaire based survey is undertaken. The questionnaire is designed keeping in view the available literature and previous surveys. The practicing managers and academicians in the area of supply chain management of perishable items are also consulted during the development of questionnaire. In the questionnaire, farmer's survey is centered towards acquiring farmer's practices and awareness in handling farm produce (MMP and FV) within the framework of cold chain management.

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The questionnaire is tested for two main types of validity, which are content validity, and construct validity. Content validity represents the adequacy with which a specific domain of content is sampled (Nunally, 1978) and that the instrument item has items that cover all aspects of variables being measured. Content validity cannot be determined numerically. Its determination is subjective and judgmental. It primarily depends on an appeal to proprietary of content and the way it is presented (Nunally, 1978).

The instrument developed in this study demonstrates the content validity as the selection of measurement items was based on both, an exhaustive literature review and evaluation by academicians and practicing managers during the pre-testing. The content validity was further tested during pilot survey as per the guidelines provided by Forza (2002). After a careful review of respondents' answers to questionnaire during the pilot survey, some questions were modified to convey their intended meaning, and some questions were deleted from the questionnaire as per the suggestion received from the respondents.

QUESTIONNAIRE ADMNISTRATION

Target Respondents

Maintaining the scope of the research, randomly (convenience random sampling) farmers are selected who are in the business of either milk or milk products or fruits and vegetables. Firstly, the purpose of the survey was made clear to them and then their consent for interview was asked for. Given the nature of the issues to be addressed in the farmer's questionnaire, it was decided to carry out the interviews on a face-to-face basis (rather than handing over questionnaire to them). This was felt to be particularly important as questions include few terms that are relatively unusual for farmers, and therefore the face-to-face context was considered more effective. In addition, the personal interview approach is one which is typically adopted for discussing issues of this nature within other comparable research (Skerratt & Midmore, 2000; Patton, 1990; Dey 1993).

A total of 120 farmer respondents (60 each from both the chosen sectors) were randomly selected. These farmers were resident of North India (Delhi, Rajasthan, Haryana and Uttrakhand) having their own farms and livestock.

FINDINGS

Related to Cold Chain Practices at Farm Level

Post-harvest losses of fresh produce are very serious in developing countries like India. It is a matter of worry that a farmer devotes so much time on to fresh produce, spends so much money on maintenance like irrigation, fertilization, animal vaccination and protection measures, but major share of the fresh produce is wasted about a week after harvest and that because of the ill practices and inadequate knowledge. Further, there are number of intermediaries and fluctuating consumer prices which finally result farmers not getting fair share of the consumer rupee. In this survey, the questionnaire administrated to farmers, contained issues related to farmer's practices and awareness towards maintaining cold chain at farm level for reducing postharvest losses.

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It was observed that literacy and poor awareness level are one of the main causes for the backwardness of Indian farmers. Literacy is the ability to read and write to a competent level which leads to awareness, which is knowledge of or competence in a subject or area of activity. Most of the respondents (92.33%) had low level of formal education (secondary or below). About 19% of respondents had no formal education background. However, despite low level of education all the farmer respondents were agreed, when asked if temperature abuse in any way can cause harm to their produce. Further when asked the time of a day to pick up crops, about 48% replied as 'early morning' and 22% agreed with 'as per the schedule of dispatch', only 7% of farmers insisted to pick up crops at night to benefit of low temperature at nights. This showed that farmers are not taking advantage of natural pre-cooling as they are not aware or influenced by the superstition that harvesting at night is an ill omen.

As observed in Figure 1, when farmers were asked about other practices (excluding yield) that are important after yield, for getting a good return, proper handling (Mean=4.2, SD=0.765) has emerged as the most influential practice for improving the value of produce, followed by sorting (Mean=3.87, SD=0.445) and cleanliness and hygiene (Mean=3.54, SD=0.654). Pre-cooling (Mean=3.46, SD=0.521) was given fourth rank. It was also observed that farmer respondents emphasized on temperature of commodity (Mean=4.16, SD=0.564), handling (Mean=3.12, SD=0.625) and relative humidity (Mean=3.26, SD=0.581), as the factors affecting the microorganism development. This showed that farmers are aware of the adverse consequences of poor temperature maintenance at farm level but they are not giving due importance to cold chain practices. In general, some of the reasons for this ignorance can be attributed to limited financial capacity and high cost associated with cold chain facilities.

As shown in Figure 2, when farmers were asked to assign weights to the reasons for wastages of their products at farm level, postharvest losses (Mean=4.05, SD=0.673) came into view as the most affecting reason followed by high cost of refrigeration of fresh produce (Mean=3.88, SD=0.672) and inadequate support from the Government (Mean=3.2, SD = 0.805).

From the literature and discussion with academics and practicing managers, factors identified that cause depletion (wastage) of fresh produce from a farm to till it reaches a consumer were, inadequate harvesting, packaging and handling skills, lack of pre-cooling facilities at farm level, lack of adequate containers for the handling of food, improper use of cold chain facilities, inadequate refrigerated vehicles to move the food to market before it spoils, high cost associated with cooling facilities, inadequate skills of staff (drivers, supervisors, managers), traditional processing and marketing systems, loss in product value with time, lack of communication link between producer and wholesaler, too lax or unduly strict legal standards, over purchase of cheap but highly perishable food products, lack of conscientious and knowledgeable management, and bumper crops that overload the post-harvest handling system. The response is in Figure 3.

A continuous loss in product value with time (Mean=4.125, SD=0.60) with High cost associated with cooling facilities (Mean=4, SD=0.614), and Inadequate harvesting, packaging and handling skills (Mean=3.18, SD=0.528) emerged as the top three reasons for the wastage of fresh produce from a farm to till it reaches a consumer. This can be easily visualized that all of these can be curbed properly if a due attention on cold chain practices is given.

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Figure 1. Factors affecting the returns of farmers other than yield

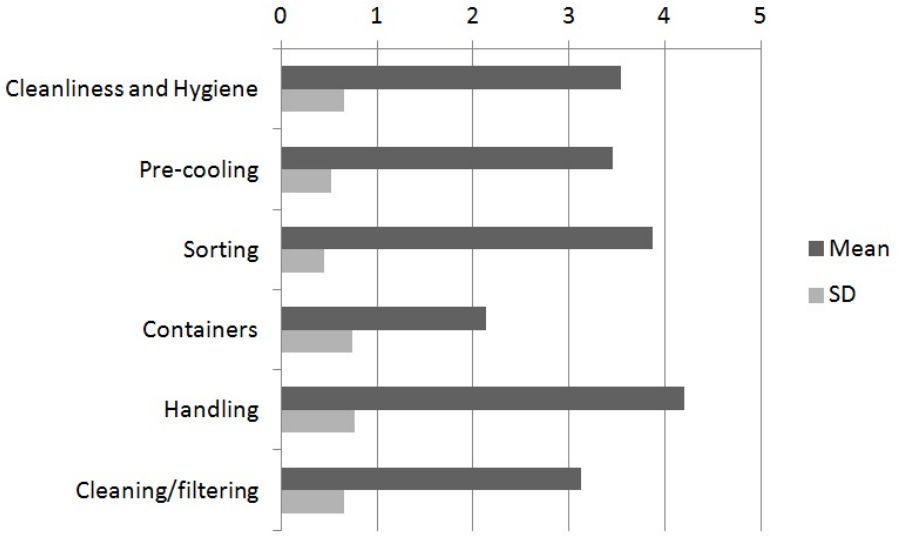

Figure 2. Factor resulting wastage of fresh produce at farm level

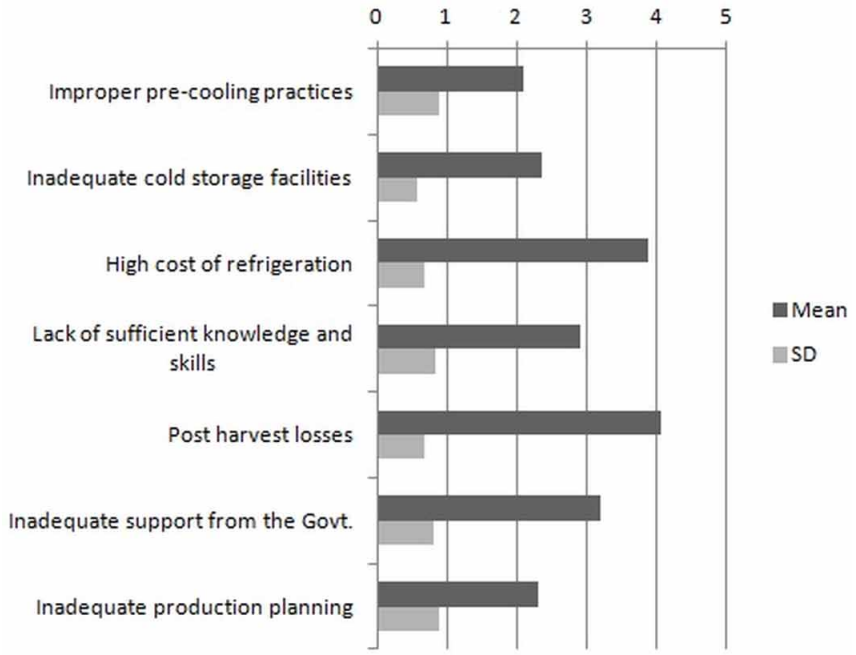

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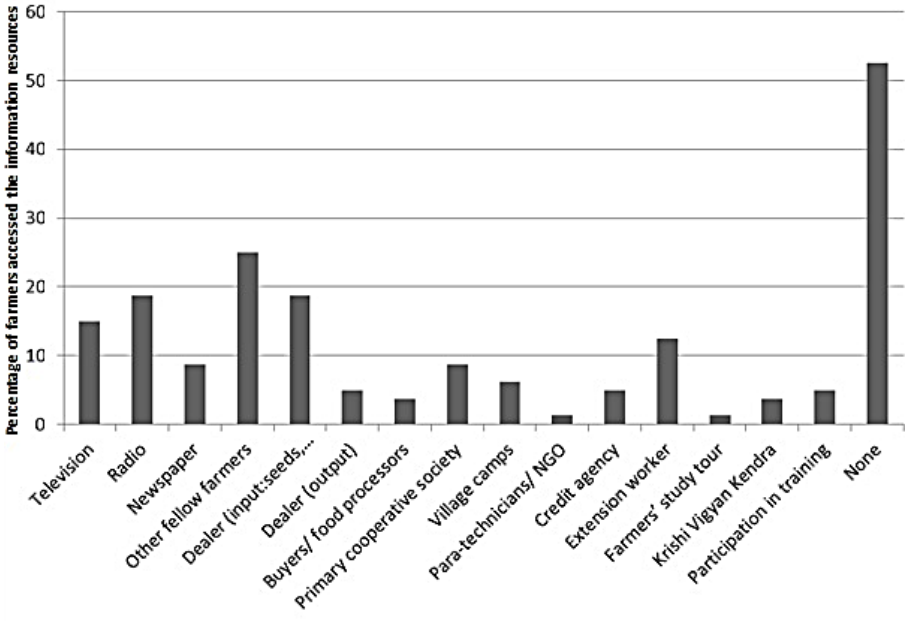
Figure 3. Factors that cause wastage of fresh produce from a farm until it reaches a consumer



Related to Education and Awareness Level of Farmers

Farmers generally lacks management skills, they are not fully acquitted with the new trends and innovations in agriculture sciences. They require extension education services to educate them on postharvest as well as marketing techniques. In this section of the survey, the farmers were asked about the information network they have, how much reliable it is and how far they have used it. Figure 4 shows the information sources used by farmers in India during the past one year to obtain information that can help them in increasing their returns.

It was observed that about 50 percent of the farmers had not used any sources for upgrading their knowledge. Out of those who did use sources, the most used source emerged as 'the other fellow farmers', who are doing well from past few years. Radio and the dealer who delivers seeds and fertilizers were the second-most used source. Television followed thereafter. The government extension workers ranked fifth, followed by the primary cooperative society and newspaper. Less than 1 percent of Indian farmers accessed NGOs, private sector extension, or para-technicians.

The respondents were also asked to rank the quality of information they received as good, satisfactory, or poor. Figure 5 shows the result. About 50% of the respondents ranked the quality of information received from most of the information sources as good. Most of the respondents suggested improvement in the quality, timeliness and reliability of the information provided.

Hypothesis Testing

In this section, the validity of hypotheses is tested. Multivariate regression analysis, correlation analysis and independent T-tests are used to test the hypotheses on SPSS. For the validity of multiple linear regres-

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Figure 4. Percentage of farmers who accessed given information resources during the past one year to improve agricultural technology

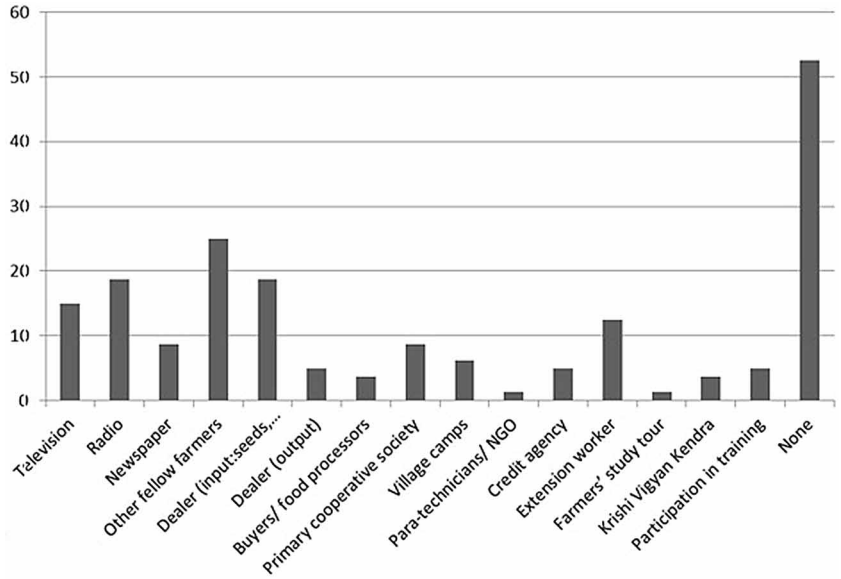
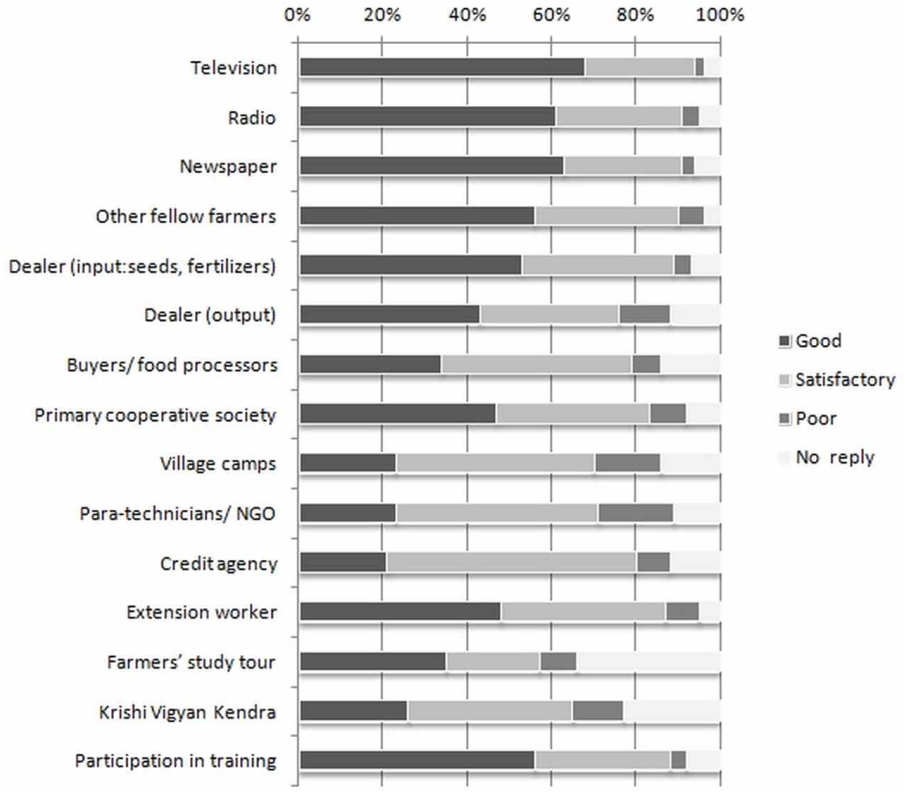


Figure 5. Farmer's satisfaction with the quality of information from various information sources



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sion, it is essential that the independent variables in any regression equation are mutually independent and do not have strong dependence or correlation among themselves. According to George & Mallery (1999), a linear regression equation between the dependent and independent variables is possible if there is no linear dependency among the predictor (independent) variable. To compute correlations between predictor variables is always a wise step. Variable that correlated higher than 0.5 should be scrutinized carefully before such are included in a regression analysis. At the same time the Variance Inflation Factor (VIF) should also be considered to measures the impact of collinearity among the variables in a regression model. The regression model having VIF more than 10 Values are often regarded as indicating multi collinearity (Miles et al., 2001). We propose to conduct linear regression analysis for testing hypotheses. The Pearson correlation coefficients for independent variable are calculated before conducting the regression analysis. The low correlation coefficients indicate that there is no significant correlation among the independent variable and linear regression can be preceded. For quick reference each of the proposed hypotheses is reproduced before it is tested for its validity.

H1: Post harvest losses between farm and cold storage are positively influenced by (a) inadequate pre-cooling facilities, (b) insufficient knowledge among farmers, (c) high cost of product refrigeration and (d) inadequate support from government.

A multivariate regression analysis is carried out on SPSS to test this hypothesis. In this test the dependent variable is "Post harvest losses between farm and cold storage", and the independent variables are: "Inadequate pre-cooling facilities", "Insufficient knowledge among farmers", "High cost of product refrigeration" and "Inadequate support from government". The results of this analysis have been presented in Table 1.

The regression model derived from this analysis is:

Post-harvest losses = 0.729 + 0.363 (high cost of refrigeration) + 0.235 (inadequate pre-cooling practices at farm level) + 0.224 (inadequate support from the Govt.) + 0.172 (insufficient knowledge and skills).

As the independent variables in the model influence the dependent variable at a high significance level (p value are less than 0.05), the hypothesis is accepted.

Table 1. Multiple regression analysis for Hypothesis 1

	Regression Coefficients		t	Sig.
	B	Std. Error		
(Constant)	.729	.377	2.466	.016
Inadequate pre-cooling practices at farm level	.235	.062	3.767	.000
High cost of refrigeration	.363	.084	4.325	.000
Insufficient knowledge and skills	.172	.075	2.286	.025
Inadequate support from the Govt.	.224	.072	3.112	.003

$R^2 = 0.525$.

Dependent Variable: Post harvest losses.

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H2: There is a significant difference of perception between Milk and milk Product (MMP) and Fruits & Vegetables (FV) sector at farm level, regarding pre-cooling practices.

In question related to this hypothesis, respondents were asked to assign weights to 'pre-cooling practices' at farm level for not getting sufficient value for their products. On the five-point Likert scale, 1 and 5 correspond to very low weight to very high weight. The descriptive statistics of the responses for both the sectors are shown in Table 2

It is observed from the descriptive statistics that MMP sector is more concern about the pre-cooling practices. An independent sample t-test (Table 3) is conducted to test this hypothesis. In this test MMP sector is compared with FV sector.

The results of the test indicate that the MMP sector significantly differ (at p= 0.000) from FV sector in the pre-cooling practices at farm level. The result of the independent t-test is sufficient to accept the proposed hypothesis.

Hypothesis 3

H3: Loss in the product value with time is positively influenced by (a) inadequate handling skills, (b) improper use of cold storage, (c) inadequate refrigerated transportation, and (d) high cost of cold chain facilities.

In the testing of this hypothesis, "Loss in the product value with time" is taken as an independent variable. The dependent variables are: "Inadequate handling skills", "Improper use of cold storage", "Inadequate refrigerated-transportation", and "High cost of cold chain facilities".

The regression model derived from this analysis is:

Loss in the product value with time = 0.486 + 0.341 (inadequate handling skills) + 0.282 (improper use of cold chain facilities) + 0.269 (high cost associated with cooling facilities) + 0.128 (inadequate refrigerated transportation).

Table 2. Descriptive statistics related to Hypothesis 2

Issue for Comparison	Sector	Mean	N	Standard
Pre-cooling practices at farm level	MMP	3.26	40	0.834
	FV	2.13	40	0.552

Table 3. Independent sample t-test for pre-cooling practices at farm level (MMP verses FV)

Issue for Comparison	Mean Difference	Degree of Freedom	t Value	Sig. (2-Tailed)
Pre-cooling practices at farm level	1.1	78	6.957	0.000

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Table 4. Regression analysis for Hypothesis 3

	Regression Coefficients		t	Sig.
	B	Std. Error		
(Constant)	.486	.262	2.154	.036
Inadequate handling skills	.341	.084	4.039	.000
Improper use of cold chain facilities	.282	.054	5.170	.000
Inadequate refrigerated transportation	.128	.061	2.108	.037
High cost associated with cooling facilities	.269	.058	4.628	.000

$R^2 = 0.651$.

Dependent Variable: Loss in product value with time.

From the above equation it is observed that the coefficient of "Inadequate harvesting, packaging and handling skills" is 0.341, which is higher than the coefficients of other variables. Therefore among all other variables it has maximum influence upon the losses in the product value with time. However, in order to assess the usefulness of each variable in the model, one cannot simply compare the coefficients to see the unique contribution of each variable. Beta coefficients are an attempt to make the regression coefficients more comparable as these coefficients indicate the relative importance of the variables without taking the constant into considerations.

For this model with four independent variables, the value of R^2 is 0.651. This value of explains 65.1% variability in the "loss in product value with time". As all the independent variables influence the "Loss in product value with time" at a high significance level (p value less than 0.037) the hypothesis is accepted.

Major Findings

1. Post-harvest losses of fresh produce at farm level are very serious in India. It was observed that literacy and poor awareness level are the main causes for the backwardness of Indian farmers.
2. It was observed that farmers are aware of the adverse consequences of poor temperature maintenance at farm level but they are not giving due importance to cold chain practices. It is the lack of funds that forces farmers to ignore the use of cold storage, even when available and effectively managed. Many farmers depend on almost daily sales for their income and hence may be forced to accept a lower price immediately, rather than to store their produce in the anticipation of a higher price.
3. It was also observed that small farmers do not have their own means of transport of their products. So they are dependent on intermediaries to get means of transportation. This again causes delay which means piling up of loss.
4. There are a number of intermediaries and fluctuating consumer prices which finally result farmers not getting fair share of the consumer rupee.
5. As observed 'proper handling' of perishables is considered as the most influential practice for improving the value of produce, followed by 'proper sorting' and *cleanliness*. *Pre-cooling* was given fourth rank.
6. Regarding the use of information sources by farmers that can help them in increasing their returns; it is observed that about 50 percent of the farmers had not used any sources for upgrading their knowledge. Out of those who did use sources, the most used source emerged as information from

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'the other fellow farmers', who are doing well from past few years. *Radio, Television* and the *dealer* who delivers seeds and fertilizers were the next used source.

7. There is inefficient communication link between farmer members and company mangers. Losses will always occur in the absence of a dependable communication system.
8. In the absence of timely and correct information about prices, arrivals and market trends, compounded with the problems of low cash-at-hand and proper advice, farmers are forced to sell their produce at lower-than-expected rates.
9. Containerization is also, the weakest aspect in the procurement chain especially till it reaches company store room. In general, packaging materials of unsuitable quality, such as large sacks, rough wooden boxes, second-hand cartons, bamboo baskets, or rattan containers are liable to cause produce to suffer from bruising, crushing and puncturing.

DISCUSSION AND POLICY IMPLICATION

The present generation of farmers has lost much in terms of indigenous agricultural knowledge and skills and in the integrity of the social organization in which indigenous innovation capacity is embedded. Public policy in developing countries has failed to invest in educating farmers on how to deal with variable agro-ecosystems and a changing world (Van den Berg & Jiggins, 2008).

Post-harvest losses from physical and pathological (microorganism development) damage to perishables can be minimized by taking care while harvesting and by proper storage at conditioned environment, but limited economic background may obstruct farmer to take such care and treatment. A low-cost cooling system can help poor farmer for extending the life of perishables and can help in drastically changing traditional handling and storage limitations. New innovative measures can help in temperature reduction at low cost that could make a big difference. Usually the fruits and vegetables are picked manually by many inexperienced workers. Further bulk of these fresh produce are either undertaken various traditional methods of storage or to be sold to agents (intermediaries) at very low cost. A perception of immediate high cost of hiring cold storage space does not allow a farmer to perceive the justified advantage of the refrigerated storage. The observation also suggested that there are very less extension education program from the government.

There are manifold reasons which can reduce the value of product. Improper handling can result excessive exposure to rain, drought or fluctuating temperature. In correct stage of product maturity, contamination by micro-organism and physical damage can further reduce the value of fresh produce. It was also observed that small farmers do not have their own means of transport of their products. So they are dependent on intermediaries to get means of transportation. This again causes delay which means piling up of loss.

A farmer requires understanding the value of information especially about the new trends and cost effective innovations to preserve perishables. A well aware farmer can know about market prices, sellers, buyers, transporters, other intermediaries and relevant information. Now days with little communication cost accessing this information are easier than before. It is observed that still farmers stuck to agents (who exploit them) especially for sale of perishables. Using the communication devices there are many ways to find customers. A proper planning can always help farmers in getting right buyer. A proper awareness can always help farmers in getting profit and bargaining power while dealing with middle men.

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One of the underlying reasons for such problems is the lack of knowledge, skills and unawareness about the market information. Small Indian farmers are poverty stricken, illiterate and dependent on monsoon. The poor market information and low value addition capacity, gives them low margins and low risk-taking abilities (Bhalla, 2005). A little bargaining power and heavy dependence on their farm produce for basic needs pile up farmer's woes and compel them in becoming victims to the exploitative market intermediaries who deny them a fair share of the consumer rupee. Thus, small farmers enter a vicious circle and then find it difficult to come out (Sridhar & Ballabh, 2006).

Consistent temperature maintenance is an imperative constraint throughout the cold chain. The temperature of fresh produce should be maintained below 5^{o}C to reduce the proliferation of spoilage microorganisms and human pathogens. Quality loss at farm, which is the first link of the cold chain, drastically degrades the value of the produce in the subsequent links. Product condition at market reflects the cumulative quality losses at each link of the cold chain. At farm level there are few environmental conditions that can be managed to get good quality product to the next link. These are product temperature and humidity surrounding the product, ethylene gas concentration around ethylene sensitive products, and atmospheric composition (Smale et al., 2006).

From the farmers' perspective, the cold chain management is not easy even when operating in a developed economy such as the US and UK. It gets even more challenging in developing economy like India. In most developed economies, with affirm support from robust infrastructure, there is limited uncertainties in business process related to logistics. However, in developing economies logistics tends to poses several types of challenges due to unpredictable environment, weaker infrastructure and uncertainty in availability of basic necessities like water, power etc.

CONCLUSION

In this paper, the results of a questionnaire-based survey on the awareness and practices of Indian farmers towards the readiness as an active link in cold supply chain are reported. The two main objectives of the survey were firstly, to examine the current practices and issues related to Indian farmers preparedness towards cold chain and secondly, to test the validity of some hypotheses that have been formulated. The description of the methodology adopted to achieve the survey-oriented research objectives was also discussed. Subsequent to this, observations from the survey have been reported and discussed. It was observed from the survey findings that pre-cooling practices at farm level have significant influence on postharvest losses and value loss of perishables throughout the cold chain. Also, the practices of inadequate transparency in pricing at farmer end are also witnessed. Lack of awareness about the use of IT for better informed, Improper handling, loading and loading of products, Fragmented production, leading to fragmented chains, Traders dominate the chain are also major reasons for the poor stare of farmers and thus a farmer is totally a separated link. As per the study conducted under Government of India, the state of Indian farmers is characterized by prevalence of small and tiny holding that are financially non-viable. Discrimination between small farmers and big farmers by traders, extension service providers, government officials etc., were also mentioned by the farmers during the interview.

It was also observed that lack of knowledge and skills in staff involved in the cold chain has also significant influence on quality and safety measures. Traceability and service level improvement are important factors for any cold chain and requires sufficient attention. Between the MMP and FV sectors, it is observed that MMP sector is relatively more conscious about the cold chain practices at farm level.

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The situation in most of the developing economies is by and large similar to Indian condition. These finding may help developing economies in policy level decision making. Finally, it can be concluded that these findings have apparently led to the focus of industry and academia to study the various issues, related to CCM in the companies who are in the business of perishables.

REFERENCES

Aidoo, K. E. (1993). Post-harvest storage and preservation of tropical crops. *International Biodeterioration & Biodegradation*, *32*(1-3), 161–173. doi:10.1016/0964-8305(93)90048-7

Allais, I., & Letang, G. (2009). Interactions among cooling, fungicide and postharvest ripening temperature on peaches. *International Journal of Refrigeration*, *32*(6), 457–465.

Ames, H. (2006). Authentication from a cold chain perspective. *Pharmaceutical Commerce*. Retrieved from http://www.pharmaceuticalcommerce.com/frontEnd/main.php?idSeccion=327

Beuchat, L. R., & Ryu, J. H. (1997). Produce handling and processing practices. *Emerging Infectious Diseases*, *3*(4), 459–465. doi:10.3201/eid0304.970407 PMID:9366597

Bogataj, M., Bogataj, L., & Vodopivec, R. (2005). Stability of perishable goods in cold logistic chains. *International Journal of Production Economics*, *93–94*, 345–356. doi:10.1016/j.ijpe.2004.06.032

Brackett, B. G. (1992). In vitro fertilization in farm animals. In A. Lauria, & F. Gandolfi (Eds.), *International Symposium on Embryonic Technology in Domestic Species: Trends in Research and Applications*. Portland Press.

Buurma, J., & Saranark, J. (2006). Supply-chain development for fresh fruits and vegetables in Thailand. In R. Ruben, M. Slingerland, & H. Nijhoff (Eds.), *Agro-Food Chains and Networks for Development*. Dordrecht: Kluwer/Springer Verlag.

Dahlenburg, A. (2001). *Customising the cold chain for your export product: a scientific perspective*. Cold Chain Logistics Conference. Retrieved from http://www.transport.sa.gov.au/pdfs/freight/lamp_docs/coldchain_papers/dahlenburg.pdf

Dey, I. (1993). *Qualitative Data Analysis: A User-friendly guide for social scientists*. London: Routledge. doi:10.4324/9780203412497

Duiven, J. E. & Binard, P. (2002). *Refrigerated Storage: New Developments*. International Institute of Refrigeration. Retrieved from http://www.iifiir.org/en/doc/1042.pdf

Fernandez-Trujillo, J. P., Cano, A., & Artes, F. (2000). Interactions among cooling, fungicide and postharvest ripening temperature on peaches. *International Journal of Refrigeration*, *23*(6), 457–465. doi:10.1016/S0140-7007(99)00067-5

Forza, C. (2002). Survey research in operations management: A process based perspective. *International Journal of Operations & Production Management*, *22*(2), 31–40. doi:10.1108/01443570210414310

George, D., & Mallery, P. (1999). *SPSS for windows, Step by step*. Allyn and Baconpp.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Griffith, C. J. (2006). Food safety: Where from and where to? *British Food Journal*, *108*(1), 6–15. doi:10.1108/00070700610637599

Jain, N. (2007). Food retail opportunities and challenges. *International conference on Agribusiness and food industry in developing countries: Opportunities and challenges*.

James, S. J., Evans, J., & James, C. (2008). A review of the performance of domestic refrigerators. *Journal of Food Engineering*, *87*(1), 2–10. doi:10.1016/j.jfoodeng.2007.03.032

Jarimopas, B., Rachanukroa, D., Singh, S. P., & Sothornvit, R. (2008). Post-harvest damage and performance comparison of sweet tamarind packaging. *Journal of Food Engineering*, *88*(2), 193–201. doi:10.1016/j.jfoodeng.2008.02.015

Joshi, R., Banwet, D. K., & Shankar, R. (2009). Indian cold chain: Modeling the inhibitors. *British Food Journal*, *111*(11), 1263–1280. doi:10.1108/00070700911001077

Joshi, R., Banwet, D. K., & Shankar, R. (2010). Consumer Link in cold chain: Indian scenario. *Food Control*, *21*(8), 1137–1142. doi:10.1016/j.foodcont.2010.01.008

Khan, A. U. (2005). *The domestic food market: is India ready for food processing?*. Conference on SPS Towards Global Competitiveness in the Food Processing Sector, Pune, India. Retrieved from http://www.idfresearch.org/pdf/dommarket.pdf

Lemeilleur, S., & Codron, J. M. (2011). Marketing cooperative vs. commission agent: The Turkish dilemma on the modern fresh fruit and vegetable market. *Food Policy*, *36*(2), 272–279. doi:10.1016/j.foodpol.2010.11.024

Manikas, I., & Terry, L. A. (2009). A case study assessment of the operational performance of a multiple fresh produce distribution centre in the UK. *British Food Journal*, *111*(5), 421–435. doi:10.1108/00070700910957276

Manzini, R., Accorsi, R., Ayyad, Z., Bendini, A., Bortolini, M., Gamberi, M., Valli, E., & Toschi, T.G. (2014). Sustainability and quality in the food supply chain. A case study of shipment of edible oils. *British Food Journal*, *116*(12), 2069 – 2090.

Meenke, C. P. (2006). *Always Keep Cool*. Germanischer Lloyd Certification (GLC). Retrieved from http://coolchain.org/uploads/certified!2006-01ECCQI.pdf

Miles, J., & Shevlin, M. (2001). *Applying regression and correlation*. Thousand Oaks, CA: Sage Publications.

Narula, S. (2011). Reinventing cold chain industry in India: Need of the hour. Interview with Mr Sanjay Aggarwal. *Journal of Agribusiness in Developing and Emerging Economies*, *1*(2), 97–99. doi:10.1108/jadee.2011.52401baa.001

Pai, T. K., & Sastry, S. K. (1989). Effects of storage conditions on colour change of selected perishables. *International Journal of Refrigeration*, *12*(6), 350–353. doi:10.1016/0140-7007(89)90067-4

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Patton, M. Q. (1990). *Qualitative Evaluation and Research Methods*. London: Sage Publications.

Rediers, H., Claes, M., Peeters, L., & Willems, K. A. (2009). Evaluation of the cold chain of fresh-cut endive from farmer to plate. *Postharvest Biology and Technology*, *51*(2), 257–262. doi:10.1016/j.postharvbio.2008.07.017

Rosset, P., Cornu, M., Noel, V., Morelli, E., & Poumeyrol, G. (2004). Time–temperature profiles of chilled ready-to-eat foods in school catering and probabilistic analysis of *Listeria monocytogenes* growth. *International Journal of Food Microbiology*, *96*(1), 49–59. doi:10.1016/j.ijfoodmicro.2004.03.008 PMID:15358505

Salin, V., & Nayga, R. M. Jr. (2003). A cold chain network for food exports to developing countries. *International Journal of Physical Distribution & Logistics Management*, *33*(10), 918–933. doi:10.1108/09600030310508717

Shewfelt, R. L., Prussia, S. E., & Sparks, S. A. (2014). *Challenges in Handling Fresh Fruits and Vegetables* (3rd ed.). Postharvest Handling. doi:10.1016/B978-0-12-408137-6.00002-8

Shukla, M., & Jharkharia, S. (2013). Agri-fresh produce supply chain management: A state-of-the-art literature review. *International Journal of Operations & Production Management*, *33*(2), 114–158. doi:10.1108/01443571311295608

Singh, R. B. (2007). Linking farmers to market. *International conference on Agribusiness and food industry in developing countries: Opportunities and challenges*.

Skerratt, S. & Midmore, P. (2000). *People-centred analysis: the use of qualitative evaluation to assess sustainable rural development*. RICS Research Conference Roots. Retrieved from http://www.rics.org/site/download_feed.aspx?fileID=2592&fileExtension=PDF

Smale, N. J., Moureh, J., & Cortella, G. (2006). A review of numerical models of airflow in refrigerated food applications. *International Journal of Refrigeration*, *29*(6), 911–930. doi:10.1016/j.ijrefrig.2006.03.019

Smith, J. N. (2005). Specialized logistics for a longer perishable supply chain. *World Trade*, *18*(11), 46–48.

Sridhar, G., & Ballabh, V. (2007). Indian Agribusiness Institutions for Small Farmers: Role, Issues and Challenges. In Institutional Alternatives and Governance of Agriculture. Academic Foundation.

Srivastava, R. (2006). *Role of Logistics in Foods Business*. ISB Hyderabad. Retrieved from http://www.isb.edu/simc2006/html/PDFfiles/RajeshSrivastava_Hyderabad.pdf

Sun, D. W., & Zheng, L. (2006). Vacuum cooling technology for the agri-food industry: Past, present and future. *Journal of Food Engineering*, *77*(2), 203–214. doi:10.1016/j.jfoodeng.2005.06.023

Tanksale, A., & Jha, J. K. (2015). Implementing National Food Security Act in India: Issues and challenges. *British Food Journal*, *117*(4), 1315–1335.

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Ukuku, D. O., & Sapers, G. M. (2007). Effect of time before storage and storage temperature on survival of Salmonella inoculated on fresh-cut melons. *Food Microbiology*, *24*(3), 288–295.

Zhang, G., Habenicht, W., & Spie, W. E. L. (2003). Improving the structure of deep frozen and chilled food chain with tabu search procedure. *Journal of Food Engineering*, *60*(1), 67–79. doi:10.1016/S0260-8774(03)00019-0

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Section 7
Critical Issues and Challenges

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Chapter 73
The Loss and Damage of Environmental Ethics in the Threshold of African Culture:
Environmental Ethics and African Culture

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ABSTRACT

It has been argued that human actions through pollution and other activities have imperil survival, harm health and dislocate the well-being of man on earth. This argument's corollary is that, given the curious datum that human beings are implicated in loss and damage of the environment, actions performed by individuals have aggregate negative consequences on the environment. Yet, what African culture is and how it matters in environmental ethics is regrettably unexplored and disproportionately contested. This study examines the contributions of culture toward the preservation and protection of the environment for future generation. The study adopts qualitative methodology and content analysis, as well as "relational theory" to respond to the thesis that African culture has a moral responsibility and an in-built mechanism to protect human interactions with nature and environment. The findings show that culture has the capacity to avert loss and damage of the African environment through African ethics.

INTRODUCTION

Regardless of all the distinctions that can be made on a theoretical level amongst ethicists and their different value positions in environmental ethics, there seems to be a growing need today in the world to articulate a pragmatic environmental ethics that can guide our actions, decisions and preferences in the individual, social, economic, corporate and public decision-making contexts (Pojman, 2001). This is why in Africa; environmental ethics is part of the larger issue of how to live an ethical life. This clearly manifest in the verity that harm to the natural environment though come in great measure from the collective detrimental actions and practices of the inhabitants constitutes the collective responsibility

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of all. It is against this backdrop that it is proper to state that cultural and geographical contexts shape environmental orientations in all societies, Africa inclusive (Murove, 2004). This also explains why there exist interactions between the people and their environment which are as old as human civilization.

However, the problem of managing those interactions has today been transformed by unprecedented increases in the rate, scale, and complexity of crisis, degradation and other environmental challenges. In spite of this development, African societies, as organized and functioning human communities, have undeniably developed for itself ethical systems such as ethical values, principles, rules and norms intended not only to guide her social and moral behavior but protect her environment (Masaka & Chemhuru, 2010). This clearly depicts the sense in which human beings in Africa value nature as a vital component in the construction of their environmental ethics.

Nonetheless, the problems and crises afflicting the management and preservation of Africa's environment today are primarily the symptoms of the deep-rooted, long-term effects of centuries of neglect and insensitivity (Weberzik & Wilson, 2008). It is apparent that Africans have always been dependent on the natural resources in their environment for their livelihood. That is why about 70% of the people in Africa rely solely on forests for their food, shelter, energy and even medicine. This lends credence to the fact that the character of the environmental changes that today's lifestyle and technological advancement has produced and the increased public awareness of the importance of the natural environment connotes that we have entered a new age of environmental challenges (Omari, 1990). Across the world however, people are beginning to understand that part of what is needed to meet these challenges is the development of a new and more robust environmental ethics. This study therefore provides an overview of some of the environmental issues facing Africa and examines the role of African culture cooperation in meeting these challenges. An environmental performance analysis is used to identify the loss and damage of environmental challenges in Africa, as well as the significance of environment in African ethical life.

Conceptual Clarification

In order to commence an effective conversation on this paper, it is pertinent that we offer some clarification of notions that would facilitate effortless comprehension of the subject matter of our discussion. They include the following: environmental ethics, environment, African environment, deep ecology, and Humanistic ethics.

Environmental Ethics

Environmental ethics is a theory and practice about appropriate concern for, values in, and duties to the natural world. In this study, environmental ethics is understood as a research field and academic discipline, which focuses on principles and values regulating human relations towards nature, either as a whole or in its particular forms, the prerequisites and consequences of these relations, and theoretical, normative and practical issues related to them. Environmental ethics is deeply connected to the environmental sciences, on the one hand, and the humanities on the other hand (Guha, 2000). These are important epistemic resources for environmental ethics. Environmental ethicists need to understand environmental problems to be able to provide their ethical analyses. Environmental issues, like global climate change, air pollution, reduction of biodiversity and wilderness, desertification, etc., are practical issues and in so far as they have been produced mostly by un-precautious human activity, they cannot be solved by scientific and technological means only. Humans as individuals and communities should

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recognize their responsibilities to solve such problems and this may be possible only on the basis of a fundamental shift in their outlook and value attitudes towards nature. Environmental Ethics aims to clarify these responsibilities, the condition of their possibility, their value foundations and behavioral implications (Harris, 2005).

The field of environmental ethics concerns human beings' ethical relationship with the natural environment. Although several philosophers have written on this topic throughout history, environmental ethics only developed into a specific philosophical discipline in the 1970s (Velasquez & Rostankowski, 1985). This emergence was no doubt due to the increasing awareness in the 1960s of the outcome and impact of technology, industry, economic expansion and population growth which were exerted on the environment. The development of such awareness was however aided by the publication of Rachel Carson's Silent Spring, in 1962, which alerted the public on the widespread use of chemical pesticides posing a serious threat to public health and leading to the destruction of wildlife. Of similar significance was Paul Ehrlich's 1968 book, "the Population Bomb", which warned of the devastating effects the spiraling human population had on the planet's resources (Velasquez and Rostankowski 1985). Of course, pollution and the depletion of natural resources have not been the only environmental concerns since that time. Others were the dwindling plant and animal biodiversity, the loss of wilderness, the degradation of ecosystems, and climate change were all issues that have implanted themselves into both public consciousness and public policy over subsequent years. In the light of this, the job of environmental ethics is to outline our moral obligations in the face of such concerns. In a nutshell, the two fundamental questions that environmental ethics must always strive to address are: what duties do humans have with respect to the environment, and why? The latter question usually needs to be considered prior to the former. In order to tackle just what our obligations are, it is usually thought necessary to consider first why we have them (Ojomo, 2011). For example, do we have environmental obligations for the sake of human beings living in the world today, for humans living in the future, or for the sake of entities within the environment itself, irrespective of any human benefits? Different philosophers have given quite different answers to this fundamental question which, as we shall see, has led to the emergence of quite different environmental ethics (Brechin & Kempton, 1994).

Environment

Environment is broadly defined as a community's natural surroundings (air, water and land) that contain natural resources (wood, herbs and medicine) for which the availability, accessibility and quality shape rural livelihoods and the overall health and wellbeing. Therefore, the local environment refers to the local setting within which proximate natural resources support rural livelihoods (Harris, 2005). The state of the local natural environment is central to the well-being of millions of rural households in developing countries. Environmental concern represents a specific component of broader environmental perceptions such as problem of resource availability, accessibility and quality. The moral values and cognitive beliefs of a culture play an important role in how well human beings adapt to their natural environment. Therefore, our approaches to environmental ethics should differ slightly depending on the cultural heritage and religious traditions through recognition of ecological knowledge, and an awareness of how modern cultural values have destroyed sustainable resource uses (Godofsky, 2010). We should appreciate the way in which moral ideals motivate persons to care for the world around them. It is through ethics that our roles are clarified through the value system in policy decisions and giving moral reasons for alternative course of action. By respecting nature, we can even achieve the ecological integrity towards the green

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economy. Ethics helps in resolving some of the outstanding value conflicts that thwart conservation and development projects and even in defining a new social paradigm (Foltz, 2003).

African Environment

African environment is made up of Africa's terrain which includes lands, deserts, hills, mountains, rivers, lakes and coasts. These terrains have endured several millennia of modification caused by human activities. The forest mosaic, soils, vegetation and population settlements also encountered diverse transformations from time immemorial. Indigenous and exotic species, and new knowledge have contributed to the biodiversity in plants, animals and viruses on the continent. New crops like maize, cassava and cocoa have adapted to semi-arid savannah woodland, rainforests, coastal swamps and highland plateau (Ojomo, 2011). Africa's climate consisting of wet summers and dry winters dramatically changes life, vegetation and access to water on the continent. The animal kingdom in Africa comprises both diminutive and huge mammals. Fauna includes domesticated and wild, herbivorous and carnivorous species. Herbivores are in the majority and are sustained by vegetation; grasses, bush and trees, while carnivores – feline, canine, and avian – subsist on the herbivores. Omnivorous species live on different types of food including both plants and animals (Ojomo, 2011).

The African environment is also home to a range of benign and malignant disease agents, and some of them are protozoans, viruses, and nematodes which cause epidemic and endemic illnesses to both humans and animals. On the other hand, insects like lice, mosquitoes, locusts, tsetse fly, black, green flies and ticks are hosts or vectors of disease agents and make seasonal migrations following moist, vegetation and temperature influencing other fauna and flora in different ways. However, humans are probably the key determining factor in African environmental history (Callicott & Clare, 2005). Human actions, beliefs, notions, labor and tools have played a critical role in changing African environments. Central to environmental change in Africa are multi-layered interactions involving the physical world, flora, fauna and human activity (Hjort & Salin, 1980). These interactions also encompass tradition, beliefs, ideas, perceptions and prescriptions regarding habitats and inhabitants. Indeed, the African environment comprises both tangible and intangible, human and non-human activity, and the resulting phenomenon.

Theoretical Framework

This study is based on relational theory of corporate social responsibility taxonomy which has its root from the complex web of society-environment relationships. The theory emphasizes the role of social and cultural pressures imposed on institutions that can influence directorial practices and structures (Engel, 1990). Given that there is a great deal of heterogeneity of theories and approaches of moral responsibility, best practice and corporate social responsibility such as the utilitarian theory, managerial theory, and relational theory, social contract theory, etc, discussion in this paper is supported with a comprehensive analysis by Secchi (2007) and Maimunah (2003) compared with an analysis by Garriga & Mele (2006) objective responsibility.

For the purpose of this study, the stakeholder model and the social contract model have been adopted for the analysis of the interaction of environmental ethics with African culture. Stakeholder approach has been developed as one of the strategies in improving the management of the society. It is also said as a way to understand reality in order to manage the socially responsible behavior of societal institutions. The stakeholder approach further considers the society as an interconnected web of different interests where

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self creation and community creation happen interdependently; and individuals behave altruistically. Based on Garriga and Mele's (2002) analysis, stakeholder approach is both within the integrative and ethical theories, where the former emphasizes the integration of social demands and moral responsibility, while the latter focuses on the right thing to do to achieve a good society. This is strongly supported by the standpoint that considers ethical duties towards stakeholders of the society and environment, respectively. In the same vein, corporate social responsibility is derived from the moral legitimacy the individual achieves in the society and the understanding about corporate social responsibility is contained in the justification of social actions that legitimize the behavior of the individual.

Against the backdrop of the underpinnings of this theory, it is imperative that an appreciation of the relational theory analysis is the most appropriate analytic paradigm for locating the loss and damage of environmental ethics in the midst of numerous environmental challenges in Africa. At the center of the adopted theory is an attempt at chronological scrutiny of the problems and demands of the environment aimed at revealing not only the patterns and regularities of the incidents, but also the impact and interrelationship it has had in the configurations of society. Using this framework therefore, this study will demonstrate that the environmental problem of many societies in Africa are as a result of individual and institutional failure in acquiescing to cultural prescriptions and best practices in the preservation of the environment in Africa. This study therefore is analyzed based on the stakeholder and social contract models of the relational theory principles.

Methodology and Data Presentation

The study employed the qualitative survey research design of an ex-post facto type. The independent variable in this study is African culture as it relates to its obligation for future generation, while the dependent variable is environmental ethics in the loss and damage of the African environment. The strategy adopted for this study involved a multiplicity of ethnographic methods such as individual in-depth interviews, focus group discussions and informal discussion sessions. The study population comprises of male and female who constitute community inhabitants of the study area, elders and traditional custodians of culture. Based on the principles of informed consent and confidentiality, information was voluntarily and successfully abstracted from a total of 348 respondents comprising of: 65 male, 157 females, 20 NGO activists, 45 traditional custodians of culture, 41 researchers, and environmental ethicists who are academics, and 20 religious leaders.

This was complemented with the examination of available secondary data from various sources such as educational institutions, government agencies, advocacy groups and different NGO offices. Field notes and tape recording went on simultaneously, while interviews were transcribed, anonymized and coded accordingly. Sample of 348 subjects were purposively selected from the population (Table 1). The population was divided into six clusters representing six countries: Nigeria, Ghana, Cameroon, Sierra Leone, Ethiopia, and Kenya. Each cluster consisted of 58 respondents. The respondents were selected accidentally from each cluster and target group. Data collection was entirely based on self-report and were collected from the respondents by six (three females and three males) research assistants. The interviewers were residents of the study area who knew the culture and language of the people.

The current study aims at studying the loss and damage of environmental ethics in the threshold of African culture amidst obligation for future generation and collecting data in a large quantity to examine the development, so it made use of qualitative methodology. In order to fulfill the goal of this study, a survey which embrace In-depth interview (IDI), was adopted to verify the findings of the survey method

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Table 1. Sample and population of study

S/N	Location/Cluster	Sample	Classification	Percentage
1	Nigeria	58	Male and Female	16.5%
2	Ghana	58	Male and Female	16.5%
3	Cameroon	58	Male and Female	16.5%
4	Sierra Leone	58	Male and Female	16.5%
5	Ethiopia	58	Male and Female	16.5%
6	Kenya	58	Male and Female	16.5%
	Total	348		100% approx.

Sources: Field survey, 2015

with open questions administered. The open questions were asked in face-to-face interviews. Every individual was asked to answer the questions after contemplating about the contributions of culture toward environmental preservation. Another method utilized for the study is the Focus Group Discussion (FGD), which is also a qualitative technique adopted to verify the findings of the survey method. Six FGDs were conducted, each per a location and cluster. Each FGD comprised of eight participants from elderly male and female, activists, traditional custodians of culture, environmental ethicists, and religious leaders.

Table 2 above reveals that 111 respondents were males, representing 31.9%, while 237 representing 68.1% were females. This was contrary to a widely held belief that males are more involved in environmental issues and cultural matters than the female. Observations during the survey were that males were relatively unwilling to neither accept the survey instrument nor participate in the FGD, than female.

Table 3 above shows that majority of the respondents were literate and understood the socio-religious and cultural implications of protecting the environment as a status of communal rights to cultural and environmental self-determination for future generation. This is evident in 51.7% of the respondents in Nigeria, 51.7% in Ghana, 46.5% in Cameroon, 44.6% in Sierra Leone, 53.4%in Ethiopia, and 48.2% in Kenya who have acquired the first and the second level of education. They adhere strictly to the moral responsibility of African culture to the environment which constitutes a group value and a source of social identity. It also shows that members of this society approves of the people's sense of community in environmental issues. The data further show that the respondents were knowledgeable enough to understand the cultural context of the environment. Similarly, respondents based on their educational attainment were conversant with the instrument of data collection used for this study.

Table 4 above shows that participants in FGD and IDI were all knowledgeable about the subject matter and could discern the import of the questions asked. In the six FGD with 9 participants each, with a total of 54 participants in all, male were 16 (29.6) and female 38 (70.4). In the survey, it is apparent that

Table 2. Sex distribution of respondents

Sex	Nigeria	Ghana	Cameroon	Sierra Leone	Ethiopia	Kenya	Frequency	Percentage
Male	15(26%)	21(36%)	18(31.1%)	12(20.6%)	25(43.1%)	20(34.5%)	111	31.9%
Female	43(74%)	37(64%)	40(68.9%)	46(79.4%)	33(56.9%)	38(65.5%)	237	68.1%
Total	58	58	58	58	58	58	348	100.00%

Source: Field Survey, 2015

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Table 3. Educational qualification of respondents

Educational Status	Nigeria	Ghana	Cameroon	Sierra Leone	Ethiopia	Kenya	Frequency	Percentage
Non-Formal	11(18.9%)	10(17.2%)	7(12.1%)	7(12.1%)	11(18.9%)	12(20.6%)	58	16.8%
FSLC	19(32.7%)	20(34.4%)	20(34.4%)	19(32.7%)	20(34.4%)	16(27.5%)	114	33.8%
SSCE	10(17.2%)	7(12.1%)	15(27.5%)	15(27.5%)	13(22.4%)	15(27.5)	75	21.5%
ND/NCE	5(8.6%)	7(12.1%)	8(13.7%)	7(12.1%)	8(13.7%)	6(10.3%)	41	11.8%
HND	9(15.5%)	10(17.2%)	4(6.8%)	7(12.1%)	3(5.1%)	7(12.1%)	40	11.5%
BA/BSc	4(6.8)	4(6.8)	4(6.8)	3(5.1)	2(3.4)	2(3.4%)	19	05.5%
MA/MSc	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Total	58	58	58	58	58	58	348	100.0%

Source: Field Survey, 2015

Table 4. Qualitative research table

Focus Group Discussion Demographic Table									
		Nigeria	Ghana	Cameroon	Sierra Leone	Ethiopia	Kenya	Frequency	Percentage
Sex	Female	6 (10.3%)	5 (8.6%)	6 (10.3%)	7(12.1%)	8(13.7%)	6 (10.3%)	38	65.5%
	Male	3(5.2%)	2(3.4%)	3(5.2%)	3(5.2%)	2(3.4%)	3(5.2%)	16	27.5%
Education	Non-Formal	3(5.2%)	2 (3.4%)	4 (6.8%)	5(8.6%)	3(5.2%)	4 (6.8%)	21	36.2%
	FSLC	4(6.8%)	5(8.6%)	4(6.8%)	3(5.2%)	3(5.2%)	2(3.4%)	21	36.2%
	SSCE	2(3.4%)	2(3.4%)	1(1.7%)	1(1.7%)	3(5.2%)	3(5.2)	12	20.6%
Occupation	Farming	3 (5.2%)	2(3.4%)	2 (3.4%)	3 (5.2%)	3 (5.2%)	3 (5.2%)	16	27.5%
	Selfemployed	4(6.8%)	5(8.6)	6(10.3%)	5(8.6%)	6(10.3%)	4(6.8%)	30	51.7%
	Unemployed	2(3.4%)	2(3.4%)	1(1.7%)	1(1.7%)	Nil	2(3.4%)	8	13.7%
Indepth Interview									
Cluster		Nigeria	Ghana	Cameroon	Sierra Leone	Ethiopia	Kenya	Frequency	Percentage
Sex	Male	18 (31.0%)	12 (20.6%)	14 (24.1%)	20 (34.4%)	15 (25.8%)	19 (32.7%)	98	28.1%
	Female	40(68.9%)	46(79.3%)	44(75.8%)	38(65.5%)	43(74.1%)	39(67.2%)	250	71.8%
Level of education	Non-Formal	8(13.7%)	7(12.0%)	5(08.6%)	10(17.2%)	10(17.2%)	9(15.5%)	49	84.4%
	FSLC	30(51.7%)	30(51.7%)	35(60.3%)	28(48.2%)	24(41.3%)	26(44.8%)	173	49.7%
	SSCE	20(34.4%)	21(36.2%)	15(25.8%)	20(34.4%)	24(41.3%)	20(34.4%)	120	34.4%
Occupation	Farming	21(36.2%)	23(39.6%)	23(39.6%)	33(56.8%)	37(63.7%)	34(58.6%)	171	49.1%
	Self-employed	28(48.2%)	31(53.4%)	32(55.1%)	20(34.4%)	18(31.0%)	19(32.7%)	148	52.5%
	Unemployed	9(15.5%)	4(6.8%)	3(5.1%)	5(8.6%)	3(5.1%)	5(8.6%)	29	08.3%

Source: Field Survey FGD/IDI, 2015

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majority of the respondents that gave their responses were female signifying that they are more involved in the practice of taking care of the environment especially as it involved agriculture in the subsistent scale which they play prominent role.

Based on the findings of table 5 above, there are significant relationships among the different variables indicating that in many communities, human beings involve themselves in un-precautious human activities that destroy the environment. It is apparent therefore, that rooms for accommodation of views and obliteration of ignorance are not foreclosed. This is evident in the opinion of 244 respondents (70.1%) that African societies have developed ethical systems such as ethical values, principles, rules and norms intended to guide social and moral behaviour to protect her environment. Findings also show that moral

Table 5. Respondents' reactions about the role of culture in protecting and preserving the environment in Africa

S/No	Items for Respondents' Reaction	Percentage of Agreement		
		Agree	Disagree	Neutral
1	In Africa, is environmental ethics part of the larger issue of how to live an ethical live?	280 (80.4%)	61(17.4%)	7 (2.2%)
2	Is the cultural and geographical context a factor in environmental orientations in all societies in Africa?	275 (79.0%)	73(21.0%)	Nil
3	Are you of the opinion that African societies have developed for herself ethical systems such as ethical values, principles, rules and norms intended to guide her social and moral behaviour to protect her environment?	244 (70.1%)	131 (37.6%)	12(3.4%)
4.	Is it correct that Africa values nature as a vital component in the construction of their environmental ethics?	200 (57.4%)	148(42.6%)	Nil
5	Are you of the opinion that African environment should be preserve?	276(79.3%)	69(19.8%)	3(0.9%)
6	In your opinion, is there any functional conservation ethics embedded in the knowledge system of your community?	224(64.4%)	124(35.6%)	Nil
7	Does the reason for preserving the environment considered a valuable project to be pursued in your society?	212(60.9%)	136(39.1%)	Nil
8	Are you aware that many sacred groves and spaces have been forced to disappear in many African societies?	262(75.3%)	86(24.7%)	Nil
9	Is urbanization and development a factor responsible for the degradation of the environment many communities in Africa?	272(78.2%)	76(21.8%)	Nil
10	From cultural, natural and religious perspectives, is the conservation of the environment a good thing to do?	228(65.5%)	120(34.5%)	Nil
11	Is the traditional conservation practices regarding sacred groves, trees, forest and natural features strictly adhered to in your community today?	262(75.3%)	55(18.7%)	31(8.9%)
12	Does your community support the degradation of the environment carelessly in the name of developmental activities like urban renewal, modernization, industrialization, and economic expansion?	232(66.7%)	116(33.3%)	Nil
13	Is there enough awareness on how to preserve the environment by your people culturally given the spiraling human population?	251(72.1%)	97(27.9%)	Nil
14	Do the modern cultural values have anything to do with the destruction of the environment and sustainable resource uses?	207(59.4%)	139(39.7%)	3(0.9%)
15	Do the moral values and cognitive beliefs of your culture play a role on how well your people preserve, protect and adapt to their natural environment?	193(55.5%)	150(43.1%)	5(1.4)

Source: Field Survey IDI, 2015

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values and cognitive beliefs of African culture play a great role on how the people preserve, protect and adapt to their natural environment. 55.5 percent of the respondents agreed that unprecedented misunderstanding of how African ethics help in resolving value conflicts oftentimes thwarts conservation and moral responsibility toward the environment. In fact, it can be argued that adherence to African culture does not only bequeath an environmental obligation to preserve and protect the society for the sake of humans living in the world today but also for the future generation.

Discussion of Finding

The study indicates a significant correlation between the cultural and geographical context of environment ethics and African societies. This study found out that in Africa, human actions, beliefs, notions, labour and tools, all play a critical role in changing African environment. The issues of environmental ethics are momentous and involve moral choices of enormous scale, which we must make. Our moral responsibility to nature and to the future is of unprecedented significance and a responsibility that we cannot escape. That is the essence of environmental ethics.

The study reveals that this effort have produced mixed results because of failure to take cognizance of the complex nature of the environmental issues involving politics, culture, rights and history of the people and institutions. This is in spite of the fact that several attempts made and facades as a rescue enterprise in many societies disregards the imperative of environmental ethics as challenging involving life-threatening concerns. This study further discovers that by failing to recognize the very dynamism of the concept of African environmental ethics, a dilemma is created by turning the campaign against African environmental crisis, based on the nature of the crisis which is anchored on poverty, industrialization and economic pressures. Therefore, the dichotomy and conflict between tradition and modernity represented in the prevailing social structures, constitutes a masks complex patterns of the nature of the environmental crisis seeking understanding and attention. However, evidence from the field further suggests that both traditional and modern social structures have led to environmental degradation, oppression and destruction. According to Mmama Bassey Antia, the high level inaction and lack of attention to environmental matters today are the reason why we have high numbers of death and ill-health in our society.

In sum, it is understandable to argue that in Africa, environmental ethics is a larger issue of how to live an ethical live. As a means of further justifying the practice of environmental ethics, Madam Nkoyo Owoanam avows that cultural and geographical factors of environmental orientations is crucial for all societies in Africa. This position explains why African societies have developed for herself ethical systems such as ethical values, principles, rules and norms intended to guide her social and moral behaviour to protect her environment. At this juncture, there is essentially the need to consider how individual choices and cultural self-determination play out in the justification for environmental protection.

Religiously speaking, the study also discovered that in Africa, the maintenance of certain tradition and, by extension, a specific cultural identity such as the traditional conservation practices manifest in sacred groves, shrines, spaces, trees, forest and natural features strictly adheres to religious beliefs, culture and tradition of the Africans regarding the obligation to the environment. This behaviour when critically evaluated suggests a link with the people's traditional religion. From the responses of most respondents, the study reveals that the standard African man and/or woman are the one with moral responsibility to the environment. In the FGD for instance, it was gathered that the moral values and cognitive beliefs of African culture play a central role on how well African people preserve, protect and adapt to their natural environment.

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Moral Responsibility of African Culture to Environmental Ethics

The issues of environmental ethics are momentous and involve moral choices of enormous importance that we can make and even, which we must make. Moral responsibility normally implies knowledge, capacity, choice, and value significance (Agius & Chircop, 1998). Our moral responsibility to nature and to the future is of unprecedented significance and urgency, and it is a responsibility that we cannot escape. That is the essence of environmental ethics. Until fairly recently, human actions and effects on the environment were regarded as neutral simply because we assumed nature was both impersonal and too vast to be injured by our interference. Environmental ethics is concerned with the issue of responsible personal conduct with respect to natural landscapes, resources, species and non-human organisms (Bakut, 2006). In Africa, the African environment allows for a tripartite interaction of beings such as human beings, non-human animals and spiritual beings.

Consequently, Africans are obliged with a moral responsibility to show worth and value to their fellow human beings, non-human animals, as well as the spirit beings. Respect and gratitude to the ancestors as spirit beings is realised by continuing to care for nature in the present, and emulating the example of previous generations, by ensuring that the next generation also inherits an environment "in good shape" (Agius & Chircop, 2006). In this responsibility, a two-sided concept of stewardship in the management of the environment involving obligations to both ancestors and descendants which motivates environmental carefulness is required. Of all the duties owed to the ancestors, none is more imperious than that of husbanding the resources of the land so as to leave it in good shape for posterity (Ekeli, 2004).

African idea of environment has a deeper worth and weight against which it is considered immoral to abuse or misuse the environment. This explain why African worldview presents an environment as a background on which to measure and locate the significance and relevance of the human life and which spells out the danger of damaging the environment. Therefore, the environment in the African thought ought not be seen and understood as an economic item or a social space, but where to locate the significance and relevance of life (Lizanne, 2005). According to Iroegbu (2005), Africans have a deep reverential deference for life where its beginning, growth and end is elaborately celebrated. (Iroegbu, 2005). Life in Africa is held to be good because of its ability to regenerate perpetuity. By perpetuity is meant the ability to regenerate life itself. Thus the African thinking of celebration of life stems from a distinct framework that can be captured by the cult of perpetuity and ancestorship. The environment in Africa is thus seen as a metaphysical interpretation which provides a moral lens or duty that drives the Africa theory of life.

From this perspective, the environment is intended to serve as a moral support hence it should be treated fairly well since it will be wrong to expect a good thing from an environment that has been badly treated by its inhabitants. It is therefore, these elements of reciprocity that the African moral world demands. Consequently, it is then totally wrong and contrary to an African environmental world if the source of ill-will and discord finds its root in the resources of the environment because by doing so, the environment is negative or destructive moral agent (Ugwuanyi, 2011). This analysis of moral responsibility explains why environmental ethics has only recently attracted the attention and concern of environmentalists and the general public. Today, it is a common knowledge that humans know that they can cause massive and permanent damage to natural landscape, resources and ecosystems. Not only do humans know that they can cause these insults, they also know how they can cause them, and how they can prevent or remedy them. But the fact that knowing this exacts a moral obligation to act

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with care, foresight and at times, with forbearance and constraint constitutes veritable operation space for environmental ethics.

Cultural Agents of Articulating Environmental Ethics in Africa

In African society, environmental activities are always linked with cultural and religious activities, with art and magic, if not with the realm of the mystical. African communities usually focus on the interrelatedness of all systems in the natural African world including the spiritual world (Adegoroye, 1997). When looking at the environmental ethics platform of African people, we can conclude that harmony with nature is the key concept. Man is not above nature, but the flourishing of both man and nature has value. This explains why in the traditional society, African people live in great harmony with the plants of the environment, excluding the wild animals. The traditional ecological knowledge goes beyond noting the interrelatedness of specific organisms. It embraces an all-encompassing world view of total relationship (Ojomo, 2011). This is where the sense of communality and oneness with the earth features very strongly in African societies (Mangena, 2013). This study is however, of the opinion that the attempts to find new solutions to the current environmental crisis in our contemporary societies can benefit immensely from looking back at the traditional ways as well as indigenous knowledge and culture of the people of Africa. Environmental ethics in Africa therefore, can best be articulated as found in the African folktales, riddles, taboos, sacred groves and spaces, trees, and features as well as rituals.

Taboos

The belief in the supernatural world is still prevalent among African communities. For this reason, Africans belief in certain avoidance rules has moral implications on the human person and how one has to relate with his surrounding environment. In Africa, taboos form an integral part and parcel of her morality (Essien, 2013). Among the people, environmental taboos have a pivotal moral role toward the ontological wellbeing of both the individual person and the environment at large. Prohibitions and restrictions through taboos on indefensible use of certain plant species, forests, mountains, rivers, pools and nonhuman animals, among other ecological species in the ecosystem, is not a new knowledge among many Africans, but reflects a long held African tradition and culture (Masaka & Chemhuru, 2010). This mentality is currently very lively and continues to shape the environmental ethics of several African societies. Although Africans have greatly felt the impact of the full weight of the domineering influence of western values, colonization and globalization, they have continued to cling on to some of their cherished values, including taboos.

With regard to the continued relevance of taboos in contemporary African societies, Gelfand (1973) rightly notes that "Africa possesses much that is worth retaining and the prospects are that they will save a good deal of it in succeeding generations." Despite the tide of modernity and cultural imports, contemporary African societies remain attached to some of their fundamental values, such as taboos. Whether, one has received a western education or has been imbued with a huge dosage of the western ways of life, unfailing adherence to certain aspects of African culture is an actuality as evident in taboos. Given that violation of African taboos are believed to invite an angry reaction at a supernatural level (Tangwa, 2011), fear of the unknown discourages the would-be offender of the African moral code to act in such ways that negates the moral code. One aspect of the African cosmology that has not succumbed to the weight of cultural globalization is the primacy of the spiritual world. Thus, since violation of

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taboos is thought to invoke the anger of the spiritual world, no one is prepared to act in ways that anger the spiritual world even though one had no sufficient knowledge to validate such claims.

As a result of conceptualizing taboos not simply as avoidance rules that are merely observed by the Africans, but as a cultural agent of articulation of environmental ethics as well as an instructive tools aimed at inculcating desirable behavior, this study evaluates the extent to which taboos inform an 'environmental ethic' that emphasizes on deep ecological awareness even though they may appear, on the surface, to be simple prohibitions on unsustainable use of certain aspects of nature, such as sacred sites, mountains, rivers, pools, and some nonhuman animals (Essien, 2013. African environmental taboos consequently transcend simple prohibitions on certain sacred sites, plants and nonhuman animal species, pools, and rivers, among others, and enforce a desirable and sustainable use of the environment. In this regard, Gelfand (1973) argues, that "when a collection of African averting regulation is considered, it is evident that correct behavior is being emphasized." Thus taboo wisdom is examined as promoting desirable environmental ethics among the African people.

Cultural Folktales

By examining the folktales and riddles of the African people, it will be discovered that the people see many of the different occurrences and modes of expression in life as very much influencing others. But in order to understand the role and place of culture and oral traditions in the environmental ethics of African people, it is pertinent to situate the 'folktales and riddles of the people in its proper perspective (Lizanne, 2005). In Africa, oral traditions are one of the sources of social, economic, environmental and philosophical knowledge in non-literate cultures. It helps non-literate people to acquire a wide range of knowledge (Kelbessa, 2002). It seems that most African tribes use oral media like folktales, riddles, proverbs and songs to teach and entertain the young ones as well as the old. It is a way of sharing norms, beliefs and wisdom, and instructs the young as well as the rest of the society on acceptable and commendable behaviour. These oral media sources include the historical origins, migrations, war and settlement, records of land heritage, moral principles, social and political life, God, knowledge of birds, animals, plants, geologic features and the relationship between human beings and the natural environment which differs very much from general western norms and ways of living (Lizanne, 2005).

Because majority of African people are still very much dependent on natural resources for survival, and because they are living in and among nature and wild animals, environmental education begins in each and every family. Fathers and mothers teach their children how to behave and live with the natural environment. Understanding starts at an early age and develops gradually (Kelbessa, 2002). This wisdom and instruction regarding the relationship with the natural environment is thus transmitted since early childhood through the use of folktales and riddles containing some moral lesson. These moral lessons embody values, items of advice or warning, orders or prohibitions which are useful to develop environmental consciousness (Kelbessa, 2002). Although the African concept that harmony between man and the environment leads to the prospering of man, which is a valuable lesson to the west, the effects of such actions on environment, especially on animals, is better experienced than imagined. It is a veritable source of cultural diffusion and environmental ethics realization.

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Cultural Riddles

Environmental ethics found in African riddles like folktales constitutes another source of knowledge in Africa toward protecting the environment. Riddles are characterized by question-and-answer form. However, in most cases, the question appears as a statement rather than as an interrogative in form. More generally, riddles are associated with children's amusement in contrast to the more serious use of proverbs by their elders (Essien, 2013). Riddles have the role of nourishing the intellect. However, the riddles in Africa elicit how the society sees themselves and their livestock mirrored in nature, as well as nature mirrored in the society. It is as if the patterns in nature find different forms in which to express itself and although its agent may differ, the expression stays very similar. This leads to the people learning lessons from occurrences in nature.

The Values of Plants

The African intimate knowledge of plants is another important aspect of their environmental ethics. This is manifested in the medicinal value of plants as herbal remedies as well as the role of spirituality regarding these remedies. Plants in African context play an important role in the people's protection of the natural environment (Taringa, 2006). In Africa, the natural vegetation has numerous uses in the daily life of the people including as firewood, building material, weapons, jewelry, household utensils for personal hygiene, and as food. The fact that the rural people in Africa live in close proximity with nature, and are therefore so very much dependent on their environment for survival, give them an advantage with regards to living in harmony with nature. A very good example is the fact that the traditional diet is much less damaging to the environment than that of the westerners (Omari, 1990).

Sacred Places

Sacred places are another concept among Africans which serves as a bridge between man and nature, and/or the physical and spiritual realms. It is not important whether a certain place or tree or river is really filled with spirit or whether it is the people's beliefs that make it sacred in their eyes. What is rather important is that the people see these places as worthy of respect (Boersema, 2001). It is as if the division between the spiritual and the physical are smaller in these places, almost non-existent. This concept is easily extended to a larger area and environment, even if not in the same intensity. The concept of increased spiritual value in certain places on earth is demonstrated by the words of John Mbiti (1970). They include rocks, trees, mountains, wells, and springs which are recognized as receptacles for spirits displaying in season their various properties, fertilizing, therapeutic and oracular. The earth as a living being has a far reaching impact for environment and conservation policies and attitudes. It is the opinion of this study that the most important aspect of sacred places is that of reverence for the earth environment which culminates into its protection and preservation.

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CONCLUSION

This study emphasizes the importance of integrating cultural values, ideals and indigenous knowledge into contemporary management of the environment and natural resources as well as suggests for its use in planning and conservation of our environment. The paper has tried to establish a new foundation for a different approach toward environmental ethical hypothesis from African cultural perspective. The study demonstrates that humans are key determining factor in African environmental ethics and their actions, beliefs, notions, labor and tools have played a critical role in changing African environments. It was also discovered that central to environmental change in Africa are multi-layered interactions involving the physical world, flora, fauna and human activity which encompasses tradition, beliefs, ideas, perceptions and prescriptions regarding habitats and inhabitants. Given that the global community today is being confronted with diverse ethical issues which include, amongst others, the issue of ethics in the public as well as private spheres. Human beings were until recently, unable to see and foresee the harm done as a result of our interactions with nature (Weberzik & Wilson, 2008).

This study observes that in our dealings with the environment, we are in short, called upon to reflect, act, or perhaps to refrain from acting in a manner, which testifies to our worth as moral persons and as a moral culture. The caveat however is that we have an obligation to help ensure the existence of a clean environment and welfare of future generations through a functional environmental ethics. The most imperative question therefore is how to balance our obligations toward actual future people, that is, our future-directed obligations, with our obligations toward those presently existing, that is, our present-directed obligations. While it is sometimes claimed that we can have no idea what interests and concerns future people will have, this is without doubt exaggerated. Because future people will share roughly the same interests and needs that we already share with our contemporaries, our conditional moral duties toward them will resemble our present obligations toward each other: to not act in ways that could harm those people or their fundamental interests is a moral responsibility. It is ethically imperative that one should always live and behave in a way that maximizes harmonious existence in the present as well as in the future. In other words, our human behavior at present must take into account the concerns of the future generations which become an investment in the future.

REFERENCES

Adegoroye, G. (1997). Environmental Considerations in Properly design Urban development and Renewal. In A. Osuntokun (Ed.), *Dimensions of Environmental Problems in Nigeria*. Ibadan: Davidson Press.

Agius, E., & Chircop, L. (1998). *Caring for Future Generations: Jewish, Christian and Islamic Perspectives*. Westport: Praeger Publishers.

Bakut, T. B. (2006). The Environment, Peace and Conflict in Africa. In S. G. Best (Ed.), *Introduction to Peace & Conflict Studies in West Africa*. Ibadan: Spectrum Books Limited.

Boersema, J. J. (2001). How to Prepare for the Unknown? On the Significance of Future Generations and Future Studies in Environmental Policy. *Environmental Values*, *10*(1), 35–58. doi:10.3197/096327101129340732

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Brechin, S., & Kempton, W. (1994). Global Environmentalism: a challenge to the post-materialism thesis? *Social Science Quarterly,* 75(3), 245-269.

Callicott. J. B., & Palmer, C. (Eds.), (2005). *Environmental Philosophy: Critical Concepts in the Environment*. London: Routledge.

Ekeli, K. S. (2004). Environmental Risks, Uncertainty and Intergenerational Ethics. *Environmental Values*, *13*(4), 421–448. doi:10.3197/0963271042772578

Engel, J. R. (1990). Introduction: Ethics of Sustainable Development. In J.R Engel, & J.G Engel (Eds.), Ethics of Environment and Development: Global Challenge, International Response. Belhaven Press.

Essien, E. D. (2013). The Hidden Dimension of Ibibio Taboos. *Uniuyo Journal of Humanities*, 16/17(1), 256-275.

Foltz, R. C. (Ed.), (2003). Worldviews on Religion and the Environment: A Global Anthology. Belmont, CA: Wadsworth/Thomson Learning.

Garriga, L., & Mele, F. (2002). Environmental disclosure by companies involved in initial public offerings. *Journal of Accounting, Auditing and Accountability*, *15*(1), 94–105. doi:10.1108/09513570210418914

Gelfand, M. (1973). *The Survival Values of an African Culture. Gwelo*: Mambo Press.

Godofsky, J. (2010). Future Generations and the rights to survival: A deontological analysis of the moral obligations of present to the future. TCNJ Journal of student scholarship, 12(4), 90-104.

Guha, R. (2000). *Environmentalism: A Global History*. New York: Longman.

Harris, P. (2005). Environmental Perspectives and behavior in China. *Environment and Behavior*, *38*(1), 5–21. doi:10.1177/0013916505280087

Hjort, A. and Salin, M. (1980). *Ecology and politics; Environmental stress and security in Africa*. Uppsala: Scandinavian institute of African Studies.

Iroegbu, P., & Echekwube, A. (2005). *Kpim of Morality Ethics: General, Speicial and Professional*. Ibadan: Heinemann.

Kelbessa, L. (2002). *Indigenous Environmental Ethics in the light of modern issues of environment*. Nairobi: Konrad Press Ltd.

Lizanne du Plessie. (2005). *The Culture and Environmental Ethics of the people of Kaikipia in Kenya. Stellenbischi*: University of Stellenboschi.

Madam Nokyo Owoanam. (2015). *11 Ediomo Street (Oral Interview)*. Uyo, Akwa Ibom State.

Maimunah, I. (2009). Corporate Social Responsibility and its role in community development: An International perspective. *Journal of International Social Research*, *2*(4), 200–203.

Mama Bassey Antia. (2015). *, 27 Yellow Duke Street (Oral Interview)*. Calabar, Cross River State.

Masaka, D., & Chemhuru, M. (2010). Taboos as sources of Shona people's environmental ethics. *Journal of Sustainable Development in Africa*, *12*(7), 121–133.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Mbiti, J. S. (1970). *Concept of God in Africa*. London: Camelot Press Ltd.

Mengena, F. (2013). Discerning Moral Status in African Environment. *Phronimon*, *14*(2), 26–44.

Murove, M. F. (2004). An African commitment to ecological conservation: The Shona concepts of Ukama and Ubuntu. *The Mankind Quarterly*, *14*(2), 195–215.

Ojomo, P. A. (2011). *Environmental ethics: an African understanding.* Retrieved from http://www.readperiodicals.com/201103/2323094941.html

Omari, C. K. (1990). Traditional Africa Land Ethics. In J. R. Engel & J. G. Engel (Eds.), *Ethics of Environment and Development: Global Challenge, International Response*. Belhaven Press.

Pojman, L. P. (2001). (ed.), Environmental Ethics: Readings in Theory and Application. Wadsworth.

Secchi, S. (2007). Managerial interpretations and organizational context as predictors of corporate choice of environmental strategy. *Academy of Management Journal*, *43*(4), 681–697.

Tangwa, G. (2004). Some African reflections on biomedical and environmental ethics. In PA. Ojomo. 2011. *Environmental ethics: an African understanding.* Retrieved from http://www.readperiodicals.com/201103/2323094941.htm

Taringa, N. (2006). How environmental friendly is African traditional religion? Exchange. *Journal of Missiological and Ecumenical Research*, *32*(2), 31–45.

Ugwuanyi, L. O. (2011). Advancing Environmental Ethics through the African worldview. *Mediterranean Journal of Social Sciences*, *2*(4), 107–114.

Velasquez, M., & Rostankowski, C. (1985). Ethics and the Environment. In M. Velasquez & C. Rostankowski (Eds.), *Ethics: Theory and Practice*. New Jersey: Prentice Hall.

Weberzik, C., & Wilson, C. (2008). *Environment for African Development: A Sustainable Future through science and technology, Pacifico-Yokohama*. United Nations University Institute of Advanced Studies.

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Chapter 74
Understanding Glacial Retreat in the Indian Himalaya: Historical Trends and Field Studies From a Large Glacier

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ABSTRACT

One of the most important and visible indicators of global climate change is the recession of glaciers in many parts of the world. The findings of the IPCC Assessment Report (2007) suggest that there has been a significant decline in mountain glaciers and snow cover, which has contributed to the increased sea levels and water flow changes in river basins. In the latter half of 20th century, an increase in the rate of retreat has been observed in Himalayan Glaciers since advent of industrialization. The paper attempts to present a critical review and understanding of the recent changes in retreat of selected Himalayan glaciers from potential climate change. The study explores scientific evidence and analysis of observed data from a large and a small glacier in the Indian Himalaya. This will help in understanding the vulnerability of retreat of the glaciers based on their size. The larger glaciers are unlikely to disappear in the near future, due to its large mass balance and large response time due to climatic changes. Future adaptation needs, research and action for downstream communities, ecosystems and impacts on power sector are discussed.

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INTRODUCTION

The Cryosphere plays a major role in the Earth's climate system by impacting on the surface energy budget, the water cycle, sea level etc. and has control on the physical, biological and social environment over a major portion on the Earth. The cryosphere is most sensitive to temperature change hence capable of providing the most visible signatures of climate change. There are many indicators of climate change like changes in surface temperature, precipitation, extreme weather events, glaciers, ocean and land ice and sea level. Icesheets and glaciers changes are closely related with the global sea level changes impacting the global ocean circulation and marine ecosystems. The warming trend has been reported in the vertical profiles of temperature measured through the entire thickness of mountain glaciers, or through ice sheets climate over recent decades (Lüthi and Funk, 2001; Hoelzle *et al*., 2011). The loss of glaciers and snow cover near populated areas have direct impacts on the livelihood of the local communities in terms of water resources for drinking, agriculture, hydropower etc.

Over the last few decades, changes in climate and local weather conditions have impacted the world's glaciers both in terms of structure and characteristics, reflected in the form of advancement or retreat of glacial snouts (IPCC, 2007; UNEP, 2007). The changes in the length, width, area, volume and mass balance of the glaciers are among the most directly visible signals of global warming and these changes are the primary reasons why glacial observations have been used for climate system monitoring for many years (Haeberli, 1990; Wood, 1990), especially in areas where time series data on climate (mainly temperature and precipitation) is difficult to get and where climate change signals are not yet clear (Yadav et al., 2004; Roy and Balling, 2005). Thirty reference glaciers that have been studied in detail since 1975 show an average annual mass loss of 0.58 metres (m) water equivalent in the past decade, which is four times the rate for the period 1976-85 (UNEP, 2007).The IPCC, 2013 report (The physical science basis) clearly reflects the warming trend on the planet and state that "The last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850 while in the Northern Hemisphere, 1983–2012 was likely the warmest 30-year period of the last 1400 years (medium confidence)". Unnatural rates of glacial melting, related to the changing climate, can have serious implications on the hydrology of the associated river systems and consequently on the livelihoods of millions of people who are dependent on these rivers and their ecosystems.(Stern,2007). Overexploitation of water resources and changes in hydrological cycle could be vital to future developmental strategies of the fertile belt of Northern India where agricultural productivity, irrigation etc.is to a large extent dependent on availability of freshwater resources (Mall et al, 2006).

The right approach, thus, in addressing these impacts is to have a better scientific understanding through long-term observations and analysis of the interactions of the different components of the mountain ecosystems with their climate. Then the lager data can be helpful in predicting the future scenarios and utilizing the information to formulate effective adaptation and management strategies. There is also a pressing need for disaster management and rehabilitation policies in areas affected by the glacial retreat, particularly focusing on agriculture, meadows and other livelihood support structures of the local people.

A growing body of scientific knowledge solidly indicates that carbon concentrations are changing the global climate and that there would still be significant changes to the global climate even if emissions would drastically reduce and fall to zero. The world is anticipating a 2°C warming above the pre-industrial level, and this will result in some unavoidable changes, the effects of which need to be understood, especially in fragile and endangered ecosystems. Generating a deeper understanding of the climate impacts on critical indicators such as glaciers are needed as there is inadequate documented scientific evidence

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within India on the impact of climate change on the Himalayan ecosystems. This would help in developing regional climate projection models which are more accurate in providing information on future impacts. The recent observation of IPCC (2013) reveals that the globally average temperature show a warming of 0.85 (0.65 to 1.06)°C, over the period 1880 to 2012 as calculated on linear trend basis.

Glacial Retreat in the Himalayas

In the Himalayan region, glaciers and snow cover have been thinning since the end of 19th century in line with the global trends. With significant snout fluctuations, most of the glaciers in the Himalayan mountain ranges have been retreating and their rate of retreat is much faster than that of glaciers in other parts of the world (Cruz et al., 2007). These changes correspond to the rising surface temperature trends in the Himalayas which have been reported to be higher than the global average warming (UNESCO, 2007; Jianchu et al., 2007; Barnett et al., 2005). A study of the temperature trends in the North West Himalayan region (Bhutiyani et al., 2007) shows that a significant warming of 1.6°C has occurred over the last century with warming in winter taking place at a faster rate, with the highest warming rates recorded in the period 1991 -2002. Apart from warming, other factors like high human population density near these glaciers, deforestation and land use changes have also been responsible for the decline and shrinkage of glaciers (Cruz et al., 2007). At current rates of retreat, the smaller valley type glaciers are more likely to decline at a faster rate in the future, with uncertain impacts on the downstream areas.

The dynamics of a glacier are influenced by climatic factors including temperature, precipitation, amount of snowfall and wind. However, establishing firm linkages between climatic variability due to anthropogenic factors and glacier retreat requires long-term studies and monitoring. Mass balance and glacier snout monitoring have been important methods for the assessment of the volumetric and geometric changes in the glaciers brought about by advancement or recession (Dobhal et al., 2007).

In India, although high mountain glaciers occur across all the Himalayan range states of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh, although only a few have been studied for long term monitoring or documented in terms of glacial retreat. Recent studies from 466 glaciers of the Indian Himalayas indicate that there has been a 21% reduction in the glaciered area from 2,077 square kilometers (sq km) in 1962 to 1,628 sq km in 2004 (Kulkarni et al., 2007). Smaller glaciers of less than one sq km have reduced in area by as much as 38% compared to a 12% retreat of the larger glaciers.

In the Indian Himalayas, studies on snout recession/mass balance measurements have been carried out on a few glaciers and some studies have been able to generate long-term monitoring data (Dobhal et al., 2007; Kumar et al., 2007; Wagnon et al, 2007). Studies by various institutions on the changing characteristics of glaciers in the Himalayas are limited (see box: Studies on some important glaciers in the Himalayas), generating an important debate on the role of climate change in the extent of glacier loss (Raina, 2009).

These glaciers have left behind imprints of their unnatural retreat, which is in tandem with the discrete but well defined phases of global warming. The melting process has two key adverse impacts on the environment. One is the loss in the reserve of freshwater and the other is a significant rise in sea levels (Kaser et al., 2006).

While the global view (IPCC, 2007) suggests that a large percentage of glaciers are declining worldwide, there are conflicting views also on the rate of retreat in the era of industrialization. Some

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studies suggest that a few glaciers in the Himalayas may be showing reduced retreat patterns or actually increasing. e.g., the reduction in the retreat rate of Gangotri Glacier for 2004-05 (Kumar et al., 2007).

STUDY AREA

The Gangotri glacier, is one of the largest mass of ice and snow in the western Himalayan region of India and is located in District Uttarkashi in the state of Uttarakhand in India (Figure 1-2). The location derives considerable religious significance as an important sacred site as a source of the river Ganga which flows through several North Indian states before flowing into the Bay of Bengal. As such the region and the shrine at Gangotri, attracts thousands of pilgrims every year. The glacier along with other tributary glaciers (Figure 3) is a vital source of freshwater water supply, for much of the northern plains which has a large human population living downstream. The water discharge from the glacier flows initially as the river Bhagirathi before meeting the Alaknanda river at the confluence at Devprayag to form the river Ganga. Snow and glacial melt water contribute nearly 29% to the annual flows of the Ganga (up to Devprayag) and hence potential impacts on these glaciers due to various factors are likely to affect this large river system (Singh et al., 2009).

The north-west facing glacier is a typical valley type glacier originating in the Chaukhamba group of peaks in the Himalaya. Other smaller glaciers act as tributaries and join the main stem of the glacier to form the larger Gangotri group of glaciers. Including the tributaries, this covers an area of 210.60 sq. km(ETM+1999). The area and length of the main trunk of the glacier is 56.59 sq. km and 29.13 km respectively. The average width of the glacier is 1.85 km. The glacier, lies between 79°4' 46.13" E-79°16' 9.45" E and 30°43'47.00" N-30°55' 51.05" N (ETM+1999) with elevation ranging from 4,015–6,145 meters above sea level (SRTM data analysis).

Figure 1. Location Map of Gangotri glacier

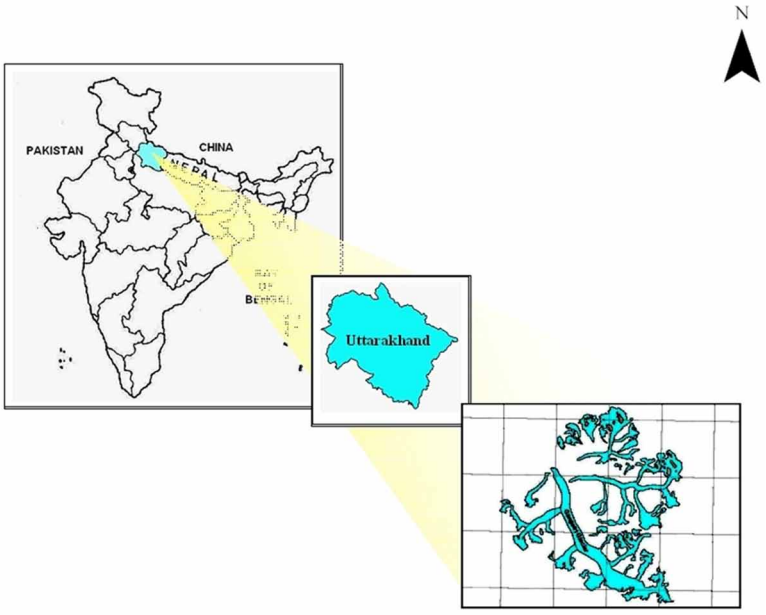

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Figure 2. Location Map of Gangotri glacier and Snout of Kafni glacier

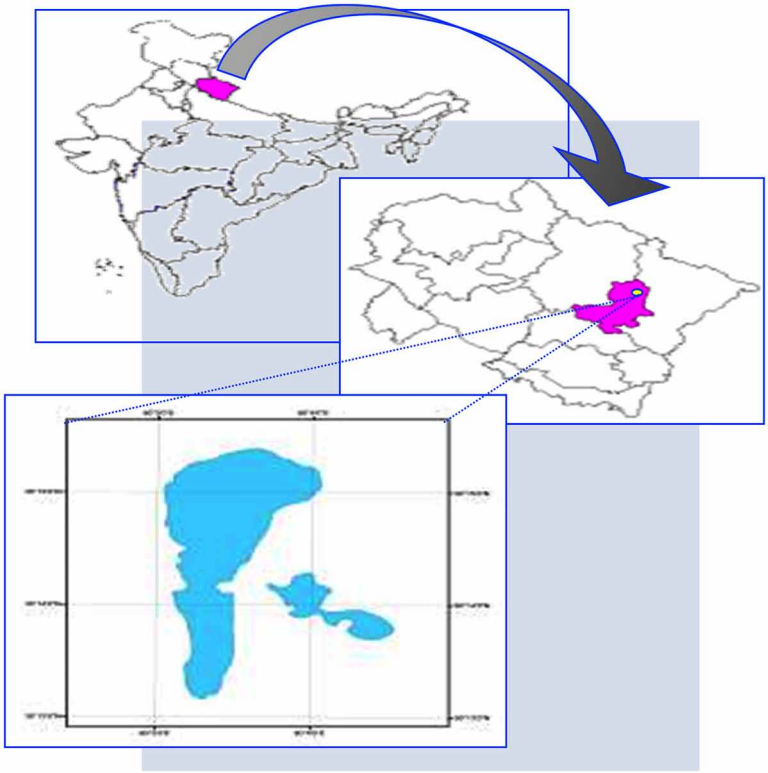
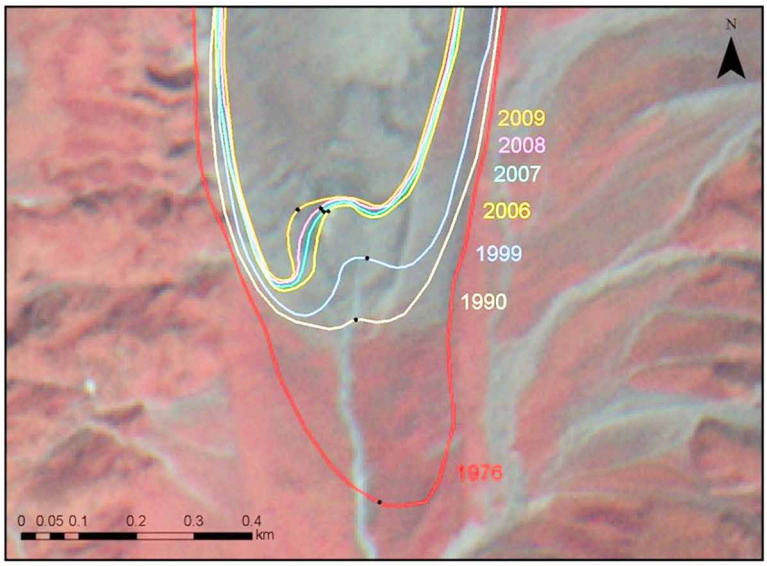


Figure 3. Location Map of Gangotri glacier



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The snout of the glacier occurs at an altitude of about 3,949 m above sea level, and from where the Bhagirathi originates (GPS observation, 2008). The snout position (2008) is at 73º4' 47.26" E and30º55' 36.45" N. Table 1 provides an overview of the characteristics of the glacier system.

Gangotri Glacier Retreat: A Historical Perspective

As one of the largest known glaciers in the Indian Himalayas, the Gangotri glacier often evokes considerable interest among glaciologists, geologists, water resource specialists, and mountaineers. It is said that the region has been frequented for at least hundred years by various groups in trying to understand the glacial system and process including reasons for retreat. Several workers have carried field studies on the snout and other sites on the glacier which has been receding since the last 'Little Ice Age', which ended in the 19th century. Interestingly, many of the tributary glaciers which source the river Ganga have also reduced with a few even being separated from the main trunk of the glacier. According to Srivastava (2001), this is evident by systematic studies since 1935 on the movement of the glacier snout, and by the presence of recessional evidences features such as terminal and lateral moraines. In the past century, the retreat rate of the glacier has shown a rising trend. It has been observed by glaciologists that the snout of the Gangotri glacier has retreated by about two km in the last 100 years. Both the snout retreat and area vacated by the Gangotri glacier has been documented by several scientists (see Table 2).

Table 1. Gangotri glacier inventory

Glacier Coordinates	**30°43"22" - 30°55'49" N 79°4'41" - 79°16'34" E**
GSI identification number	5O131 06029
Highest elevation (m asl)	7138
Lowest elevation (m asl)	4000
Surface area (km^2)	143.58
Ablation (km^2)	92.48
Accumulation (km^2)	51.11
Mean width (km)	1.50
Maximum length (km)	30.20
Ablation zone length (km)	26
Accumulation zone length(km)	4.20
Mean depth(km)	0.20
Ice volume (km^3)	28.716
Tributaries: Chaturangi Glacier Raktvarn Glacier Kirti Glacier	 length 22.45 km; area 67.70 km^2 length 15.90 km; area 55.30 km^2 length 11.05 km; area 33.14 km^2

Source: (GSI), 2001; Naithani et al., 2001; Singh et al., 2006)

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Table 2. Snout retreat and area vacated by Gangotri glacier (1935-96)

Period	Annual Snout retreat (m)	Average annual surface area vacated (sqm /year)	Reference
1935- 1956	4.35 (small cave) 10.16 (large cave)	2500	Jangpani (1958)
1956-1971	27.33	10032	Vohra (1971)
1971-1974	27.34	594	Puri and Singh (1974)
1974-1975	35	13975	Puri (1984)
1975-1976	38		Puri (1984)
1976-1977	30	14875	GSI, 2001
1977-1990	28.08	15096	Puri (1991)
1990-1996	28.33	22370	Sangewar (1997)
Source: Srivastava et al., 2001(GSI, 2001)			

Local Climate Conditions Around the Gangotri Glacier

The combination of high altitude temperature and precipitation along with other climate factors like wind chill, humidity etc. often plays a key role in development of the state of glaciers and their associated hydrological features with impacts on water flow in the downstream region. Meteorological analysis of long-term data becomes a fundamental aspect in determining the structural changes taking place in glaciers. Various scientific institutions have been studying the Gangotri glacier for the past few years and have collected extensive data on the meteorological parameters (rainfall and temperature) through standard meteorological observatories installed near the glacier snout.

Rainfall

Precipitation is an important element in the evolution of a glacier worldwide and with reference to Gangotri past data suggests that the much of the region around Gangotri landscape receives less than 15 mm of daily rainfall during the summer season (Singh et al., 2005). A few exceptions in precipitation days in the form of extreme weather events like snow storms also occur. When studying precipitation trends on glaciers, it is noticed that August and September usually receive higher rainfall as compared to the other months. This is a continuous trend and even in recent years (2008-90 one can see higher precipitation patterns in those months from data obtained from weather stations installed at Bhojwasa. It has also been found that early morning and late evening are the most probable times for the occurrence of rainfall (Singh *et al*., 2005).

Temperature

Temperature in the ablation season increases for a few months after which it starts decreasing. July has been found to be the warmest month on the basis of the mean-maximum and minimum temperatures. Daily variations in temperature show that the maximum temperature is observed around 1400 hours, while the minimum is observed in the early morning hours (Singh *et al*., 2005). Changes in minimum

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temperature have been seen to be more significant than those in the maximum temperature. It has also been found that the 'maximum diurnal temperature range' occurs in May and October while August shows the least variation in temperature range. This is probably due to the presence of a cloud cover during the rainy season.

Hydrology

The major sources of runoff at Gangotri are melting snow and ice. As a general assumption, since this area receives low rainfall, there is unlikely to be a heavy runoff from the region. Stream flow at the Gangotri glacier shows a wide variation depending on various factors. Early on and towards the end of the ablation season, day and night time flow volume show little variation ; however as the peak melting time approaches during the day, there is a comparative reduction in the nighttime flow. Despite this,it is also also observed that there is a continuous but low water flow pattern even when night temperatures are lower than normal. For large glacier this is a reflection of strong meltwater storage characteristics. Monthly variation of flow shows that the discharge starts rising from May and maintains a high flow during June to August with maximum average discharge in August. The discharge starts reducing from September onwards. Singh *et al.*, (2006) have also reported similar results in the discharge flows from the glacier.

METHODOLOGY

Field studies at Gangotri glacier for monitoring local climate and hydrological conditions involved using primary field data through the use of i) Differential Global Positioning System (DGPS) for assessment of snout positions at different time periods and ii) use of Remote Sensing satellite imagery along with iii) existing secondary data from earlier studies. DGPS measurements have been extensively used for locating the snout position in glaciological studies including at Gangotri during various field visits starting from 2006. While the task of long term data collections and observations is often tedious, due to inconsistency and access to field sites due to inclement weather conditions, it still remains an important factor for accuracy in any glacial research. In this context, it is important to note that due to variability in local climate, the snout position is quite dynamic and inter-seasonal changes are seen in the exact position of the snout. Primary data was collected on snout position during the months of September and October since 2006. This was supplemented by meteorological and local climate data through an automatic weather station (AWS) installed at Bhojwasa near the snout of the glacier. Apart from the glacial and meteorological monitoring, data was collected about the discharge patterns of the glacial meltwater. Remote sensing data was collected using satellite imageries of 1976, 1990, 1999 and 2006 by delineating the glacier boundary using ERDAS 9.0 and auto calculating the area using GIS methodology.

RESULTS AND DISCUSSION

A comparative analysis of the glacier's snout position was carried out using data from secondary sources and interpretations from various satellite imageries over the past three decades. Satellite imageries available since 1976 formed the baseline for the analysis of the fluctuations in snout position together with

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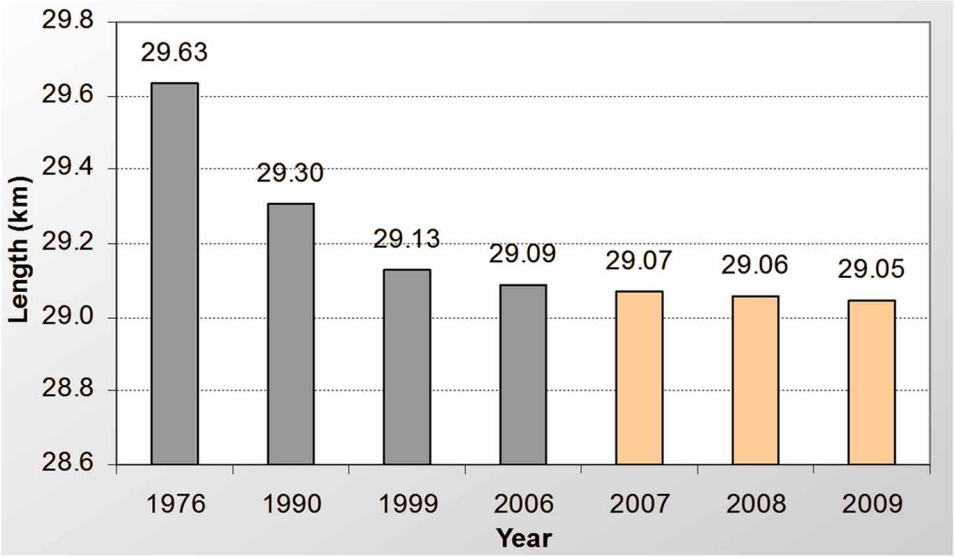
Figure 4. Length of Gangotri glacier in different years



DGPS observations since 2006. A study of data from available sources suggests that the main trunk of the Gangotri glacier has been in a continuous state of recession and fragmentation during the past century. The length of the glacier has been computed for different years based on available data from various scientific agencies and workers. These trends show that the length of the glacier has reduced by about 0.59 km in 33 years, from 1976-2009, with an average retreat rate of 17.59 m/year (see Figure 4).

Based on the comparison of satellite imageries of the Gangotri glacier for the years 1976, 1990, 1999 and 2006, our analysis shows that the glacier is not only receding in length but also in terms of glaciated area from all the sides. The possible reasons behind this retreat may be linked with two main factors: (a) reduction in snowfall and (b) an increase in the temperature of the region. Cumulative analysis shows that between 1976 and 2006, the glacier area reduced by 15.5 sq.km, with an average loss of 0.51 sq.km per year. This reduction in glacier area is 22.9% over 1976 (see Figure 5). The glacier area reduced by 7.2 sq. km between 1976 and 1990, in fourteen years, with a 10.6% reduction in the glacial area. In nine years, between 1990 and 1999, the glacial area reduced by 4.3 sq.km and resulting in 7% reduction in area when compared to 1990. However, the rate has increased between 1999 and 2006, with glacial area reducing by 4.1 sq.km and a 7.25% reduction in area over 1999. This also indicates that in some years there is a reverse trend in the rate of retreat of the glacier as compared to preceding years. It is possible therefore that local climate conditions and fluctuations may be responsible for the reduced rate of retreat at different time intervals.

The calculation of the snout retreat using a DGPS based system involves assessment of point to point snout data that gives the straight line distance of the two points that may include the shift of the water outlet point (left/right) in the curvilinear shape of the larger snout. Traditional methods using a simple GPS methodology often assess the shift of the snout position in the glacier flow direction through measuring the perpendicular distance on the curvilinear shape of the snout. This measurement normally gives a lesser value if the snout point has moved either left or right rather than in the glacier flow direction as compared to the previous position.This can be critical since fluctuations are often noticed in the

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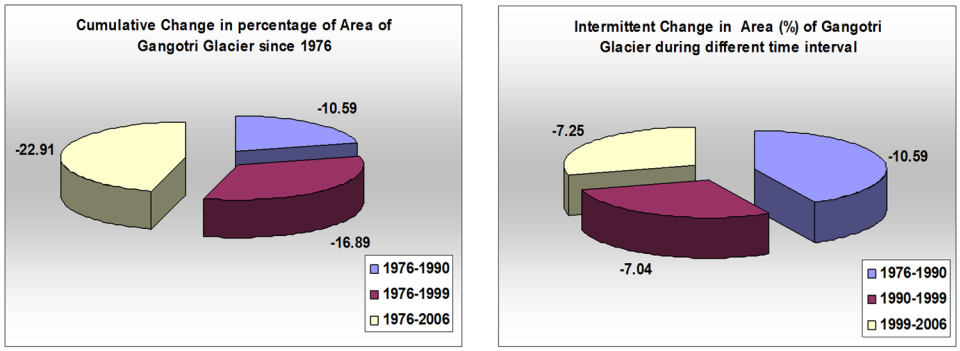
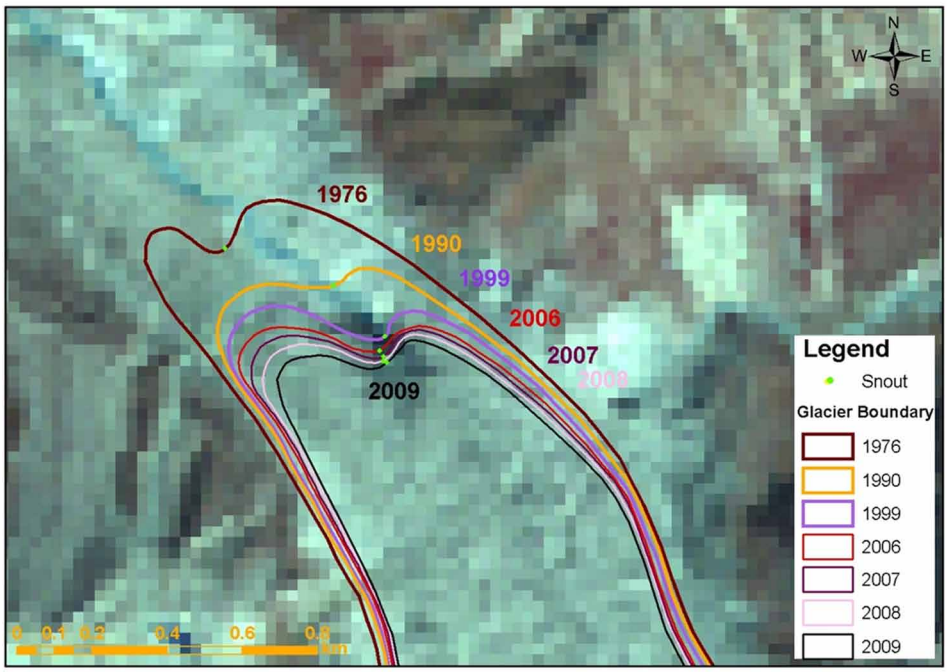
Figure 5. The cumulative and intermittent reduction in the area of Gangotri Glacier since 1976



snout positions for larger glaciers which have a significantly large area. Based on this measurement, we observed that the snout retreat during 2006-07 was 17.85 m when compared to snout position of 2006. In the subsequent years, the retreat rate has reduced 13.06 m in 2007-08 and 10.57 m in 2008-09. It can be inferred that retreat of the glacier between 2007 and 2009, is lower than the long term average. More importantly, while there is an overall average retreat noticed, fragmentation of the Gangotri glacier is likely to be of larger concern in the context of reduced water flows of the glacial system in the long term. The retreat of the Gangotri Glacier snout is shown by overlaying the glacier boundary on the Enhanced Thematic Mapper (ETM$^+$) 1999 imagery (see Figure 6).

Figure 6. Snout position of the Gangotri glacier during 1976 to 2009



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Hydro-Meteorological Trends

Assessment of summer season discharge data at the snout in the past few years indicates that there are variations on a diurnal and monthly basis. Flows recorded at different times of the day were found to be highest during the evening hours (1700 hours) while discharge rates are lowest during the morning hours (see Figure 7). These results also corroborate earlier findings by Singh *et al*.,(2006) where high diurnal fluctuations in discharge rates during daytime and low rates at Bhojwasa were observed.

With the commencement of the summer season, increased water discharge reaches a peak during July and August due to the combined impact of more melting of ice, which is driven by higher average temperatures and rainfall in the catchments. The discharge starts reducing in September and reaches a very low level throughout the accumulation season. During winters, the flow is reduced and keeps almost at a constant value. The combined impact of low winter temperature (subzero) and higher albedo (90-95% for fresh snow) reduces the winter discharge rate to quite a low level.

The daily average temperature and average discharge for the ablation and accumulation season at Bhojwasa (Figure 8), is indicative of a positive correlation of 0.73 between the average temperature and average discharge during the ablation season. However, these parameters are negatively correlation (0.46) in the accumulation season, which shows a lower influence of temperature on melting because most of the solar radiation is reflected back to the atmosphere due to the snow covered valley that has a high albedo effect. The preliminary trends observed during the study in 2008 seemed to suggest that the volume of discharge and flow patterns is also being influenced by the temperature variations in the valley. This is in consonance with results obtained by other studies (Singh *et al*., 2006) over the past decade. However, it may be mentioned here that large glaciers like Gangotri need to be closely monitored for water discharge during both ablation and accumulation season and only long term trends can suggest any significant variations in retreat patterns. For smaller glaciers, which do not have a clearly

Figure 7. Diurnal discharge pattern at Bhojwasa, Gangotri 2008

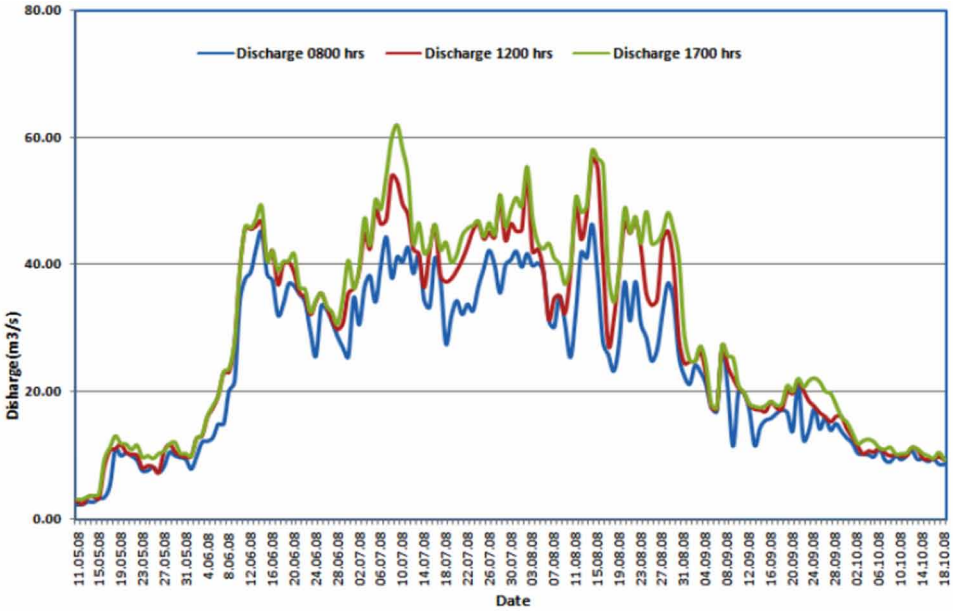

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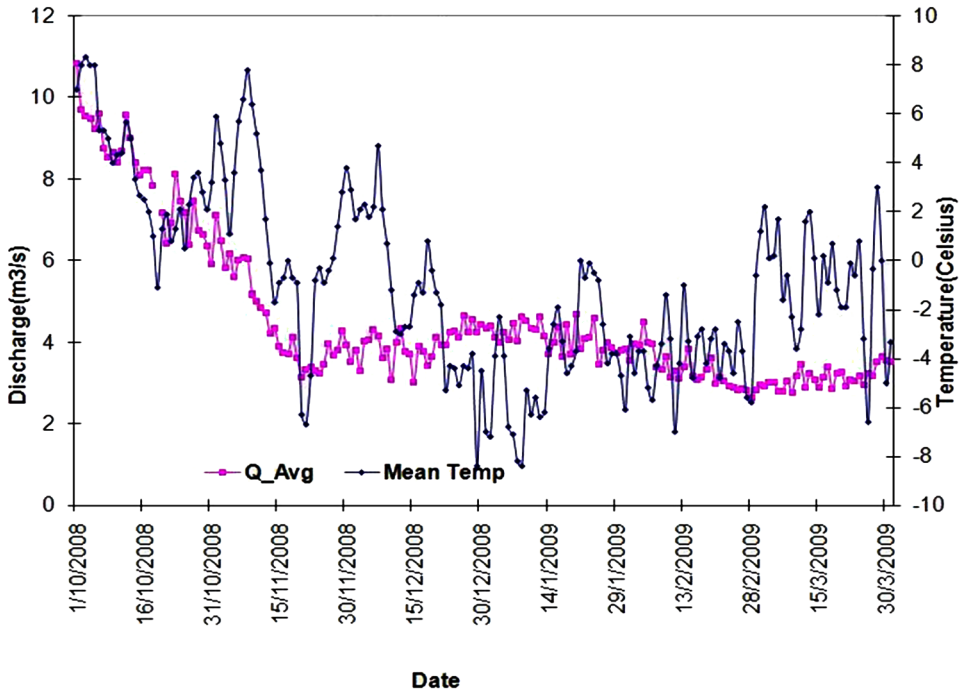
Figure 8. Average temperature and discharge during winter 2008-09 at Bhojwasa, Gangotri



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demarcated ablation and accumulation zone, retreat rates may need to be monitored critically. While these results are specific to the snout at Gangotri, comparisons with similar studies indicate a consistent pattern in the rate of discharge and temperature increase for the region.

With regard the impact of mid-day temperature on evening discharge in the glaciated basin, a positive correlation of 0.63 between the 1200 hours temperature and the 1700 hours discharge at Bhojwasa (see Figure 9) is noticed. However, during October the discharge rate declines as the average temperature starts reducing (see Figure 9).

Trends in the Gangotri region (see Figure 9) reflect that temperatures start reducing from September. The maximum temperature reaches up to 18° C in June and July and remains mostly around 14°C during May to August. The early morning temperature (0800 hours) remains at around 9° C till August and falls to zero in mid-September. As winter advances, the intraday temperatures in December also show a variation with morning temperature at sub-zero levels and moving down to - 15°C. During peak winter months, the morning and evening temperature is subzero while noon temperatures may be above 0° C. During March, the morning temperature remains below zero, while the noon and evening temperature varies around 5°C .

CONCLUSION

The entire Himalayan region is known to have the largest concentration of glaciers in the world excluding the polar region. According to the WWF, the region is called the “Water Towers of Asia” as it

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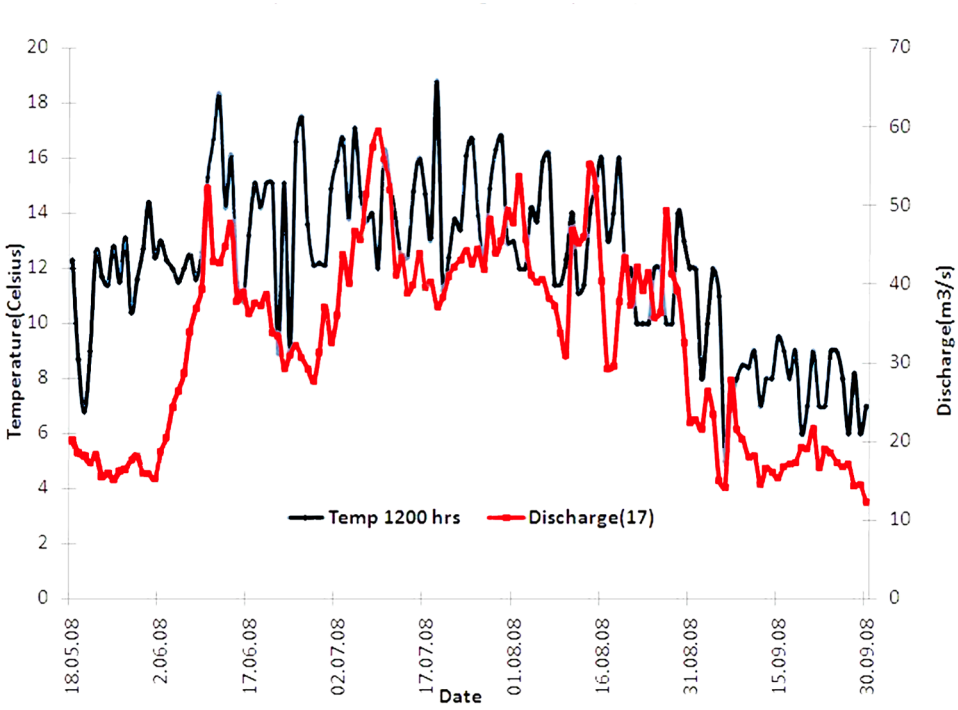
Figure 9. Influence of mid day temperature (1200 hrs) on evening discharge (1700 hrs) at Bhojwasa, Gangotri



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provides around nearly 86,000,000 cubic meters of water annually. These Himalayan glaciers feed seven of Asia's great rivers, namely the Ganga, Indus, Brahmaputra, Salween, Mekong, Yangtze and Huang Ho(WWF,2005).The current study has attempted to provide an understanding of the characteristics of large glacier like Gangotri, in the context of melting patterns and local hydrometeorological conditions. We also believe that the science of climate change is complex particularly while monitoring glaciated basins but also in studying large vs smaller glaciers. In long term, temperature variations may obviously be a key aspect to changes taking place in a glacier, but impacts of other climate/non climate stressors like local variability in monsoon, developmental concerns, industrial growth, tourism etc. may also play an equally critical role.

From a basin perspective, a combination of climate variability and non-climate stressors will have serious consequences for the freshwater ecosystems of the Ganga basin with long term impacts for eco-system, livelihoods, agricultural and industry in the catchment of the basin. As the Gangetic plains are considered a major food basket to the economy of the northern Indian plains, changes in environmental flows along the basin ecosystem may also affect region's agricultural productivity and industrial activity, but also have consequent impacts on future economic growth in terms of Gross Domestic Product (GDP). In a carbon constrained world, where greenhouse gas emissions are rising, beyond the level considered unsustainable, the economic costs of taking mitigation actions on limiting climate impacts now, would have far lesser implications than if actions were to be taken at a later stage. (Stern, 2007).

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Larger vs. Smaller Glaciers

Field studies indicate that larger glaciers like Gangotri which occur a vast area are unlikely to show major declines in the near future, due to its relatively large mass balance. Although this study did not take into account changes occurring in a smaller valley type glaciers in the region, it may be worthwhile to mention that smaller glaciers with low mass balance and ice volume are likely to retreat at a faster rate. This could lead to increased losses in glaciated portion as well as their tributary glaciers,(see Figure 3) a trend which has been observed across the Himalayas for many other smaller glaciers (Dobhal *et al*, 2004). Regional climatic variations could threaten the fragile nature of these glaciers which are likely to disappear at a much faster rate or be considerably reduced in length as compared to the larger ice bodies. These glaciers are perhaps more vulnerable to local climate variations and hence long term and continuous assessment is required to monitor the hydro-meteorological parameters existing in their vicinity to develop predictive models for future water resource scenarios.

Larger glaciers like Gangotri show a continuous recessionary trend in recent years through this and other studies (Singh *et a*l., 2006). However, at present this trend may have a limited influence on the water flows downstream primarily due to the large extent of the glaciered area. The movement of larger glaciers is dynamic and snout retreat is a delayed response, but the fragmentation of the larger glaciers needs to be continuously monitored.

The Climate Change Angle

There is limited consensus and considerable degree of variations in studies on glaciers as reported amongst the scientific community and policy makers on the true extent of Himalayan glaciers retreating due to impacts of global climate change,(IPCC,2007,Raina,2009). The results of this study is a pointer to the fact that regional climatic variations along with changes in social and economic dimensions may also play a critical role in the behavior of these glaciers. Local communities living closer to Gangotri have indicated changes in snowfall levels in the winter months resulting in less soil moisture, which in turn is changing cropping patterns and availability of water.

Though glacial retreat is a natural phenomenon with the earth moving towards a warming phase, the accelerated rate of retreat could result from a combination of other impact factors also. Based on our study and past scientific data, it is clear that climate change has a visible impact on the status and condition of some of the glaciers as is evident through the increase in the net loss of ice mass year after year. Hence, it becomes difficult to predict the glacier retreat or advance scenarios with confidence. It is worthwhile to note that the phenomenon of global warming and climate change will impact not only temperature but also the other variables like intensity and quantity of precipitation, cloud cover, wind and radiation. The influence of other climate factors and stressors like precipitation, flooding and extreme weather events in the Himalayan region is well documented (Bhutiyani et al 2007, Raina, 2009, Mall, *et al*, 2006). However despite this the characteristics and nature of the Himalayan ecosystem and monsoonal effects remains less understood.

Since region specific climate models are limited, a long term monitoring of meteorological parameters is crucial before arriving at definitive conclusion regarding the impact of climate change.

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Non-Climatic Stressors

Non-climatic stressors, such as rapid economic growth, including tourism and infrastructure development for industries like construction, large hydropower etc., are increasing pressure on the fragile Himalayan ecosystem. Unplanned development has already resulted in severe pressures on both local ecology and communities. The impacts of climate change and changes in climate variability would further create additional stress. This is exemplified by instances of extreme weather event in the region in the form of landslides, cloudburst, flooding etc. which has affected not only local communities, biodiversity but also industry. The decline in glacial area and variations in annual runoff patterns in the future gains importance in the context of hydro power planning and development of the Himalayan states. We propose that future studies should also focus on the impact of regional climate variables together with non- climatic stressors like local pollutants, changing urbanization trends, tourism etc. Implementing the Mission on Himalayan Ecosystem as part of the National Action Plan on Climate Change (NAPCC) of the Government of India would therefore be a key priority.

Way Forward

Continuing pursuits in scientific excellence has resulted in critical evidence of changes in the glaciers of the Himalayas by many workers, but probably not very accurately as there is inadequate record of organized, systematic and long term observed data monitoring. However, integrating the growing body of anecdotal evidence, observations of the local communities, policy directions along with the recent initiatives of the UNFCCC may provide the impetus to focusing on glaciological studies in the Himalayas.

The dynamics of the monsoon are influenced by Himalayan systems which act as a reservoir to sustaining agriculture, providing freshwater and groundwater recharge, and are home to a unique ecosystem with many endemic species (WWF, 2009). With the Himalayan region transcending geographical barriers glacier based studies may requires not just local action but also trans-boundary cooperative arrangements.

Future efforts in building the resilience of the local community and the ecosystems should take into account a concerted and integrated approach through local, regional and national policy. There is an urgent need by communities, scientists, industry groups and policymakers to take a closer look at the linkages between local impacts, scientific research, policy interventions and the larger understanding of using resource conservation technologies and practices for promoting societal benefits.

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REFERENCES

Barnett, T. P., Adam, J. C., & Lettenmaier, D. P. (2005). Potential impacts of a warming climate on water availability in snow-dominated regions. *Nature*, *438*(7066), 303–309. doi:10.1038/nature04141 PMID:16292301

Bhutiyani, M. R., Vishwas, S. K., & Pawar, N. J. (2007). Long-term trends in maximum, minimum and mean annual air temperatures across the Northwestern Himalaya during the twentieth century. *Climatic Change*, *85*(1-2), 159–177. doi:10.100710584-006-9196-1

Cruz, R.V., Harasawa, H., Lal, M., Wu, S., Anokhin, Y., Punsalmaa, B., … NinhHuu, N.(2007). *Asia Climate Change 2007*: *Impacts, Adaptation and Vulnerability.* Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

Dobhal, D. P., Gergan, J. T., & Thayyen, R. J. (2004). Recession and morphogeometrical changes of Dokriani glacier (1962–1995) Garhwal Himalaya, India. *Current Science*, *86*(5), 692–696.

Dobhal, D. P., Gergan, J. T., & Thayyen, R. J. (2007). Mass balance and snout recession measurements (1991-2000) of Dokriani glacier, Garhwalhimalaya, India. Climatic and anthropogenic impacts on the variability of water resources. Technical Document in Hydrology No. 80. UNESCO.

Haeberli, W. (1990). Glacier and permafrost signals of 20th century warming. *Annals of Glaciology*, *14*, 99–101.

Hoelzle, M., Darms, G., Lüthi, M. P., & Suter, S. (2011). Evidence of accelerated englacialwarming in the Monte Rosa area, Switzerland/Italy. *Cryosphere*, *5*(1), 231–243. doi:10.5194/tc-5-231-2011

IPCC. (2007). *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change(IPCC)*. New York: Cambridge University Press.

IPCC. (2013). *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the IntergovernmentalPanel on Climate Change*. Cambridge, UK: Cambridge University Press.

Jianchu, X., Shrestha, A., Vaidya, R., Eriksson, M., & Hewitt, K. (2007). *The Melting Himalayas. Regional Challengesand Local Impacts of Climate Change on Mountain Ecosystems and Livelihoods. ICIMOD Technical Paper*. Kathmandu: ICIMOD.

Kaser, G., Cogley, J. G., Dyurgerov, M. B., Meier, M. F., & Ohmura, A. (2006). Mass balance of glaciers and ice caps: Consensus estimates for 19612004. *Geophysical Research Letters*, *33*(19), 5. doi:10.1029/2006GL027511

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Kulkarni, A. V., Bahuguna, I. M., Rathore, B. P., Singh, S. K., Randhawa, S. S., Sood, R. K., & Dhar, S. (2007). Glacial retreat in Himalaya using Indian Remote Sensing satellite data. *Current Science*, *92*(1), 69–74.

Kumar, R., Hasnain, S. I., Wagnon, P., Arnaud, Y., Chevallier, P., Linda, A., & Sharma, P. (2007). Climate change signals detected through mass balance measurements on benchmark glacier, Himachal Pradesh, India. Climatic and anthropogenic impacts on the variability of water resources. Technical Document in Hydrology, 80. UNESCO.

Lüthi, M., & Funk, M. (2001). Modelling heat flow in a cold, high-altitude glacier: Interpretation of measurements from ColleGnifetti. *Swiss Alps. J. Glaciol.*, *47*(157), 314–324. doi:10.3189/172756501781832223

Mall, R. K., Gupta, A., Singh, R., Singh, R. S., & Rathore, L. S. (2006). Water resources and climate change: An Indian perspective. *Current Science*, *90*(12), 1610–1626.

Naithani, A. K., Nainwal, H. C., & Prasad, C. P. (2001). Geomorphological evidences of retreat of Gangotri glacier and its characteristics. *Current Science*, *80*, 87–94.

Raina, V. K. (2009). *Himalayan Glaciers – A State-of-Art Review of Glacial Studies, Glacial Retreat and Climate Change. Ministry of Environment and Forests, discussion paper*. Government of India.

Roy, S.S., & Balling, R.C., Jr. (2005). Analysis of trends in maximum and minimum temperature, diurnal temperature range, and cloud cover over India. *Geophysical Research. Letters, 32*, 4.

Singh, P., Haritashya, U. K., Kumar, N., & Singh, Y. (2006). Hydrological characteristics of the Gangotri Glacier, central Himalayas, India. *Journal of Hydrology (Amsterdam)*, *327*(1-2), 55–67. doi:10.1016/j.jhydrol.2005.11.060

Singh, P., Haritashya, U. K., Ramasastri, K. S., & Kumar, N. (2005). Prevailing weather conditions during summer seasons around Gangotri Glacier. *Current Science*, *88*(5), 753–760.

Singh, P., Polglase, L., & Wilson, D. (2009). Role of Snow and Glacier melt runoff modeling in Hydropower projects in the Himalayan Region. *International Conference on Water, Environment, Energy and Society*.

Srivastava, D. (2001). *Glaciology of Indian Himalaya: A Bilingual Contribution in 150 Year of geological survey of India. Special Publication No. 63*. GSI.

Stern, N. (2007). *Stern Review on the Economics of Climate Change*. Cambridge, UK: Cambridge University Press. doi:10.1017/CBO9780511817434

UNEP. (2007). *Global outlook for ice & snow*. UNEP/GRID-Arendal.

UNESCO. (2007). *Case Studies on Climate Change and World Heritage*. UNESCO World Heritage Centre.

Wagnon, P., Linda, A., Arnaud, Y., Kumar, R., Sharma, P., Vincent, C., ... Chevallier, P. (2007). Four years of mass balance on ChhotaShigri Glacier, Himachal Pradesh, India, a new benchmark glacier in the western Himalaya. *Journal of Glaciology*, *53*(183), 603–611. doi:10.3189/002214307784409306

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Wood, F. B. (1990). Monitoring Global Climate Change: The Case of Greenhouse Warming. *Bulletin of the American Meteorological Society*, *71*(1), 42–52. doi:10.1175/1520-0477(1990)071<0042:MGCCTC>2.0.CO;2

WWF. (2005). *An Overview of Glaciers, glacier retreat and its subsequent impacts in the Nepal*. WWF.

WWF. (2009). *The Eastern Himalayas – Where World Collide*. WWF.

Yadav, R.R., Park, W.K., Singh, J., & Dubey, B. (2004). Do the western Himalayas defy global warming? *Geophysical Research Letters*, *31*(17).

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Chapter 75
Segmenting Paddy Farmer's Attitude and Behavior:
A Study Towards the Green Fertilizer Technology Adoption Among Malaysian Paddy Farmers – Adoption of GFT

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ABSTRACT

Agriculture is the major driving force of Malaysian economic. The aim of this research study is to segment the behavior of paddy farmers in Malaysia and understand how they influence adoption, a green fertilizer technology (GFT). The first objective of this chapter is to establish the thinking which enables a society to bridge the gap between embracing GFT among paddy farmer in Malaysia. Furthermore, the study builds the conceptual framework and examine the relationship among the relevant construct of this conceptual framework which was found by critically examining the different agricultural innovation literature. To make this conceptual framework robust it is found in the literature that theory of planned behavior and theory of reasoned action play a major role in segment farmer's behavior towards the adoption of GFT. Policy implications and/or suggestions for future research are deliberated for each issue and factor that affecting the adoption of GFT.

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INTRODUCTION

The market of the 21st century is a giant network, which covers the whole globe. The market is divided into hundreds of domestic markets and international markets. There are thousands of organizations and millions of consumers, a wide range of products and services to be offered. A great skill is needed to be able to manage these markets. The marketing science studies show markets from bottom to top, develops techniques in managing consumers, competitors, partners, dealing with products and advertising strategies. Every single company has a marketing strategy. It might be well-structured or not thought through at all, but yet there is one in every company. One of the first steps on the way to a marketing strategy is completing market segmentation. Nowadays it is very important for a company to have a crystal clear understanding of its marketing strategy. Any attempts in doing marketing and product positioning won't work as they should unless a company has an understanding of its clients and develops a marketing strategy.

Market segmentation is one of the most basic and essential parts of developing a marketing strategy. During the past hundred years, the market has grown enormously: there are lots of new products and consumers' needs getting more and more twisted and complicated over time. Technology and innovations encourage farmers' wants and companies' imagination, which is why markets become more complicated. With continuous growth and development of different market segments, it is important for a company to have a deep knowledge of consumers and markets. This study concentrates on market research, specifically on market segmentation: what kind of information and advantages can be gained out of market segmentation. The purpose of this study is to provide to exemplifying that how market segmentation can determine the right target (paddy farmers) farmers for GFT which is name as One BAJA.

In the beginning of the study, the researcher will explain the segmentation process of marketing and after that, it will follow by the analysis as per the questionnaire led and using respectively the Minerva model and the Mosaic model. In the first part of the study, the market segmentation process will be defined later the different types of market segmentation and the variables will explain. These types are significant when identifying the right target customer's farmers to a product (One BAJA). There are four major types of segmentation first is the demographic segmentation, which is considered the most shared one that deals with basic demographic factors such as age, income, gender etc. and divides the target farmers into segments based on these variables. Whereas, the geographic segmentation divides the target farmers into segments based on geographical areas such as nations, regions, cities, etc. The psychographic segmentation divides the farmers into segments according to their values and lifestyle. Finally, the behavioral segmentation divides the target customer farmers into segments based on their attitude toward product.

On the basis of the description of the types, it will be concluded which of the types are best suited when identifying the target farmers of respectively the landline telephone and the mobile telephone, in this case, being the demographic and the behavioral segmentation. The second step for (One BAJA) team is the segmentation process which is a matter of right target marketing. After identifying the target customers (farmers), the fertilizer company essentially chooses which segment to target. Subsequently the fertilizer company then must decide which market strategy to choose i.e. undifferentiated marketing, where the fertilizer company does not consider differences between the segments and targets the market with one offer, differentiated marketing, where the company targets many market segments with offers specially designed for each segment or concentrated marketing, where the fertilizer company chooses one or few markets. Furthermore, the third and final step of the segmentation process is the matter of right positioning.

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The fertilizer company (One BAJA) will have identified and evaluated the target customer it is then essential to choose what position the (One BAJA) wants to occupy in the chosen segments. In order for the One BAJA to achieve a successful positioning i.e. when the (farmers) find that the product satisfies their expectations and desires, there are steps the (One BAJA) must follow. These include amongst others; the fertilizer company (One Baja) must understand what the farmers expect and believe to be most important when deciding on a purchase, the fertilizer company (One Baja) must develop a product which caters specifically for the farmers' needs and expectations different analysis.

LITERATURE REVIEW

Segmentation

Segmentation involves finding out what kinds of consumers with different needs exist. In the auto market, for example, some consumers demand speed and performance, while others are much more concerned about roominess and safety (Kotler, 2012). In general, it holds true that "You can't be all things to all people," and experience has demonstrated that firms that specialize in meeting the needs of one group of consumers over another tend to be more profitable (Adnan, Nordin, & Redza, 2017). Whereas, Figure 1 states the different level of segmentation. However, in the line of this research our target consumer is paddy farmers in Malaysia.

Why Segmentation?

When it comes to marketing strategies, most people spontaneously think about the 4P (Product, Price, Place, Promotion) –maybe extended by three more Ps for marketing services (People, Processes, Physical Evidence) (Kotler, 2012; Kotler, Armstrong, Saunders, & Wong, 2003). Market segmentation and the identification of the target market are an important element of each marketing strategy? They are the basis for determining, any particular marketing mix (Kotler, 2012; Kotler et al., 2003). Literature of (Kotler, 2012; McDonald & Wilson, 2011) suggested that. Whereas, Figure 2 depicts the marketing segmentation process.

MAIN FOCUS OF THE CHAPTER

Segmentation and Marketing Planning

One of the essential issues in the marketing strategy of a company is marketing research. Marketing research gathers information about markets which concern the company as well as its potential farmers / current farmers (Wittman, Beckie, & Hergesheimer, 2012). The overall purpose is to get a clear picture of what is a current market, which market segments are related to a company, what are their needs and wants (Kotler, 2012). An outcome of a marketing research is a development of a strategy or improvements to it for reaching out to those market segments and satisfying their needs, or a strategy for a marketing company's specific product (McDonald & Wilson, 2011). Kristoferson and Bokalders

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Figure 1. Segmentation

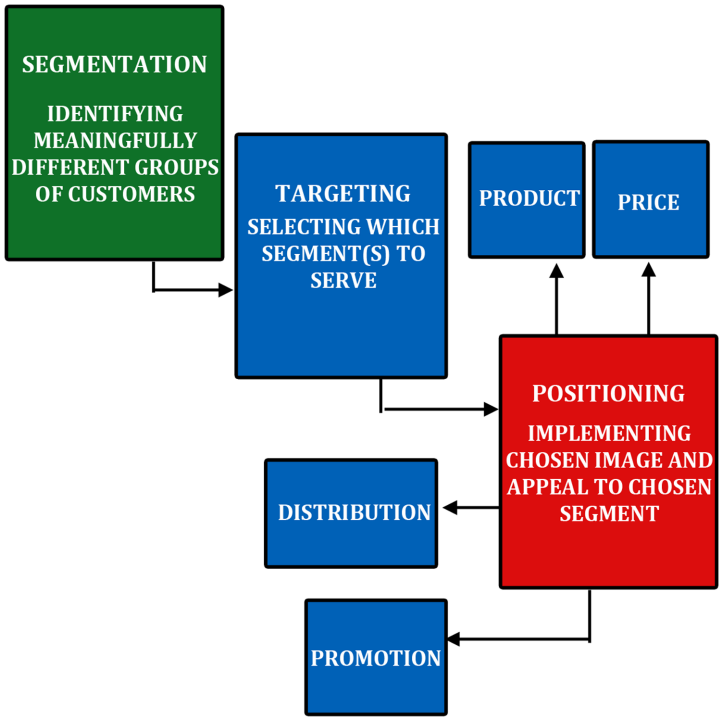
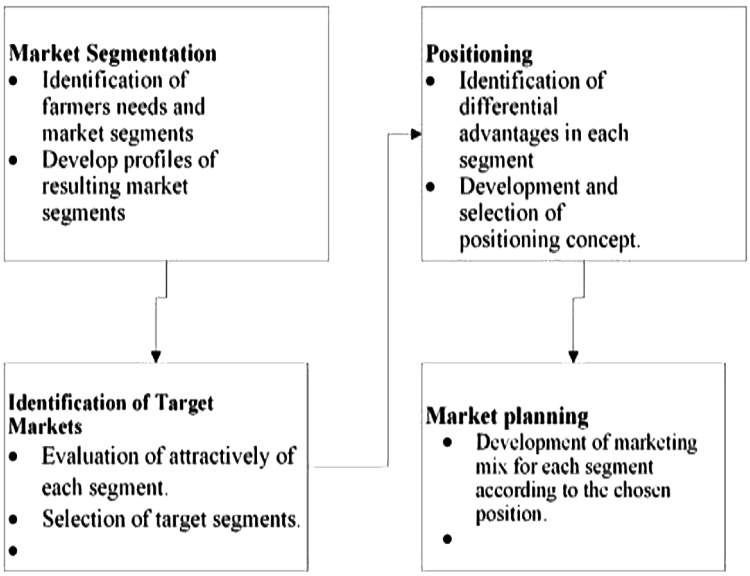


Figure 2. Market segmentation process



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(2013) marketing research consists of information about actual and potential farmers, needs, products, technologies, and competitors.

To collect information about markets, either primary or secondary sources should be used in different type of marketing strategies. Furthermore, (Armstrong, Adam, Denize, & Kotler, 2014; McDonald & Wilson, 2011) highlighted the point that marketing research consists of information about actual and potential farmers, needs, products, technologies, and competitors. To collect information about markets, either primary or secondary sources should be used. Usually, it is way easier and faster to collect information from secondary sources, which are: published articles in journals, newspapers, commercially published market researchers, government statistics, yearbooks, Internet, and other published materials. Primary sources are the ones which are collected from the original source: with the help of questionnaires, interviews, experiments or product tests with consumers.

A combined way of the research process is quite often used by companies – when there is not enough information from secondary sources, information is collected directly from primary sources (Sacks et al., 1996). There are several types of marketing research that are carried out by marketers:

- Customer research
- Promotion research
- Distribution research
- Sales research
- Marketing environment research

THEORY OF MARKET SEGMENTATION

It all started from early economic theory, where it was discovered that demand is connected to the level of competition and pricing (McDonald, 2012). Based on the article of Croft (1994) "The international consumer market segmentation managerial decision process", lots of information about the theory of market segmentation were discovered. The market segmentation concept itself has its roots starting from the 1930s when Chamberlin and Robinson proposed their theories of imperfect competition. Only in 1950s marketing writer Wendell Smith stated his point that the recognition of diversity or heterogeneity in demand and supply proposed the existence of two quite different marketing strategies, which are in use even in our modern world– product differentiation and market segmentation.

Market Segmentation

The market segmentation is mentioned as being one of the key elements of modern marketing and is, as mentioned, the process of dividing the market into several groups and/or segment(s) based on factors such as demographic, geographic, psychological and behavioral factors. By doing so the marketers will have a better understanding of their target audience and thereby make their marketing more effective (Furnham & Gunter, 2015). This is due to the fact that by using the analytical process that puts farmers first, the marketer will get more satisfied farmers and thereby gain a great advantage over competitors (Kotler, 2012). There are four levels defined by (Kotler, 2012; Kotler & Caslione, 2009) are segments, niches, local areas, and individuals. Therefore, the following marketing strategies arise segment market-

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ing, niche marketing, local marketing and individual marketing, as well as mass marketing (Croft, 1994). Furthermore, in the line of this study, we segment the fertilizer industry in Malaysia.

- Mass marketing's advantage is that it has the biggest potential market, however, it becomes more difficult to practice mass marketing over time due to a huge range of products offered to consumers.
- Segment marketing isolates the broad market and adapts so that products match one or a few sectors' needs. Segment marketing's benefits are more efficient marketing and communications in terms of reaching out to consumers. It allows the company to create a more segment-adjusted product and price according to its audience. Also the ways of communicating to consumers and distributing products become easier.
- Niche marketing focuses on subgroups within segments of the market; the company knows its clients so well that it is able to offer very specific products to a consumer when other competitors cannot offer similar products. The client is ready to pay a premium price for that offer. Niche farmers usually have a very distinct set of wants and needs usually not satisfied. The niches of the market do not attract that many competitors due to their small size and specific expectations.
- Micromarketing is the practice of serving individual clients and their individual needs and wants, which goes beyond segment or niche marketing. Philip Kotler broadened this concept into a deeper one by dividing Micromarketing into local marketing and individual marketing.

MARKET SEGMENTATION BASES

According to M. Hutt and Speh (2012), two major categories for business to business market segmentation bases are a macro segmentation and micro-segmentation. Macro segmentation concentrates on the characteristics of an organization and its situation, such as size, geographic location, operating market, industry, etc. On the other hand, micro-segmentation requires a lot more detailed information and observations about companies, such as buying decision criteria, the importance of buying and attitudes within each macro segment defined. Philip Kotler and K. Keller ("Marketing Management", 2009 p. 355) on the other hand have their own vision on segmentation variables of business markets.

Even though it is pretty close to what has mentioned above, it just introduces a slightly different way of thinking. Kotler's and Keller's major segmentation variables are: demographic (industry, company size, location); operating variables (technology, user or nonuser status, customer capability); purchasing approaches (power structure, nature of existing relationships, general purchase policies, purchasing criteria); situational factors (urgency, specific application, size of order); personal characteristics (buyer-seller similarity, attitude towards risk, loyalty).Macro segmentation is a common choice of companies when doing market segmentation.

GEOGRAPHIC LOCATION

Geographic segmentation includes such variables as location, macro-economic factors, customer concentration, etc. It can be done by countries, states, towns or even continents such as,

- **Organization's Size:** The size of an organization can be measured by a few factors: the amount of employees or revenues. In different economies and different markets, there are different defini-

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tions for small to big companies, depending on the wealth of the economy, the size of the country and the size of the market.

- **Industry Classification:** Industry segmentation is a first one to do when dividing markets into groups. Moreover, it is one of the most complicated sub-variables due to a wide range of industries and sub-industries, and new ones appear with time and high technologies. One of complications related to industry segmentation is companies operating in many industries at the same time. Nowadays it is quite normal to operate in several industries and be successful in them.
- **Characteristics Relevant to the Organization:** In case a company finds some other factors related to the descriptive characteristics of its market, it can use those factors for the segmentation process. It can totally depend on the type of business, services and partnership history and other factors.
- **User/Nonuser Status:** It is important for a farming organization to know who its active users are, who are interested in its services and who are not. That will give useful insights on who was reached and who was not. Most of the companies keep track of their past activities and past results, that is where the information on segmentation upon user/nonuser can be received from.

IMPORTANCE AND BENEFITS OF MARKETING SEGMENTATION IN MALAYSIAN AGRI-INDUSTRY

Nowadays, the market segmentation concept is considered as a big and important part of marketing theory. Marketing is all about identifying and satisfying the needs of farmers, and the needs of possible farmers need to be identified as well as farmers need to be analysed. Market segmentation gives an agricultural industry a possibility to satisfy their farmers' needs in a smart way: to offer products

A STUDY ON AGRICULTURE INDUSTRY OF MALAYSIA

In history, Malaysia was an agricultural country, proceeding to its independence in 1957. The agriculture industry has been a backbone of the Malaysian economy (Hosseini & Wahid, 2013). Whereas, Dr. Mahathir Muhammad, the former prime minister of Malaysia with his Vision 2020, imagined Malaysia as an advanced industrialized country in the coming year of 2020 (Brooker,2012; Nagarajan, 2008). Furthermore, he mentioned in this vision that agriculture is the "sunset industry "for the nation (Bakar, 2009; Melchior, 2011). Moreover, agriculture remains an important part of the national budget in the new era for the gradually growing population with the challenge to deliver both food security and safety, and sustainable growth and wealth formation. As, (Ramli et al., 2013; M. Shaffril et al., 2010) describe the Malaysia's land area measures for agriculture is about 329,733 square km, most of the soil is acidic hence, infertile.

Additionally, the agriculture sector engaged as the backbone of the country's economy and had ominously contributed to the 11.6% GDP, till it remained outshined by contributions from the manufacturing sector as the country moves rapidly towards industrialization from the mid-1970's (Haris, Hamzah, Krauss, & Ismail, 2013). Therefore, the agriculture sector has persisted glumness previously, the government agencies focus on the manufacturing sector, but during the economic crisis in 1997, Malaysian

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industrial sector faces the severe downfall. Whereas, in the agricultural industry has been proven as an effective medium to overcome self-sufficiency (Shaffril, Asmuni, & Ismail, 2010).

The country's agricultural sector has experienced various phases of transformation (Azadi, Ho, &Hasfiati, 2011). Now, after all, these phases of transformation, the agriculture sector contributes more to Gross Domestic product (GDP) increased from RM17.01 billion in 1995 to 18.22 billion in 2000 (8th Malaysian Plan). It also gained government attention in the 9th Malaysian Plan (2005-2010), agriculture is declared as the 3rd largest income generator for Malaysian. In the Malaysian agriculture sector, there are several commodities like palm oil, cocoa, livestock's fisheries and paddy. But, the government gives more emphasis more on the paddy industry because it is the basic good for the nation (FAO, 2012). Approximately, it is projected that around 300,000 farmers are involved in paddy cultivation (Moeskops et al., 2010).

Paddy is the staple food for more than three billion people all around the world. At least 114 countries grow rice and more than 50 have an annual production of 100,000 tonnes or more (Dastagiri, Gajula, & Patil; Edwards, 2015). Rice is the main food for most countries in Asia and, about 90% of the global rice area, production and consumption are concentrated on (Noppers, Keizer, Bolderdijk, & Steg, 2014). At this time, when the world's population is already reeling from higher food prices, many countries have already banned or restricted their rice exports, which pushes up the price of rice even higher (Edwards, 2015). Paddy yields have been increasing since the 1960s, but since the 1990s, the increase in rice production has been slower than population growth. Indeed, it is anticipated that rice production will need to increase by 30% by 2025 in order to cater for the world's growing population (Othman, 2012).

The current study is to look at Malaysia's paddy fertilizer sectors. Malaysia's paddy fertilizer sector is considered unique in several ways or elements. The government of Malaysia pays special attention to paddy farming. Therefore, the food crop has strategic value where rice is grown in both Peninsular and East Malaysia which is shown in Figure 3 (Haris, Hamzah, Krauss, & Ismail, 2013). About 300,500ha in peninsular Malaysia and 190,000 ha in East Malaysia are developed for rice production (Ahmad & Tahar, 2014).

There are eight granaries area in Malaysia named as MADA, Kedah, KADA, Kelantan, and Northwest Selangor project, SeberangPerai IADA, Penang, Perak and Ketara. IADA is the main paddy producer that meets seventy two percent (72%) of the demand of Malaysia stated by the Ministry of Agriculture and Agro-based Industry, (MARDI, 2010). Furthermore, it is predicted by the lawful agency that paddy will produce RM 988 million in 2010 (DOAStat, 2013). Nevertheless, if we relate paddy with other commodities of agriculture, there is still lot need to be done to strengthen paddy as the main agriculture sector in Malaysia. As per the report of (FAOstat, 2009a) the yearly production of rice stands at 2.51 million metric tons which is not sufficient. Stability of paddy plantation is essential in Malaysia as it is recognized as staple food for the majority of Malaysian.

Paddy is considered as important and essential food for both its citizen and the government, which is grown on 672,000 hectares (1.66 million acres) and the production is estimated at 3.66 metric tons per hectare which is not up to the consumption mark (Othman, 2012). Resolve this issue of low production with sustainable mean government has started providing all paddy farmers subsidized fertilizer since 1970 (Noh, 2012). On average, a Malaysian consumes around 300kg of rice per capita (FAOstat, 2012). There are many strategies to increase production in sustainable contexts. Recently, the government of Malaysia had allocated RM 100 million in the 2013 budget for the development and management of paddy industry including the subsidized fertilizer (Noh, 2013a). Furthermore, the government has taken various efforts to strengthen the paddy and rice industry like establishing many organizations.

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Figure 3. Map of Peninsular Malaysia
Source:(Tey, 2013)

For instance, paddy marketing accountability was taken over by National paddy and rice board (NPRB) which was established in 1971. In the year of 1996, NPRB got privatized and changed to (Plan, 1996) PadiBerasNasionalBerhad, by having a mission to strengthen the paddy industry (Fahmi, Samah, & Abdullah, 2013). The Government's rigorous effort continues to be one of the big agendas. During the review (NinthMalaysianplans, 2006) 70% of 2.5 billion was allocated to national food security. But currently, the country produces only 60-65% of its requirement. It meets the remaining through imports, mostly from Thailand (Haris et al., 2013). Inasmuch, substantial progress has been made in the doubling of paddy production in the last 30 years (Grassini, Eskridge, & Cassman, 2013). However, there is still a need to increase the production to meet the need of the population without unsuitable practice (Adnan, Nordin, & Noor, 2017) It is mostly a farmer's effort that contributes in large measures to paddy production in the country. A multitude of factors could be relevant this disparity of production and sustainability (Nhamo, Rodenburg, Zenna, Makombe, &Luzi-Kihupi, 2014).

The paddy plantation needs to be cultivated by new ideas and methods. Farmers need to adopt One BAJA fertilizer to increase the production without damaging the environment. This contributes toward the sustainable environment (Unescap, 2011), because it increase the crop farm production system that avoids the use of synthetic fertilizers and pesticides, hormones, antibiotics and takes measures to protect

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the environment and increase the production (Othman, 2012). The annual growth rate of rice production from year 2000 to 2013 was about 1.47% and the production of rice increased from 2.14 million metric tons (MT) in 2000 to 2.63 million MT in 2013. However, the Self-Sufficiency Level (SSL) of rice in Malaysia was 70% in 2000, 72% in 2007 and it increased to 74% in 2013 (Lee, Kim, &Vohs, 2011). Consistent with the National Agriculture Policy (NAP), the Malaysian government wishes to escalate the SSL of paddy. The SSL of paddy production can be achieved by effective fertilizer application. Malaysia is a dynamic player as a consumer and producer of fertilizer. But most of the fertilizer used in Malaysia is produced out of the country. The total value of fertilizer imported into Malaysia has been on the rise from RM 1.47 billion in 2003 to RM 3.4 billion in 2007 and this has caused huge foreign exchange losses to the country (Nordin, Noor, & bin MdSaad, 2014). This indicates that there is a large market potential for locally produced fertilizers as import substitute as well as for local producers to move up the value chain.

To enhance the agriculture production and to get optimum plant growth, nutrients must be accessible in sufficient and balanced amount (Chen, 2006). Nevertheless, the traditional method of agricultural farming in which chemical-based fertilizers are heavily used has contributed to increased global warming and greenhouse effect. Moreover, increasing soil destruction and immense use of biochemical fertilizer, particularly the rice cultivation made the Malaysian government to introduce the 'National Green Technology Policy' (NGTP) in 2009. NGTP put emphasis on boosting and implementing the green technology in agriculture (Vlek& Byrnes, 1986).

GREEN FERTILIZER TECHNOLOGY DEVELOPMENT

The worldwide concerns about worsening environmental conditions necessitate the need for eco-friendly agriculture products (Hashim&Ho, 2011; Roopan et al., 2013). Green technology policy refers to the development and application of products, equipment, and systems used to converse the natural environment and resources which minimize and reduces the negative impact of human activities (Hashim&Ho, 2011; Roopan et al., 2013). The continual application of traditional fertilizers in Malaysian paddy production has been creating adverse environmental impact with negative social consequences. The development of an eco-friendly fertilizer is hence timely and appropriate. Green fertilizer technology in the form of control release fertilizer (CRF) has numerous advantages. These advantages are:

- It increases fertilizer efficiency and crop yield,
- It reduces losses of nutrients through leaching, runoff, volatilization, and denitrification,
- It saves time, cost, and labor in reducing the frequency required for fertilizer application compared to the conventional method,
- It synchronizes the release of all macro- and micro-nutrient in the soil necessary for crop plantation.

CONTROL RELEASE FERTILIZER "ONE BAJA" RESEARCH PROGRAM

A group of researchers from several public and private universities in Malaysia has embarked on a research program named as "One Baja". The primary objective of the One Baja research program is to develop a green fertilizer technology by featuring a green production of ammonia as well as a controlled-release

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mechanism of urea for paddy farming fertilizer. This One Baja research program received a grant worth (Ringgit Malaysia) RM 12 million from the Ministry of Higher Education (MOHE) of Malaysia. The aims of this research program are:

- To model and synthesize ammonia and urea in a magnetic induction reaction zone with the presence of a catalyst and catalyst support;
- To design, multi-functional layers of biodegradable granulated urea and to develop a new coating formulation material to increase nutrient uptake;
- To systematically model the process design of Enhanced Efficiency Fertilizer (EEF) plant as well as to calculate the energy saving of the new system;
- To run efficacy test on the newly developed EEF products and to conduct some economic impact analysis via stakeholder communication.

NECESSITY OF THE STUDY FOR ONE BAJA

This remarkable achievement is a result of policy done by the Party and Government, which has paid attention to agricultural development. In addition, the agriculture has also applied the scientific and technical methods and effective usage of fertilizers in farming. In order to promote agriculture development, both in quantity and quality basis, the industry needs the support and contribution of all economic components, of which the important role of fertilizer production enterprises is undeniable. Fertilizers facilitate plants to have high productivity and quality products. Fertilizer companies must manufacture diversified and good products to meet the market needs. This would be a responsibility as well as a challenge for FELDA, RISDA, FELCRA and FOA when the firm provides urea and NPK fertilizers in the market. Before 2006, the production of fertilizer companies did not meet the need of the market; thus, the marketing activities were not paying enough attention and promoted by the fertilizer companies.

Background of Study

In average, Malaysia produces 2.67 ton of paddy each year (DOS, 2012). However, more than 60% of the production comes from the northern region where two of three largest granary areas in Malaysia are located. Furthermore, Muda Agriculture Development Authority (MADA) alone contains around 40,000 families who work as farmers (MADA, 2007). It makes the northern region of Malaysia as one of the main rice producers in Malaysia and contains the largest number of farmers compared to other regions. There are three major granary areas under MADA, IADA KADA. These regulatory bodies are responsible for managing farmers in terms of irrigation, planting, and technical advice. Under this management authority, there are several small groups of management team known as "Pertubuhan Peladang Kawasan" or PPK (Area Farmers Organization) which is the local union of farmers in the area. Their role is managing and planning for any errands for a single planting season. Furthermore, PPKs are also responsible for managing the purchase of non-subsidized fertilizer and storing the subsidized ones before the disbursement to the farmers. To this end, it is necessary for the company to carefully analyze the macro and industry environment and then map out the appropriate marketing solutions for NPK fertilizers of One BAJA. All the above-mentioned contents are covered in the specific study.

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DATA SOURCES AND RESEARCH METHODOLOGY

The research methodology is used in this study is a case study and this methodology meets the research's objective. Data used in the study were taken from both reliable secondary data about One BAJA operation collected in the process of working with One BAJA and primary data collected from interviewing agents and customers in target market about its products, prices, places and promotions and from author's observation. There are a number of techniques used to conduct a case study research will be:

- Interviewing staff and experts
- Economic statistic method
- Methods of description and comparison

This Project management all in all is a methodology and a discipline that intends to bring benefits to its One Baja fertilizer: managing complex change, using prudent resources on the right projects, using creativity and knowledge of specifically chosen team members, setting quality objectives. Its success is driven by the project 7 on schedule, expenses within budget, meeting predefined quality goals, meeting the expectations, objectives, goals and mission of the customers, effective teamwork, new business improvements and productive outcome. However, market segmentation is an important asset of the project planning phase, too. It does help managers to develop a proper set of projects (products/services), target it to the right people with the right strategy technique.

MARKETING MIX (4P)

Product is the most basic element in the marketing mix. The product can have tangible features including quality, design, function, package and brand. It can also have intangible features such as delivery service, warranty, training, etc. Price is a no less important element of market mix, which includes: whole sale and retail prices, discount, credit. Price must be in consistence with the value customers received and be competitive. Place is one of the major elements of marketing mix. This refers to how an organization will distribute the product or service they are offering to the end user. The company must understand the importance of distribution, and select the right intermediary for effective distribution. Promotion is all activities to communicate the product's advantages and convince target customer to buy that product. Promotion may include many actives to reach the target market. Company must set up activities such as, advertising, promotion, public relation, direct marketing. Thus, the research on the basic 4 p's of marketing mix is to check the market strategies of One BAJA such as positioning, product promotion and price

Positioning Strategies

Positioning of NPK fertilizer basing on the analysis of One BAJA comparative advantage and the result of interviews with customers in target markets, One BAJA can position its NPK products in the target market as follows: There are a lot of different kinds of Malaysia NPK Fertilizer of different brands namely: This data show the major player of manufacturers for compound fertilizer. Malaysian NPK Fertilizer (MNF) is the largest single factory manufacturer. (FPM got two factories at PasirGudang). There is compaction, granulated (method). If bio granulation it means during compaction process, they

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put biofertilizer element during the compaction. We still import compound fertilizer, but the amount is not simply 3 million (requirement – manufactured) because some of the requirements involve straight fertilizer. MNF Sdn Bhd is major producers of paddy fertilizer. Table 1 highlights the Malaysian fertilizer producer. These brands have a remarkable reputation in the market, yet some companies own the backward technology, which makes poor product quality and unstable price. One BAJA is a new player with the advantage of modern technology in order to make products of superior quality. Also, the company considers the high quality product as the comparative advantage to penetrate and attract customers. The aim of market penetration is to offer diversified products and upgrade the product consumption. Whereas, Table 1 illustrated the Malaysian fertilizers producers.

Product Strategies

Product strategies study, design the suitable package for consumers and diversify the products with different types of packaging and weight, namely 10 kg, 25 kg, 50 kg, 100 kg, which will satisfy all demands of consumers. Frequently update and summarize the One BAJA market information, analyze

Table 1. List of Malaysian fertilizer producer

	Compound fertilizer manufacturer	Capacity (MT)	Type of process	Locations	
1	FPM Sdn Bhd	300,000	Liquified Urea	Pasir Gudang	Peninsula
2	Malaysian NPK Fertilizer Sdn Bhd	270,000	Liquified Urea	Gurun, Kedah	Peninsula
3	CCM Fertilizers Sdn Bhd	270,000	Liquified Ammonical	Shah Alam	Peninsula
4	CCM Fertilizers Sdn Bhd	230,000	Liquified Urea	Bintulu	Sarawak
5	Agromate Sdn Bhd	200,000	Liquified Urea	Lahad Datu	Sabah
6	Kemira-Kuok Fertilizers Sdn Bhd	120,000	Granulated	Port Klang	Peninsula
7	Narsco-Kuok Fertilizers Sdn Bhd (Agrifert / Kuok Brothers)	120,000	Granulated	Pasir Gudang	Peninsula
8	Agri-Bintulu Fertilizers Sdn Bhd (Agrifert / Kuok Brothers)	120,000	Granulated	Bintulu	Sarawak
9	United Compound Fertilizers Sdn Bhd	100,000	Compaction	Kuantan	Peninsula
10	All Cosmos Industries Sdn Bhd	80,000	Bio Compaction	Pasir Gudang	Peninsula
11	TM-Kay Fertilizers Sdn Bhd (Agrifert / Kuok Brothers)	80,000	Granulated	Port Klang	Peninsula
12	Agri-Sabah Fertilizers Sdn Bhd (Agrifert / Kuok Brothers)	50,000	Granulated	Sandakan	Sabah
13	PK Fertilizers Sdn Bhd	25,000	Granulated	Pasir Gudang	Peninsula
14	Twin Arrow Fertilizer Sdn Bhd	25,000	Granulated	Port Klang	Peninsula
15	Consolidated Fertiliser Corporation (CFC) Sdn Bhd	20,000	Granulated	Port Klang	Peninsula
16	Sasco Sdn Bhd	20,000	Granulated	Lahad Datu	Sabah
	Total MT	2,030,000			

Source:(Safitri&Andriyani, 2011)

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and evaluate the information, identify the market trend, competitors' abilities, recommend solutions and strategies to bring into full play the products' competitive advantages. Frequently visit the primary consumers, farmers, who directly use the products, to **assess** their knowledge as well as the satisfaction from the products. For this reason, One BAJA should focus on high quality products, which have high demand, to convince the customers and distributors. One BAJA should invest in technology, which is more modern than that of other competitors, to create competitive advantages and superior products. One BAJA market is a fierce market; therefore, in order to survive and go far in the market, One BAJA need to invest in R&D activities in the long-term to differentiate their products with those of competitors.

Price Strategies

In terms of pricing a product, One BAJA is a newcomer; thus, the company needs a flexible pricing strategy, price determination must be taken into consideration of production costs, domestic and foreign prices and especially competitors' pricing. Being a fertilizer producer, the company deeply aware that its main customers are farmers, who are mostly living in poverty, underfunding and having a limited scientific understanding. To create favorable conditions for farmers to buy fertilizers on the installment plan, the company needs a late payment mechanism from 3 to 6 months so the farmers can purchase the fertilizer.

Promotion Strategies

Promotion strategy regarding the promotion and communication strategy, One BAJA should pay attention to, the following activities: The Company needs to hold seminars in the localities within the target market to introduce the product, which can help farmers and retailers aware of the products and the superior quality of NPK fertilizer against other competitors. In order to popularize as well as provide information about NPK products, the company needs to select media channels which are close to farmers such as agriculture programs broadcasted on radio and TV. The company should also take the agents in the urea nitrate market as a channel to introduce about NPK products. It is an important channel and popular with farmers. Besides that, One BAJA fertilizer awareness strategies through ICT should be proposed in the future as a promotional tool for the department of Agriculture, Malaysia organic farming.

The use of ICT can be used as a tool by the Department of Environment and the Ministry of Energy, Green Technology and Water for their sustainability promotion among Malaysian farmers. One Baja successful promotion with the help of ICT innovation will enhance the sustainability awareness through its recognition at the Malaysia Technology Expo (MTE) 2009. According to the National Green Technology Policy Malaysia, effective promotion and public awareness are two of the main factors that would affect the success of sustainable development among farmers through the adoption of One BAJA fertilizer. This is particularly significant as such adoption requires a change of mindset of the farmers through various approaches, including effective education and information dissemination to increase public awareness of sustainable agriculture and on ways to conserve the environment. This awareness of One BAJA fertilizer among paddy farmers in Malaysia with the help of ICT application with the element of captology, integrated into a persuasive learning environment can play an innovative role in promoting sustainable practices in agriculture. This research also aims to relate the issues of adoption of One BAJA fertilizer by using ICT in order to disseminate information about sustainable paddy farming practices in Malaysia. The government also plans to increase the usage of ICT in all sectors to increase productivity. Mastery of the use of information technologies will be emphasized to enhance the acquisi-

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tion and dissemination of new knowledge and technologies, and to motivate greater youth participation in technology development and transfer. Advances in "expert systems" or computer simulated scenario analysis will be exploited to enhance on-farm advice and information exchange to agriculture producers through extension. The most innovative approach is the development of a new product or process to solve a new problem or usage. An example is the Digital Video Disk (DVD), which illustrates an old process with a new usage. DVDs employ the same basic technology as CDs; however, the means for compression and reading hardware are more advanced.

Another example of product innovation is an electronic mail security that involves virus protection software (Othman et al., 2012). However, almost as quickly as new software and processes are developed for protecting a firm's information, new problems emerge. It is a constant war of innovation nowadays, in Malaysia there are many innovations in ICT in learning and promoting sustainability issues, including learning through VR, sustainable agriculture in multimedia and VR application, persuasive technology, educational games, serious games, criteria in choosing the learning games and positive impact of computer games on education and training. According to the Planning and Information Technology Department of MADA, the usage of ICT was existing in their daily operations. This is especially true when they convey information to the public through their website (http://www.mada.gov.my/). It is similar in Kajang, Bandar Baru Tunjong, Tanjung Karang and Sabak Bernam Agriculture Departments. They have all developed their own web-based information systems for the purpose of disseminating information about innovation in the fertilizer industry.

DIFFERENT TYPE OF FERTILIZER IN MALAYSIA

Mineral Fertilizers

Mineral fertilizers account for more than 90 percent of fertilizers used by all types of farming systems in Malaysia. The main fertilizers are urea, ammonium sulphate, calcium ammonium nitrate, phosphate rock, super phosphates, ammonium phosphate, potassium chloride, potassium sulphate and NPK, NP and PK compound fertilizers. Due to the rapid expansion in crop production, especially of plantation crops (rubber, oil-palm, cocoa, and paddy) there has been a corresponding increase in fertilizer use. Potassium fertilizers have shown the largest increase and very effective for the crops.

Organic Fertilizers

The government is promoting the use of organic fertilizers in Malaysia for two main reasons. Firstly, organic agriculture is seen as important for the sustainable use and management of natural resources. Secondly, in the NAP3, organic agriculture is identified as a niche market opportunity for fruits and vegetables. In an effort to reduce the dependence on mineral fertilizers and to move towards more natural and healthier methods of food production, the government is promoting programmers that encourage the recycling and use of agricultural waste.

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Table 2. Number and area of organic producers per State in 2001. Source: (Wai, 2001)

State	Number	Area(ha)
Selangor	4	10.8
Negri Sembilan	10	90
Melaka	2	1.1
Johor	2	3.5
Pahang	6	11.6
Sabah	2	12
Sarawak	1	2
Total	27	131

PRODUCTION AND MARKETING OF THAT FERTILIZER

Most of the fertilizer used in Malaysia is produced abroad. Urea, ammonium based and organic fertilizers are produced in large amounts, but the urea used in Malaysia for agriculture is not locally produced material. This is because the prilled urea produced in Malaysia fetches a high price in the international market and is therefore exported. The parent fertilizer producing company has two subsidiaries involved in the production of urea. These are one subsidiary was incorporated in 1980 and located in Bintulu, Sarawak. The plant has a capacity to produce 600 000 tonnes of granular urea and 420 000 tons of prilled urea per annum.The other came into operation in 1999 and is located in Gurun, Kedah. It has an annual capacity of 650 000 tonnes granular urea. This second plant exports about 65 percent of its products to Australia, Thailand and other South East Asian agricultural countries. The remainder is sold to the National Farmers' Association, Malaysia's largest urea consumer, for distribution in Malaysia. Most of the companies involved in fertilizer production engage in the mixing of straight fertilizers to produce compound fertilizers. The fertilizer industry in Malaysia is efficient and highly competitive. There are over 50 companies involved in the branded fertilizer trade with over 350 brands of various forms of fertilizers (Malaysian Agriculture Directory and Index, 2004). The normal channels of distribution are shown in Figure 4. The Government, in its drive to help farmers, particularly smallholders, to procure fertilizers has: stimulated fertilizer consumption through subsidy and credit schemes; facilitated the supply and distribution of fertilizers through FELDA, RISDA, FELCRA and FOA; stimulated the establishment of a large number of distribution points through farmers' cooperatives improved the cost-value ratio between fertilizers and agricultural produce by providing price support; provided extension services, research on fertilizer use and quality control. The government has also encouraged suppliers to market fertilizers in packages smaller than 50-kg bags, to allow farmers who cannot afford 50-kg bags to purchase lesser quantities.

FERTILIZER USAGE IN PADDY INDUSTRY MALAYSIA

In the context of Malaysian paddy industry, reliance on fertilizer usage to increase yield requires a good relationship fostered between the farmers as consumers, generally represented by farmer organizations, and manufacturers or retailers as suppliers (Ismaila, 2008; Zainal, Shamsudin, Mohamed, Adam, &

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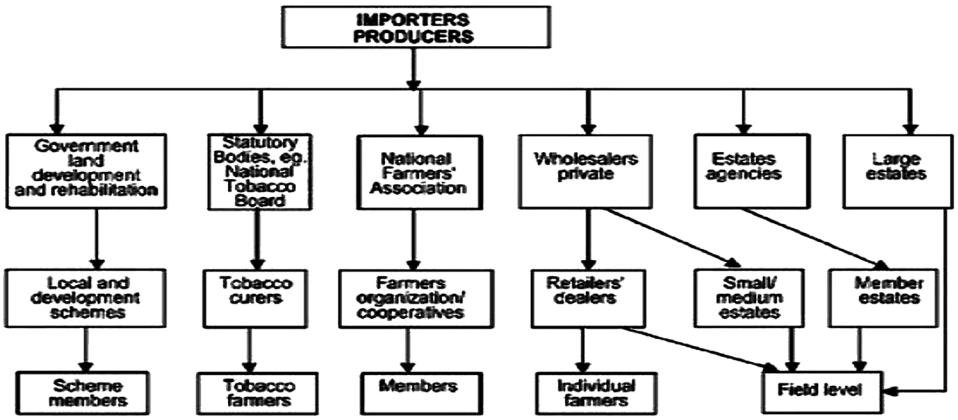
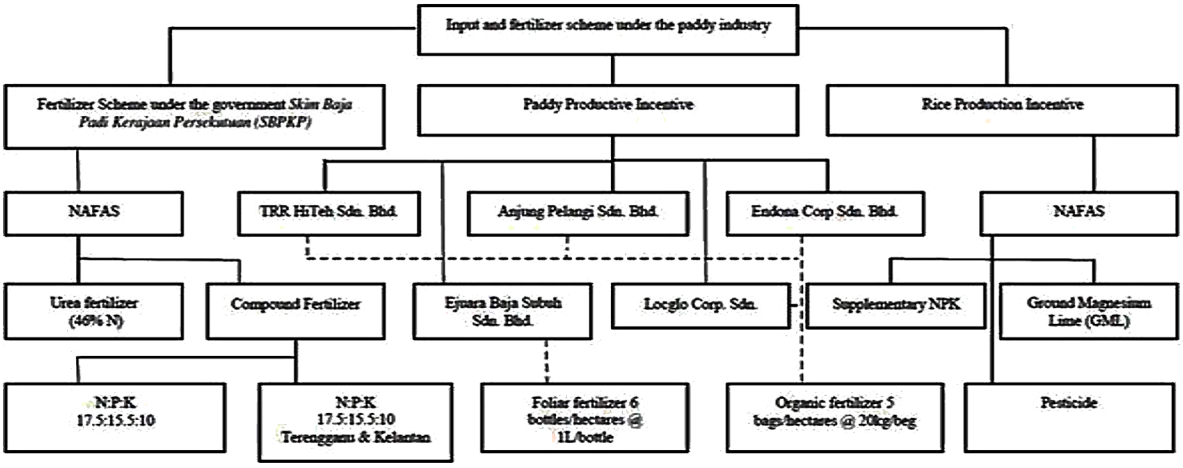
Figure 4. Marketing and distribution channel of fertilizers in Malaysia



Kaffashi, 2014). The relationship does not merely involve purchasing and selling products as it also requires professional advice to the farmers. For instance, in the case of introductions to new technology or products would require feedback from the consumers. The government's effort to strengthen the paddy and rice industry continues to be one of the main agenda. The Ninth Malaysia Plan saw 70% of RM 2.5 billion, and later RM 3 million during the mid-review, allocated to national food security. The paddy sector in Malaysia is a heavily subsidized industry, which the summary of the input and fertilizer subsidies is as follows:

Despite the rigorous efforts and initiatives by the Government, Fahmiet al. (2013) mentioned that Malaysia's rice production is considered inefficient in terms of cost and production. It has also been noted that there are also issues and challenges specifically on the supply of fertilizer that has an impact on the yield of paddy. Some of the challenges in fertilizer supply revolve around the following issues (reported in BeritaTransformasiPertanian: Lahir Peladang Progres if, 2012): Ensuring that fertilizer

Figure 5. Input and fertilizer subsidy in paddy agriculture
Source:(A. Rizal et al., 2014)



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is supplied only to eligible farmers, more frequent visits to meet the farmers for monitoring, timely distribution of fertilizer to farmers. Malaysian government spent about 30 million USD annually on chemical fertilizer. As illustrated in Figure 5 National Farmer Association (NAFAS) has been the sole distributor of the subsidized fertilizer to the paddy farmer's nationwide (A. R. A. Rizal, Nordin, Saad, & Ismail, 2012). Hence, there is a need to ensure that the subsidized fertilizer is supplied to and received only by eligible farmers which require efficient communication management, specifically between the suppliers and consumers. In of this research study One BAJA need proper segmentation in order to be successful in the market**.**

FUTURE RESEARCH DIRECTIONS

This paragraph summarizes the review results and suggests future directions of One Baja fertilizer and procedures. The specific research field is relatively new and possible future perspectives have to be emphasized so that new innovation can be effective in order to increase the production.

Investment positive:

- Rising population increased the demand of chemical fertilizer usage and changing diets, putting a heavy demand on higher crop yields. With limited available acreage for planting, fertilizers will be increasingly needed to produce strong yields.
- Crop prices have most likely hit with upward potential in the near future Increases in crop prices will directly result in higher sales of fertilizers.
- Using One BAJA fertilizer is a strong an opportunity exist for paddy farmers in Malaysia to increase the production without damaging the environment.

Investment negative:

- Most fertilizer companies specialize in a specific fertilizer type since fertilizers are dependent on various conditions, companies can experience cyclicality. Investing in the wrong fertilizer farmers in a downward cycle could result in heavy losses.

Key to monitor:

- Crop prices will have the most immediate effect on fertilizer consumption. Farmers will be more likely to purchase and utilize fertilizer when they experience high margin. One Baja fertilizer is also known as control released fertilizer

CONCLUSION

The study has met the goal of mapping out some marketing solutions that are suitable for the NPK target market of One BAJA. To this end, the author has logically revised the marketing literature, including concepts relating to marketing, models to analyze macro and industry environment and marketing mix. Based on the literature review, the author has analyzed the situation of One BAJA NPK fertilizer. The

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study covers the macro and industry environment analysis of NPK fertilizer, major rivals' marketing mix. Then, the analysis of NPK market has laid the foundation of the marketing strategies to develop One BAJA NPK target market. With such a wide range of activities and a huge market to serve, it is important to have a structured marketing strategy and a marketing plan. In order to accomplish that, one needs to know the customers of the market. That is why market segmentation plays such a big role in marketing planning and marketing strategy. However, the results of One Baja research program validated that it is a value-added research program. Since the value of the obtained benefits is more than the funding devoted (RM12 million) on this particular research.

Overall, the marketing strategies of One Baja results indicated that the RM 12 million research program provided by the government can potentially generate benefits value of RM 1,824 million per year for the Malaysian fertilizer industry. In summary, the study concludes that the participants in research collaboration appear to get significant benefits and it also increase the paddy production. The most important benefit realized by the government is that the new green fertilizer technology in the form of CRF developed in this research program will have a high impact on the domestic paddy farming, the ecosystem as well as on the value proposition of the fertilizer industry. In a nutshell, this technology is economically efficient in the context of the fertilizer application frequency as compared to the conventional methods.

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REFERENCES

Adnan, N., Nordin, S. M., & Noor, A. N. (2017). *A Comparative Study on GFT Adoption Behaviour Among Malaysian Paddy Farmers. In Green Marketing and Environmental Responsibility in Modern Corporations* (pp. 239–263). IGI Global. doi:10.4018/978-1-5225-2331-4.ch012

Adnan, N., Nordin, S. M., & Redza, A. (2017). *Benefit of One Baja Fertilizer for Attaining Agricultural Sustainability among Malaysian Paddy Farmers: Agricultural Sustainability among Malaysian Paddy Farmers. In Business Infrastructure for Sustainability in Developing Economies* (pp. 143–160). IGI Global. doi:10.4018/978-1-5225-2041-2.ch008

Advisory, F. (1993). Development and Information Network for Asia and the Pacific (FADINAP). *Proceedings of the regional FADINAP seminar on fertilisation and the environment*.

Ahmad, S., & Tahar, R. M. (2014). Selection of renewable energy sources for sustainable development of electricity generation system using analytic hierarchy process: A case of Malaysia. *Renewable Energy*, *63*, 458–466. doi:10.1016/j.renene.2013.10.001

Ahmad, S., & Tahar, R. M. (2014). Selection of renewable energy sources for sustainable development of electricity generation system using analytic hierarchy process: A case of Malaysia. *Renewable Energy*, *63*, 458–466. doi:10.1016/j.renene.2013.10.001

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Ahmed, O. H., Hanif, M., Husni, A., Abd Rahim, A., & Musa, M. H. (2001). Pineapple residue management practices and fertilizer regimes: Effects on P and K uptake, yield and some economic implications. *Pertanika. Journal of Tropical Agricultural Science*, *24*(2), 123–129.

Armstrong, G., Adam, S., Denize, S., & Kotler, P. (2014). *Principles of marketing*. Pearson Australia.

Azadi, H., Ho, P., & Hasfiati, L. (2011). Agricultural land conversion drivers: A comparison between less developed, developing and developed countries. *Land Degradation & Development*, *22*(6), 596–604. doi:10.1002/ldr.1037

Bakar, B. B. (2009). T*he Malaysian agricultural industry in the new millennium: Issues and challenges*. Academic Press.

Balbus, J. M., Boxall, A., Fenske, R. A., McKone, T. E., & Zeise, L. (2013). Implications of global climate change for the assessment and management of human health risks of chemicals in the natural environment. *Environmental Toxicology and Chemistry*, *32*(1), 62–78. doi:10.1002/etc.2046 PMID:23147420

Balogun, R. B., Ogbu, J. U., Umeokechukwu, E. C., & Kalejaiye-Matti, R. B. (2016). *Effective Microorganisms (EM) as Sustainable Components in Organic Farming: Principles, Applications and Validity. In Organic Farming for Sustainable Agriculture* (pp. 259–291). Springer.

Bean, J., & Hussey, L. (2012). *Marketing Public Sector Services: essential skills for the public sector*. HB Publications.

Brashear Alejandro, T., Javalgi, R. G., Gross, A. C., Benoy Joseph, W., & Granot, E. (2011). Assessing competitive advantage of emerging markets in knowledge intensive business services. *Journal of Business and Industrial Marketing*, *26*(3), 171–180. doi:10.1108/08858621111115895

Brooker, D. (2012). Build it and they will come? A critical examination of utopian planning practices and their socio-spatial impacts in Malaysias intelligent city. *Asian Geographer*, *29*(1), 39–56. doi:10.1080/10225706.2012.659192

Croft, M. J. (1994). *Market segmentation: A step-by-step guide to profitable new business*. Cengage Learning Emea.

Djellal, F., Francoz, D., Gallouj, C., Gallouj, F., & Jacquin, Y. (2003). Revising the definition of research and development in the light of the specificities of services. *Science & Public Policy*, *30*(6), 415–429. doi:10.3152/147154303781780227

FADINAP. (1984). Report. Marketing, distribution and use of fertilizer in Malaysia. FADINAP.

Fahmi, Z., Samah, B. A., & Abdullah, H. (2013). Paddy Industry and Paddy Farmers Well-being: A Success Recipe for Agriculture Industry in Malaysia. *Asian Social Science*, *9*(3), 177. doi:10.5539/ass.v9n3p177

FAO. (2012). Retrieved from http://www.fao.org/docrep/x0262e/x0262e06.htm

Fred van Raaij, W., & Verhallen, T. M. (1994). Domain-specific market segmentation. *European Journal of Marketing*, *28*(10), 49–66. doi:10.1108/03090569410075786

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Furnham, A., & Gunter, B. (2015). *Corporate Assessment (Routledge Revivals): Auditing a Company's Personality*. Routledge.

Grassini, P., Eskridge, K. M., & Cassman, K. G. (2013). Distinguishing between yield advances and yield plateaus in historical crop production trends. *Nature Communications*, 4. PMID:24346131

Haris, N. B. M., Hamzah, A., Krauss, S. E., & Ismail, I. A. (2013). Relationship between Decision-Making Inputs and Productivity among Paddy Farmers" in Integrated Agriculture Development Areas (IADAs), in Malaysia. *International Journal on Advanced Science*, *Engineering and Information Technology*, *3*(1), 64–70.

Haris, N. B. M., Hamzah, A., Krauss, S. E., & Ismail, I. A. (2013). Relationship between Decision-Making Inputs and Productivity among Paddy Farmers" in Integrated Agriculture Development Areas (IADAs), in Malaysia. *International Journal on Advanced Science*, *Engineering and Information Technology*, *3*(1), 64–70.

Hashim, H., & Ho, W. S. (2011). Renewable energy policies and initiatives for a sustainable energy future in Malaysia. *Renewable & Sustainable Energy Reviews*, *15*(9), 4780–4787. doi:10.1016/j.rser.2011.07.073

Homburg, C., Kuester, S., & Krohmer, H. (2013). *Marketing management: A contemporary perspective*. McGraw-Hill Higher Education.

Hosseini, S. E., & Wahid, M. A. (2013). Feasibility study of biogas production and utilization as a source of renewable energy in Malaysia. *Renewable & Sustainable Energy Reviews*, *19*, 454–462. doi:10.1016/j.rser.2012.11.008

Hunter, W., Hutschemaekers, G. J., Unger, J.-P., de Paepe, P., Ghilbert, P., Soors, W., ... Rissanen, P. (2003). AP Nauta, J. von Grumbkow. *Policy*, *3*, 4.

Hutt, M., & Speh, T. (2012). *Business marketing management: B2B*. Cengage Learning.

Hutt, M. D., & Speh, T. W. (1984). The marketing strategy center: Diagnosing the industrial marketers interdisciplinary role. *Journal of Marketing*, *48*(4), 53–61. doi:10.2307/1251510

Ismaila, S. S. (2008). *Off farm employment among paddy farmers in the Muda and Kemasin Semarak granary areas*. Universiti Putra Malaysia.

Jenkins, M., & McDonald, M. (1997). Market segmentation: Organizational archetypes and research agendas. *European Journal of Marketing*, *31*(1), 17–32. doi:10.1108/03090569710157016

Kearney, D. (2013). Food Deprivations as Crimes against Humanity. *NYUJ Int'l L. & Pol.*, *46*, 253.

Kotler, P. (2012). *Kotler on marketing*. Simon and Schuster.

Kotler, P. (2012). *Kotler on marketing*. Simon and Schuster.

Kotler, P., Armstrong, G., Saunders, J., & Wong, V. (2003). *Principi di Marketing (Italian Translation of Principles of Marketing)*. ISEDE and Prentice Hall International.

Kotler, P., & Caslione, J. A. (2009). *Chaotics: the business of managing and marketing in the age of turbulence*. AMACOM Div American Mgmt Assn.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Kotler, P., & Keller, K. L. (2009). *Dirección de marketing*. Pearson educación.

Kristoferson, L. A., & Bokalders, V. (2013). *Renewable energy technologies: their applications in developing countries*. Elsevier.

Lee, K., Kim, H., & Vohs, K. D. (2011). Stereotype threat in the marketplace: Consumer anxiety and purchase intentions. *The Journal of Consumer Research*, *38*(2), 343–357. doi:10.1086/659315

Levina, O. (2010). *Business market segmentation: Segmenting market for AmCham Finland*. Academic Press.

McDonald, M. (2012). *Market Segmentation*. Wiley Online Library. doi:10.1002/9781119207863

McDonald, M., & Wilson, H. (2011). *Marketing plans: How to prepare them, how to use them*. John Wiley & Sons.

McDonald, M., & Wilson, H. (2011). *Marketing plans: How to prepare them, how to use them*. John Wiley & Sons.

Melchior, M. R. (2011). From Design Nations to Fashion Nations? Unpacking Contemporary Scandinavian Fashion Dreams. *Fashion Theory*, *15*(2), 177–200. doi:10.2752/175174111X12954359478681

Miorandi, D., Sicari, S., De Pellegrini, F., & Chlamtac, I. (2012). Internet of things: Vision, applications and research challenges. *Ad Hoc Networks*, *10*(7), 1497–1516. doi:10.1016/j.adhoc.2012.02.016

Moeskops, B., Buchan, D., Sleutel, S., Herawaty, L., Husen, E., Saraswati, R., ... De Neve, S. (2010). Soil microbial communities and activities under intensive organic and conventional vegetable farming in West Java, Indonesia. *Applied Soil Ecology*, *45*(2), 112–120. doi:10.1016/j.apsoil.2010.03.005

Nagarajan, S. (2008). Indians in Malaysia towards vision 2020. *Rising India and Indian communities in East Asia*, 375-398.

Nhamo, N., Rodenburg, J., Zenna, N., Makombe, G., & Luzi-Kihupi, A. (2014). Narrowing the rice yield gap in East and Southern Africa: Using and adapting existing technologies. *Agricultural Systems*, *131*, 45–55. doi:10.1016/j.agsy.2014.08.003

Noppers, E. H., Keizer, K., Bolderdijk, J. W., & Steg, L. (2014). The adoption of sustainable innovations: Driven by symbolic and environmental motives. *Global Environmental Change*, *25*, 52–62. doi:10.1016/j.gloenvcha.2014.01.012

Noppers, E. H., Keizer, K., Bolderdijk, J. W., & Steg, L. (2014). The adoption of sustainable innovations: Driven by symbolic and environmental motives. *Global Environmental Change*, *25*, 52–62. doi:10.1016/j.gloenvcha.2014.01.012

Nordin, S. M., Noor, S. M., & Saad, M. S. M. (2014). Innovation Diffusion of New Technologies in the Malaysian Paddy Fertilizer Industry. *Procedia: Social and Behavioral Sciences*, *109*, 768–778. doi:10.1016/j.sbspro.2013.12.542

Othman, Z. (2012). *Information and communication technology innovation as a tool for promoting sustainable agriculture: a case study of paddy farming in west Malaysia*. University of Malaya.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Patel, R. (2013). The long green revolution. *The Journal of Peasant Studies*, *40*(1), 1–63. doi:10.1080/03066150.2012.719224

Prabovo, N. E., Foster, H. L., Nelson, S., Sitepu, B., & Nelson, P. (2012). *Practical use of oil palm nutrient physiological efficiency with regard to nutrient recovery and agronomic efficiencies at different Sumatran sites*. Academic Press.

Ramli, N. S., Hassan, M. S., Samah, B. A., Ali, M. S. S., Shaffril, H. A. M., & Azaharian, Z. S. (2013). Problems in using agricultural information from television among farmers in Malaysia. *Asian Social Science*, *9*(9), 70. doi:10.5539/ass.v9n9p70

Rizal, A., Redza, A., Md Nordin, S., Saad, M., Shamsuri, M., & Wahab, H. (2014). Inter-Organization Communication Management between Organizations in a Subsidized Fertilizer Market in Malaysia. *Global Business and Management Research: An International Journal*, *6*(3), 229–236.

Rizal, A. R. A., Nordin, S. M., Saad, M. S., & Ismail, K. (2012). Engagement Strategies for Stakeholder Management in New Technology Development in the Fertilizer Industry-A Conceptual Framework. *Proceedings of World Academy of Science, Engineering and Technology*.

Rizal, A. R. A., Nordin, S. M., Saad, S. M., & Wahab, H. (2013). Communication Management between Organizations in a Subsidized Market: The Case of Paddy Fertilizer in Malaysia. *Asian Journal of Research in Social Sciences and Humanities*, *3*(12), 1.

Roopan, S. M., Madhumitha, G., Rahuman, A. A., Kamaraj, C., Bharathi, A., & Surendra, T. (2013). Low-cost and eco-friendly phyto-synthesis of silver nanoparticles using Cocos nucifera coir extract and its larvicidal activity. *Industrial Crops and Products*, *43*, 631–635. doi:10.1016/j.indcrop.2012.08.013

Sacks, F. M., Pfeffer, M. A., Moye, L. A., Rouleau, J. L., Rutherford, J. D., Cole, T. G., ... Wun, C.-C. (1996). The effect of pravastatin on coronary events after myocardial infarction in patients with average cholesterol levels. *The New England Journal of Medicine*, *335*(14), 1001–1009. doi:10.1056/NEJM199610033351401 PMID:8801446

Safitri, R., & Andriyani, A. (2011). Keefektifan Pemberian Posisi Semi Fowler Terhadap Penurunan Sesak Nafas Pada Pasien Asma di Ruang Rawat Inap Kelas III RSUD Dr. Moewardi Surakarta. *Gaster Jurnal Ilmu Kesehatan, 8*(2), 783-792.

Shaffril, H. A. M., Asmuni, A., & Ismail, A. (2010). Menu. *Journal of International Social Research*, *3*, 450–458.

Shaffril, M., Azril, H., Uli, J., Asiah, M., Ali, N. A., Abu Samah, B., ... Thomas, K. (2010). Can quality of work life affect work performance among government agriculture extension officers? A case from Malaysia. *Journal of Social Sciences*, *6*(1), 64–73. doi:10.3844/jssp.2010.64.73

Taylor, S., & Todd, P. (1995). Decomposition and crossover effects in the theory of planned behavior: A study of consumer adoption intentions. *International Journal of Research in Marketing*, *12*(2), 137–155. doi:10.1016/0167-8116(94)00019-K

Tey, Y. S. (2013). *The Adoption of Sustainable Agricultural Practices: An Integrative Approach for Malaysian Vegetable Farmers*. The University of Adelaide.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Windeshausen, H. N. (1973). Market Segmentation: Concepts and Applications. *Journal of Marketing (pre-1986), 37*(4), 124.

Wittman, H., Beckie, M., & Hergesheimer, C. (2012). Linking local food systems and the social economy? Future roles for farmers markets in Alberta and British Columbia*. *Rural Sociology*, *77*(1), 36–61. doi:10.1111/j.1549-0831.2011.00068.x

Zainal, Z., Shamsudin, M. N., Mohamed, Z. A., Adam, S. U., & Kaffashi, S. (2014). Assessing the Impacts of Climate Change on Paddy Production in Malaysia. *Research Journal of Environmental Sciences*, *8*(6), 33.

ADDITIONAL READING

Chen, J. H. (2006). The combined use of chemical and organic fertilizers and/or bio fertilizer for crop growth and soil fertility. In *International Workshop on Sustained Management of the soil-rhizosphere system for efficient crop production and fertilizer*.

Fahmi, Z., Samah, B. A., & Abdullah, H. (2013). Paddy Industry and PaddyFarmers Well-being: A Success Recipe for Agriculture Industry inMalaysia. *Asian Social Science*, *9*(3), 177. doi:10.5539/ass.v9n3p177

Hashim, H., & Ho, W. S. (2011). Renewable energy policies and initiatives for a sustainable energy future in Malaysia. *Renewable & Sustainable Energy Reviews*, *15*(9), 4780–4787. doi:10.1016/j.rser.2011.07.073

Liew, Y. A., Omar, S. S., Husni, M. H. A., Abidin, M. Z., & Abdullah, N. A. P.(2010). Effects of Micronutrient Fertilizers on the Production of. Malaysianjournal of soil science, 14, 71-82.

Vlek, P. L., & Byrnes, B. H. (1986). 7. The efficacy and loss of fertilizer N inlowland rice. *Fertilizer Research*, *9*(1-2), 131–147. doi:10.1007/BF01048699

KEY TERMS AND DEFINITIONS

Business-to-Business (B2B): Refers to a situation where one business makes a commercial transaction with another. This typically occurs when: A business is sourcing materials for their production process (e.g. a food manufacturer purchasing salt).

Market Segmentation: A marketing strategy which involves dividing a broad target market into subsets of consumers, businesses, or countries that have, or are perceived to have, common needs, interests, and priorities, and then designing and implementing strategies to target them.

Marketing Research: The process or set of processes that links the producers, customers, and end users to the marketer through information used to identify and define marketing opportunities and problems; generate, refine, and evaluate marketing actions; monitor marketing performance; and improve understanding of marketing as a process.

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One Baja Fertilizer: In Malaysia green fertilizer technology in the form of Control Release Fertilizer (CRF).

Segmentation Bases: The dimensions that can be used to segment a market. "A segmentation basis is defined as a set of variables or characteristics used to assign potential customers to homogeneous groups.

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NOMENCLATURE

CRF: Control released Fertilizer
PPK: Pertubuhan PeladangKawasan
NAFAS: National Farmer Association
BERNAS: Padiberas NasionalBerhad (National Rice Company)
BLS: Barat Laut Selangor (North West)
DOA: Department of Agriculture
GAP: Good Agricultural Practice
IRRI: International Rice Research Institute
IADA: Integrated Agriculture Development Area
KADA: Kemubu Agricultural Development Authority (Kelantan)
KETARA: Northern Terengganu
KOREF: Kahang Organic Rice Eco Farm
KSM: Kerian Sungai Manik (Perak)
MADA: Muda Agricultural Development Authority
MARDI: Malaysian Agricultural Research and Development Institute

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Chapter 76
Competitiveness of Turkey in the Sectoral Transformation Process:
A Comparative Analysis With the BRIC Countries

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ABSTRACT

The aim of this study is to measure the competitiveness of Turkey by making a comparative analysis between the Turkish agricultural, industrial, and services sectors involved in foreign trade and the corresponding sectors of the BRIC (Brazil, Russia, India, China) nations. In addition to the determination of their relative competitiveness, assessments will be made about their competitiveness over time by analyzing the direction of the sectoral trends of the above-mentioned countries. In the study, after a brief theoretical overview, a summary of the literature related to the subject is provided, followed by a comparison of the competitiveness of the three sectors (agriculture, industry, and services) made by calculating the revealed comparative advantages (RCAs) of Turkey and the BRIC countries.

INTRODUCTION

In Turkey, as a consequence of the planned development period that started in 1963 following the implementation of the import substitution industrialization strategy, the share of agriculture has started to decrease while the share of industry has started to increase in terms of both production and employment. The increase of the share of industry in terms of Gross Domestic Product (GDP), an indicator of being a developed nation, has raised the share of the services and industrial sectors while reducing that of

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agriculture. As a result of the outward industrialization model after 1980, this transformation evidenced in the main sectors has also emerged in the foreign trade structure. During the transformation process, the share of industrial production, especially for export, has rapidly risen while imports, and therefore the volume of foreign trade, have increased.

When the development of the sector shares in terms of global GDP is considered, the increasing global share of the services sector is highlighted. Within the framework of Turkey's import substitution industrialization strategy, the process by which the share of agriculture has begun to decrease and the share of industry has begun to increase, which develops the services sector, indicates a generally desirable economic development. This structural transformation trend, shifting emphasis from industry to services, is more evident in developed countries that have completed their industrialization. As the level of development of a country's economy increases, the shares of agriculture and industry decrease, while the share of the services sector increases.

Today, it is apparent that some countries with great industrialization potential other than Turkey have come to the forefront, and that Turkey is in fierce competition with these nations. According to the Global Competitiveness Index (GCI) developed by the World Economic Forum, Turkey is situated in the second group, in the classification of "the Attacking Countries." Also classified in this second group are the BRIC countries (Brazil, Russia, India, China), whose combined economy is expected to exceed that of any one of the current richest countries by 2050. During the process of sectoral transformation being experienced in Turkey, a comparative analysis with the BRIC countries in terms of international competitiveness is thought by economists to play a guiding role in determining policies for the future.

From this point of view, the aim of this study is to measure the competitiveness of the agriculture, industry, and services sectors in foreign trade for Turkey and the BRIC countries and to analyze the measurements comparatively. In addition to determining their relative competitiveness, assessments will be made about the direction of the sectoral trends over time for the countries in question. In the study, a brief theoretical introduction is followed by a review of literature related to the subject. Then, the competitiveness of foreign trade in the agriculture, industry, and services sectors will be compared by calculating the revealed comparative advantage (RCA) indexes for Turkey and the BRIC countries.

THE INDUSTRIAL TRANSFORMATION PROCESS AND COMPETITIVENESS

Technological advances, increased international competition, and the decline of transportation costs and tariffs creates the opportunity for different processes to be performed in different countries by dividing major production activities with different levels of intensity into smaller sub-processes. Global business division increases the export of industrial products of the developed countries and the leads them to use more imported capital and intermediate goods by integrating national economies into the world economy. Thus, while the comparative advantages of the developed countries have become great in terms of intermediate goods, the relative advantages of the developing countries have increased in terms of finished goods. With these increasing comparative advantages, the developing countries are able to allocate resources for infrastructure investments, follow technological improvements more closely, and begin to pay attention to the quality of labor power.

Therefore, new production techniques are being applied in the industrial sector by which costs are reduced and higher shares of international markets are obtained. Additionally, the advanced economies,

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while leaving the production and hence the trade of a number of industrial goods and turning to the services sector, are specializing in the technology, knowledge, and skilled-labor-intensive phases of the production processes (Rojec & Damijan, 2008).

The developing countries have more competitiveness in the agricultural sector in which they are able to leverage the natural resource and agricultural areas where qualified labor is not as essential as in other main sectors, such as the industrial and services sectors, since developing countries do not have access to sufficient resources for infrastructure investment from either public or private sectors. Therefore, geographical conditions and climatic features are considered to be one of the most important sources of competitiveness for the economies of developing countries. These countries have advantages in terms of geographic location, geographic characteristics, and climatic conditions that favor the competitiveness of their agricultural production and cause the share of agriculture in their total exports to remain high compared to their industrial and services sectors.

In the developed countries of today, the share of agriculture is less than 5%, the share of industry is 20% and the share of services is 70 percent. In comparison, in developing countries, the share of agriculture is between 15-20% and the share of services is less than 60%. Additionally, in the developing countries, the share of agriculture is more than 20% and the share of services is down to 50 percent (Kalkınma Bankası, 2014). The transitional trend from industrial production to the services sector has been more significantly observed in the developed countries, which have completed their industrialization. As the level of sophistication of a country's economy increases, the share of the services sector increases, while the shares of the agriculture and industry sectors decrease.

This transformation in the services sector, accompanied by economies gradually opening outward, reducing limitations on foreign capital investments, and expanding privatization, has also been observed in the sectoral distribution of foreign capital investments which have increased in recent years. While the share of primary production sectors and the manufacturing industry in total foreign investment has declined significantly, the share of the services sector has increased.

The sectoral trends in the economy of Turkey have been continuing for many years and have the characteristics of a process of structural transformation that developed countries have experienced much earlier. The increase in foreign investments in the services sector enables the services sectors in countries where such investments are made to advance their development around issues related to capital, technology, management, and the restructuring of companies (Türkiye Vakıflar Bankası T.A.O. Hazine Başkanlığı Ekonomik Araştırmalar Müdürlüğü, 2007). In Turkey, during the planned development period that started in 1963 and within the framework of the import substitution industrialization strategy, the share of agriculture in production and employment has started to decrease, and the share of industry has started to increase.

Turkey's pursuit of its import substitution development strategy in the 1970s, which paralleled the oil crises and the high worldwide inflation rates experienced in this period, was stymied by a foreign currency bottleneck that resulted in a situation in which investments and imports of required intermediate goods could not be executed; by the 1980s, it was clear that Turkey would no longer be able to continue to pursue this strategy. In 1980s, an export-oriented development model started to be implemented, and an intensive process of opening outward was experienced. In 1980, the share of agriculture of the Turkish GDP was 26%, the share of industry was 25% and the share of the services sector was 49%; in 2014, the share of agriculture had declined to 9%, and the shares of the industry and services sectors had increased to 27% and 64%, respectively (Kalkınma Bakanlığı, 2014).

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In general, this process indicates a desirable development in terms of economic development. The increase of the volume of production of the services sector is primarily associated with production in the industrial sector. The forward and backward connections of the industrial sector and the expanding effect that they create in the economy stimulate the development of the services sector and become the basic dynamics driving economic growth. This structural transformation, at the same time, also has positive effects on the productivity of the Turkish economy. When the value added per employee between the sectors is compared, it is clear that industry is the most important sector of the economy and that the value added per person in the agricultural sector is at the level of one fourth that of the industrial sector. (Acar, 2008, pp. 32–33).

THE BRIC COUNTRIES AND COMPETITION

The rapidly growing economies of Brazil, Russia, India, and China were collected under the grouping acronym BRIC in 2001 by Jim O'Neill, chief economist of the giant U.S. investment bank, Goldman Sachs. O'Neill has advocated that a space should be opened in the platform directing the global economy for these countries and that they should have a larger say in the global economy since the BRIC economies have grown much faster than the original G-7 member countries. It is thought that if these four developing countries maintain their current economic growth, their combined economy will become the largest in the world by 2050, while the U.S. economy will drop to fifth place. Only 10 years since being labeled the BRIC countries, these nations have assumed their place among the largest economies of the world.

Today, the BRIC countries, which make up 40% of the world's population, cover more than 25% of the earth's surface and take in 15% of the world's income, are candidates to become the global economy's most powerful economic actors in the near future due to both their possession of the world's fastest growing markets and their accelerating production potential.

The BRIC countries do not have uniform structure in terms of competition. China, which is among the countries placed in this group, maintains the position of the group's relatively fastest growing country. However, in recent years, the real estate boom in China, the slowdown in the world trade, and fluctuating capital movements in economically advancing countries are contributing to the possibility of a long-term negative impact on the global economy by delaying the recovery process of China. In spite of this, China maintains its leading position among the BRIC countries by a substantial margin.

Following China, Brazil shows the most significant growth among the BRIC countries. India experienced an unexpected economic downturn in the last quarter of 2011. As a result, it has lagged behind Brazil, which it was formerly in front of, and its development gap with China has increased even more. Finally, Russia, just as with India, has been experiencing economic difficulties.

As an indication of the share that the global business divisions of these fast-growing economies have achieved, the sectoral distribution in their economies is seen in Table 1. In all of the BRIC countries and in Turkey, the share of agriculture is the lowest and the share of services is the highest in terms of GDP. India is the country with the highest agricultural share in terms of GDP with 17.39 percent. While the share of agriculture is around 10% in China and Turkey, this share in Brazil and Russia has remained around 5%. China is the country with the highest share of industry, followed by Russia. The share of industry of Turkey and BRIC countries, excluding China and Russia, are close to one another. Brazil is the country where the share of the services is the highest. Turkey follows Brazil. Although the share of agriculture in the developed countries is below 3%, the share of the services is above 70%;

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Table 1. BRIC countries sectoral distribution of GDP (%)

	Agriculture	Industry	Services
China	10.05	43.89	46.09
Brazil	5.24	24.98	69.32
India	17.39	24.77	57.03
Russia	4.25	36.16	59.90
Turkey	9.14	27.06	64.41
Developed Countries	2.06	24.81	70.67

Source**:** Kalkınma Bakanlığı, Temel Ekonomik Göstergeler, 2014

the sectoral distribution of BRIC countries and Turkey as percentages of GDP is similar to the sectoral distribution of the developed countries in the respect that the share of agriculture is the lowest and the share of services is the highest.

The development of the agriculture, industry, and services sectors, which are three major sectors of the countries' economies, is affected by numerous conditions, primarily including globalization, economic and political development, technological change, consumption preferences, and climatic and geographical features. In recent years the global economy has experienced numerous crises in the developed nations. In contrast, the growth and competitiveness of the ascendant economies of the BRIC countries have generally continued on an upward trend. Turkey has also paralleled the improved economic performance of the BRIC countries during recent years, and global competition among the above-mentioned countries has increased. While the projections made for the coming years indicate that Turkey and the BRIC countries will receive a much larger share of the world's added value and will increase their global competitiveness, the BRIC countries' efforts to obtain the largest share of the pie in the international markets are escalating competition between them and Turkey.

COMPETITIVENESS: THEORETICAL FRAMEWORK

The increasingly global character of the world economy has led to the creation of different approaches and definitions related to competitiveness. In academic research, international competitiveness has been defined using two approaches. In the micro-level approach, competition between enterprises inside a given country and the effects of this competition in national/international markets are examined; in the macro-level approach, the focus has been the position of the country with regard to international competition. To include both approaches, competitiveness can be expressed as the offering of products and services produced under free market conditions to international markets and taking part in these markets while in the meantime increasing real incomes (Scoot & Lod, 1985).

From these and similar definitions related to competitiveness, it generally understood that competitiveness requires three essential features (Çivi et al., 2008):

1. The country should focus on its own unique features, capabilities, and potential in order to catch up with rival countries in the production and distribution of products and services.

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2. The main purpose of having competitiveness is to ensure the enhancement of living standards and the general welfare. These enhancements can be ensured by promoting harmonious arrangements among all of the specialized institutions in the country by paying adequate attention to activities such as trade, investment, and production.
3. Many indicators, including international market share, the trade balance of the country, production, and employment, are indicators used to measure competitiveness.

It can be concluded that the performance of countries in international trade is an important criterion for their international competitiveness. In addition, the above-mentioned indicators allow comparisons to be made at various levels in terms of competitiveness; for example, foreign trade performance indexes are used to empirically measure competitiveness pertaining to foreign trade. In studies within the framework of trade that apply approaches based on classical foreign trade theories, the Balassa index (Balassa, 1965), also known as the revealed comparative advantage (RCA) index, and its derivations are primarily used.

Measuring Competitiveness: The Revealed Comparative Advantage (RCA) Approach

Two of the most common methods for determining competitive advantage in foreign trade are the absolute advantage approach of Adam Smith and the comparative advantage approach of David Ricardo. For measuring competitiveness based on classical foreign trade theories, the revealed comparative advantage (RCA) approach was developed by Balassa (1965). This comparative advantage index is one of the criteria used to determine the goods and services for which a country has a competitive advantage or is at a competitive disadvantage.

The RCA index, proposed by Balassa (1965) and also referred to as the Balassa index, is formulated as follows:

$$RCAij = (Xij / Xit) / (Xwj / Xwt)$$

Xij represents the exports of country i in goods j; Xit represents the total exports of country i; Xwj represents the world's exports of goods j; and Xwt represents total world exports. Thus, the share of one type of goods in the total exports of the country is compared with the share of the same goods in the total exports of the world. If this proportion is greater than one for a given country, it means the share that country has of the export of goods j is greater than the export share of the rest of the world in goods j, and thus shows that this country has a comparative advantage in goods j. Conversely, if the proportion is smaller than one, it means that the country has a comparative disadvantage relative to goods j.

Literature Pertaining to Measuring Competitiveness

Regarding measuring competitiveness and the concept of competitiveness, numerous studies are available that measure competitiveness using the RCA developed by Balassa (1965) and similar indexes. In the literature, in almost all of the studies involving the RCA index, comparative competitiveness analyses are performed without using econometric methods. A large number of studies on Turkey that employed the RCA index are on the measurement and comparison of Turkey's competitiveness in EU markets.

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For example, Erlat and Erlat (2005), working with the RCA, measured the competitiveness of Turkey for the years 1990–2000 and compared it with the competitiveness of the EU-15 countries. According to the RCA index results obtained in the study, similarities were observed between Turkey and Belgium, Denmark, Finland, Greece and Spain. On the other hand, it was concluded that the competitiveness of Turkey has also risen in areas other than the traditional sectors while its competitiveness has declined in raw material-intensive goods.

Yılmaz (2003) compared the competitiveness of Turkey between the years1996–1999 with the competitiveness of Bulgaria, Romania, the Czech Republic, Poland, Hungary, and the EU. Among these countries and region, the competitiveness of Turkey and the Czech Republic were found to be the highest. Indeed, in the studies of Karakaya and Özgen (2002) along with the studies of Kösekahyaoğlu and Özdamar (2011), the conclusion that the competitiveness of Turkey is higher than the other countries was reached. This state of affairs has suggested to some that the EU membership of Turkey could harm the exports of Greece, Portugal, and Spain.

Turkey has been searching for ways to increase its volume of foreign trade, especially the volume of exports in line with expansion models put into practice after the industrial strategies of the 1980s for exports; similarly, it has been seeking foreign trade expansion in the customs union launched with the EU, the BSEC (Black Sea Economic Cooperation Region), which it has been trying to establish with its neighbors to the north, and the Economic Cooperation Organization which it has been trying establish with its neighbors to the east. In this context, Sandalcılar (2011) analyzed Turkey-Syria trade on the basis of commodity groups with the RCA index. The analysis concluded the rise in the foreign trade volume of Turkey has been reflected in its trade with its southern neighbor Syria, and it was determined that Turkey has a comparative advantage in the Syrian market. However, the civil war in Syria has terminated the increase in trade volume.

Some of the studies on Turkey using the RCA index are on the measurement and comparison of its competitiveness with countries such as China and India, which are the world's fastest developing countries whose international competitiveness is being increasingly scaled up and which, along with Turkey, have made a name for themselves on the global stage in recent years. Among these studies, Lohrman (2000) has evaluated Turkey's pre- and post-customs union competitiveness by measuring the country's RCA indexes for the 1994–1997 period. According to the RCA indexes, Lohrman (2000) has concluded that Turkey has started to gain competitiveness in some sectors that require intensive use of qualified labor, attributing this to the liberalization of countries having access to cheap labor, such as China and Malaysia, and their ability to rival Turkey in labor-intensive sectors.

Ferman et al. (2004), again using the RCA index, drew attention to the fact that China and India are the closest rivals of Turkey in EU markets. Similarly, Altay and Gacaner (2003), having investigated the competitive situation of China and Turkey in the textile and clothing sectors in EU and U.S. markets, stated that Turkey has a greater competitive advantage in U.S. markets in comparison with China.

In their study, Kösekahyaoğlu and Özdamar (2011) examined the competitiveness of China, India, and Turkey during the period 1990–2009 for five different commodity groups: "raw-material-intensive goods," "labor-intensive goods," "capital-intensive goods," "easily counterfeitable goods," and "hard-to counterfeit, research-based goods." The results have indicated the competitiveness of the three examined countries, as expected, depended for the most part on labor-intensive goods; however, recently and for India in particular, the importance of capital-intensive goods has further increased. Moreover, it was shown that Turkey is in a position of greater advantage regarding labor-intensive goods in particular and regarding easily counterfeitable goods with respect to China; with respect to India, Turkey's position is

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less advantageous regarding raw-material-intensive goods and easily counterfeitable goods, but it has better export expertise regarding capital-intensive goods.

In summary, these and similar studies measuring competitiveness using the RCA index show that this index provides important information about competitiveness. In this regard, evaluations will be made according to the results of the RCA index pertaining to the measurement and comparative analysis of the competitiveness of the agriculture, industry, and services sectors in foreign trade for Turkey and the BRIC countries.

COMPARATIVE ANALYSIS OF THE COMPETITIVENESS OF TURKEY WITH THE BRIC COUNTRIES DURING THE SECTORAL TRANSFORMATION PROCESS

In the sectoral transformation process, the increasing share of the services sector is noteworthy. The fact that the share of agricultural production has started to diminish and the share of industrial production has started to increase and that this increase has benefitted the services sector is a desirable improvement in terms of economic development. This structural transformation trend of a shift from industry to services is much more obvious in the developed countries which have completed their industrialization. In this context, the observation of sectoral transformation trends and measurement of competitiveness are of importance for the BRIC countries and also for Turkey, which is classified with "the Attacking Countries" according to the Global Competitiveness Index.

Aim of the Study

The aim of the study is to measure the competitiveness of Turkey and the BRIC countries, whose agriculture and services sectors are rapidly growing as a component of foreign trade, and also to make a comparative analysis of their competitiveness. Assessments about the direction of sectoral trends of the mentioned countries will thereby be made possible, and similarities to Turkey can be highlighted.

Data and Method

In the study, the following RCA index has been used as a criterion for sectoral and overall competitiveness of Turkey and the BRIC countries in foreign trade assessments.

$$RCAij = (Xij / Xit) / (Xwj / Xwt)$$

In the case that $RCAij > 1$, the share of goods k (sector) of a country j during a period t is greater than its share in total global exports during the same period. The country has a revealed comparative advantage regarding the given product (sector) and has been specialized.

In the case that $RCAij < 1$, the share of goods k (sector) of a country j during a period t is smaller than its share in total global exports during the same period. The country has been specialized in the given product (sector) but does not have a revealed comparative advantage

In the case that $RCAij = 1$, the share of goods k (sector) of a country j during a period t is equal to its share in the total global exports during the same period. The level of specialization of the country is the same as that of the world (Hinloopen and Marrewijk, 2000).

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Hinloopen and Marrewijk (2000) have classified the RCA index into four separate categories in order to demonstrate the power of the comparative advantage between countries. These categories are shown in Table 2.

In the calculation of the RCA index, the total export figures and sectoral export figures for Turkey and the BRIC countries as well as total global exports and sectoral export figures between the period 1994 and 2013 have been used on annualized basis. The data related with foreign trade have been compiled from data of the World Trade Organization (WTO).

Application Findings

In the study, the RCA index findings are given first according to the order of the initial letters of the countries in the acronym *BRIC*, and finally for Turkey. Observations are made about competitiveness in accordance with the obtained results; finally, the comparative analysis is detailed.

Brazil

Figure 1 shows that Brazil further increased its existing advantage in the agricultural sector between 1994 and 2003. Hence, it can be stated the foreign trade competitiveness of Brazil in the agricultural sector is high. Brazil, which is an important producer of agricultural products, has two main agricultural regions. The region located in the southern part of the country receives much more precipitation. It has a half-temperate climate, more fertile land, more advanced technology and input utilization, sufficient infrastructure, and more qualified farmers. Most of the Brazilian grains, oilseeds, and exported products are produced in this region. The other agricultural region is located in the arid northeast and the Amazon basin. The distribution of precipitation in this region is not balanced. The region does not have fertile land, sufficient infrastructure, or capital for development. Though production there has been mostly dedicated to self-sufficiency, it has become increasingly important for the export of forestry products, cocoa, and tropical fruits. Among the products of Brazil that are exported the most are coffee, soybeans, sugarcane, cocoa, rice, meat, poultry, corn, oranges, cotton, wheat, and tobacco (Gitmez, 2013).

Industrial production in Brazil is concentrated in the following sectors: steel, metallurgical products, machinery, electrical and communications equipment, tools, chemicals / petrochemicals, food and beverages, textiles, clothing and footwear, cellulose and paper, and plastics (İTKİB, 2012). However, as these sectors require new technologies, sophisticated materials and biotechnology must be employed. As a result of the fact that these requirements have not yet been completely fulfilled, it is considered that Brazil's competitiveness in the industrial sector remains at a low level.

Table 2. RCA classification

Class	RCA Index Value	Situation
Class A	$0 < \text{RCA index} \leq 1$	Without Comparative Advantage
Class B	$1 < \text{RCA index} \leq 2$	Weak Comparative Advantage
Class C	$2 < \text{RCA index} \leq 4$	Medium Comparative Advantage
Class D	$4 < \text{RCA index}$	Strong Comparative Advantage

Source: Hinloopen and Marrewijk (2000); Erkan (2012)

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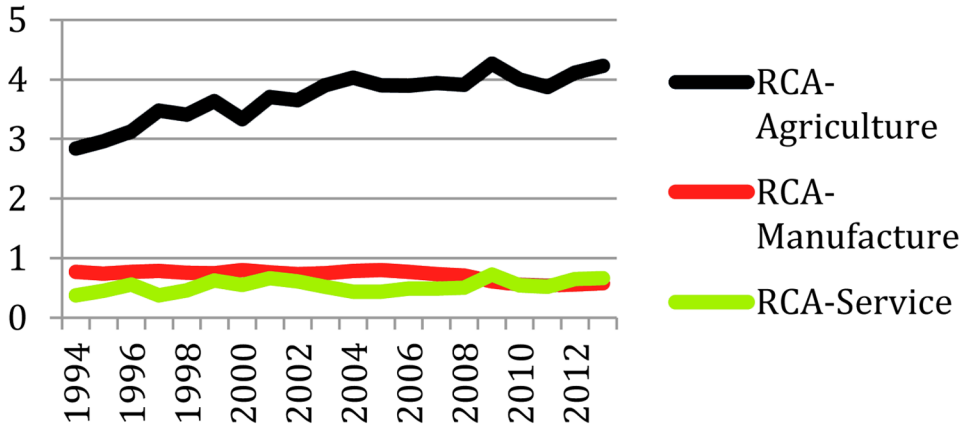
Figure 1. Comparative advantage of major sectors in Brazil



In Table 3, from the RCA index results, it is seen that Brazil, which does not have comparative advantage in industrial and services sectors, has reached a strong comparative advantage level of 4.22 in the agricultural sector.

The services sector is the sector in which competitiveness is the weakest in Brazil, despite having the largest share in the Brazilian economy. It is in the services sector that telecommunications, banking, trade, and data processing sectors have come into prominence; as a result, the services sector has gained more power in the domestic market. However, being an importer of services, just as many developing countries are in this sector, the foreign trade deficit of Brazil is increasing. This situation hinders the country from obtaining a higher level of competitiveness. Despite having experienced global crisis periods, the fact that Brazil has maintained its presence among the BRIC countries can be explained by its being a supplier country that is rich in natural resources.

Russia

In Figure 2, it is remarkable that while the comparative advantage of the Russian agricultural sector increased steadily until 1998, it started to decline after 1998. It is known that, despite Russia being a large country in terms of area, a significant portion of its land and the climate conditions are not suitable for agriculture. A similar decline, though not as steep as in the agricultural sector, has also been experienced in the industrial sector. It is thought that factors such as the decline in world prices of oil and minerals (which are main export products of Russia), the effects of the economic crisis experienced in Russia in

Table 3. Competitiveness of Brazil in major sectors

Sectors	Current RCA Index	Current Situation
Agriculture	4.22	Strong
Manufacturing	0.58	Without
Services	0.66	Without

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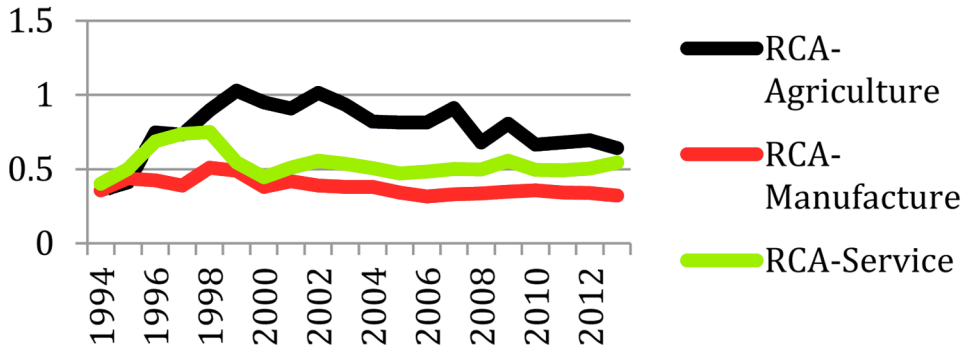
Figure 2. Comparative advantage of major sectors in Russia



1998, and disrupted investor confidence in developing markets due to crises in Asian have played a role in the decrease of Russia's comparative advantages (ISO-AIA, 2010).

In addition, Russia has a structure based on industrial infrastructure and energy, inherited from the USSR, which focuses primarily on the technologically underdeveloped and low-added-value defense and processing sectors. Even in fields such as aerospace and aviation, where Russia has competitive advantages in terms of technology, production rates have decreased due to lack of investment and loss of labor capital (DEİK, 2012). Moreover, it can be said the disappearance of the subsidies that remained from the Soviet era has further weakened the competitiveness of the manufacturers in the international arena.

With the impact of the 1998 crisis, significant declines have also been experienced in the comparative advantage of the services sector in Russia. The fact that the potential of areas such as tourism, transportation, telecommunications, and banking, which have an important place in the services sector, are not being completely utilized (e.g., inability to make the necessary presentations in tourism) hinders the export of services, which is kept at a low level and prevents the acquisition of comparative advantages. Table 4 shows that there is no comparative advantage in any of the major sectors in Russia and that its competitiveness in foreign trade is weak.

India

As seen in Figure 3, among the BRIC countries, the most distinguishable transformation of sectoral advantages has been experienced by India. Since 1994, while its comparative advantages supporting the competitiveness of its agricultural and manufacturing sectors in foreign trade have decreased, the service sector has increased its advantages. It is known that the Indian economy has two different structures. On one side, there is the service sector, which directs the most qualified labor of the middle class

Table 4. Competitiveness of Russia in major sectors

Sectors	Current RCA Index	Current Situation
Agriculture	0.64	Without
Manufacturing	0.32	Without
Services	0.54	Without

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and possesses global competitiveness based on knowledge; on the other side, there is the agricultural sector, which mostly employs less-educated labor, is affected by climatic situations, and is dependent on precipitation (Öz, 2007). Although the manufacturing sector is traditionally inadequate due to poor quality goods, this situation has begun to change in the recent years.

Unlike other East Asian countries, labor shifting from agriculture to other sectors is being experienced much more slowly in India. Since 2000, the annual growth of the agricultural sector has been realized at a rate as low as 2%. This was a period in which the competitiveness of the Indian agricultural sector had begun to decline. The increase in food prices in 2008 highlighted the necessity of making further investment in the sector in order to ensure food sufficiency. As a result of the investments made, a period of increased competitiveness in the agricultural sector has been entered.

The service sector that includes trade, tourism, banking, transport and communications activities has rapidly grown in India in recent years. The information technology sector, including telecommunications and software fields, is the sector that has shown the greatest development. India is one of the world's leading countries in the field of software. It is known that a total of 5,000 companies, a total of 60% of which are domestic ones, operate in the sector which has been structured as export-oriented. However, Table 4 shows that although the services sector has been sophisticated in India, it is apparent the highest competitiveness has already been reached in agriculture.

China

China is distinctly important, showing as it does the highest growth among the BRIC countries. Especially in the 1990s, with the emphasis placed on industry, the development of this sector has accelerated and

Figure 3. Comparative advantage of major sectors in India

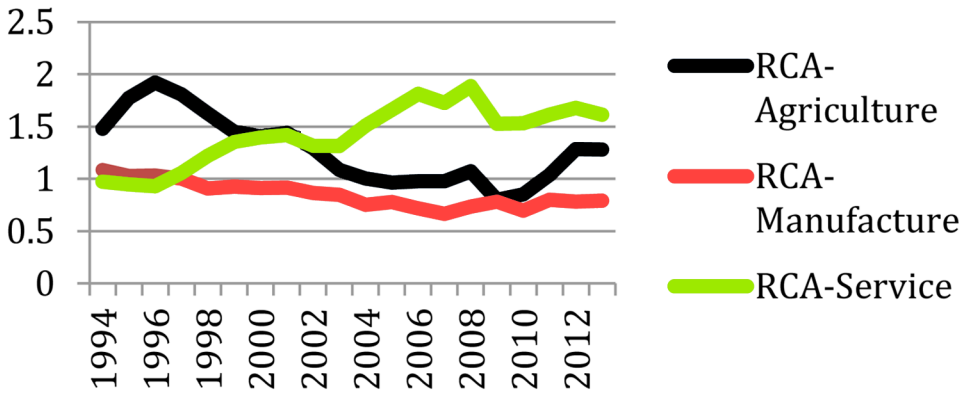

Table 5. Competitiveness of India in major sectors

Sectors	Current RCA Index	Current Situation
Agriculture	1.27	Weak
Manufacturing	0.79	Without
Services	1.61	Weak

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the Chinese economy has reached competence in many industrial fields. Modern metallurgy, mining and energy equipment, aircraft construction, automobile manufacturing, large machinery parts, castings, the aerospace industry, large energy circuits, electronics, communications equipment, and measuring tools are considered to be the major fields in which the Chinese economy has recently been operating (Öz, 2006).

These developments have been triggering the development of a comparative advantage for China in the industrial sector. The trend of the increasing comparative advantages of China in the manufacturing sector, as shown in Figure 4 and Table 6, can be accepted as a further indication of development in the manufacturing sector. However, the urbanization rate in the country has reached 52%, leading to suppressed income growth in rural areas as compared with the cities. As this is the case, comparative advantages in the agricultural sector and competitiveness there have been steadily declining.

However, while global economic integration and technological developments are causing an increase in the trade of services, the fact that international transactions, formerly impossible or prohibitively expensive, have become cheaper has provided possibilities for activities such as tourism, transportation, and banking, which are within the scope of the services sector, to be produced and sold by China as well. However, it is considered that that the infrastructure problems of the services sector and too much importance given to the industrial sector in the current situation represent obstacles to the achievement of competitiveness and the adequate utilization of the potential of the services sector.

Turkey

The state of Turkey's comparative advantage and competitiveness in the major sectors has shown a different development with regard to the BRIC countries. Today, the fact that the levels of competitiveness

Figure 4. Comparative advantage of major sectors in China

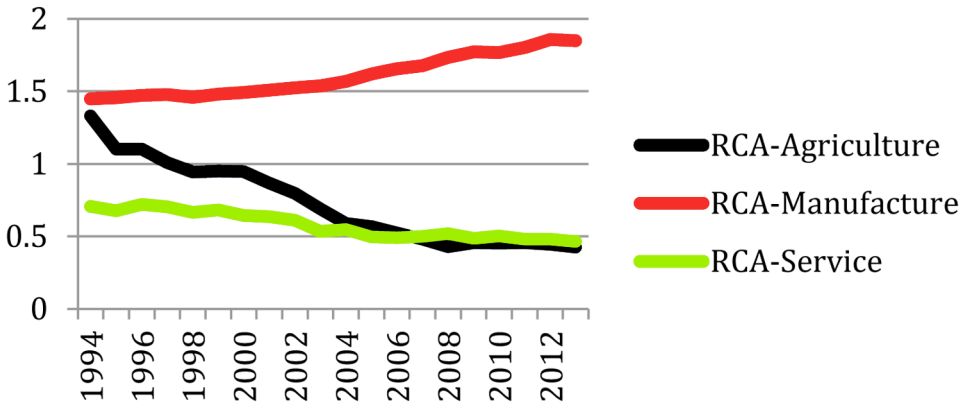

Table 6. Competitiveness of China in major sectors

Sectors	Current RCA Index	Current Situation
Agriculture	0.42	Without
Manufacturing	1.84	Weak
Services	0.46	Without

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of Turkey in the major sectors are quite similar is noteworthy. In Figure 5, while the services sector had the highest competitiveness at beginning of the 1990s, the agricultural and industrial sectors followed it. A process has occurred over the past twenty years in which the competitiveness of the services sector has been weakening and competitiveness of the agricultural and industrial sectors has been increasing, thereby closing the gaps among them, and the competitiveness levels of the three sectors have become too close to one another (Meçik & Afşar, 2014).

The agricultural sector in Turkey, which has great potential, has been making various contributions to the development of the country and to achieving competitiveness. Most important among those contributions are providing raw materials for industry, creating demand for industrial products, and contributing to GDP and exports. The agriculture-based industries in the manufacturing industry in Turkey hold a rather important position in the economy. The reason is that most of the raw material requirements of industrial enterprises based on agriculture are fulfilled from domestic resources. Indeed, the share of the agricultural industry in the number of workplaces in the manufacturing industry is around 50% (Demirbaş & Tosun, 2005). Thus, it can be stated that the agricultural sector has an important role in the development of the industrial sector.

However, technological developments and state subsidies have played an important role in development of industry and have been effective in obtaining competitiveness for that sector in the foreign markets. In addition, the development of the industrial sector has played a major role in the development of the services sector. Currently, the share of the services sector in Turkey is at the level of approximately 65%. However, when the competitiveness of the services sector is considered, a significant decline is evident after the first decade of the 2000s. Two of the biggest causes of this situation are that the supply of qualified labor has remained inadequate and that the number of enterprises in the services sector has increased.

In Table 7, it can be seen that Turkey's competitiveness in all major sectors is not very strong. The services sector, which was moderately competitive at the beginning of the 1990s, has begun to lose power due the effects of the labor in this sector shifting to the industrial sector. Additionally, the competitiveness of the industrial sector has increasingly scaled up and begun to take a significant share of foreign trade. The sectors which carry out the production of industrial products that are involved in trade in Turkey are the sectors that largely determine Turkey's role in the global economy.

While production grew in traditional sectors such as textiles, leather, tobacco, and food, Turkey had remained behind in sectors with higher technology levels, such as automotive, office machinery, and electrical machinery; however, Turkey has recently begun to establish competitive advantages in

Figure 5. Comparative advantage of major sectors in Turkey

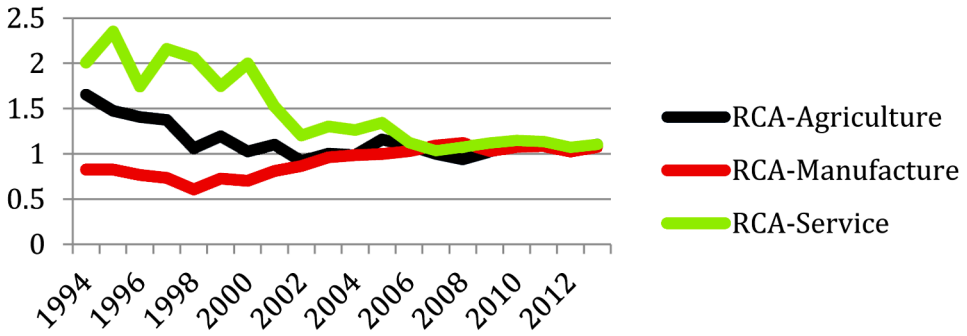

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Table 7. Competitiveness of Turkey in major sectors

Sectors	Current RCA Index	Current Situation
Agriculture	1.10	Weak
Manufacturing	1.07	Weak
Services	1.10	Weak

some of these sectors. (Acar, 2008, pp. 33–34). The inclusion of the East Asian countries in the global competitive race has complicated the situation of sectors which are both exporters and producers for the domestic market. The cheap labor advantage these nations possess often makes the situation of the labor-intensive sectors difficult.

Similar to the industrial sector, the services sector has also been experiencing a comprehensive transformation. In the transformation of the services sector, it is noteworthy that shops that conduct their activities without registrations are ceding their locations to organized retail stores which conduct all of their activities with registrations. This situation has significant ramifications for the logistics sector which is a sub-branch of the services sector.

The moderate competitiveness of the agricultural sector at the beginning of the 2000s has gapped down to a level of weak competitiveness over the past decade. When compared with the BRIC countries, Turkey is a developing country that has competitiveness at the same time, although it is low in all major sectors. However, the structural transformation process which Turkey is passing through carries with it a number of risks. It is thought that the country's inability to avoid an account deficit and unemployment problems is associated with this structural transformation. In this regard, strategies should be developed at the sector level to promote the continuation of the structural transformation without hindering economic development.

The Comparative Status of the Countries on the Basis of the Main Sectors

It has been determined that the BRIC countries and Turkey, which are evaluated as belonging to the same group of candidate countries with the potential to become the strongest actors in the world in the near future due to both their rapidly developing markets and increasingly growing production potential, do not have very similar structures in terms of competitiveness. This becomes clear when the competitiveness of the BRIC countries and Turkey is evaluated on the basis of major sectors. In the agricultural sector, Brazil, Turkey, and India have comparative advantage, but only Brazil has high competitiveness. The countries having comparative advantage in the industrial sector are China and Turkey. The comparative advantage of China and Turkey in the industrial sector is not supported by high competitiveness. If an assessment is made on the basis of the services sector, India and Turkey, from among the five countries subjected to investigation, are the two that have achieved comparative advantage. These countries are also the ones whose services sector comprises the largest share of GDP after Brazil. However, as observed in the other sectors, high competitiveness could not be achieved based on the comparative advantage of India and Turkey in the services sector.

When the transformations in the sectoral structure are examined, it must be stated that the most important transformations have been realized in the services sector. While global economic integration and technological developments have caused the trade of services to increase, the fact that international

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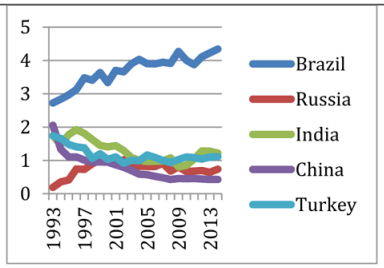
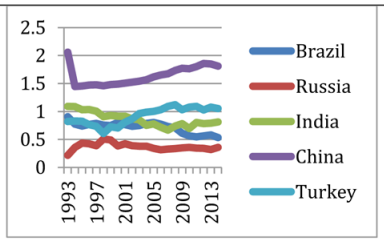
Figure 6. Competitiveness and the status of comparative advantage of the major sectors and competitiveness (BRIC Countries and Turkey)

AGRICULTURE



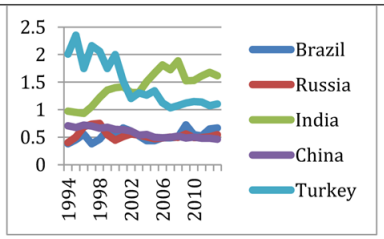
	RCA	
Brazil	4,34	Strong
India	1,22	Weak
Turkey	1,11	Weak
Russia	0,74	-
China	0,42	-

INDUSTRY



	RCA	
China	1,81	Weak
Turkey	1,05	Weak
India	0,81	-
Brazil	0,53	-
Russia	0,36	-

SERVICES



	RCA	
India	1,62	Weak
Turkey	1,10	Weak
Brazil	0,66	-
Russia	0,55	-
China	0,46	-

transactions which were formerly impossible or expensive have become cheaper, in addition to the increase in population and the mobility of transactions, has enabled the activities covered by the services sector to be produced and sold by many companies.

The developing countries are trying to avoid the problem of instability in their export incomes by diversifying their goods and markets and by aiming for the export of goods having higher domestic added value and based on more advanced technology. An alternative way of increasing foreign currency incomes

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and stabilizing conditions is to increase the trade of services. However, this strategy is in the export of goods, as the developing countries do not have the power to compete with the developed countries in the trade of services as well (Değer, 2006). Nevertheless, developing countries such as Turkey and the BRIC countries, which have advantages in terms of historical and natural beauty, have an opportunity to mitigate the dimensions of the problem with the foreign currency incomes they obtain from tourism. Although tourism is not the only effective sector for achieving economic growth in developing countries, the developments experienced in this sector have been able to provide new economic opportunities for some countries.

CONCLUSION

According to the results of this study, which has attempted to measure the competitiveness of the agricultural, industrial, and services sectors in the foreign trade of Turkey and the BRIC countries as well as to make a comparative analysis, Turkey and the BRIC countries do not have very similar structures in terms of sectoral competitiveness. For example, although the countries have obtained comparative advantage in some sectors, Brazil does not have any significant competitiveness except for its high competitiveness in the agricultural sector.

Of all the economies subjected to analysis in this investigation, Turkey is in the position of being the only country that has achieved similar competitiveness in all sectors. The RCA index for Turkey was found to be at the same level in the three major sectors, each with a ratio of approximately 1.10. Turkey is expected to build on the competitiveness that it has achieved with new investments to reach higher competitiveness.

Brazil has high competitiveness only in the agricultural sector, in which its RCA index is 4.22. The natural resources and the fertile agricultural areas that Brazil possesses are considered to be effective in this.

Russia, possibly due both to the fact that it has not made adequate use of the industrial infrastructure left to it by the Soviet Union and that is has suffered the effects of an economic crisis, has not achieved competitiveness in the foreign trade of any sector. Russia should seek to regain its qualified labor pool and to recapture its competitiveness in foreign trade by encouraging investment in other sectors in addition to the defense sector.

India has competitiveness in the agricultural and services sectors. The competitiveness of these two sectors in foreign trade might be associated with two developments in that country. While on one side India has a modern and knowledge-based services sector that directs the most qualified labor of the middle class, on the other side, an agricultural sector that employs less-educated labor, is affected by the climatic conditions, and depends on precipitation has developed. These developments have facilitated the increase in the competitiveness of the two sectors.

China is of distinct importance because it is the country with the greatest economic growth. Especially in 1990s, the development of the industrial sector accelerated and the focus given to industry in China allowed the Chinese economy to achieve competence in many industrial fields. The development of the industrial sector can also be seen from the fact that the RCA index in the industrial sector of China is 1.84. According to its RCA indexes, industry is the only sector in which China is competitive. It should be immediately noted that China's competitiveness in that sector is not high. However, as the country

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that has achieved the greatest economic growth, the competitiveness of the Chinese industrial sector in foreign trade is expected to be higher in the coming years.

Although Turkey and the BRIC countries do not have a similar structure in terms of sectoral competitiveness, when the transformations in the sectoral structure are examined, it is evident the most important transformations have occurred in the services sector. While global economic integration and technological developments have caused the trade of services to increase, the fact that international transactions that were formerly impossible or expensive have become cheaper along with the increase in population and in the mobility of transactions has enabled the activities covered by the services sector to be produced and sold by many companies.

While the welfare gain and high income levels associated with the development of the manufacturing industry in the developed countries have resulted in an increase in the importance of the services sector, the effects of activities such as banking, marketing, distribution, communications, and tourism, which are representative parts of the sector, have become much more obvious. Today, in many countries, the share of the services sector in national income and employment is more than the share of other sectors.

The services sector, the relative weight of which has clearly increased during the economic development process, has increased even more in significance and entered into a structural transformation process along with increasing globalization and in parallel with the developing technology of recent years. In this process, the increase of the share of sectors whose share in foreign trade was formerly scant, the emergence of new services sectors such as software, and the increase of the share that the services sector receives directly from foreign investments have been matters of concern. The fact that the developed countries have purposely shifted their investments in the services sector to developing countries, where educated and cheap labor is available, and that they have met their need for services through these countries has been the matter of discussion and debate.

REFERENCES

Acar, O. (2008). Türkiye Ekonomisindeki Yapısal Dönüşümün Dinamikleri. *Uluslararası Ekonomik Sorunlar Dergisi*, 30-39.

Altay, N. O., & Gacener, A. (2003). Türkiye'nin Rekabet Dinamikleri: Tekstil ve Konfeksiyon Sektörü Rekabet Gücünün Karşılaştırmalı Analizi. ERC/ODTÜ VII. Uluslararası Ekonomi Kongresi, Ankara, Turkey.

Balassa, B. (1965). Trade Liberalization and 'Revealed' Comparative Advantage. *The Manchester School of Economic and Social Studies*, *33*(2), 99–124. doi:10.1111/j.1467-9957.1965.tb00050.x

Çivi, E., Erol, İ, İnanlı, T., & Erol, E.D. (2008). Uluslararası Rekabet Gücüne Farklı Yaklaşımlar. *Ekonomik ve Sosyal Araştırmalar Dergisi*, *4*(4), 1-22.

Değer, K. (2006). Turizme ve İhracata Dayalı Büyüme: 1980-2005 Türkiye Deneyimi. *Atatürk Üniversitesi İktisadi ve İdari Bilimler Dergisi*, *20*(2), 67–86.

DEİK. (2012). *Rusya Federasyonu Ülke Raporu*. Retrievd on September 12, 2013, from: https://www.deik.org.tr/KonseyIcerik/4024/Rusya_Federasyonu_%C3%9Clke_B%C3%BClteni.html

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Demirbaş, N., & Tosun, D. (2005). Türkiye'de Tarımın Sanayi ile Entegrasyonu, Ortaya Çıkan Sorunlar ve Çözüm Önerileri. ADÜ. *Ziraat Fakültesi Dergisi*, *2*(2), 27–34.

Erkan, B. (2012). Ülkelerin Karşılaştırmalı İhracat Performanslarının Açıklanmış Karşılaştırmalı Üstünlük Katsayılarıyla Belirlenmesi: Türkiye-Suriye Örneği. *Zonguldak Karaelmas Üniversitesi Sosyal Bilimler Dergisi*, *8*(15), 195–218.

Erlat, G., & Erlat, H. (2005). Do Turkish Exports Have Comparative Advantage With Respect to the European Union Market, 1990-2000. *Topics in Middle Eastern and North African Economies Journal*, *7*.

Ferman, M., Akgüngör, S., & Yüksel, A. H. (2004). Türkiye'nin İhracat Rekabet Gücü ve Sürdürülebilirliği: Avrupa Birliği Pazarında Rakip Ülkeler ve Türkiye Açısından Bir Karşılaştırma. In Türkiye İktisat Kongresi Tebliğ Sunuşları. Gelişme Stratejileri ve Makroekonomik Politikalar.

Gitmez, E. (2013). *Brezilya Ülke Raporu*. Şanlıurfa, Turkey: T.C. Karacadağ Kalkınma Ajansı Yayını.

Hinloopen, J., & Marrewijk, C. V. (2000). On the Empirical Distribution of the Balassa Index. *Weltwirtschaftliches Archiv*, *137*(1), 1–35. doi:10.1007/BF02707598

ISO-AIA. (2010). *Rusya Ülke Raporu*. Retrieved on Marcy 9, 2013, from: http://www.aia-istanbul.org/files/bilgibankasi/pazarlar/ulkeler/russia_ulkeraporu.pdf

İTKİB. (2012). *Bir Tekstil Pazarı Olarak Brezilya: Temel Ekonomik Göstergeler, Genel ve Sektörel Bilgiler*. Retrieved on December 11, 2014, from: http://www.itkib.org.tr/ihracat/DisTicaretBilgileri/raporlar/dosyalar/BREZILYA_ULKE_RAPORU_Agustos_2012.pdf

Kalkınma Bakanlığı. (2014, July/August). *Temel Ekonomik Göstergeler*. Author.

Karakaya, E., & Ozgen, F. (2002). *Economic Feasibility of Turkey's Economic Integration with The EU: Perspectives from Trade Creation and Trade Diversion, VI*. Ankara, Turkey: ERC/ODT Uluslararası Ekonomi Kongresi.

Kösekahyaoğlu, L., & Özdamar, G. (2011). Türkiye, Çin ve Hindistan'ın Sektörel Rekabet Gücü Üzerine Karşılaştırmalı Bir İnceleme. *Uludağ Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, *30*(2), 29–49.

Lohrman, A. (2000). Development Effects of the Customs Union Between Turkey and the European Union Catching up–or the Heckscher Ohlin–Trap. *Russian and East European Finance and Trade*, *36*(4), 26–44.

Meçik, O., & Afşar, M. (2014). Türkiye Ekonomisinde Yapısal Dönüşümler ve İşgücü Piyasasında Gelişmeler. *Optimum Ekonomi ve Yönetim Bilimleri Dergisi*, *1*(2), 1–23.

Öz, S. (2006). *Küresel Rekabette Yükselen Bir Güç: Çin*. TÜSİAD-Sabancı Üniversitesi Rekabet Forumu.

Öz, S. (2007). *Küresel Rekabette Yeni Bir Güç: Hindistan*. TÜSİAD-Sabancı Üniversitesi Rekabet Forumu.

Rojec, M., & Damijan, J. P. (2008). Relocation via Foreign Direct Investment from Old to New EU Member States: Scale and Structural Dimension of the Process. *Structural Change and Economic Dynamics*, *19*(1), 53–65. doi:10.1016/j.strueco.2007.11.005

Sandalcılar, A. R. (2011). Turkiye-Suriye Dış Ticaretinin Sekturel Analizi. *Ataturk Universitesi İktisadi ve İdari Bilimler Dergisi*, *25*(3-4), 213–229.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Scoot, B. R., & Lodge, C. (1985). *US Competitiveness in the World Economy*. Boston: Harvard Business School Press.

Türkiye Vakıflar Bankası T.A.O. (2007, September). Hazine Başkanlığı Ekonomik Araştırmalar Müdürlüğü Sektör Araştırmaları. *Küreselleşme Sürecinde Dünya ve Türkiye Ekonomisinde Sektörel Yapıdaki Dönüşüm Üzerine Bir İnceleme*.

WTO. (2015). *Statistical Data Base*. Retrieved on November 30, 2015, from: http://stat.wto.org

Yılmaz, B. (2003). *Turkey's Competitiveness in the European Union: A Comparison with Five Candidate Countries and the EU15*. Ezoneplus Working Paper, No. 12. Berlin, Germany: Freie Universitat.

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Chapter 77
Sustainability, Environmental Sustainability, and Sustainable Tourism:
Advanced Issues and Implications

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ABSTRACT

This chapter reveals the overview of sustainability; the overview of environmental sustainability; environmental sustainability and climate change; environmental sustainability, water resources, and energy consumption; and the overview of sustainable tourism. Sustainability is the important issue that attempts to bridge social science with civic engineering and environmental science with the technology of the future. Environmental sustainability is important because it ensures people have water and resources, and adopting its practices protects the environment and human health. Sustainable tourism is a growing segment of the global tourism industry that makes the positive contributions to the environmental, socio-cultural, and economic well-being of destinations and local communities around the world. Sustainability, environmental sustainability, and sustainable tourism are rooted in three issues that are considerably linked to fossil fuel depletion, climate change due to carbon dioxide emissions, and the increasing costs of energy and water.

INTRODUCTION

Sustainability is the business strategy that drives the long-term corporate growth and profitability by mandating the inclusion of environmental and social issues in the business model (Kasemsap, 2017a) and requires the transformation in the environmental inputs used for products and processes (da Ronch, di Maria, & Micelli, 2013). Sustainable consumption is an integral element of sustainable development and an issue of paramount importance, increasingly recognized by the international community (Kasemsap, 2017b). Sustainability integrates the environmental, economic, and societal aspects (Grigoroudis,

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Kouikoglou, & Phillis, 2012) regarding the triple bottom line (TBL) (Tullberg, 2012). The topic of sustainability has moved from the borders of supply chain management (SCM) research to the mainstream and is an area of significant research activity (Pagell & Shevchenko, 2014).

Sustainability concerns may exist when current generations' preferences for environmental benefits occurring in the very long term are equal or higher with respect to those for benefits occurring in the long term (Faccioli, Hanley, Torres, & Font, 2016). Environmental sustainability is an important issue for many individuals, businesses, and governments (Shakir, 2011) and is the predominant prerequisite for social sustainability (Soliman, 2015). For all types of businesses, environmental sustainability is of great concern (Evangelista, Huge-Brodin, Isaksson, & Sweeney, 2014) and drives companies to extend their green effort across their supply chain (Wu, Wu, Chen, & Goh, 2014) toward green supply chain management (GSCM) and sustainable supply chain management (SSCM) (Seuring & Muller, 2008).

With the effects of climate change becoming an increasing concern, the tourism sector must urgently respond by mitigating its emissions and adapting tourism businesses to the changing climate conditions (Michailidou, Vlachokostas, & Moussiopoulos, 2016). Stakeholders' and customers' pressure on sustainability has pushed many companies to transform the environmental sustainability concepts into the business practices (Kumar, 2016). Stakeholders understand the stakes of sustainable tourism as either the lost opportunities for the environmental development due to the failed regulation of a natural resource, or as deteriorating the social relations due to the failed maintenance of socio-cultural values (Hultman & Sawe, 2016).

This chapter aims to bridge the gap in the literature on the thorough literature consolidation of sustainability, environmental sustainability, and sustainable tourism. The extensive literature provides a contribution to practitioners and researchers in order to maximize the business impact of sustainability, environmental sustainability, and sustainable tourism in sustainable settings.

Background

Mounting pressure for sustainable business practices has led to a greatly increased focus on highlighting sustainability drivers throughout the supply chain (Foerstl, Azadegan, Leppelt, & Hartmann, 2015). Due to the recognition of environmental issues in the traditional activities, organizations need to address the problem of sustainability in their operations (Ahi & Searcy, 2013). Sustainability has the unique issues related to market competition, global limitation of energy, availability of raw material, environmental protection crisis, and increased global population (Bajaj, Jha, & Aggarwal, 2013). Environmental sustainability is the foundation to sustainability in the sense that humanity needs the environment to continuously provide natural resources and to continuously deal with its wastes for humanity to sustain itself (Fitzpatrick, 2016).

Environmental issues attract the concern of global supply chain practitioners (Muduli, Govindan, Barve, & Geng, 2013). Current researchers and practitioners give special attention to environmental issues to achieve business needs (Caniato, Caridi, Crippa, & Moretto, 2011). Sustainability changes the existing practices and creates the management systems (Linton, Klassen, & Jayaraman, 2007). Companies can optimize their supply chains by integrating risk management and sustainability programs to improve the environmental sustainability (Kara & Fırat, 2016). The company's perceptions about factors affecting the decisions for the implementation of sustainable practices shares a relationship with the company's expectations while applying sustainable initiatives (Manikas, Ieromonachou, & Bochtis, 2014).

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Tourism is the marketing of the enjoyable perspective and other features of a travel destination, and provision of facilities and services for the pleasure travelers (Kasemsap, 2015). Tourism and hospitality industry is one of the most important industries in the modern business world (Kasemsap, 2016a). Recent phenomena, such as climate change, a hypermobile society, and the shared economy (Dredge & Gyimothy, 2015), significantly add the new layers of complexity to the sustainable tourism. A number of recent discussions of tourism and sustainability have emphasized the problems, gaps, and deficiencies in sustainable tourism (Bramwell & Lane, 2013) and have addressed to a limited capability to find the suitable solutions which are acceptable to the commercial market and which adequately respond to sustainability challenges toward sustainable tourism.

ASPECTS OF SUSTAINABILITY, ENVIRONMENTAL SUSTAINABILITY, AND SUSTAINABLE TOURISM

This section emphasizes the overview of sustainability; the overview of environmental sustainability; environmental sustainability and climate change; environmental sustainability, water resources, and energy consumption; and the overview of sustainable tourism.

Overview of Sustainability

Sustainability is an evolutionary advancement of developing the management of systems through the enhanced knowledge (Faisal, 2010). Sustainability disclosure is greater for firms with a proactive communication strategy as manifested through press release activity (Herbohn, Walker, & Loo, 2014). Govindan et al. (2014) stated that manufacturing industries effectively implement environmental practices in their existing SCM. It is difficult for firms to achieve a balance between the traditional efficiency-based performance and environmental benefits, which influences green management at the business and functional levels (Mollenkopf, Stolze, Tate, & Ueltschy, 2010).

Lamming et al. (1999) discussed three dimensions of economic, environmental, and social perspectives as the broad elements of sustainable development. Sustainability incorporates the dimensions of corporate social responsibility (CSR) that include TBL factors (Seuring & Muller, 2008) and ethics (Vachon & Mao, 2008). Sustainable development is a major solution for reducing waste by effective resource utilization (Diabat, Kannan, & Mathiyazhagan, 2014). Sustainable development enterprise practically achieves the economic, environmental, and social benefits (Hart & Milstein, 2003). Sustainable development is interpreted to require the improvement in the areas of economic, environmental, and social performances (Searcy, Karapetrovic, & McCartney, 2008). Sustainable development improves industries' environmental performance (Diabat et al., 2014).

Schwarz et al. (2002) stated that putting the concept of sustainable development into operation requires the cost-effective ways to evaluate performance and measure improvement. Issues associated with supply chain governance, standards for sustainable SCM, collaboration with suppliers, performance measurement, and accountability within supply chain are explored in global business (Morali & Searcy, 2013). Proactive green initiatives yield competitiveness, economic benefits, better CSR, and sustainability (Molina-Azorin, Claver-Cortes, Lopez-Gamero, & Tari, 2009). Sustainability factors play the significant role in SCM (Wen, Xu, & Wang, 2013).

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Businesses face the new challenges for adopting the good environmental practices (Sezen & Turkkantos, 2013). Hart and Milstein (2003) analyzed the global challenges associated with sustainable development, thus indicating strategies that contribute to a more sustainable world while driving shareholder values. Kuik et al. (2010) indicated that traditional supply chains should develop into SSCM regarding economic, environmental, and social benefits. SSCM can be defined as the integration of economic, environmental, and social practices within the global supply chain that provides green products, excellent services, and accurate information (Xie & Allen, 2013), thus sharing those benefits with all employees, shareholders, and business partners (Kuik et al., 2010).

Overview of Environmental Sustainability

Sustainability has become an important issue because of great concerns about the social, environmental, and economic effects of the increasing population and economic growth, as well as consumption of natural resources (Abereijo, 2016). Environmental sustainability has two major components to it: the sustainability of natural resource utilization and the impact on the environment due to wastes and land utilization (Fitzpatrick, 2016). Identifying the challenges of environmental sustainability in the form of environmental indicators, assessment, and strategies will be a good start for the organizations to be sustainable (Mukherjee, Kamarulzaman, Vijayan, & Vaiappuri, 2016).

Environmental concerns attract the increasing attention in the educational and scientific communities (Dogbey, Quigley, Che, & Hallo, 2014). Environmental collaboration with customers and suppliers based on knowledge sharing can reduce the total environmental impact (Aboelmaged, 2014). In order to enhance the environmental sustainability, organizations need to control their operations and link them with their environmental strategies (Sen, 2016). Sustainable manufacturing strives to produces the products by minimizing the negative environmental impact (Singh, Olugu, & Musa, 2016). Technological changes can be considered as a key driver to help knowledge acquisition on the environmentally sustainable use of information and communication technology (ICT) resources due to various innovations that have positively contributed in the learning process (Bekaroo, Bokhoree, & Pattinson, 2016).

Environmental reporting provides the comprehensive perspective to inform the target groups about the proper environmental strategies and to present the transparent profile (Akkaya, Wolf, & Krcmar, 2011). GSCM is the management that utilizes the green concept by coordinating and maintaining procurement and production process in order to produce, deliver, and reuse the products (Kasemsap, 2016b). Lean supply chain and green supply chain strategies help companies maximize the improvement of Lean Production in operations management regarding environmental sustainability (Kasemsap, 2016c). Green supply chain is capable of increasing corporate value while considering its impacts on all processes of physical distribution, production, and environment (Kasemsap, 2016d).

Environmental Sustainability and Climate Change

Many environmental policies typically relate to an increasing number of time-persistent environmental problems (e.g., climate change, nuclear waste, and groundwater pollution) which arise because of the accumulation in the environment of the long-lasting pollutants interacting in a complex way with ecosystem processes' dynamics (Underdal, 2010). The world's climate is changing, and the changes have an enormous impact on people, ecosystems, and energy use (Londhe, 2016). Climate change is one of the greatest threats to modern civilization and is a great challenge to economic development in the 21st

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century (Dinda, 2016). Climate plays an important role in destination choice and the timing of travel (Scott & Lemieux, 2010). For example, ski tourism depends on snow conditions (Shih, Nicholls, & Holecek, 2009).

Understanding the climate change-human health interaction is imperative for following a pathway of sustainable development (Roy, Ghosh, Mukhopadhyay, & Ghosh, 2016). The effects of climate change increase the renewable projects developed by municipalities and public private sectors toward achieving environmental sustainability (Bostancı, 2015). Environmental vulnerability assessment studies increase in the field of climate change impact assessment and in the areas of hazard impact analysis, food insecurity, poverty, and development economics (Senapati & Gupta, 2016).

Environmental Sustainability, Water Resources, and Energy Consumption

Climate change poses the uncertainties to the management of water resources (Kumar, 2016). The impact on aquatic life due to the inadequate environmental flow, reduction in availability of water in the nearby natural water resources, and the increase in the rate of deforestation are the significant environmental impacts in the comparatively longer run (Kumar & Katoch, 2016). Because water is essential to life, addressing water pollution and environmental sustainability issues is of great concern to environmentalists and public health specialists (McKeown & Bugyi, 2016).

For decades, the issue of energy utilization has been a subject of global discourse because of its role in technology development and its negative impact on environment across countries (Fruergaard, Astrup, & Ekvall, 2009). Government needs to intensify the educational efforts toward enlightening people about the requirement for the sustainable utilization of energy resources (Ifegbesan, Rampedi, & Annegarn, 2016). In the context of current global energy supply, biofuels have the limited supply capability and cannot supply the major portion of current global energy demand, however they can replace the liquid fossil fuels with the second and the third-generation biofuels (Murphy, Woods, Black, & McManus, 2011).

Overview of Sustainable Tourism

Changes in sustainable tourism and the model of sustainable tourism, in the varying economic and political situations, have led to the appearance of new directions in sustainable tourism policy, which affect the entire sector (Torres-Delgado & Palomeque, 2012). Tourism is the climate-sensitive economic sector, considering that climate change affects a number of key factors in sustainable tourism (Michailidou et al., 2016). Sustainability is recognized as an important tool for handling the negative impacts of tourism and attaining its long-term environmental viability (Liu, 2003) and has become the important issue for tourism, environmental management, and environmental studies (Lee & Hsieh, 2016).

Sustainable tourism is the concept of visiting a place as a tourist and trying to make a positive impact on the environment, society, and economy (Kasemsap, 2016e). Sustainable tourism can be applied to all forms of tourism (Akrivos, Reklitis, & Theodoroyiani, 2014) and is highly dependent on the ability to increase the financial benefits, achieved by all participants in the tourism sector, including the ability to maintain the social, cultural, and environmental heritage (Janusz & Bajdor, 2013). Nature destruction is the important threat for sustainable tourism in a destination, therefore tourism development must include environment as part of tourism resources required to be developed in terms of quality and variety (Sutawa, 2012). Sustainable tourism requires a profitability trade-off where the additional costs related to sustainability do not result in the increased economic returns (Moeller, Dolnicar, & Leisch, 2011).

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Tourism culture can be recognized as a precedent and antecedent of more sustainable tourism development (Canavan, 2016). Sustainable travelers are a travel market to be considered within the tourism marketing and business world (Nickerson, Jorgenson, & Boley, 2016). While the intrinsic benefits of sustainable tourism to the environment, culture, and residents of tourism destinations has been heavily researched (Boley & McGehee, 2014), the discussion of the economic benefits associated with sustainable tourism has been more conceptual in nature (Hassan, 2000). Most energy utilization in sustainable tourism is based on fossil fuels and the sector continues to emit the increasing levels of greenhouse gas (GHG) emissions (Hall, 2013). Current trends in tourism stand in contrast to a global policy momentum that aims for the long-term transformation of the economy to mitigate the GHG emissions and increase the resource efficiency (Lipman, de Lacy, Vorster, Hawkins, & Jiang, 2012).

The green economy paradigm presents the new situation of change for sustainable tourism (Law, de Lacy, Lipman, & Jiang, 2016). A community that utilizes tourism as an alternative method of strengthening its economic development must develop sustainable tourism to meet the demands of its residents (Puczkó & Rátz, 2000). The development of sustainable tourism is difficult without the participation of the community residents (Gursoy & Rutherford, 2004). Factors that influence the local community support for sustainable tourism development have been extensively studied by tourism scholars (Lee, 2013). These factors, such as attitudes (Lepp, 2008), perceived effects (Dyer, Gursoy, Sharma, & Carter, 2007), and perceived benefits (Nunkoo & Ramkissoon, 2011), may affect the residents' support for sustainable tourism development.

The expansion of the tourism industry encourages stakeholders to invest in the sector without considering the possible side-effects of such investments on the environment and on social development (Sorensson & von Friedrichs, 2013). The role of stakeholders in the implementation of sustainable tourism is becoming more prominent in both academia and industry (Waligo, Clarke, & Hawkins, 2013). Stakeholders have the potential impact on the sustainable tourism development initiatives (Hall, 2007) toward managing tourism more sustainably and considering different sustainable tourism perspectives (Dodds, 2007). Stakeholder collaboration represents the widely accepted approach to solving the problems associated with a lack of understanding and few shared common goals among many stakeholders involved in sustainable tourism development (Fyall & Garrod, 2005).

Questions of crisis, the environment, and tourism are connected to the wider discussion about sustainability and sustainable tourism (Ghaderi & Henderson, 2013). A common practice of sustainable tourism is to utilize an indicator system for designing and implementing tourism models that focuses on the sustainability approach (Lozano-Oyola, Blancas, González, & Caballero, 2012), toward managing crises (de Sausmarez, 2007), managing community tourism (Choi & Sirakaya, 2006), assessing tourism destinations (Pérez, Guerrero, González, Pérez, & Caballero, 2013), measuring tourism practices (Blackstock, White, McCrum, Scott, & Hunter, 2008), and selecting criteria for policy implementation and scientific recognition (Tanguay, Rajaonson, & Therrien, 2013).

Making tourism sustainable is not easy, mainly because the imprecise nature of the concept of sustainability makes it difficult to apply (Torres-Delgado & Palomeque, 2014). Regarding sustainable tourism, the scientific community has considered the impacts of climate change on tourism on global scale (Amelung, Nicholls, & Viner, 2007), country scale (Hamilton & Tol, 2007), and destination scale, such as coastal areas (Moreno & Becken, 2009), islands (Becken, 2005), ski areas (Scott, McBoyle, Minogue, & Mills, 2006), and parks (Jones & Scott, 2006).

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FUTURE RESEARCH DIRECTIONS

The classification of the extensive literature in the domains of sustainability, environmental sustainability, and sustainable tourism will provide the potential opportunities for future research. Clean technology aims to reduce the reliance on the non-renewable resources and to enhance the environmental sustainability. The significant issues concerning clean technology include sourcing for the energy needed to maintain a hardware environment, including servers, workstations, and other integral parts of an organization's technological infrastructure. Green technology encompasses the evolving group of both methods and materials, from techniques for generating energy to non-toxic cleaning products. Green technology helps reduce the adverse effects on the environment toward improving productivity, efficiency, and operational performance of the technology itself. An examination of linkages among sustainability, environmental sustainability, sustainable tourism, clean technology, and green technology would seem to be viable for future research efforts.

CONCLUSION

This chapter highlighted the overview of sustainability; the overview of environmental sustainability; environmental sustainability and climate change; environmental sustainability, water resources, and energy consumption; and the overview of sustainable tourism. Sustainability is one the newest degree subjects that attempts to bridge social science with civic engineering and environmental science with the technology of the future. As a set of goals sustainability describes the desired conditions of the environment and the ability of humans to receive benefits directly and indirectly from it, in the present as well as in the future. As practices and behaviors, sustainability describes human actions that support and enhance the human well-being derived through interaction with the environment, and which support the ability of human society to interact with the environment in ways that discourage the reduced benefits.

Environmental sustainability is important because it ensures people have water and resources, and adopting its practices protects the environment and human health. The doctrine of sustainability aims to maintain the conditions in which nature and humans can survive by appropriately utilizing the natural components of the environment. Sustainability, environmental sustainability, and sustainable tourism are rooted in three issues that are considerably linked to fossil fuel depletion, climate change due to carbon dioxide emissions, and the increasing costs of energy and water.

Sustainable tourism is a growing segment of the global tourism industry that makes the positive contributions to the environmental, socio-cultural, and economic well-being of destinations and local communities around the world. Offering market-linked long-term solutions, ecotourism provides effective economic incentives for conserving and enhancing bio-cultural diversity and helps protect the natural and cultural heritage of the beautiful planet. The economic, social, and environmental aspects of sustainable tourism development must include the interests of all stakeholders including indigenous people, local communities, visitors, industry, and government.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

REFERENCES

Abereijo, I. O. (2016). Ensuring environmental sustainability through sustainable entrepreneurship. In A. Goswami & A. Mishra (Eds.), *Economic modeling, analysis, and policy for sustainability* (pp. 234–249). Hershey, PA: IGI Global. doi:10.4018/978-1-5225-0094-0.ch012

Aboelmaged, M. G. (2014). A stakeholder perspective of sustainable supply chain management: Evidence from a developing country. In J. Wang (Ed.), *Management science, logistics, and operations research* (pp. 139–166). Hershey, PA: IGI Global. doi:10.4018/978-1-4666-4506-6.ch009

Ahi, P., & Searcy, C. (2013). A comparative literature analysis of definitions for green and sustainable supply chain management. *Journal of Cleaner Production*, *52*(1), 329–341. doi:10.1016/j.jclepro.2013.02.018

Akkaya, C., Wolf, P., & Krcmar, H. (2011). Efficient information provision for environmental and sustainability reporting. In *Green technologies: Concepts, methodologies, tools and applications* (pp. 1587–1609). Hershey, PA: IGI Global. doi:10.4018/978-1-60960-472-1.ch705

Akrivos, C., Reklitis, P., & Theodoroyiani, M. (2014). Tourism entrepreneurship and the adoption of sustainable resources: The case of Evritania prefecture. *Procedia: Social and Behavioral Sciences*, *148*, 378–382. doi:10.1016/j.sbspro.2014.07.056

Amelung, B., Nicholls, S., & Viner, D. (2007). Implications of global climate change for tourism flows and seasonality. *Journal of Travel Research*, *45*(3), 285–296. doi:10.1177/0047287506295937

Bajaj, S., Jha, P. C., & Aggarwal, K. K. (2013). Single-source, single-destination, multi product EOQ model with quantity discount incorporating partial/full truckload policy. *International Journal of Business Performance and Supply Chain Modelling*, *5*(2), 198–220. doi:10.1504/IJBPSCM.2013.053493

Becken, S. (2005). Harmonising climate change adaptation and mitigation: The case of tourist resorts in Fiji. *Global Environmental Change*, *15*(4), 381–393. doi:10.1016/j.gloenvcha.2005.08.001

Bekaroo, G., Bokhoree, C., & Pattinson, C. (2016). Impacts of ICT on the natural ecosystem: A grassroot analysis for promoting socio-environmental sustainability. *Renewable & Sustainable Energy Reviews*, *57*, 1580–1595. doi:10.1016/j.rser.2015.12.147

Blackstock, K. L., White, V., McCrum, G., Scott, A., & Hunter, C. (2008). Measuring responsibility: An appraisal of a Scottish national park's sustainable tourism indicators. *Journal of Sustainable Tourism*, *16*(3), 276–297. doi:10.2167/jost787.0

Boley, B. B., & McGehee, N. G. (2014). Measuring empowerment: Developing and validating the resident empowerment through tourism scale (RETS). *Tourism Management*, *45*, 85–94. doi:10.1016/j.tourman.2014.04.003

Bostancı, S. H. (2015). Sustainability strategies and projects of Turkish municipalities. In K. Thomas (Ed.), *Handbook of research on sustainable development and economics* (pp. 56–71). Hershey, PA: IGI Global. doi:10.4018/978-1-4666-8433-1.ch004

Bramwell, B., & Lane, B. (2013). Getting from here to there: Systems change, behavioural change and sustainable tourism. *Journal of Sustainable Tourism*, *21*(1), 1–4. doi:10.1080/09669582.2012.741602

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Canavan, B. (2016). Tourism culture: Nexus, characteristics, context and sustainability. *Tourism Management*, *53*, 229–243. doi:10.1016/j.tourman.2015.10.002

Caniato, F., Caridi, M., Crippa, L., & Moretto, A. (2011). Environmental sustainability in fashion supply chains: An exploratory case based research. *International Journal of Production Economics*, *135*(2), 659–670. doi:10.1016/j.ijpe.2011.06.001

Choi, H. C., & Sirakaya, E. (2006). Sustainability indicators for managing community tourism. *Tourism Management*, *27*(6), 1274–1289. doi:10.1016/j.tourman.2005.05.018

da Ronch, B., di Maria, E., & Micelli, S. (2013). Clusters go green: Drivers of environmental sustainability in local networks of SMEs. *International Journal of Information Systems and Social Change*, *4*(1), 37–52. doi:10.4018/jissc.2013010103

de Sausmarez, N. (2007). Crisis management, tourism and sustainability: The role of indicators. *Journal of Sustainable Tourism*, *15*(6), 700–714. doi:10.2167/jost653.0

Diabat, A., Kannan, D., & Mathiyazhagan, K. (2014). Analysis of enablers for implementation of sustainable supply chain management: A textile case. *Journal of Cleaner Production*, *83*, 391–403. doi:10.1016/j.jclepro.2014.06.081

Dinda, S. (2016). *Handbook of research on climate change impact on health and environmental sustainability* (pp. 1–711). Hershey, PA: IGI Global. doi:10.4018/978-1-4666-8814-8

Dodds, R. (2007). Sustainable tourism and policy implementation: Lessons from the case of Calvia, Spain. *Current Issues in Tourism*, *10*(1), 296–322. doi:10.2167/cit278.0

Dogbey, J., Quigley, C., Che, M., & Hallo, J. (2014). Using smartphone technology in environmental sustainability education: The case of the Maasai Mara region in Kenya. *International Journal of Mobile and Blended Learning*, *6*(1), 1–16. doi:10.4018/ijmbl.2014010101

Dredge, D., & Gyimothy, S. (2015). The collaborative economy and tourism: Critical perspectives, questionable claims and silenced voices. *Tourism Recreation Research*, *40*(3), 286–302. doi:10.1080/02508281.2015.1086076

Dyer, P., Gursoy, D., Sharma, B., & Carter, J. (2007). Structural modeling of resident perceptions of tourism and associated development on the Sunshine Coast, Australia. *Tourism Management*, *28*(2), 409–422. doi:10.1016/j.tourman.2006.04.002

Evangelista, P., Huge-Brodin, M., Isaksson, K., & Sweeney, E. (2014). Purchasing green transport and logistics services: Implications from the environmental sustainability attitude of 3PLs. In *Sustainable practices: Concepts, methodologies, tools, and applications* (pp. 86–102). Hershey, PA: IGI Global. doi:10.4018/978-1-4666-4852-4.ch005

Faccioli, M., Hanley, N., Torres, C., & Font, A. R. (2016). Do we care about sustainability? An analysis of time sensitivity of social preferences under environmental time-persistent effects. *Journal of Environmental Management*, *177*, 356–364. doi:10.1016/j.jenvman.2016.03.039 PMID:27123670

Faisal, M. N. (2010). Sustainable supply chains: A study of interaction among the enablers. *Business Process Management Journal*, *16*(3), 508–529. doi:10.1108/14637151011049476

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Fitzpatrick, J. J. (2016). Environmental sustainability assessment of using forest wood for heat energy in Ireland. *Renewable & Sustainable Energy Reviews*, *57*, 1287–1295. doi:10.1016/j.rser.2015.12.197

Foerstl, K., Azadegan, A., Leppelt, T., & Hartmann, E. (2015). Drivers of supplier sustainability: Moving beyond compliance to commitment. *Journal of Supply Chain Management*, *51*(1), 67–92. doi:10.1111/jscm.12067

Fruergaard, T., Astrup, T., & Ekvall, T. (2009). Energy use and recovery in waste management and implications for accounting of greenhouse gases and global warming contributions. *Waste Management & Research*, *27*(8), 724–737. doi:10.1177/0734242X09345276 PMID:19808739

Fyall, A., & Garrod, B. (2005). *Tourism marketing: A collaborative approach*. Clevedon, UK: Channel View Publications.

Ghaderi, Z., & Henderson, J. C. (2013). Japanese tsunami debris and the threat to sustainable tourism in the Hawaiian Islands. *Tourism Management Perspectives*, *8*, 98–105. doi:10.1016/j.tmp.2013.09.001

Govindan, K., Mathiyazhagan, K., Devika, K., & Haq, A. N. (2014). Barriers analysis for green supply chain management implementation in Indian industries using analytic hierarchy process. *International Journal of Production Economics*, *147*, 555–568. doi:10.1016/j.ijpe.2013.08.018

Grigoroudis, E., Kouikoglou, V. S., & Phillis, Y. A. (2012). Approaches for measuring sustainability. In P. Olla (Ed.), *Global sustainable development and renewable energy systems* (pp. 101–130). Hershey, PA: IGI Global. doi:10.4018/978-1-4666-1625-7.ch006

Gursoy, D., & Rutherford, D. G. (2004). Host attitudes toward tourism: An improved structural model. *Annals of Tourism Research*, *31*(3), 495–516. doi:10.1016/j.annals.2003.08.008

Hall, C. M. (2007). *Tourism planning: Policies, processes and relationships*. Harlow, UK: Prentice Hall.

Hall, C. M. (2013). Framing behavioural approaches to understanding and governing sustainable tourism consumption: Beyond neoliberalism, "nudging" and "green growth"? *Journal of Sustainable Tourism*, *21*(7), 1091–1109. doi:10.1080/09669582.2013.815764

Hamilton, J. M., & Tol, R. S. J. (2007). The impact of climate change on tourism in Germany, the UK and Ireland: A simulation study. *Regional Environmental Change*, *7*(3), 161–172. doi:10.100710113-007-0036-2

Hart, S. L., & Milstein, M. B. (2003). Creating sustainable value. *The Academy of Management Executive*, *17*(2), 56–67. doi:10.5465/AME.2003.10025194

Hassan, S. S. (2000). Determinants of market competitiveness in an environmentally sustainable tourism industry. *Journal of Travel Research*, *38*(3), 239–245. doi:10.1177/004728750003800305

Herbohn, K., Walker, J., & Loo, H. Y. M. (2014). Corporate social responsibility: The link between sustainability disclosure and sustainability performance. *Abacus*, *50*(4), 422–459. doi:10.1111/abac.12036

Hultman, J., & Sawe, F. (2016). Absence and presence of social complexity in the marketization of sustainable tourism. *Journal of Cleaner Production*, *111*, 327–335. doi:10.1016/j.jclepro.2014.11.053

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Ifegbesan, A. P., Rampedi, I. T., & Annegarn, H. J. (2016). Nigerian households' cooking energy use, determinants of choice, and some implications for human health and environmental sustainability. *Habitat International*, *55*, 17–24. doi:10.1016/j.habitatint.2016.02.001

Janusz, G. K., & Bajdor, P. (2013). Towards to sustainable tourism: Framework, activities and dimensions. *Procedia Economics and Finance*, *6*, 523–529. doi:10.1016/S2212-5671(13)00170-6

Jones, B., & Scott, D. (2006). Implications of climate change for visitation to Ontario's provincial parks. *Leisure*, *30*(1), 233–261. doi:10.1080/14927713.2006.9651350

Kara, M. E., & Fırat, S. Ü. (2016). Sustainability, risk, and business intelligence in supply chains. In M. Erdoğdu, T. Arun, & I. Ahmad (Eds.), *Handbook of research on green economic development initiatives and strategies* (pp. 501–538). Hershey, PA: IGI Global. doi:10.4018/978-1-5225-0440-5.ch022

Kasemsap, K. (2015). The role of marketing strategies in the tourism industry. In N. Ray (Ed.), *Emerging innovative marketing strategies in the tourism industry* (pp. 174–194). Hershey, PA: IGI Global. doi:10.4018/978-1-4666-8699-1.ch010

Kasemsap, K. (2016a). Facilitating hospitality and tourism management in global business. In N. Pappas & I. Bregoli (Eds.), *Global dynamics in travel, tourism, and hospitality* (pp. 283–305). Hershey, PA: IGI Global. doi:10.4018/978-1-5225-0201-2.ch016

Kasemsap, K. (2016b). The role of sustainable performance measurement system in global supply chain. In R. Dubey & A. Gunasekaran (Eds.), *Strategic management of sustainable manufacturing operations* (pp. 331–348). Hershey, PA: IGI Global. doi:10.4018/978-1-5225-0350-7.ch014

Kasemsap, K. (2016c). The roles of lean and green supply chain management strategies in the global business environments. In S. Joshi & R. Joshi (Eds.), *Designing and implementing global supply chain management* (pp. 152–173). Hershey, PA: IGI Global. doi:10.4018/978-1-4666-9720-1.ch008

Kasemsap, K. (2016d). Multifaceted applications of green supply chain management. In A. Jean-Vasile (Ed.), *Food science, production, and engineering in contemporary economies* (pp. 327–354). Hershey, PA: IGI Global. doi:10.4018/978-1-5225-0341-5.ch014

Kasemsap, K. (2016e). Encouraging corporate social responsibility and sustainable tourism development in global tourism. In L. Guliani & S. Rizwan (Eds.), *Corporate social responsibility in the hospitality and tourism industry* (pp. 197–224). Hershey, PA: IGI Global. doi:10.4018/978-1-4666-9902-1.ch016

Kasemsap, K. (2017a). Advocating sustainable supply chain management and sustainability in global supply chain. In M. Khan, M. Hussain, & M. Ajmal (Eds.), *Green supply chain management for sustainable business practice* (pp. 234–271). Hershey, PA: IGI Global. doi:10.4018/978-1-5225-0635-5.ch009

Kasemsap, K. (2017b). Mastering consumer attitude and sustainable consumption in the digital age. In N. Suki (Ed.), *Handbook of research on leveraging consumer psychology for effective customer engagement* (pp. 16–41). Hershey, PA: IGI Global. doi:10.4018/978-1-5225-0746-8.ch002

Kuik, S. S., Nagalingam, S. V., & Amer, Y. (2010). *Challenges in implementing sustainable supply chain within a collaborative manufacturing network*. Paper presented at the 8th International Conference on Supply Chain Management and Information Systems (SCMIS 2010), Hong Kong.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Kumar, C. P. (2016). Impact of climate change on groundwater resources. In S. Dinda (Ed.), *Handbook of research on climate change impact on health and environmental sustainability* (pp. 196–221). Hershey, PA: IGI Global. doi:10.4018/978-1-4666-8814-8.ch010

Kumar, D., & Katoch, S. S. (2016). Environmental sustainability of run of the river hydropower projects: A study from western Himalayan region of India. *Renewable Energy*, *93*, 599–607. doi:10.1016/j.renene.2016.03.032

Kumar, M. (2016). Environmental sustainability in the fashion supply chain in India. *International Journal of Social Ecology and Sustainable Development*, *7*(3), 1–33. doi:10.4018/IJSESD.2016070101

Lamming, R., Faro, A., & Cousins, P. D. (1999). Environmental soundness: A pragmatic alternative to expectations of sustainable development in business strategy. *Business Strategy and the Environment*, *8*(3), 177–188. doi:10.1002/(SICI)1099-0836(199905/06)8:3<177::AID-BSE196>3.0.CO;2-1

Law, A., de Lacy, T., Lipman, G., & Jiang, M. (2016). Transitioning to a green economy: The case of tourism in Bali, Indonesia. *Journal of Cleaner Production*, *111*, 295–305. doi:10.1016/j.jclepro.2014.12.070

Lee, T. H. (2013). Influence analysis of community resident support for sustainable tourism development. *Tourism Management*, *34*, 37–46. doi:10.1016/j.tourman.2012.03.007

Lee, T. H., & Hsieh, H. P. (2016). Indicators of sustainable tourism: A case study from a Taiwan's wetland. *Ecological Indicators*, *67*, 779–787. doi:10.1016/j.ecolind.2016.03.023

Lepp, A. (2008). Attitudes towards initial tourism development in a community with no prior tourism experience: The case of Bigodi, Uganda. *Journal of Sustainable Tourism*, *16*(1), 5–22. doi:10.2167/jost630.0

Linton, J. D., Klassen, R., & Jayaraman, V. (2007). Sustainable supply chains: An introduction. *Journal of Operations Management*, *25*(6), 1075–1082. doi:10.1016/j.jom.2007.01.012

Lipman, G., de Lacy, T., Vorster, S., Hawkins, R., & Jiang, M. (2012). *Green growth and travelism: Letters from leaders*. Oxford, UK: Goodfellow Publishers.

Liu, Z. (2003). Sustainable tourism development: A critique. *Journal of Sustainable Tourism*, *11*(6), 459–475. doi:10.1080/09669580308667216

Londhe, S. L. (2016). Climate change and agriculture: Impacts, adoption, and mitigation. In S. Dinda (Ed.), *Handbook of research on climate change impact on health and environmental sustainability* (pp. 393–415). Hershey, PA: IGI Global. doi:10.4018/978-1-4666-8814-8.ch019

Lozano-Oyola, M., Blancas, F. J., González, M., & Caballero, R. (2012). Sustainable tourism indicators as planning tools in cultural destinations. *Ecological Indicators*, *18*, 659–675. doi:10.1016/j.ecolind.2012.01.014

Manikas, I., Ieromonachou, P., & Bochtis, D. (2014). Environmental sustainability initiatives in the agrifood supply chain. In Z. Andreopoulou, V. Samathrakis, S. Louca, & M. Vlachopoulou (Eds.), *E-innovation for sustainable development of rural resources during global economic crisis* (pp. 221–232). Hershey, PA: IGI Global. doi:10.4018/978-1-4666-4550-9.ch016

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

McKeown, A., & Bugyi, G. (2016). *Impact of water pollution on human health and environmental sustainability* (pp. 1–422). Hershey, PA: IGI Global. doi:10.4018/978-1-4666-9559-7

Michailidou, A. V., Vlachokostas, C., & Moussiopoulos, N. (2016). Interactions between climate change and the tourism sector: Multiple-criteria decision analysis to assess mitigation and adaptation options in tourism areas. *Tourism Management*, *55*, 1–12. doi:10.1016/j.tourman.2016.01.010

Moeller, T., Dolnicar, S., & Leisch, F. (2011). The sustainability–profitability trade-off in tourism: Can it be overcome? *Journal of Sustainable Tourism*, *19*(2), 155–169. doi:10.1080/09669582.2010.518762

Molina-Azorin, J. F., Claver-Cortes, E., Lopez-Gamero, M. D., & Tari, J. J. (2009). Green management and financial performance: A literature review. *Management Decision*, *47*(7), 1080–1100. doi:10.1108/00251740910978313

Mollenkopf, D., Stolze, H., Tate, W. L., & Ueltschy, M. (2010). Green, lean, and global supply chains. *International Journal of Physical Distribution & Logistics Management*, *40*(1/2), 14–41. doi:10.1108/09600031011018028

Morali, O., & Searcy, C. (2013). A review of sustainable supply chain management practices in Canada. *Journal of Business Ethics*, *117*(3), 635–658. doi:10.100710551-012-1539-4

Moreno, A., & Becken, S. (2009). A climate change vulnerability assessment methodology for coastal tourism. *Journal of Sustainable Tourism*, *17*(4), 473–488. doi:10.1080/09669580802651681

Muduli, K., Govindan, K., Barve, A., & Geng, Y. (2013). Barriers to green supply chain management in Indian mining industries: A graph theoretic approach. *Journal of Cleaner Production*, *47*, 335–344. doi:10.1016/j.jclepro.2012.10.030

Mukherjee, A., Kamarulzaman, N. H., Vijayan, G., & Vaiappuri, S. K. (2016). Sustainability: A comprehensive literature. In B. Christiansen (Ed.), *Handbook of research on global supply chain management* (pp. 248–268). Hershey, PA: IGI Global. doi:10.4018/978-1-4666-9639-6.ch015

Murphy, R., Woods, J., Black, M., & McManus, M. (2011). Global developments in the competition for land from biofuels. *Food Policy*, *36*, 552–561. doi:10.1016/j.foodpol.2010.11.014

Nickerson, N. P., Jorgenson, J., & Boley, B. B. (2016). Are sustainable tourists a higher spending market? *Tourism Management*, *54*, 170–177. doi:10.1016/j.tourman.2015.11.009

Nunkoo, R., & Ramkissoon, H. (2011). Developing a community support model for tourism. *Annals of Tourism Research*, *38*(3), 964–988. doi:10.1016/j.annals.2011.01.017

Pagell, M., & Shevchenko, A. (2014). Why research in sustainable supply chain management should have no future. *Journal of Supply Chain Management*, *50*(1), 44–55. doi:10.1111/jscm.12037

Pérez, V., Guerrero, F., González, M., Pérez, F., & Caballero, R. (2013). Composite indicator for the assessment of sustainability: The case of Cuban nature-based tourism destinations. *Ecological Indicators*, *29*, 316–324. doi:10.1016/j.ecolind.2012.12.027

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Puczkó, L., & Rátz, T. (2000). Tourist and resident perceptions of the physical impacts of tourism at Lake Balaton, Hungary: Issues for sustainable tourism management. *Journal of Sustainable Tourism*, *8*(6), 458–478. doi:10.1080/09669580008667380

Roy, J., Ghosh, D., Mukhopadhyay, K., & Ghosh, A. (2016). Exacerbating health risks in India due to climate change: Rethinking approach to health service provision. In S. Dinda (Ed.), *Handbook of research on climate change impact on health and environmental sustainability* (pp. 1–25). Hershey, PA: IGI Global. doi:10.4018/978-1-4666-8814-8.ch001

Schwarz, J., Beloff, B., & Beaver, E. (2002). Use sustainability metrics to guide decision-making. *Chemical Engineering Progress*, *98*(7), 58–63.

Scott, D., & Lemieux, C. (2010). Weather and climate information for tourism. *Procedia Environmental Sciences*, *1*, 146–183. doi:10.1016/j.proenv.2010.09.011

Scott, D., McBoyle, G., Minogue, A., & Mills, B. (2006). Climate change and sustainability of ski-based tourism in eastern North America: A reassessment. *Journal of Sustainable Tourism*, *14*(4), 376–398. doi:10.2167/jost550.0

Searcy, C., Karapetrovic, S., & McCartney, D. (2008). Application of a systems approach to sustainable development performance measurement. *International Journal of Productivity and Performance Management*, *57*(2), 182–197. doi:10.1108/17410400810847429

Sen, Y. (2016). How to manage sustainability: A framework for corporate sustainability tools. In M. Erdoğdu, T. Arun, & I. Ahmad (Eds.), *Handbook of research on green economic development initiatives and strategies* (pp. 418–439). Hershey, PA: IGI Global. doi:10.4018/978-1-5225-0440-5.ch018

Senapati, S., & Gupta, V. (2016). Vulnerability to climate change: Issues and challenges towards developing vulnerability indicator. In S. Dinda (Ed.), *Handbook of research on climate change impact on health and environmental sustainability* (pp. 82–104). Hershey, PA: IGI Global. doi:10.4018/978-1-4666-8814-8.ch005

Seuring, S., & Muller, M. (2008). From a literature review to a conceptual framework for sustainable supply chain management. *Journal of Cleaner Production*, *16*(15), 1699–1710. doi:10.1016/j.jclepro.2008.04.020

Sezen, B., & Turkkantos, S. (2013). The effects of relationship quality and lean applications on buyer-seller relationships. *International Journal of Business Performance and Supply Chain Modelling*, *5*(4), 378–400. doi:10.1504/IJBPSCM.2013.058204

Shakir, M. (2011). A framework for the implementation of eco-efficient business systems. In *Green technologies: Concepts, methodologies, tools and applications* (pp. 220–235). Hershey, PA: IGI Global. doi:10.4018/978-1-60960-472-1.ch203

Shih, C., Nicholls, S., & Holecek, D. (2009). Impact of weather on downhill ski lift ticket sales. *Journal of Travel Research*, *47*(3), 359–372. doi:10.1177/0047287508321207

Singh, S., Olugu, E. U., & Musa, S. N. (2016). Development of key performance measures for sustainable manufacturing in global SMEs. In S. Joshi & R. Joshi (Eds.), *Designing and implementing global supply chain management* (pp. 210–218). Hershey, PA: IGI Global. doi:10.4018/978-1-4666-9720-1.ch011

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Soliman, F. (2015). Could cultural sustainability improve organisational sustainability in cloud environments? In F. Soliman (Ed.), *Business transformation and sustainability through cloud system implementation* (pp. 1–15). Hershey, PA: IGI Global. doi:10.4018/978-1-4666-6445-6.ch001

Sorensson, A., & von Friedrichs, Y. (2013). An importance–performance analysis of sustainable tourism: A comparison between international and national tourists. *Journal of Destination Marketing & Management*, *2*(1), 14–21. doi:10.1016/j.jdmm.2012.11.002

Sutawa, G. K. (2012). Issues on Bali tourism development and community empowerment to support sustainable tourism development. *Procedia Economics and Finance*, *4*, 413–422. doi:10.1016/S2212-5671(12)00356-5

Tanguay, G. A., Rajaonson, J., & Therrien, M. C. (2013). Sustainable tourism indicators: Selection criteria for policy implementation and scientific recognition. *Journal of Sustainable Tourism*, *21*(6), 862–879. doi:10.1080/09669582.2012.742531

Torres-Delgado, A., & Palomeque, F. L. (2012). The growth and spread of the concept of sustainable tourism: The contribution of institutional initiatives to tourism policy. *Tourism Management Perspectives*, *4*, 1–10. doi:10.1016/j.tmp.2012.05.001

Torres-Delgado, A., & Palomeque, F. L. (2014). Measuring sustainable tourism at the municipal level. *Annals of Tourism Research*, *49*, 122–137. doi:10.1016/j.annals.2014.09.003

Tullberg, J. (2012). Triple bottom line: A vaulting ambition? *Business Ethics (Oxford, England)*, *21*(3), 310–324. doi:10.1111/j.1467-8608.2012.01656.x

Underdal, A. (2010). Complexity and challenges of long-term environmental governance. *Global Environmental Change*, *20*(3), 386–393. doi:10.1016/j.gloenvcha.2010.02.005

Vachon, S., & Mao, Z. (2008). Linking supply chain strength to sustainable development: A country-level analysis. *Journal of Cleaner Production*, *16*(15), 1552–1560. doi:10.1016/j.jclepro.2008.04.012

Waligo, V. M., Clarke, J., & Hawkins, R. (2013). Implementing sustainable tourism: A multi-stakeholder involvement management framework. *Tourism Management*, *36*, 342–353. doi:10.1016/j.tourman.2012.10.008

Wen, L., Xu, L., & Wang, R. (2013). Sustainable supplier evaluation based on intuitionistic fuzzy sets group decision methods. *Journal of Information and Computational Science*, *10*(10), 3209–3220. doi:10.12733/jics20102169

Wu, T., Wu, Y. C. J., Chen, Y. J., & Goh, M. (2014). Aligning supply chain strategy with corporate environmental strategy: A contingency approach. *International Journal of Production Economics*, *147*, 220–229. doi:10.1016/j.ijpe.2013.02.027

Xie, Y., & Allen, C. (2013). Information technologies in retail supply chains: A comparison of Tesco and Asda. *International Journal of Business Performance and Supply Chain Modelling*, *5*(1), 46–62. doi:10.1504/IJBPSCM.2013.051648

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

ADDITIONAL READING

Benedetto, G., Carboni, D., & Corinto, G. L. (2016). Governance of sustainable tourism in a vast area surrounding a national park. *Procedia Environmental Sciences*, *32*, 38–48. doi:10.1016/j.proenv.2016.03.010

Boley, B. B., & Uysal, M. (2013). Competitive synergy through practicing triple bottom line sustainability: Evidence from three hospitality case studies. *Tourism and Hospitality Research*, *13*(4), 226–238. doi:10.1177/1467358414528528

Buckley, R. (2012). Sustainable tourism: Research and reality. *Annals of Tourism Research*, *39*(2), 528–546. doi:10.1016/j.annals.2012.02.003

Carbone, V., Moatti, V., & Esposito, V. V. (2012). Mapping corporate responsibility and sustainable supply chains: An exploratory perspective. *Business Strategy and the Environment*, *21*(7), 475–494. doi:10.1002/bse.1736

Cole, S. (2014). Tourism and water: From stakeholders to rights holders, and what tourism businesses need to do. *Journal of Sustainable Tourism*, *22*(1), 89–106. doi:10.1080/09669582.2013.776062

Cucculelli, M., & Goffi, G. (2016). Does sustainability enhance tourism destination competitiveness? Evidence from Italian destinations of excellence. *Journal of Cleaner Production*, *111*, 370–382. doi:10.1016/j.jclepro.2014.12.069

Deville, A., Wearing, S., & McDonald, M. (2016). Tourism and willing workers on organic farms: A collision of two spaces in sustainable agriculture. *Journal of Cleaner Production*, *111*, 421–429. doi:10.1016/j.jclepro.2014.12.071

Evans, N. G. (2016). Sustainable competitive advantage in tourism organizations: A strategic model applying service dominant logic and tourism's defining characteristics. *Tourism Management Perspectives*, *18*, 14–25. doi:10.1016/j.tmp.2015.12.015

Fatimah, T. (2015). The impacts of rural tourism initiatives on cultural landscape sustainability in Borobudur area. *Procedia Environmental Sciences*, *28*, 567–577. doi:10.1016/j.proenv.2015.07.067

Filimonau, V., Dickinson, J., Robbins, D., & Huijbregts, M. A. J. (2011). Reviewing the carbon footprint analysis of hotels: Life cycle energy analysis (LCEA) as a holistic method for carbon impact appraisal of tourist accommodation. *Journal of Cleaner Production*, *19*(17/18), 1917–1930. doi:10.1016/j.jclepro.2011.07.002

Gibson, K. (2012). Stakeholders and sustainability: An evolving theory. *Journal of Business Ethics*, *109*(1), 15–25. doi:10.100710551-012-1376-5

Golicic, S. L., & Smith, C. D. (2013). A meta-analysis of environmentally sustainable supply chain management practices and firm performance. *Journal of Supply Chain Management*, *49*(2), 78–95. doi:10.1111/jscm.12006

Gossling, S., & Buckley, R. (2016). Carbon labels in tourism: Persuasive communication? *Journal of Cleaner Production*, *111*, 358–369. doi:10.1016/j.jclepro.2014.08.067

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Govindan, K., Khodaverdi, R., & Jafarian, A. (2013). A fuzzy multi criteria approach for measuring sustainability performance of a supplier based on triple bottom line approach. *Journal of Cleaner Production*, *47*, 345–354. doi:10.1016/j.jclepro.2012.04.014

Hassini, E., Surti, C., & Searcy, C. (2012). A literature review and a case study of sustainable supply chains with a focus on metrics. *International Journal of Production Economics*, *140*(1), 69–82. doi:10.1016/j.ijpe.2012.01.042

Higham, J., Cohen, S. A., Cavaliere, C. T., Reis, A., & Finkler, W. (2016). Climate change, tourist air travel and radical emissions reduction. *Journal of Cleaner Production*, *111*, 336–347. doi:10.1016/j.jclepro.2014.10.100

Hopkins, D. (2014). The sustainability of climate change adaptation strategies in New Zealand's ski industry: A range of stakeholder perceptions. *Journal of Sustainable Tourism*, *22*(1), 107–126. doi:10.1080/09669582.2013.804830

Iaquinto, B. L. (2016). Strengths and weaknesses of using mixed methods to detect the sustainable practices of backpackers: A reflexive account. *Journal of Cleaner Production*, *111*, 479–486. doi:10.1016/j.jclepro.2015.02.013

Ingelmo, I. A. (2013). Design and development of a sustainable tourism indicator based on human activities analysis in Inle Lake, Myanmar. *Procedia: Social and Behavioral Sciences*, *103*, 262–272. doi:10.1016/j.sbspro.2013.10.334

Jamal, T., & Camargo, B. (2014). Sustainable tourism, justice and an ethic of care: Toward the just destination. *Journal of Sustainable Tourism*, *22*(1), 11–30. doi:10.1080/09669582.2013.786084

Juvan, E., & Dolnicar, S. (2014). The attitude-behaviour gap in sustainable tourism. *Annals of Tourism Research*, *48*, 76–95. doi:10.1016/j.annals.2014.05.012

McLennan, C. J., Becken, S., & Watt, M. (2016). Learning through a cluster approach: Lessons from the implementation of six Australian tourism business sustainability programs. *Journal of Cleaner Production*, *111*, 348–357. doi:10.1016/j.jclepro.2015.01.085

Michailidou, A. V., Vlachokostas, C., Moussiopoulos, N., & Maleka, D. (2016). Life cycle thinking to assess the environmental impacts of tourism activity for a Greek tourism destination. *Journal of Cleaner Production*, *111*, 499–510. doi:10.1016/j.jclepro.2015.09.099

Minoli, D. M., Goode, M. K. H., & Smith, M. T. (2015). Are eco labels profitably employed in sustainable tourism? A case study on Audubon certified golf resorts. *Tourism Management Perspectives*, *16*, 207–216. doi:10.1016/j.tmp.2015.07.011

Moscardo, G., & Murphy, L. (2014). There is no such thing as sustainable tourism: Reconceptualizing tourism as a tool for sustainability. *Sustainability*, *6*(5), 2538–2561. doi:10.3390u6052538

Njoroge, J. M. (2014). An enhanced framework for regional tourism sustainable adaptation to climate change. *Tourism Management Perspectives*, *12*, 23–30. doi:10.1016/j.tmp.2014.06.002

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Ottenbacher, M. C., Schwebler, S., Metzler, D., & Harrington, R. J. (2015). Sustainability criteria for tourism attractions: A case study of Germany. *International Journal of Social Ecology and Sustainable Development*, *6*(2), 20–39. doi:10.4018/ijsesd.2015040102

Reihanian, A., Mahmood, N. Z. B., Kahrom, E., & Hin, T. W. (2012). Sustainable tourism development strategy by SWOT analysis: Boujagh National Park, Iran. *Tourism Management Perspectives*, *4*, 223–228. doi:10.1016/j.tmp.2012.08.005

Rowley, H. V., Peters, G. M., Lundie, S., & Moore, S. J. (2012). Aggregating sustainability indicators: Beyond the weighted sum. *Journal of Environmental Management*, *111*, 24–33. doi:10.1016/j.jenvman.2012.05.004 PMID:22813856

Ruhanen, L., Weiler, B., Moyle, B. D., & McLennan, C. J. (2015). Trends and patterns in sustainable tourism research: A 25-year bibliometric analysis. *Journal of Sustainable Tourism*, *23*(4), 517–535. doi:10.1080/09669582.2014.978790

Saarinen, J. (2013). Critical sustainability: Setting the limits to growth and responsibility in tourism. *Sustainability*, *6*(1), 1–17. doi:10.3390u6010001

Salerno, F., Viviano, G., Manfredi, E. C., Caroli, P., Thakuri, S., & Tartari, G. (2013). Multiple carrying capacities from a management-oriented perspective to operationalize sustainable tourism in protected areas. *Journal of Environmental Management*, *128*, 116–125. doi:10.1016/j.jenvman.2013.04.043 PMID:23728182

Smith, P., & Sharicz, C. (2011). The shift needed for sustainability. *The Learning Organization*, *18*(1), 73–86. doi:10.1108/09696471111096019

Stoddard, J. E., Pollard, C. E., & Evans, M. R. (2012). The triple bottom line: A framework for sustainable tourism development. *International Journal of Hospitality & Tourism Administration*, *13*(3), 233–258. doi:10.1080/15256480.2012.698173

Tonelli, F., Evans, S., & Taticchi, P. (2013). Industrial sustainability: Challenges, perspectives, actions. *International Journal of Business Innovation Research*, *7*(2), 143–163. doi:10.1504/IJBIR.2013.052576

Weaver, D. B. (2012). Clearing the path to sustainable mass tourism: A response to Peeters. *Tourism Management*, *33*(5), 1042–1043. doi:10.1016/j.tourman.2012.01.012

Wijesinghe, G. (2014). Reimagining the application of sustainability to the hospitality industry through a virtue ethics framework. *Journal of Sustainable Tourism*, *22*(1), 31–49. doi:10.1080/09669582.2013.819875

Williams, A. (2013). Mobilities and sustainable tourism: Path-creating or path-dependent relationships? *Journal of Sustainable Tourism*, *21*(4), 511–531. doi:10.1080/09669582.2013.768252

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KEY TERMS AND DEFINITIONS

Climate Change: The changes in the world's weather, in particular the fact that it is believed to be getting warmer as a result of human activity increasing the level of carbon dioxide in the atmosphere.

Energy Consumption: The amount of energy consumed in a process or by an organization.

Stakeholder: A person or group of people who own a share in a business.

Sustainability: The idea that products and services should be produced in ways that do not use resources that cannot be replaced and that do not damage the environment.

Sustainable Development: The economic development characterized by low growth rate, absence of pollution, and greatly diminished environmental impact.

Sustainable Tourism: The tourism committed to generating a low impact on the surrounding environment and community while generating income for the local economy and aiding social cohesion.

Triple Bottom Line: The economic, social, and environmental effects of a company's policies and actions that determine its viability as a sustainable organization.

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Chapter 78
Are GM Crops the Answer to Africa's Critical Food Security Status?
Learning From the Experiences of Developing Countries

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ABSTRACT

Despite unprecedented technological breakthroughs and rising incomes, the most basic human requirement–food security remains out of reach of many. The countries of Africa are the worst affected, and consistently score lowest on the Global Hunger Index. The downside of technological advance and increasing urbanisation is the decrease in cultivable land and water availability exacerbated by climatic unpredictability. While concerted efforts are on to control the crisis, it is time to take positive action and capture technology to boost food security. Genetically Modified (GM) crops engineered to be drought/flood resistant, reduce pesticide requirements or provide vitamins open up tremendous possibilities for enhancing food and nutrition security and counteracting negative environmental impacts. This paper reviews the current status of GM crops in Africa, the scope for expansion, possible impacts on food security and the validity of existing concerns about bio-safety and farmers' needs in the light of developing country experience.

INTRODUCTION

One of the major challenges that Africa faces today is that of ensuring food security for its population. Over the last few decades, the continent has witnessed severe food shortages, even starvation in one country or the other. This may be attributed to a variety of causes—environmental, economic, strife-related or as a result of pandemics like HIV/AIDS sweeping the continent. The continued heavy dependence on food-aid and cheap food imports also tend to undermine local agriculture and leaves the consumer

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unprotected and completely vulnerable to global price fluctuations. Food Aid dates back to the late 1950s, but the number of food emergencies have tripled since the mid-1980s (MDG Report, 2013). Climate change which brings in its wake unpredictability of temperature and rainfall as well as an increase in severe climatic events is further exacerbating the situation. In this backdrop, it is encouraging to note that a number of countries in sub-Saharan Africa have improved their food security status in the new millennium. While the decade of the 1990s witnessed extremely slow progress in Africa as against South Asia, there has been more rapid improvement, from 2000 onwards. In fact, the Global Hunger Index (GHI) 2014 finds sub-Saharan Africa outpacing South Asia. The six countries which have made substantive progress reducing their GHI scores by over 50% since 1990 are Angola, Ethiopia, Ghana, Malawi, Niger and Rwanda. Yet even today, 12 countries have GHI scores in the "alarming" or "extremely alarming" categories: Central African Republic, Ethiopia, Comoros, Mozambique, Niger, Sudan, Zambia, Sierra Leone, Madagascar (GHI scores: 20-29.9), and Burundi and Eritrea (GHI scores: 30-39.9) (GHI, 2014). The Global Hunger Index is a composite of three hunger indicators: the proportion of undernourished population, the proportion of underweight children below the age of 5 years and the infant mortality rate, which effectively represent the food security status of a country. As the GHI scores in sub-Saharan Africa are heavily weighted by the proportion of undernourished population unlike in the case of South Asia, where underweight children tend to have more impact on the score, it is not surprising to find that in these countries (with alarming or extremely alarming scores), about one-third of the population does not consume the minimum calorie requirement. In Burundi and Comoros this proportion reaches as high as 65 and 67%, respectively.

The fact that Africa is endowed with vast and underutilised natural resources like huge tracts of cultivable land, water and temperatures suitable for cultivation, makes this chronic shortfall in food production a story of unused potential. With reference to potential land area alone, the FAO (2009) estimates that the unutilised rain-fed area suitable for cultivation could be as much as 700 million ha. It is widely accepted that food shortages in the African context result from the fact that 90% of the cultivators are small and marginal farmers, almost 60% of cultivated area is un-irrigated, and the practice of cultivating a large variety of crops on small farms does not lend itself to the adoption of green revolution technologies, which have been suggested as being more suited to large scale monocultures. In addition, poverty, illiteracy and weak infrastructure preclude access to markets or improved inputs. The Millennium Development Goals Report (2013) states:

In fact, the challenges of the past have grown and become more complex, exacerbating food insecurity. Africa's agriculture is underdeveloped, and people have begun abandoning it for better livelihoods. The effects of climate change are more pronounced and Africa's population is increasing so fast that countries might be unable to produce all the food they need.

An estimated 232 million undernourished people live in Africa (FAO, 2015) of whom almost 95% are in the sub-Saharan region alone. With the population of this region projected to reach 1.5–2 billion by 2050 (FAO, 2009), it becomes imperative to seek out viable solutions to the food security issue. This paper focuses on genetically modified crops and their potential to contribute to a food secure Africa.

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Genetically Modified Crops: A Brief History

The selective breeding of plants dates back to the beginnings of settled agriculture. Improved varieties bred for higher yields, changes in colour or flavour or resistance to adverse climatic conditions underlie the development of agriculture in every country and form the basis of indigenous farming knowhow which is handed down through generations of farmers. Agricultural products most in demand in the global market like India's basmati rice, Ghana's cocoa or Hawaii's kona coffee are all the products of selective breeding practices over generations of farmers. Yet, when it comes to the question of genetic modification, there is instant alarm and stubborn resistance to such interventions, which could provide a relatively quicker avenue to improving food security and livelihoods in countries with low availability of food and high levels of malnutrition.

Genetic modification consists of the introduction of genes from a crop with the desired characteristics into the living DNA of another with a view to improving the latter variety. China was the first country to produce genetically modified (GM) crops for the market in the form of a virus resistant tobacco and a GM tomato somewhere in the late 1980s to the early 1990s. Better known is the case of the United States (US), where the first genetically modified food crop was brought into commercial use in 1994 with the *Flavrsavr* transgenic tomato being brought to supermarket shelves in the US. This variety of slow ripening tomato with a long-shelf-life received a positive response with consumers even paying a premium price for the product (Murnaghan, 2014). This breakthrough was quickly followed by the release of three more crops in 1995; The Bt potato, the first pesticide producing crop, Bt corn with insect resistant qualities and herbicide resistant Roundup Ready Soybeans. By 1996, all three crops were also approved in the UK and the European Union (GM Education, 2014).

In 1997, however, the European Commission EC novel Foods Regulation (258/97) came into effect mandating safety assessment for novel and GM foods before release into the market and by 1998 the first GM labelling rules were introduced so that consumers were informed about the use of GM ingredients in the food they were purchasing. These measures signalled the beginning of the disquiet with regard to the possible negative impacts of GM produce (GM Education, 2014).

Yet, the growth of GM crops during the same period was phenomenal. From 1.6 million hectares in 1996, these crops expanded to cover as much as 35 million hectares by 1999. The transfer of GM technology from the developed to the developing world was rapid and fifty two percent of the total area under GM crops is now in developing countries. GM crops cover a total of 148 million hectares (2010) in 29 countries across the world. This near doubling of growth makes GM the fastest crop technology to be adopted in the history of modern agriculture (Adenle, 2011). The largest producers in the developing world are Argentina, Brazil, China and India with Bt cotton dominating GM crop acreage in the Asian and African countries, and herbicide resistant soybean followed by insect resistant corn leading in the countries of Latin America (FAO, 2012).

Despite the growing unease with regard to the environmental impacts of GM crops and the intense debate on the unequal socio-economic benefits of this technology, which are likely to further accentuate the gaps between large and small farmers, as recently as 2010, the European Commission approved *Amflora*, a genetically modified potato for industrial use in paper making and adhesives in the European Union. The EC known for its strong resistance to GM crops also permits the import, but not the cultivation of GM maize for food and feed use (GM Education, 2014).

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Do GM Crops Benefit the Small Farmer?

The main argument put forward by opponents of GM crops is that the technology was developed for large scale monocultures quite unsuited to developing countries where agriculture is dominated by small and marginal landholders. The pro-GM camp quotes significant increases in productivity, reduced pesticide costs and impressive growth of farm incomes in both developed and developing countries (Brookes and Barfoot, 2013; Bennett et al. 2004; Adenle, 2011; Morse, Bennet and Ismael, 2013; and Juma, 2014). The opponents, on the other hand, cite falling yields following the initial spurt, the emergence of new pests resistant to even the GM crops and rising costs of inputs for these crops making them unsustainable for the smallholder (Amir, 2014; Kuyek, 2002; Pschorn-Strauss, 2005; Witt, Patel and Schnurr, 2006; and Belay and Guri, 2013). This section aims to adopt an objective approach to the issue by basing its conclusions on available data, rather than rhetoric.

While it is difficult to obtain data on differential impacts of GM crops on large and small farmers, it is possible to compare variations in farm income from GM crops between developed and developing countries. Assuming that over two-thirds of farmers in developing countries have small holdings, this could provide a rough estimate of the extent to which small farmers can benefit from adopting GM technologies. Currently about 52% of the global area under GM crops lies in the developing countries of Asia, Africa and Latin America.

Comparing the economic benefits of GM crops to farmers in developed and developing countries in 2011 (Table 1), it is evident that a little over half (51.2%) of farm income benefits were earned by farmers in developing countries. The largest share of these income gains has been from GM IR (Insect Resistant) cotton and HT (Herbicide Tolerant) soybeans. In the fifteen year period since the introduction of GM crops (1996–2011), the cumulative farm income gain in developing countries was 50.5% of the global figure or USD $49.63 billion (Table 1).

In terms of costs incurred for accessing GM technology, farmers in developing countries incur a lower cost than their counterparts in developed countries (Table 2). For developing country farmers the total cost was equal to 14% of total technology gains as compared to 28% for farmers in developed countries. This difference perhaps reflects factors such as weaker provision and enforcement of intellectual property

Table 1. GM crop farm benefits 2011: developing vs. developed countries (million USD)

Crop	Developed Countries	Developing Countries
GM HT soybeans	1,794.2	2,085.0
GM IR maize	5,710.4	1,394.5
GM HT maize	897.1	643.1
GM IR cotton	650.7	5,908.9
GM HT cotton	80.7	86.2
GM HT canola	433.2	0
GM virus resistant papaya and squash and GM HT sugar beet	83.3	0
Total	9649.6	10,117.7

(Brookes and Barfoot, 2013)

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rights in developing countries and the higher average level of farm income gain on a per hectare basis derived by developing country farmers relative to developed country farmers (ISAAA, 2010).

Supporting these findings, the authors (Finger et al. 2011) of a meta-analytical study of 721 single study entries for GM crops derived from a review of 203 publications based on field trials and surveys, discuss the economic benefits of GM crops and conclude:

The results presented here do support the contention that the adoption of GM crops leads on average to a higher economic performance, i.e., benefits, for farmers than conventional (non-GM) crops. This is in agreement with other studies that analyze economic performance of GM crops and is also underlined by the high (and increasing) adoption rates for GM crops in a number of countries. An important finding of the analysis is that the kind and magnitude of benefits are heterogeneous across crops, traits, countries and regions. By and large, the results suggest that the adoption of Bt cotton is particularly (economically) beneficial for the farmers in developing countries while positive effects are present but less significant for developed countries.

COUNTRY EXPERIENCES

Analysing country specific experiences with important GM crops, makes it possible to compare yields, insecticide use and net incomes between farmers adopting GM crops and those cultivating traditional varieties. In India, for example cotton is a major crop accounting for 30% of the country's agricultural GDP. However, prior to the introduction of GM cotton, the country's average cotton yield was 48% lower than the world average with farmers losing 50–60% of their crop to the cotton bollworm (ISAAA,

Table 2. Cost of accessing GM technology (million $) relative to the total farm income benefits 2011

Crops	Cost of technology: all farmers	Farm income gain: all farmer	Total benefit of technology to farmers and seed supply chain	Cost of technology: developing countries	Farm income gain: developing countries	Total benefit of technology to farmers and seed supply chain: developing countries
GM HT soybeans	1,647.6	3,879.2	3,879.2	5,526.8	606.4	2,691.4
GM IR maize	1,686.6	1,540.2	1,540.2	3,226.8	433.3	1,827.8
GM HT maize	789.6	166.9	166.9	956.5	93.9	737.0
GM IR cotton	758.5	433.2	433.2	1,191.7	536.9	6,445.8
GM HT cotton	313.1	7,104.9	7,104.9	7,418.0	40.5	126.7
GM HT canola	140.2	6,559.6	6,559.6	6,699.8	N/a	0
Others	71.1	83.3	83.3	154.4	N/a	0
Total	5,406.7	19,767.3	19,767.3	25,174	1,711.0	11,828.7

(Source: Brookes and Barfoot, 2013)

N/a = not applicable. Cost of accessing technology based on the seed premia paid by farmers for using GM technology relative to its conventional equivalents

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2012). Bt cotton was introduced in 2002 with 3 hybrids in six states - Andhra Pradesh, Gujarat, Madhya Pradesh, Karnataka, Maharashtra and Tamil Nadu. By 2012, India became the world's largest producer of biotech cotton covering 10.8 million hectares compared to the next largest producer the USA with 4.4 million hectares. The country now has 1097 Bt cotton hybrids approved for planting.

Field studies (Bennet et al. 2004) in the cotton producing state of Maharashtra in India (2002–2003) revealed that:

- Bt cotton yield increased by 45% in 2002, and by 63% in 2003 compared to non-Bt cotton varieties
- Higher revenues were attained by Bt cotton farmers compared to those who planted conventional cotton. The average income difference for 2002 and 2003 were 43% and 63%, respectively.
- The average gross margin (difference of the revenue and variable costs which include seed and insecticide costs) is much higher for Bt growers compared to growers of non-Bt varieties.
- Less insecticide input against cotton bollworms resulted in an average reduction in expenditure per hectare of 72% and 83% in 2002 and 2003, respectively. Savings in spraying were around Rs 2,471 or $54 per hectare on average (at an exchange rate of 1 US Dollar = 46 Indian Rupee[1])

Table 3 compares cotton yields and revenues for farmers adopting Bt cotton and those planting non-Bt cotton.

Table 4 compares the number and cost of insecticide sprays between adopters and non-adopters.

In addition to farm level benefits, the adoption of GM varieties appears to have had a direct impact on household food security. A comparison of households growing GM cotton in India with those that did not do so found that those adopting GM varieties consumed significantly more calories. Juma (2014) stated that: "Each hectare of GM cotton increased total calorie consumption by 74 kcal per adult equivalent per day. Furthermore, a smaller proportion of households were food insecure (7.93% of adopting GM

Table 3. Cotton yields and revenues

Year	Cotton yield (tons/ha)		Revenue from cotton yield (rupees/ha)		Gross margin (rupees/ha)	
	Adopters	Non-Adopters	Adopters	Non-Adopters	Adopters	Non-Adopters
2002	2.18***	1.50	44,600***	31,078	38,796***	26,005
2003	2.25***	1.38	56,357***	34,597	50,904***	29,279

*** $P < 0.001$
(Bennett et al. 2004)

Table 4. Number and cost of insecticide sprays against cotton bollworms

Year	Number of bollworm pest sprays per plot		Revenue from cotton yield (rupees/ha)	
	Adopters	Non-Adopters	Adopters	Non-Adopters
2002	1.44***	3.84	692***	2,432
2003	0.71***	3.11	482***	2,881

** $P < 0.01$; *** $P < 0.001$
(Bennett et al. 2004)

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cotton households compared to 19.94% of non-adopting households" The study also showed that GM cotton adoption led to consumption of more nutritious foods – such as fruits, vegetables and animal products. The authors estimate that if the households that do not currently grow GM cotton switched, "the proportion of food insecure households would drop by 15-20%".

Experiences of small farmers from China, South Africa, the Philippines and other developing countries using GM crops clearly show that small farmers can also benefit from the technology. The most consistent observation from these countries is that growing GM crops is a profitable farming endeavour.

A case similar to Bt cotton in India is that of Bt corn in the Philippines, where the Asiatic corn borer caused losses of up to 80% of production, and corn yield levels averaged only 2.8 tons per hectare. The commercial release of Bt corn in 2003 in the Philippines marked the first time that a GM food/feed crop was ever approved for planting in Asia. The initial area under Bt corn covered more than 10,000 hectares. By 2005, it had expanded to 52,000 hectares. Adoption of Bt corn in the Philippines provided small farmers with a 37% increase in yield, reduction in pesticide costs by as much as 60% and an incremental income of up to PhP 10 or USD $0.21, 132 per ha (Yorobe and Quicoy, 2006).

Table 5 compares economic differentials between Bt and non-Bt corn producers in the Philippines

In China, insect-resistant GM rice was approved for food, feed, and cultivation in 2009. Surveys of randomly selected farm households showed that small and poor farm households adopting GM insect-resistant rice obtained yields 6 to 9% higher than conventional varieties and reduced pesticide use by as much as 80% or 16.77 kg/ha, which also had positive health benefits (Huang et al. 2005). The same authors also claim an average reduction in pesticide sprayings for the Asian boll worm from 20 to 6 times per year with the introduction of Bt cotton in China and a fall in cost of production of a kilogram of cotton by 28% as compared the farmers growing non-Bt varieties (Huang, Pray and Rozelle 2002).

In Burkina Faso, almost 100,000 farmers cultivated GM cotton on 260,000 hectares in 2010 with 126 percent increase from 115,000 hectares planted in 2009. In terms of contribution to the economy of Burkina Faso, Adenle (2011) states that:

It was estimated that a benefit of over US$100 million per year could be generated based on almost 30% increase in yield. Additionally, close to a 50% reduction in insecticide sprays may be realised, thereby saving fossil fuels and lowering greenhouse gases emission, hence fighting against climate change.

Table 5. Economic indicators: Bt and non-Bt corn farms in the Philippines

Item	Wet Season 2003			Dry Season 2004		
	Bt	Non-Bt	% Diff	Bt	Non-Bt	% Diff
Yield (ton/ha)	4.30	3.31	30.0	4.89	3.79	29.0
Pesticide cost (PhP/ha)	121	159	-23.8	178	410	-56.5
Price received (PhP/kg)	7.20	6.75	6.5	8.95	8.30	8.0
Net cash income (PhP/ha)	8,552	6,249	36.8	23,341	15,489	50.6

(Yorobe and Quicoy 2006)

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South Africa, the first and biggest producer of GM crops in Africa, has benefitted substantially from growing GM crops over the past decade. It is the only African country among the five principal countries (others include: India, Argentina, Brazil and China) producing GM crops, with 63 million hectares planted in 2010 alone. The economy of South Africa has benefited a great deal from the adoption of GM technology and it has been reported to have enhanced farm income from GM maize, GM soybean and GM cotton by USD $156 million in the period 1998 to 2006, with farm income in 2006 alone estimated to be USD $67 million (James, 2008).

The best known and most often cited case is, however, the success story of small farmers growing Bt cotton in the Mahkhatini flats of South Africa, which soon became a showpiece for Monsanto and paved the way for the widespread cultivation of Bt cotton in the country. The Mahkhatini Flats are the floodplains bordering the Pongola river stretching from just below the Jozini Dam to the confluence of the Pongola and Usuthu Rivers on the Mozambique border covering some13000 hectares to the east of the Umbobo mountains. The region is extremely poor with the majority of the farmers growing mixed crops on small holdings of 2.5–5 hectares; many farms are smaller than 1 hectare. Low incomes and falling employment levels characterised the economy prior to the introduction of Bt cotton.

As a departure from assessing farm level impacts, a study of Bt cotton growers was conducted over the seasons 2003–04 and 2004–05 to assess socio-economic impacts on the livelihoods of the farmers (Morse, Bennet, & Ismael, 2013). Questionnaire based interviews of 100 cotton growers revealed that 88% of the respondents reported higher income from Bt cotton as against conventional seeds and almost 90% increased their asset base, particularly in terms of cultivable land. In addition, some 88% reported a reduction in insecticide related health problems and labour with more time to spend with their families or on other farm activities as spraying was not required.

The study also sought to assess differential impacts on male and female farmers. Gender differentials in benefits from GM crops is particularly relevant in the African context as the region has one of the highest ratios of women to men farmers in the world- almost 50%. The analysis revealed that a larger number of female farmers perceive the beneficial impacts of GM crops in terms of increased income and reduced need to access credit.

A comparison of costs and benefits of GM cultivation for three groups of farmers- those with marginal holdings below 2 hectares, those with small holdings: farm size between 2–3.5 hectares, and larger farmers with holdings above 3.5 hectares reveals that there are no major differences between the three size classes. In fact, farmers with medium sized holdings appear to have the lowest costs and the best yields and revenues, though farmers with over 3.6 hectares have the highest profit margins (Table 6).

The authors conclude that overall the adoption of Bt cotton in Makhathini has not only increased incomes for resource-poor farmers but has also had a positive impact on the livelihoods of these farmers and their households.

On the other hand, the anti-GM group cites data on yields sourced from the South African Cotton Trade industry covering the pre-GM cotton cultivation period (1997 to 2005) when almost 100% of the farmers cultivated GM varieties (Witt, Patel & Schnurr, 2006). This data shows a substantive increase in cultivated area, but little improvement in cotton yields (Table 7). Un-irrigated crops stand more or less at the pre-GM cotton yield of 600 kg seed cotton per hectare as the authors point out, but yields on irrigated lands, though highly erratic do appear to have increased.

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Table 6. Farm size differences in the economics of Bt cotton production

	Cotton	2003/2004					2004/2005				
	area	N	Mean	SD	F	Sig.	N	Mean	SD	F	Sig.
Yield (kg/ha)	<2ha	49	1024	290			47	1009	311		
	2–3.5ha	17	1058	153	0.116	ns	25	1140	257	1.811	ns
	>3.5	24	1023	259			24	1075	237		
Revenue (SAR/ha)	<2ha	49	5104	1475			47	5057	1628		
	2–3.5ha	17	5271	960	0.120	ns	25	5767	1351	1.914	ns
	>3.5	24	5068	1428			24	5334	1222		
Total Cost (SAR/ha)	<2ha	49	2759	781			47	2790	976		
	2–3.5ha	17	2922	869	0.791	ns	25	3118	621	1.478	ns
	>3.5	24	3008	893			24	3064	858		
Gross Margin (SAR/ha)	<2ha	49	2345	1159			47	2268	1093		
	2–3.5ha	17	2349	1002	0.538	ns	25	2648	1167	0.962	ns
	>3.5	24	2061	1241			24	2270	1338		

(Morse, Bennet, and Ismael 2013)

Table 7. Cotton production data in KwaZulu-Natal Estimates

Year	Area planted under irrigation (Ha)	Area planted under dryland (Ha)	Yield of cotton planted on irrigated and (Kg seed cotton per Ha)	Yield of cotton planted on dry land (Kg seed cotton per Ha)	Production (200 kg bales cotton lint)	Crop % hand-picked	Crop % ginned
1997–98	1444	6459	2100	600	1130	90	95
1998–99	1502	6785	1800	640	12683	100	80
1999–00	1155	5926	1400	420	7493	100	99
2000–01	528	3587	3000	1150	10419	100	95
2002–03	1403	321	2135	300	5500	91	98
2003–04*	2276	2537	3310	659	14715	58	
2004–05	1173	2242	2860	600	8695	65	

*Estimates
(Cotton SA cited in Witt, Patel and Schnurr, 2006)

The authors suggest that the large scale adoption of Bt cotton is more the result of a structured institutional framework which allows adopters access to seed, credit and support, than any increase in yields. They emphasize that technical interventions like Bt cotton are not inserted into a vacuum, but have to be assessed in the existing ecological, political and economic contexts. Yet on the balance they do find grounds for cautious optimism in the Makhatini area.

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The African Experience

GM Crops in Africa: Current Status

The Green Revolution brought about the transformation of agriculture in Asia and Latin America from the late sixties onwards. India in the sixties for instance, was a country with 70% of its population of almost one1 billion living in rural areas and wholly dependent on agriculture for their livelihoods. The huge demand for food had to be met by low yielding traditional food crops and almost complete dependence on rainfed agriculture, the people hovering perpetually on the verge of hunger with food imports, the only insurance against famine. The almost miraculous transformation within a period of barely two decades into a country with massive food surpluses and now a leading exporter of food grain was brought about only through political commitment to ensuring food security and the courage to embark on an unfamiliar path to agricultural development. Admittedly, the negative impacts of green revolution techniques of mono-cropping, excessive use of water, fertilizer and pesticides are beginning to emerge in some areas. There is also evidence that this technological breakthrough benefitted more the large farmers, than their counterparts with small and marginal holdings. Yet the country overall experienced an amazing breakthrough in food production and the fear of hunger is consigned to the past.

The Green Revolution unfortunately bypassed the countries of Africa, perhaps because of unfavourable physical or socio economic conditions or lack of political commitment. There is once again an opportunity for agricultural transformation opening up with the Gene Revolution; can Africa afford to lose this opportunity too?

While in the countries adopting green revolution technology, agricultural growth outpaced population growth from the seventies onwards, in Africa, per capita agricultural output was almost 20% lower in 2005 than in 1970 (Cooke and Downie, 2010). Additionally, with over 70% of the African population engaged in agriculture, Africa still imports a quarter of its food (Paarlberg, 2010).

African interest in biotechnology is reflected in the fact that with the exception of Somalia, all countries in Sub Saharan Africa are signatories to the Convention on Biological Diversity which expressly recognizes the potential of modern biotechnology in the promotion of human well being, particularly in helping meet critical needs for food, agriculture and health care (SCBD, 1992) in addition to ensuring the development of appropriate safety procedures which minimize potential threats to biological diversity and risks to human health. Yet only three countries in the continent — South Africa, Egypt and Burkina Faso have adopted GM technology with the production of food crops being limited to Egypt and South Africa. Egypt was the first North African country to grow GM crops commercially in 2008 with 700 hectares of GM maize planted and the Egyptian government planning to increase the hectarage of GM crops in future (James, 2008).

As far as significant production of GM crops goes, South Africa stands alone. The diversity of environment and socio-economic conditions in Africa is reflected in the varying country responses. The oft cited landmark anti-GM stance of Zambia is contained in the response of President Levy Mwanawasa to the offer of milled GM grains from the US during the food crisis of 2002: "Simply because my people are hungry, that is no justification to give them poison". Three other countries –Zimbabwe, Malawi and Mozambique supported this stance refusing "contaminated food", but eventually accepted food assistance in the form of milled grains. Zambia, however, continued in its refusal and eventually obtained reprieve by the supply of certified non-GM grain from Europe.

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The early acceptance and successful progress of GM crops in South Africa and Egypt can be traced to the well-established and adequately funded scientific organisations in both countries. Bt cotton, the largest GM crop in South Africa was approved for commercial release as early as 1997. South Africa is now the eighth-largest producer of biotech crops in the world, growing 2.3 million hectares of genetically modified maize, cotton, and soya in 2011 (ISAAA, 2012). Although GM technology has been in use in South Africa for nearly 17 years and is well accepted in medical applications, its use in agriculture is still a subject of intense debate. While the technology receives strong support from the scientific community, commercial farmers and the government, NGO opposition continues. However, as Cooke and Downie (2010) stated:

In many ways, the debate in South Africa reflects the reality that GMOs are a fact of life and have been for some time. Although opponents continue to question the safety of genetically modified crops and advocate the adoption of the precautionary principle, which argues for a 'when in doubt, don't' approach to GM food, most of them understand such crops are here to stay. Therefore, their efforts center on tightening the regulatory system and preventing the entry of new GMO products into the South African market.

Cooke and Downie (2010) also discuss the rejection of the USAID funded *SpuntaG2* application for a potato modified with a gene to protect against the potato tuber moth, a project given up by Egypt after eight years of field trials and one which would have made South Africa the world's first producer of GM potatoes. They emphasize the fact that the proposal was rejected on economic rather than safety grounds. The fear of losing the two main markets for potatoes and potato seed - Angola and Zambia, the first with no bio-safety laws in place and the second known for its strong anti- GM stance re-emphasizing the importance of trade as a controlling factor.

In the case of Egypt, the realisation of the country's inability to meet its growing demand for food led to an early endorsement of GM technology. Genetic engineering programmes started in 1990. The country has in place a full framework for biotechnology consisting of the Agricultural Research Center, the National Research Center, the Academy of Scientific Research and Technology, the Water Research Center, the Desert Research Center and the Universities and has been intensively researching a variety of GM food crops although none of them have reached the market (Abdallah, 2010). The Agricultural Research Center (ARC) was established as a part of the Ministry of Agriculture in 1983 and brings together 16 research institutes. The crops cover a wide range of foods including staples like salt and drought tolerant wheat, rice with improved protein content and rice varieties resistant to rice blight and stem borers, biotech maize saves on pesticide usage, gives almost 100% protection from stem borers and increases yield by 30–40% over the conventional maize varieties. In 2008, the first approved GM crop, AgeebYG a yellow hybrid maize resistant to three maize borers was launched. A range of vegetables including virus resistant melon, squash and tomatoes are awaiting approval for commercialisation (Abdallah, 2010).

Burkina Faso, the third African country with a significant production of GM crops has a very different history. One among the "Cotton 4" (C4) countries of West Africa (the other three being Mali, Chad and Benin) the country grows and exports a fine variety of cotton. Crop intensification boosted cotton yields from an average of 200 kg per ha in 1963 to a peak of 1400 kg per ha in the mid-eighties. As Vitale et al. (2008) write "Cotton quickly became the region's "white gold", one of the leading sources of export earnings and a major source of employment in rural areas where livelihoods center about cotton, accounting for 60% of household income." In Burkina Faso, over 2.2 million people derive their livelihoods from the cotton industry, with public services like schools, healthcare, roads and agricultural

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extension being funded through cotton revenues (Vitale et al. 2008). However, the peak yields of the 80s began to decline and the search for a quick solution which would improve productivity in the short term, rather than the long term horizons of pest eradication programmes led to Bt cotton. Burkina Faso's national cotton company, Société Burkinabé des Fibres Textiles (SOFITEX), began a partnership with Monsanto in 2001 to introduce Bt cotton on a commercial basis. Since then the country has emerged as the most progressive in the West African region with reference to biotechnology. After the initial seven year period of field testing, monitoring, and development of bio-safety protocols, Burkina Faso commercially released Bt cotton in 2008. Expansion has been fast paced from an initial 12,000 ha in 2008 to slightly over 125,000 ha in 2009. In 2010, an estimated 400,000 ha of Bt cotton was planted in the country (Vitale et al. 2010).

Expansion of GM Cultivation

While the major GM crop producing countries in Africa have been discussed above, this does not imply that other countries are totally disassociated with bio-technology. Laboratory tests and field trials of a variety of GM crops, both food and non-food are in process across Africa (Tables 8 and 9).

Tables 9 and 10 provide ample evidence that despite opposition and misgivings among certain groups, Africa is well on the way to accepting bio-technology as an option to resolving hunger and malnutrition, particularly in the context of deteriorating environmental conditions.

DISCUSSION AND EXPERIENCES

Are GM Crops a Feasible Option in Africa?

We have discussed the status of GM crops in Africa and have also assessed whether transgenic crops benefit the small farmer in developing countries. There appears to be substantive evidence that gene technology does improve the livelihoods of small farmers as well as of those with large holdings. Apart from benefits at the farm level, visible improvements have been documented in household asset base

Table 8. Status of genetically modified (GM) crops in Africa

Application Stage	No. of Countries	Country Names
Commercial production	3	Burkina Faso; Egypt; South Africa
Confined field testing	7	Burkina Faso; Egypt; Kenya; South Africa; Uganda; Nigeria; Malawi
Contained research	At least 15	Burkina Faso; Cameroon; Egypt; Ghana; Kenya; Mali; Mauritius; Namibia; Nigeria; South Africa; Tanzania; Tunisia; Uganda; Zimbabwe; Malawi
Developing capacity for research and development	At least 27	South Africa; Burkina Faso; Egypt; Kenya; Morocco; Senegal; Tanzania; Uganda; Zambia; Zimbabwe; Benin; Cameroon; Ghana; Malawi; Mali; Mauritius; Namibia; Niger; Nigeria; Tunisia; Algeria; Botswana; Ethiopia; Madagascar; Rwanda, Burundi, Sudan

Modified from absafrica.org (NEPAD, 2010)

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Table 9. Range of GM crops being developed in Africa

Country	Crop
Kenya	Maize and cotton (insect resistant), cassava, sweet potato (virus resistant)
Uganda	Cotton (insect resistant and herbicide tolerant), banana (nutrient enhanced, fungal resistant), cassava (viral resistant), sweet potato (weevil resistant)
Nigeria	Cassava (nutrient enhanced)
Malawi	Cotton (insect resistant)
Nigeria, Burkina Faso, Ghana	Cow pea (insect resistant)
Kenya, Mozambique, Tanzania, South Africa, Uganda	Maize (drought tolerant)
Burkina Faso, Kenya, South Africa	Sorghum (nutrient enhanced)
South Africa	Maize (herbicide tolerant, insect resistant, virus resistant), Cassava (starch enhanced), Cotton (insect resistant, herbicide tolerant), Potato (insect resistant), sugarcane (alternative sugar)
Egypt	Maize (insect resistant), Cotton (salt tolerant, Wheat (drought tolerant, salt tolerant, fungal resistant), Potato, Banana, Cucumber, Melon, Squash, Tomato (all viral resistant)

(NEPAD, 2010)

and food security in developing countries, where GM crops have been cultivated over a number of seasons. It must be emphasised here that these positive impacts do not deny the emergence of setbacks in the form of lower than expected yields, higher input costs or unintended environmental impacts, which have also been witnessed in some areas and must be given due weight in the decision making process. As Finger et al. (2011) emphasized:

GM crops are designed with particular aims in mind such as insect and herbicide resistance, not with a view to increasing yields, except indirectly through the curtailing of losses. Thus other constraints like infertile soils or drought can only be addressed by varieties designed specifically to overcome these problems. In addition there are always socio-economic problems which GM crops cannot address. Hence, considering GM crops as a panacea for poverty and hunger is groundless.

South Africa and Burkina Faso, the only countries in the African continent where GM crops have been cultivated for over a decade have both registered success on all counts equal to their Asian and Latin American counterparts; yet the opponents of GM crops not only oppose their expansion in the African region on the basis of un-established but nevertheless very real fears of biotechnology, but cite as their explanation the contention that agriculture in Africa being distinct from agriculture in other developing regions is unsuitable for the introduction of advanced technology. In evidence, they emphasize the failure of the Green Revolution in the African context and predict a similar scenario in the case of the Gene Revolution.

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Some Constraints to Agriculture

This section will inquire into the constraints that agriculture faces in Africa, why chronic food shortages persist despite abundant natural resources, the reasons behind the failure of the Green Revolution and whether the failure of one technological opportunity necessarily precludes the success of the next.

Africa is known for its diverse agro-ecological regions, abundance of water resources, though unevenly distributed, and almost unlimited land area which could be brought under cultivation — conditions which would be the envy of any agricultural country. Yet, agricultural growth has been slow and has even retrogressed leaving the region perennially short of food, open to droughts, erratic rainfall, attacks by insects and other pests, with survival being assured only by food imports or food assistance during emergencies. Over the past two decades an average of 32 countries in sub-Saharan Africa received emergency food aid each year. The numbers ranged from 22 countries in 1990 to 38 in 2009 (UNDP, 2012).

The issue is further compounded by trade barriers and poor transport systems, which leave food security, particularly in rural areas completely dependent on local production of food staples. It has been stated that "if the food available in sub-Saharan Africa were evenly distributed, all Africans could consume enough calories for their basic functioning" (UNDP, 2012). In fact 75% of the cereals and almost all the roots and tubers, the basic food crops, are grown locally.

In a bid to jump start the development process after gaining independence in the sixties, most African countries focussed on urbanization and industrialisation with the expectation of a trickledown effect to take care of the rest of the economy. The consequent neglect of the agricultural sector and the emerging policy bias, heavy taxation and government control of agriculture over the next two decades are some of the reasons for the stagnation in Africa's food production. At a time, when the developing countries of Asia set upon a trajectory to achieve self-sufficiency in food and free themselves from dependence on food imports, Africa was set on a contradictory mission. In this perhaps, lie the reasons behind the apparent failure of the Green Revolution in the region. With no political backing or supportive measures, technological revolutions are unlikely to succeed in any country and even less so in an agricultural economy characterised by small farmers.

The results of the post-independence policy framework were overvalued exchange rates supporting imports for domestic urban consumers and making agricultural exports less competitive in international markets (Binswanger and Deininger, 1997). Heavy direct and indirect taxes were also levied on agricultural activities. In effect:

these biased policies increased the combined effective tax rate on agriculture (from industrial protection, direct taxation and exchange rate policies) from 5% in the late 1950s to close to 25% in the late 1970s (UNDP, 2012).

Although most staples were unaffected by taxation or support, the food markets came under heavy control. The net outcome was to turn relative prices against farmers.

With the entry of structural adjustment policies, the bias against agriculture was lifted, but the UNDP (2012) states that:

The state retrenchment of the 1980s–1990s disabled the sector as an early driver of growth and retarded the kind of structural transformation needed to increase food security and reduce poverty. Rising population growth compounded the setback, as the need for food outpaced the continent's capacity to produce.

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Although there has been a substantial reduction in agricultural tariffs, trade barriers still persist in sub-Saharan Africa slowing the growth of intra-regional trade in food, particularly staples. The 'border effect' or the additional costs of crossing the border between two countries is substantial, and is exacerbated by the price differentials between producing and consuming zones. For example, Brenton, Portugal-Perez and Regolo (2013) find that the effect on relative prices of crossing the Niger–Nigeria border is equivalent to adding an additional 594 km to the distance to markets.

Promoting inter-regional trade in food staples and reducing the costs of bringing food to the market could effectively reduce chronic food insecurity as well as vulnerability to risks. Engel, Jouanjean and Awal (2013) emphasize the importance of facilitating food trade and a more coherent trade policy in the arid and semi arid regions of the Sahel and the Horn of Africa, where the frequency of food shortages is making the population particularly vulnerable.

However, some positive developments are beginning to emerge:

Up until early 2000, the agriculture sector in Sub-Saharan Africa went through policy and budgetary neglect that led to growth stagnation but this has now changed: agricultural GDP in Sub-Saharan Africa as a whole grew by more than 3.5% in 2008, surpassing the population growth rate, and grain production growth rates have been kept above 3% (Ackello-Ogutu, Okoruwa, & Bahal, 2012).

Contrasting Experiences With Agricultural Technology in Africa and Asia

While both Africa and Asia faced severe food shortages and the recurring threat of hunger and starvation in the early sixties, development policies in the two regions, as mentioned above, were sharply divergent. Asian governments prioritised food security from the mid-1960s onwards by supporting the agricultural sector to adopt high yielding varieties of food staples known to be highly responsive to fertilizer, water and other inputs. Cereal production increased by 3.4 times during the period 1961– 2010, and per capita availability of cereals also rose sharply by as much as 44%. In Africa, on the other hand, development focussed on industry and export-based cash crops with the expected adverse impacts on food production and the livelihoods of small farmers. Although cereal production in sub-Saharan Africa has tripled over the same period, population growth has outpaced production with the result that per capita output has actually fallen by 13% (UNDP, 2012).

The basic difference between increased cereal production in Asia and Africa is that Asia owes about 44% of its increased production to higher yields, while in the case of Africa, the increase comes in area under cereals, and the exclusive contribution of higher yields is just about one-third of the increase in production. However, this must not be considered a negative factor. It only serves to underline the fact that there is much scope for improving yields in Africa, if the opportunity offered by currently available technologies is grasped. According to the UNDP African Human Development Report (2012):

African farming thus contrasts with the Asian norm of cultivating mainstream staples and cash crops, fertilized and often irrigated, unmixed in a single field on fully settled farms under individual tenure. In sub-Saharan Africa, reliance on many crops and traditional farming practices has resulted in less research and extension (per unit of output and per hectare) than in Asia. More fundamentally, sub-Saharan Africa has not benefited from the farm science–based, input-responsive boost in agricultural productivity that occurred in Asia.

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Farming in Africa is characterised by smallholders typically growing a variety of crops, sometimes as many as ten including staples for the home and cash crops for sale. Cultivation is predominantly rain-fed and practised on weathered soils with low fertility and little mechanisation. Low population densities result in poor road network and restricted access to markets. The relative isolation of the African farmer also adversely impacts his access to modern inputs or extension services. "Only 30% of the rural population in sub-Saharan Africa lives within 2 km of an all season road in sharp contrast to South Asia's 58%" (Roberts, Shyam, & Rastogi, 2006).

Across the region (Sub Saharan Africa) just a little over 200 million hectares are cultivated, leaving four-fifths unused. "Excluding protected areas, land covered by forests and regions already settled, and limiting the definition of suitability to five crops, the balance of suitable unused agricultural land is about 200 million hectares, which, if brought into production, would double the amount of cultivated land in sub-Saharan Africa" (Berg and Ostry, 2011). Thus viewed from a different perspective, what appear to be Africa's disadvantages in agriculture, may well prove to be opportunities in the making in the form of unused and underused arable land and unused potential to boost agricultural productivity (UNDP, 2012).

While Africa's agro-ecological zones are more diverse than Asia's, this does not necessarily suggest an impediment to the introduction of improved technologies. The solution would lie in local- specific interventions tailored to meet specific needs and address problems specific to the region. Examples include among others, the development of drought-tolerant varieties of millet and sorghum for farmers in the Sahel and the Horn of Africa (Hunt and Lipton, 2011), GM bananas in Uganda and Bt black-eyed peas in Nigeria (Juma, 2014). Juma and Gordon (2014), while strongly endorsing the technological revolution in Africa, even go so far as to say:

Biotechnology is only a starting point. The introduction of Bt cotton, for example, requires system-wide investments along the entire cotton value chain. This means that the adoption of biotechnology can serve as a trigger for investing in R&D, rural infrastructure, technical training and entrepreneurship (and leapfrog agricultural development in the country.

As aptly summarised in the first African Human Development Report, (UNDP, 2012):

No lack of knowledge, ideas or vision stands between sub-Saharan Africa and this brighter future. And certainly no failure to commit to a new agricultural revolution, as evidenced in African leaders' affirmation of their commitment to agriculture in the Maputo Declaration and the Comprehensive Africa Agriculture Development Programme. But realizing the vision will require policies to increase yields up to the frontier of current science, through faster and wider adoption of better technology, and then policies to expand that frontier so that agricultural yields continue to rise. With rapid growth in agricultural productivity, anchored in rising yields of staple crops, sub-Saharan Africa can reduce mass poverty and ensure food security for most of its people.

CONCLUSION

On all issues discussed above, the evidence is in favour of GM crops, yet most African countries are reluctant to adopt GM technology. A major factor may be financial constraints. As Miller (2007) writes:

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The high level of investment needed in GM research and its application has constrained African participation and has led to research that primarily focuses on developed country needs. Transgenic research is very expensive when compared to more traditional biotechnology techniques. For example, the IRMA project is estimated to have cost USD $6 million over 5 years and the transgenic sweet potato research USD $2 million, compared to the average funding of tissue culture and marker technology projects costing on average USD $300,000.

The lack of in-country research has prevented the dissemination of authentic information about GM crops, which would be readily acceptable to the local population. The reluctance to accept information from International Agencies, which are perceived as having their own agenda has created a climate conducive to anti-GM activists. Adenle (2011) writes:

Africa's relatively slow embrace of the "gene revolution", particularly GM technology, has, in part, stemmed from lack of access to GM crops available to beneficiaries such as farmers and scientists. This is partly due to international influence against GMOs.

The communication gap further fuels fears of being held to ransom by seed producing multinational companies, as the terminator gene precludes the traditional practices of seed saving and exchange. Juma (2014) however, adds a rider stating that:

The problem is not simply the presence of large corporations but the low level of the development of domestic seed firms. Such local firms can help focus on indigenous crops. They can also play key roles as business partners with foreign farms.

He further adds that new research shows that in Africa, local start-ups with local scientists are at the forefront of bio-technology research, not multi-nationals.

Yet another fear is that of losing the largest market for agricultural produce- the European Union, which is known to have stringent laws against the import of GM crops. This has led to the adoption of a Go Slow approach by the governments of many African countries (Adenle, 2011). A recent IFPRI (2013) research study concludes:

This European model does not correspond to African needs and realities, however. GM crops can aid farmers by reducing both losses from pests and the costs of weeding. For European countries, in which only a tiny percentage of the population grows crops such as maize, cotton, and soybeans, these advantages are negligible. In Africa, though, where 60% or more of the population depends directly on agriculture for income and subsistence, far more people could benefit directly from biotechnology that includes agricultural GMOs. ....Rather than imitate other regions' regulatory systems, African countries south of the Sahara need to consider and develop their own regulations for biotechnology development that balance risk avoidance (and the accompanying regulation costs) against such technology's net benefits for farmers.

A reasonable conclusion also, is that the fear of short term export losses is also unfounded as the major export crops from Africa are tea, coffee, vegetables and flowers, not staples, which are more likely to be genetically modified.

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It must be conceded that these fears are not totally unfounded, but they do not pose insurmountable obstacles to the adoption of this new technology. As Adenle (2011) writes:

Given both the lack of global consensus on GMOs and the growing need to regulate GMO products, the US may offer a good example for Africa and the rest of the world. It is one of the few developed countries to grow GM crops on a commercial basis (more than 70% of foods in the US contain GMOs) and is a leader in the safe application of GMO product.

It appears then, that Africa's path to enhanced food security through the adoption of GM technology is a viable one, given adequate political backing and wholehearted commitment to meeting the needs of the African people.

REFERENCES

Abdallah, N. (2010). GM crops in Africa: challenges in Egypt. *GM Crops*, *1*(3), 116–119. Retrieved 29 May 2014 from, http://www.tandfonline.com/doi/pdf/10.4161/gmcr.1.3.12811

Ackello-Ogutu, C., Okoruwa, V., & Bahal, G. N. (2012*). Long-term challenges to food security and rural livelihoods in Sub-Saharan Africa*. Briefing Paper Number 2, 2012. Washington DC: GDN Agriculture Policy Series. Retrieved 6 June 2014 from, http://www.gdn.int/admin/uploads/editor/files/SSA_2_PolicyBrief_Food_Security.pdf

Adenle, A. A. (2011). Response to issues on GM agriculture in Africa: are transgenic crops safe? *BMC Research Notes*, *4*, 388. Retrieved 1 June 2014 from, http://unu.edu/publications/articles/are-transgenic-crops-safe-gm-agriculture-in-africa.html

Amir, P. (2014). GM crops-no gain for small farmers. *SciDevNet*. Retrieved 30 May 2014 from, http://m.scidev.net/south-asia/agriculture/opinion/gm-crops-no-gain-for-small-farmers.html

Belay, M., & Guri, B. (2013). Why African farmers do not want GMOs. *Truthout*. Retrieved 29 May 2014 from, http://webcache.googleusercontent.com/search?q=cache:http://www.truth-out.org/news/item/20058-why-african-farmers-do-not-want-gmos

Bennett, R., Ismael, Y., Kambhampati, U., & Morse, S. (2004). Economic impact of genetically modified cotton in India, *Agbioforum, 7*(3), Article 1. Retrieved 2 June 2014 from, http://www.agbioforum.org/v7n3/v7n3a01-morse.htm

Berg, A. G., & Ostry, J. D. (2011). *Inequality and unsustainable growth: two sides of the same coin?* IMF Staff Discussion Note 11/08. Washington, DC: International Monetary Fund. Retrieved 15 July 2014 from, https://www.imf.org/external/pubs/ft/sdn/2011/sdn1108.pdf

Binswanger, H. P., & Deininger, K. (1997). Explaining Agricultural and Agrarian Policies in Developing Countries. *Journal of Economic Literature*, *35*(4), 1958–2005. Retrieved from http://www-wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/1997/05/01/000009265_3971126124251/Rendered/PDF/multi_page.pdf

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Brenton, P., Portugal-Perez, A., & Regolo, J. (2013). *Food prices, road infrastructure, and border effects in central and eastern Africa*. Retrieved 8 July 2014 from, https://editorialexpress.com/cgi-in/conference/download.cgi?db_name=CSAE2013&paper_id=919

Brookes, G., & Barfoot, P. (2013). *GM crops: global socio-economic and environmental impacts 1996-2011*. Dorchester, UK: PG Economics Ltd. Retrieved 10 July 2014 from, http://www.europabio.org/sites/default/files/report/2013globalimpactstudyfinalreport.pdf

Cooke, J. G., & Downie, R. (2010). *African perspectives on genetically modified crops: assessing the debate in Zambia, Kenya and South Africa*. A report of the CSIS global food security project. Washington, DC: Centre for Strategic and International Studies. Retrieved 8 June 2014 from, http://csis.org/files/publication/100701_Cooke_AfricaGMOs_WEB.pdf

Education, G. M. (2014). *A brief history of genetic modification*. Retrieved 19 July 2014 from, http://www.gmeducation.org/faqs/p149248-20brief%20history%20of%20genetic%20modification.html

Engel, J., & Jouanjean, M.-A. (2013). *The history, impact and political economy of barriers to food trade in sub-Saharan Africa: an analytical review*. London: ODI. Retrieved 14 June 2014 from, http://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/8803.pdf

FAO. (2009). *High level expert forum, How to feed the world in 2050: The special challenge for sub Saharan Africa*. Retrieved 12 July 2014 from, http://www.fao.org/fileadmin/templates/wsfs/docs/Issues_papers/HLEF2050_Africa.pdf

FAO. (2012). *Statistical Yearbook, Part 4, Genetically Modified crops.* Rome. Retrieved 29 May 2014 from, http://www.fao.org/docrep/015/i2490e/i2490e04d.pdf

FAO. (2015). The State of Food Insecurity in the World 2015. *Meeting the 2015 International Hunger Targets: taking stock of uneven progress.* Rome: FAO. Retrieved 26 January 2016, from http://www.fao.org/3/a-i4646e.pdf

Finger, R., El Benni, N., Kaphengst, T., Evans, C., Herbert, S., Lehmann, B., . . . Stupak, N. (2011). A meta-analysis on farm-level costs and benefits of GM crops. *Sustainability, 3*, 743–62. Retrieved 6 July 2014 from, http://www.mdpi.com/2071-1050/3/5/743

Global Hunger Index (GHI). (2014). *The Challenge of Hidden Hunger*. Welthungerhilfe, IFPRI, Concern Worldwide.

Huang, J., Hu, R., Rozelle, S., & Pray, C. (2005). Insect-resistant GM rice in farmers' fields: Assessing productivity and health effects in China. *Science*, *308*(5722), 688–690. doi:10.1126cience.1108972 PMID:15860626

Huang, J., Pray, C., & Rozelle, S. (2002). *Enhancing the crops to feed the poor. Nature, 418,* 678–84. Retrieved 12 July 2014 from, http://www.nature.com/nature/journal/v418/n6898/pdf/nature01015.pdf

Hunt, D., & Lipton, M. (2011). *Green Revolutions for Sub-Saharan Africa?* Briefing Paper AFP BP 2011/01. Chatham House, Africa Programme. Retrieved 17 July 2014 from, www.chathamhouse.org/sites/default/files/public/Research/Africa/bp0111greenrevolution.pdf

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

IFPRI. (2013). *Genetically Modified Crops in Africa: Economic and Policy Lessons from Countries South of the Sahara.* International Food Policy Institute Issue Brief 80. Retrieved 12 August 2014 from, http://www.ifpri.org/sites/default/files/publications/ib80.pdf

International Service for the Acquisition of Agri-Biotech Applications (ISAAA). (2010). *Are GM crops Africa's path to food security?* Retrieved 6 June 2014 from, http://www.voanews.com/content/are-gm-crops-africas-path-to-food-security-64567512/157007.html

International Service for the Acquisition of Agri-Biotech Applications (ISAAA). (2012). *S. Africa GM crop area hit record in 2011: Report*. Reuters. Retrieved 12 August 2014 from, http://af.reuters.com/article/investingNews/idAFJOE82705320120308

James, C. (2008). *Global status of commercialized biotech/GM crops: 2008* (ISAAA Brief No. 39). Ithaca, NY: International Service for the Acquisition of Agri-biotech Applications. Retrieved 9 July 2014 from, https://isaaa.org/resources/publications/briefs/39/download/isaaa-brief-39-2008.pdf

Juma, C. (2014). Feeding Africa: why biotechnology sceptics are wrong to dismiss GM. *Guardian Professional*. Retrieved 12 June 2014 from, http://www.theguardian.com/global-development-professionals-network/2014/may/27/gm-crops-food-security-calestous-juma-africa

Juma, C., & Gordon, K. (2014). *Leapfrogging African agriculture*. Retrieved 15 June 2014 from, http://www.brookings.edu/~/media/Research/Files/Reports/2014/foresight%20africa%202014/06%20foresight%20african%20agriculture%20juma%20gordon.pdf

Kuyek, D. (2002). The past predicts the future: GM crops and Africa's farmers. *Seedling*. Retrieved 15 July 2014 from, http://www.grain.org/article/entries/344-the-past-predicts-the-future-gm-crops-and-africa-s-farmers

Millennium Development Goals (MDG) Report. (2013). *Section III-food security in Africa-issues, challenges, lessons. Assessing progress in Africa towards the millennium development*. Retrieved 6 June 2014 from, goals.http://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/Millennium%20Development%20Goals%20%28MDGs%29%20Report%202013%20-%20Section%20III%20-%20Food%20Security%20in%20Africa%20-%20Issues-Challenges-Lessons.pdf

Miller, M. (2007). *Genetically modified crops in Africa*. UNEP. Retrieved 5 May 2014 from http://www.eoearth.org/view/article/152943

Morse, S., Bennet, R., & Ismael, Y. (2013). *Impacts of GM cotton and maize on household livelihoods in South Africa.* University of Reading. Retrieved 9 July 2014, from bch.cbd.int/database/attachment/?id=1575

Murnaghan, I. (2014). *Development and history of GM foods*. Retrieved 10 August 2014, from http://www.geneticallymodifiedfoods.co.uk/development-history-gm-foods.html

New Partnership for Africa's Development (NEPAD). (2010). *Status of crop biotechnology in Africa*. Retrieved 4 July 2014 from, http://www.nepadbiosafety.net/subjects/biotechnology/status-of-crop-biotechnology-in-africa

Paarlberg, R. (2010, November 30). GMO foods and crops: Africa's choice. *New Biotechnology*, *27*(5), 609–613. doi:10.1016/j.nbt.2010.07.005

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Pschorn-Strauss, E. (2005). Bt Cotton in South Africa: the case of the Makhatini farmers. *Seedling*, 13–24. Retrieved 10 July 2014 from, www.grain.org/article/entries/492-bt-cotton-in-south

Roberts, P. K. C., Shyam, & Rastogi, C. (2006). Rural access index: a key development indicator. *Transport Papers 10*. Washington, DC: World Bank. Retrieved 5 July 2014 from, www.worldbank.org/transport/transportresults/headline/rural-access/tp-10-final.pdf

Secretariat of the Convention on Biological Diversity (SCBD). (1992). *The Convention on Biological Diversity*. Montreal, Canada: Text and Annexes.

UNDP. (2012). *Africa human development report: towards a food secure future*. New York: UNDP Regional Bureau for Africa. Retrieved 4 July 2014 from, http://www.undp.org/content/dam/undp/library/corporate/HDR/Africa%20HDR/UNDP-Africa%20HDR-2012-EN.pdf

Vitale, J., Glick, H., Greenplate, J., & Traore, O. (2008). The Economic Impact of Second Generation Bt Cotton in West Africa: Emperical Evidence from Burkina Faso. *International Journal of Biotechnology*, *10*(2-3), 167–183. doi:10.1504/IJBT.2008.018352

Vitale, J. D., Vognan, G., Ouattarra, M., & Traore, O. (2010). The Commercial Application of GMO Crops in Africa: Burkina Faso's Decade of Experience with Bt Cotton. *AgBioForum*, *13*(4), 320-332. Retrieved 10 August 2014 from, http://soybeaninnovationlab.illinois.edu/sites/soybeaninnovationlab.illinois.edu/files/cotton%20prfotiabilityv13n4a05-vitale.pdf

Witt, H., Patel, R., & Schnurr, M. (2006). Can the poor help GM crops, Technology, representation & cotton in the Makhathini Flats, South Africa. *Review of African Political Economy, 109*, 497–513. Retrieved 12 June 2014 from, http://rajpatel.org/wp-content/uploads/2009/11/Can-the-Poor-help-GM-Crops_final-printed-version.pdf

Yorobe, J. M., Jr., & Quicoy, C. B. (2006). Economic Impact of Bt Corn in the Philippines. *The Philippine Agricultural Scientist*, *89*(3), 258–67. Retrieved 5 July 2014 from, https://www.isaaa.org/programs/impact_assessment_of_crop_biotechnology/download/Economic%20impact%20of%20Bt%20corn%20in%20the%20Philippines.pdf

ENDNOTE

[1] Applicable in 2002–03.

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Chapter 79
Agricultural Growth Accounting and Total Factor Productivity in Jordan: Trends, Determinants, and Future Challenges

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ABSTRACT

This article develops new estimates of historical agricultural productivity growth in Jordan. It investigates how public policies such as agricultural research, investment in irrigation capital, and water pricing have contributed to agricultural productivity growth. The Food and Agriculture Organization (FAO) annual time series from 1961 to 2011 of all crops and livestock productions are the primary source for agricultural outputs and inputs used to construct the Törnqvist Index for the case of Jordan. The log-linear form of regression equation was used to examine the relationship between Total Factor Productivity (TFP) growth and different factors affecting TFP growth. The results showed that human capital has positive and direct significant impact on TFP implying that people with longer life expectancy has a significant impact on TFP growth. This article concludes that despite some recent improvement, agricultural productivity growth in Jordan continues to lag behind just about every other region of the world.

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1. INTRODUCTION

Jordan has experienced spells of high growth, but the country has always faced the challenge of sustaining them. In the first half of the 1980s, Jordan's Gross Domestic Product (GDP) growth averaged 7.4 percent. Subsequently, as the regional economies entered into recession in the wake of a sharp fall in oil prices, the country's growth plummeted to -14 percent in 1988 and it took about 18 years for Jordan's GDP per capita to revert to its level of the late 1980s. Jordan posted an average 6.7 percent growth during 2000-2008, then the country's growth dropped sharply to 2-3 percent during the global financial crisis of 2009-2010. Jordan's resilience to exogenous shocks has remained extremely weak over the last 30 years.

The contribution of agriculture to the GDP in relative terms declined sharply from 40% in the 1950s to less than 4% in 2011 (Bahdousheh et al. 2010), while its contribution in absolute terms has increased from Jordan Dinar (JD) 32 million in 1964 to JD 560 million in 2010 (The Central Bank of Jordan, 2011). Despite the increase in absolute monetary terms, the contribution of agriculture to the national economic growth is very modest, reflected in the remarkable decline in the sector's share compared to other sectors.

The importance of the agricultural sector stems from the fact that it is not only the major source of food items especially dairy products, fruits and vegetables, but is also one of the sources of hard currencies originated from exports. About 25% of the total poor in Jordan live in the rural areas depending mostly on agriculture (e.g., livestock keepers, small holder farm households, and landless former agriculturalists), and in spite of poor motivation of the rural youth, agriculture is an important employer of the rural communities. Additionally, cultural, social, and environmental considerations and mainly because of its strong forward and backward linkages with other sectors and activities, agriculture remains a very important sector that must be considered in the rural development and poverty reduction plans. The sector employed about 124,000 people (a total of 2.1% of the entire population or about 7.7% of the active labor-force of 1.771 million), and contributed to 17% of total national exports (equivalent to JD 795 million) in 2011 (MOA, 2012).

A major weakness of the sector is caused by the scarcity of irrigation water and overexploitation of groundwater; use of poorly treated brackish and sewage water, land fragmentation and reduction in the size of agricultural holdings; weak extensions services; poor transportation, packaging and processing; infrastructure; unfavorable price policies, and low investment in marketing infrastructure, post-harvest and quality enhancing facilities (e.g., grading, packing, storage). The claim that agriculture consumes 62% of the Jordanian scarce water resources leaving scant reserves for domestic and industrial use is unrealistic and is yet to be proven. However, the claim generally reflects the extent of poor water use practices in agriculture, and indicates the need for adopting alternative and modern agricultural practices and techniques.

The agricultural output growth is usually due to three types of factors: area growth, yield growth, and prices change. Area growth is related to an increase in the quantities of inputs use in addition to land. However, yield growth is generated by both inputs use growth and total factor productivity (TFP) growth. Then, TFP growth is the result of both technical change and the efficiencies deployed to lead to increased output. Growth patterns could be then defined as a trade-off between these two sources which determines TFP growth. Although all choices of growth patterns can achieve the substantive growth of TFP, the distributions between both sources should be coordinated.

There have been virtually no sector-level studies on agricultural productivity in this region or on the role of public policies in improving productivity growth. This article develops new estimates of historical productivity growth and water use in Jordan. It investigates how public policies such as agricultural

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research, investment in irrigation capital, water pricing, and others have contributed to agricultural productivity growth. The findings from this article will have important implications for agricultural development policy in the region.

The remainder of this article is divided into five sections. Section 2 provides a literature review on the empirical approaches used to measure the agricultural productivity in in Jordan and many other countries. Section 3 presents the methodologies used to measure TFP, and discusses the data used in Jordan to measure TFP growth. Section 4 presents results obtained from the analyses of outputs, inputs and TFP measurements, and then describes and summarizes the key findings of the TFP determinants. Finally, Section 5 presents the conclusions and policy implications.

2. BACKGROUND AND LITERATURE REVIEW

Agriculture productivity analyses performed to date show that most developing countries are experiencing relatively negative productivity growth with technical change being the main source of this regression. Kawagoe and Hayami (1985) showed agricultural productivity decrease in 22 Least Developed Countries (LDCs), but an increase in the 21 developed countries included in the sample. Kawagoe and Hayami (1985) found similar results for the same data set using an indirect production function approach that is similar to the indexing approach, except that input shares are estimated by using marginal productivities from an aggregate production function instead of prices. Lau and Yotopoulos (1989) also found in their analysis declining agricultural productivity for LDCs in the 1970s but an increase in the 1960s, although they used different functional forms.

In later research, Qualset, McQuire, and Warburton (1995) state that California's rich agricultural productivity is founded on its biological diversity, both native and exotic. Native species contribute genetic resources and play a vital part in preserving land, air, and water quality. Qualset et al. (1995) assert that exotic species introduced from around the globe provide the raw genetic material for nearly all of California's agricultural commodities. Through generations of selective breeding, native and exotic biodiversity have been used to solve agricultural problems. Such biodiversity — termed "agrobiodiversity" — includes not only crops, livestock and their wild relatives, but the species that interact with and support them: pollinators, symbionts, competitors, pests, parasites, predators, and biological control agents. Qualset et al. (1995) suggest that long-term security and flexibility of California agricultural production requires conservation of both exotic genetic resources and native California habitats.

Trying to explain measured productivity decline in developing countries, Fulginiti and Perrin (1993, 1998) related poor productivity performance to economic policy. They found that those countries with heavy agriculture taxes had the most negative rates of productivity change. They suggested that price policies or other interferences with the agricultural sector might stifle potential productivity gains. Fulginiti and Perrin also suggested, as an alternative explanation, that the methods and data used in these studies may have inaccurately measured technical regression. Arnade (1998) estimated agricultural efficiency change indices, technical change indices and productivity indices using nonparametric Malmquist indices for 70 developed and developing countries during 1961 - 1993.

A total of 36 of the 47 developing countries included in this sample showed negative rates of technical change, whereas most of the developed country indices rose or followed mixed paths. In contrast, recent studies of agricultural productivity growth in developing countries have showed positive and rapid growth. Coelli and Rao (2003) examined the growth in agricultural productivity in 93 countries during

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1980 - 2000. Their results showed an annual growth in total factor productivity growth of 2.1%, with efficiency change contributing by 0.9% per year and technical change providing the other 1.2%. There is little evidence of technological regression found in the earlier studies. Those results are explained as a consequence of the use of a different sample period and an expanded group of countries.

Nin et al. (2003) re-examined the nonparametric procedure for estimating the Malmquist productivity index. They argued that the technical regression observed is principally the consequence of biased technical change together with the definition of technology used to estimate the Malmquist Index. They eliminated this effect by applying a broader cumulative definition of technology than is normally used to estimate the Malmquist Index. Their results using this new approach reversed the previous findings and showed that most countries in their sample of 20 developing countries experienced positive productivity growth with technical change being the main source of this growth.

Al-Karablieh (2004) in his study of analysis of the TFP in Jordanian agriculture, analyzed the agricultural outputs of Jordan during 1983 - 1997 using the Tornqvist quantity index. In this study, data on output produced, input used, and their respective prices for the period were obtained from the Jordanian Department of Statistics (DOS) and were supplemented with several other sources. Output growth, during the period under study, principally came from the growth of fruits, vegetables, and poultry. Growth rates for all other crops and livestock were unbalanced due to few research and development efforts on those relative to fruit and vegetables. The average growth rate of TFP was 3.9% during 1983 - 1997.

During 1983 - 1987, the average growth rate of TFP was 6.1%, but dropped later to an average of growth rate of only 0.7% during 1993 - 1997. Although land remained static, labor, fertilizers, pesticides and water increased. The increase in output during the whole period was mainly 70% due to the technological change, whereas 30% was due to the increase in the inputs used. Much of the additional productivity is expected to come from cereals and livestock products; therefore, policy prescriptions should be allocated to direct research and development efforts towards efficient production of those along with fruit and vegetables. Given land is considered the most limiting factor and labor is the most elastic factor, the shift towards production of high value crops will increase aggregate output growth and at the same time employment.

Belloumiet et al. (2009) investigates the patterns of agricultural productivity growth in 16 Middle East and North Africa (MENA) countries during 1970 - 2000 using a nonparametric, output-based Malmquist index to examine whether author estimates confirm or invalidate the previous studies results indicating the decrease of agricultural productivity in developing countries. They showed that, on average, agricultural productivity growth increased at an annual rate of 1% during the whole period. Their estimations show that technical change is the main source for this growth. Those results weaken as a whole the findings of the other studies; however, they find a decrease in agricultural productivity mainly for developing countries suffering from political conflicts and wars. This article fills the void of hardly any agricultural studies on MENA countries collectively, especially on productivity trends.

Telleria et al. (2011) used the Malmquist Index to measure agricultural productivity. It is a powerful tool providing insights into whether or not a country is approaching what may be termed as "best practices" by using and disseminating existing technology (efficiency change), and/or by innovating technology (technical change). Using the Malmquist Index on a sample of 12 countries within West Asia and North Africa (WANA) indicated that between 1961 and 1997, Turkey, Tunisia, Syria, and Algeria (in that order) were the "most productive" countries.

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3. CONCEPTUAL FRAMEWORK

3.1. Methodological Approach

Productivity is defined as the efficiency of a production system, and as such would be a ratio of units of output per unit of input to the system (James & Carles, 1996). It is also defined as the production value (or quantity) divided by the amount of factors consumed in the production process. Generally, productivity is the relationship between the quantity of output and the quantity of input used to generate that output. It is a ratio of output to input (Productivity = Output/Input). The output used for productivity calculation could be of different forms such as produced goods or provided services. Outputs may be expressed in physical (quantities) or financial (value) terms. Inputs are resources used to produce outputs. Most common forms of inputs are labor, capital, and intermediate inputs.

Productivity has an effect on organizations/economies/sectors growth. In fact, higher productivity results in performances enhancement (production increases) and higher profits (e.g., minimal factors costs, better selling prices, marketing capacities). Enhanced skills in transforming inputs to outputs play critical role in enhancing productivity and competitiveness. In fact, with the same amount of inputs, some farmers can produce more than others depending on their skills, knowledge level, and cognitive capacities.

The two most commonly used measures of productivity are single (partial) factor productivity (SFP) and total (multifactor) factor productivity (TFP). When multiple inputs of heterogeneous nature are used in the production process, aggregation of these inputs may require the use of price indices. This implies that productivity can be affected by both changes in relative prices of inputs and by the input use per unit of output (Kathuria et al. 2013). Precise definitions of partial and TFP will be presented in this article. However, the main focus will be on the TFP since it is the method we are using in the APWEC-MENA project to account for agricultural sector growth in Tunisia, Jordan, and Egypt.

There are basically two approaches to measure TFP growth: the frontier and non-frontier approaches. Each of these approaches is further divided into parametric and non-parametric techniques. Non-frontier approaches include growth accounting methods (or non-parametric index-based methods/TFP index numbers) and econometric parametric approaches. Frontier approaches include the non-parametric Malmquist index methodology and the stochastic production frontier method; which is a parametric approach. A common feature of the TFP index number is that the empirical estimation of different TFP indexes is based on different weighting methods of inputs and outputs. In most empirical studies, the Divisia, Solow, and the Törnqvist Indexes are frequently used. Among index number methods, the Tornqvist-Theil Index, which is an approximation to the Divisia Index, was employed to construct the aggregate output index and aggregate input index.

In the literature on productivity measurement, the Törnqvist Index is the changing-weight index that has been most frequently examined and used. The Törnqvist Index, which was developed in the 1930s at the Bank of Finland (Törnqvist, 1936), makes use of logarithms for comparing two entities (e.g., two countries or two firms), or for comparing a variable pertaining to the same entity at two points in time. When used to compare inputs for two time periods within the context of productivity measurement, the Törnqvist Index employs an average of cost-share weights for the two periods being considered. The index number is computed after first determining a logarithmic change (or rate of proportional change). Explanation on theoretical properties and issues in measurement of the productivity through the Tornqvist Index can be found in Diewert (1978) and Coelli et al. (2005).

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The Tornqvist output, input, and TFP index in logarithm for can be expressed as follows:

$$\text{Output index: } \operatorname{Ln}\left(\frac{Q_t}{Q_{t-1}}\right) = \tfrac{1}{2}\sum_j \left(R_{j,t} + R_{j,t-1}\right)\operatorname{Ln}\left(\frac{Q_{j,t}}{Q_{j,t-1}}\right) \quad (1)$$

$$\text{Input index: } \operatorname{Ln}\left(\frac{X_t}{X_{t-1}}\right) = \tfrac{1}{2}\sum_i \left(S_{i,t} + S_{i,t-1}\right)\operatorname{Ln}\left(\frac{X_{i,t}}{X_{i,t-1}}\right) \quad (2)$$

$$\text{TFP index: } \operatorname{Ln}\left(\frac{TFP_t}{TFP_{t-1}}\right) = \operatorname{Ln}\left(\frac{Q_t}{Q_{t-1}}\right) - \operatorname{Ln}\left(\frac{X_t}{X_{t-1}}\right) \quad (3)$$

Where;

Rj,t is the share of output (j) in total revenue in time (t),
Qj,t is the output (j) in time (t),
Si,t is the share of input (i) in total input cost, and
Xi,t is the input (i) in time (t),

3.2. Data Sources and Data Collection Procedure

The Food and Agriculture Organization (FAO)'s annual time series from 1961 to 2011 of all crops and livestock productions, land areas, labor, machinery, animal capital, and fertilizer consumption are the primary source for agricultural outputs and inputs used to construct the Törnqvist Index for the case of Jordan. The FAO data is complemented, when needed, with data from national statistical agencies, especially when such alternative data is more accurate or up to date. Data from FAO was continuously cross checked with the available (sometimes limited) data from national sources in order to be sure of its reliability. Moreover, the TFP determinant variables where primarily collected from national sources, while some of them were also collected from international databases, as it is for the UNDP-human development index.

3.3. Hypothesis for Estimation of the Missing Data

As mentioned above, inputs and outputs data was mostly gathered from online FAO database. However, we faced some missing observations and were therefore obliged to use different assumptions to complete them. Below is a description of the different estimation procedures of these variables:

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Total Agricultural Output

This variable was available in both FAO and the DOS. However, we considered the FAO values in our output index calculation since most of our inputs variables were also from the FAO source. The calculation of the agricultural output value from the FAO dataset was based on available information about different agricultural commodities production (in metric tons) and prices (FAO have a dataset of historical agricultural commodities prices). Multiplying produced quantities of each commodity by its unit price provide the overall annual value of that commodity. By summing up crops commodities and livestock commodities, we obtain the annual crops output values and annual livestock values (see Figure 1). For the missing commodity prices observations, we were simply applying different constant inflation rates for different commodities based on their current prices.

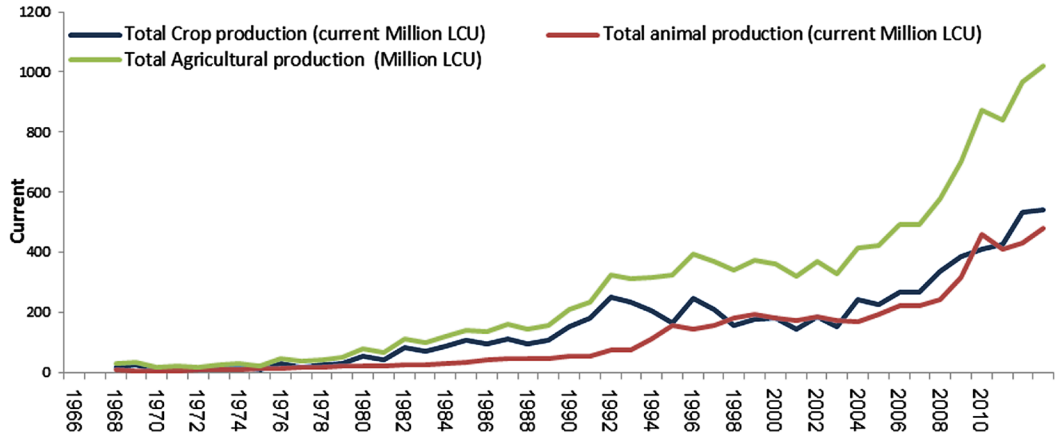
Total Agricultural Inputs

The FAO publishes data on cropland (rain-fed and irrigated), permanent pasture, labor employed in agriculture, animal stocks, the number of tractors in use, and inorganic fertilizer consumption. We supplement these data with better or more up-to-date data from national sources whenever available. For fertilizer consumption, the International Fertilizer Association has more up-to-date and more accurate statistics than does the FAO on fertilizer consumption by country, except for small countries.

Labor

this variable represents the annual volume of number (number of active persons) and value (in current JD) of the total labor mobilized in the agricultural sector. This variable was primarily collected from the DOS. The number of workers in the agricultural sector was not difficult to find as information, but the historical labor value was critical. We relayed on secondary data about daily wages in the agricultural sector to estimate this value. Secondary data about daily wages in the agricultural sector in Jordan were available from the DOS, but starting only from the 1990s. One observation of the wages in the 1960s

Figure 1. Crops and Livestock Output Values in Jordan (in current JD / from 1966 to 2011) Source: Own elaboration (2014)



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was obtained from consulting experts, and then a constant inflation rate of this value was applied every five years until the 1990s.

Seeds

Seed quantity was available in FAO datasets, but the FAO did not provide any seeds pricing data. Because cereals are the most important component of the overall seeds quantity, we decided to use an average price of cereals as proxy of the cereal seeds.

Machinery

This variable is reflected by the annual number and value of tractors in use. Other types of machineries were not used to account for this vector. The unit prices of tractors (in current local currency) were calculated based on the annual machinery import value drawn from the FAO database. From this annual unit value, an annual cost of machinery services was derived by amortizing the price of machine over 15 years and assuming a fixed marketing margin.

Pesticides

It was not possible to find any pesticides quantities. Instead, we used the number of cropped hectares treated by different types of pesticides as a proxy. This latest variable was available at the DOS. It was also difficult to find the annual total value of pesticides used in the agricultural sector of Jordan. This latter value was, however, estimated from the annual value of pesticides importations (available in the FAO database) corrected by a marketing margin of 85%. This marketing margin was identified from some primary data about average farms expenditure in treatment products. The margin is high mainly because private companies import active ingredients and transform them locally, thus producing important quantities of treatment productions.

Fertilizers

Aggregated fertilizers quantities were available from FAO data, the DOS, and the International Fertilizer Association (IFA). However, values from the IFA and FAO sources were highly similar so we decided to use the FAO data. The aggregated fertilizers value was, however, calculated based on average unitary price which was estimated through: 1) the international fertilizers price index (IFA: international fertilizer industry association); and 2) the average unitary price of 1963 (from FAO source).

Animal Feed

Animal feed quantities were also estimated from FAO sources, more precisely from the annual "commodity balance sheets". These annual sheets provide the quantity (in tons) of each agricultural commodity allocated for animal feed. By summing up through all of these commodities, we obtained the total quantity of feed consumed by the livestock activity. It was remarkable that cereals usually constitute more than 85% of the total annual animal feed. Therefore, an annual average cereal unitary price was used to calcu-

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late the feed value in Jordan. For the remainder of the feed share (other than cereals), half of the annual average cereal unitary price was used since we supposed that cereals are the most expensive among feed.

Capital Stock

was also calculated based on the FAO data for the period 1975 - 2007. In the calculation, we were considering the following components: "land development", "livestock fixed assets", "plant crops", and "structures for livestock". Each of these values was amortized based on the following rates, successively: 99 years, 10 years, 20 years, and 25 years. These depreciation rates are in line with the accounting system in the respective countries. The final capital stock formula is then: CS ($year_t$) =sum ((land development/99) + (Livestock fixed assets/10) +(plant crops/20)+(structure for livestock/25)). The capital stock values are reported in the FAO data as '2005 Constant USD'. We first changed the values to current US Dollars (based on US inflation rates) and then we applied the exchange rates to obtain the current JD values. The period 1960 - 1970 corresponds to the period of complicated political situation for Jordan with neighboring countries. This was our interpretation of the declining TFP indexes between 1966 and 1974.

Natural Resources

includes land, rangelands, and water used for irrigation. The annual land area was available in the FAO dataset while the value of natural resources was calculated by the residual imputation method. It is, in fact, considered as being the residual difference between the overall agricultural output and the sum of all inputs values.

3.4. Data Limitations and Missing Values

Some limitations of these calculations should be noted given the nature of the data on which they are based. The first limitation is that revenue and cost shares are held constant over time. Some of the data variables were not available for the whole period 1961 - 2012 in the FAO STATA. For input data there were a missing data fertilizer inputs during 1961 - 1993 and values of labor also during 1991 - 1993 were also missing, in addition to labor numbers, mechanization values were also missing during 1961 - 1973. Water values and quantities were also missing during 1961 - 1990; national statistics from the ministry of water and irrigation were used to fill the missing data from the FAO STATA. Seeds data were also missing for the period 1961 - 1990, so data also from the DOS were collected to fill the data gap.

However, an examination of the output data shows that for major commodity categories (e.g., cereal crops, oil crops, fruits and vegetables, meat, milk). On the input side, there has been more movement in cost shares among the major categories, but these changes occur gradually over decades. Thus, the likelihood of major biases in productivity measurement over a decade or two is not large, although this does remain a potential source of bias for longer-term comparisons. The principal advantage of these TFP growth estimates, however, is that the calculations have a standardized quality.

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4. RESULTS AND DISCUSSION

The annual average growth rates in the total output index (TOI), total input index (TII) and total factor productivity index (TFPI) between 1966 and 2011 are shown in Figure 2 and Table 1. The results estimated for individual years appeared to vary widely because of fluctuations in the prices of inputs and outputs. The TFP index (Figure 2 and Table 1) shows an important fluctuation over the analysis period. This fluctuating trend is mainly due to the fluctuation of the Output index, which is explained by the variability of rain-fed agriculture in Jordan due to highly variable climate conditions.

Figure 2 and Table 1 show an increasing trend of the output, inputs, and TFP indexes in Jordan. However, these values should be further analyzed in order to investigate the components the TFP growth and attributes clear shares to the different growth sources.

Consequently, we conducted an econometric estimation of the relationship between TFP growth and different factors, including the most important factors that we consider crucial on the TFP determinants for the Jordanian case. In a stylized form, we used the following regression model (expected signs in parentheses):

$$TFP = f\ (HC, BTD, SRP, MC, RR, SIL, TO, INF, SM) \quad (4)$$

Where:

TFP = Total Factor Productivity in the Jordanian agricultural sector
HC (+) = Human Capital: Health status as measured by life expectance (Years)
BTD (+) = Balanced territorial development Indicators: Rural GDP per capita (US$/Capita)
SRP (+) = Share of the rural population (in %)
MC (+) = Main crop (Tomatoes in Jordan): Share of total cropland harvested (in %)
RR (+) = Resources reallocation: Agricultural employment share (in %)

Figure 2. Törnqvist Output, Inputs, and Total Factors Productivity Indexes, for the Jordanian Agricultural Sector (1966 - 2011) Source: Own elaboration (2014)

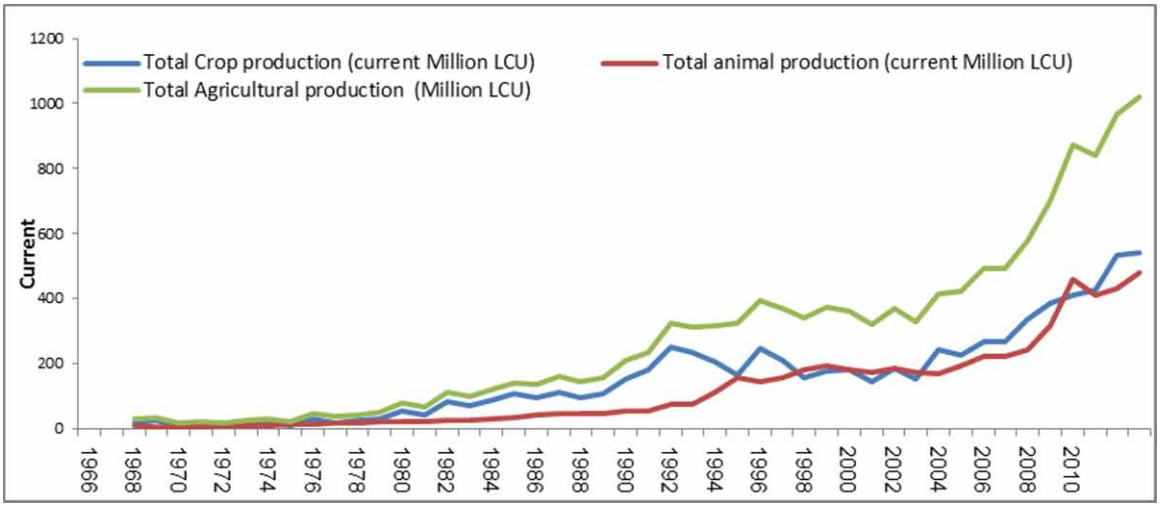

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Table 1. Normalized (base 100 for 1966) Values of Output, Input and TFP Indexes

Years	Normalized Output Index	Normalized Input Index	Normalized TFP Index
1966	100	100.00	100
1970	135.23	52.48	38.81
1975	169.87	61.82	36.39
1980	185.79	110.59	59.52
1985	219.66	147.19	67.01
1990	250.02	202.86	81.14
Years	Normalized Output Index	Normalized Input Index	Normalized TFP Index
1995	301.69	275.04	91.17
2000	291.92	281.24	96.34
2005	420.05	341.24	81.24
2010	326.82	426.51	130.50
2011	323.60	443.75	137.13
2012	323.22	443.75	137.29

Source: Own elaboration (2014)

SIL (+) =Share of irrigated land/total agriculture land (in %)
TO (+) = Trade Openness: (Import +export)/total production (in %)
INF (+) = Infrastructure: Road density (km /km2 agricultural land) - 1000 Km
SM (+) = Sustainable management: Share of agriculture in water use (in %)

The log-linear form of equation (4) allows for estimating coefficients that can be directly interpreted as elasticities. In addition, as highlighted in the pioneering work by Jud and Hyman (1974), equation (4) contains a weak residual variance relative to other functional forms for the same data set and adjusts the data better than the linear specification for both forecasted parameter signs and statistical significance. The standard Ordinary Linear Squared (OLS) method, if applied to non-stationary data series, can produce spurious regression. That is, the OLS regression can give high R2, low Durbin-Watson (DW) statistics, and significant t-values of the estimated coefficients, suggesting a significant relationship between dependent and explanatory variables, when in fact they are completely unrelated.

Conventionally, the factors explaining TFP have been studied by expressing variables in logarithmic form. This is similar to the first differencing of variables in time series analysis. Provided the original series are integrated of order 1, as is normally the case, expressing the variables in logarithmic terms ensures a stationary data series and means that the OLS method can safely and directly be used (Hendry, 1995).

The log-linear form of regression equation as indicated above was used to examine the relationship between TFP growth and different factors that affect TFP growth. While investments in agricultural research provide an obvious mechanism for TFP growth through technical change, the other variables (economic policy, human capital, infrastructure, and the absence of armed conflict) help to establish an enabling environment for economic growth. These factors enable farmers to access new technologies and markets, increase returns to savings and investments, and provide incentives for farmers to reallocate resources to the most profitable enterprises.

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The results showed in Table 2 that human capital has a positive and direct significant impact on the TFP which implies that people with longer life expectancy have a significant impact on TFP growth. The other determinant which showed to have positive and significant impact on TFP is the share of the main crop which is tomato crop in Jordan as tomatoes are among the most important vegetables grown in the country. There are two areas where tomatoes are grown. The total area planted with tomatoes was 8,115 hectares in 2000 and increased to 12,954 hectares in 2011 which reflected positively on TFP growth.

The independent variable of share of irrigated land/total agriculture land (in %) has showed positive and significant impact on TFP as indicated by the result of regression analysis. The total area used under irrigation in Jordan is estimated at 76,911.62 hectares in 2000 for fruit trees, filed crops, and vegetables; this area is estimated at 95,653.84 hectares in 2012 with a 24% increase that explains the direct and significant impact on TFP. The investment in irrigation capital and the modern and efficient use of irrigation systems that been used for the cultivation in the irrigated area has posted the productivity of the agricultural sector significantly.

The independent variable Infrastructure expressed in road density (km /km2 agricultural land) - 1000 Km found to have positive but no significant impact on TFP, thus implying that government investments in agricultural roads will post the overall productivity of the agricultural sector and allows more access for farmers for local market and new markets. The independent variables of Balanced territorial development Indicators: Rural GDP per capita (US$/Capita), the share of the rural population (in %), and sustainable management expressed in share of agriculture in water use (in %) found to have negative and significant impact on TFP as shown in the regression analysis in Table 2. However, the agricultural employment share and trade openness: (Import +export)/total production (in %) variables showed negative relationship and has no and significant impact on TFP.

5. CONCLUSION AND POLICY IMPLICATIONS

This article has summarized the data collection and calculation procedures for the estimation of TFP of the Jordanian agricultural sector for the period 1961 - 2011. Data was collected from different sources and some missing values were estimated and/or approximated through some proxy variables and assumptions. The list of assumptions was discussed above.

The agricultural output growth is usually due to three types of factors: area growth, yield growth, and prices change. Area growth is related to an increase in the quantities of inputs use in addition to land. However, yield growth is generated by both inputs use growth and TFP growth. Then, the TFP growth is the result of both technical change and better allocative efficiency of the used factors. Growth patterns could be then defined as a trade-off between these two sources which determines TFP growth. Although all choices of growth patterns can achieve the substantive growth of TFP, the distributions between both sources should be coordinated.

Despite some recent improvement, agricultural productivity growth in Jordan continues to lag behind just about every other region of the world. While there are important data challenges in measuring trends in agricultural productivity, most studies agree that agricultural TFP in Jordan was stagnant or declining in the 1960s and 1970s, but turned positive around the mid-1980s. A number of factors appear to have contributed to the renewal of agricultural productivity growth observed in recent decades. One driver is human capital that shown to have positive and direct significant impact on the TFP and the share of the main crop which is tomato crop in Jordan and the share of irrigated land/total agriculture land.

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Table 2. TFP Determinants in the Jordanian Agricultural Sector (1967–2011)

	Dependent Variable LnTFPt		
Parameters	**Estimated coefficients**	**t-ratios**	**p-value**
Constant	-6.38	-1.79	0.08
LHCt (Human Capital)	3.08	5.08	0.00
LBTDt (Balanced territorial development Indicators)	-2.68	-1.46	0.15
LSRPt (Share of the rural population)	-0.53	-1.79	0.08
Parameters	Dependent Variable LnTFPt		
	Estimated coefficients	t-ratios	p-value
LMCt (Share of the main crop – tomatoes - of total cropland harvested)	5.68	1.43	0.23
LRRt (Resources reallocation: Agricultural employment share)	-0.77	-0.51	0.62
LSILt (Share of irrigated land/total agriculture land)	0.57	2.96	0.01
LTOt (Trade Openness)	-0.34	-1.15	0.26
LINFt (Infrastructure)	0.70	0.53	0.60
LSMt (Sustainable management)	-6.38	-1.79	0.08
T	45		
R2	0.44		
F-statistic	3.66 (p<0.003215)		
Log likelihood	13.54		

Source: Author's calculation based on coefficient estimates of the linear regression model.

The Infrastructure expressed in road density (km /km2 agricultural land) - 1000 Km have positive but no significant impact on TFP, thus implying that government investments in agricultural roads will post the overall productivity of the agricultural sector and allows more access for farmers for local market and new markets. In addition to investing in agricultural research, strengthening the broader enabling environment for farmers to access technology, markets, and the necessary support services have helped raise agricultural productivity in Jordan. The main implication policy of this research is that estimating growth in TFP is difficult, but it is essential for assessing the country past and potential economic performance and the gains in TFP drive gains in income and growth.

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REFERENCES

Al-Karablieh, E. (2004). An Analysis of Total Factor Productivity in Jordanian Agriculture (1983-1997), Dirasat. *Agricultural Sciences*, *1*(31), 99–113.

Arnade, C. (1998). Using a Programming Approach to Measure International Agricultural Efficiency and Productivity. *Journal of Agricultural Economics*, *49*(1), 67–84. doi:10.1111/j.1477-9552.1998.tb01252.x

Bahdousheh, M., ... (2010). Country Case Study-CFS. *National Initiatives for Food Security and Nutrition*, Committee on World Food security.

Belloumi, M., & Salah Matoussi, M. (2009). Measuring agricultural productivity growth in MENA Countries. *Journal of Development and Agricultural Economics*, *1*(4), 103–113. Retrieved from http://www.academicjournals.org/JDAE

Coelli, T. J., Prasada, D., Rao, D. S., O'Donnell, C. J., & Battese, G. E. (2005). *An Introduction to Productivity and Efficiency Analysis* (2nd ed.). New York: Springer.

Coelli, T. J., Rao, D. S., & Prasada, D. (2003). *Total Factor Productivity Growth in Agriculture: A Malmquist Index Analysis of 93 Countries, 1980- 2000*. CEPA Working Papers, School of Economics, University of Queensland, Brisbane, Queensland, Australia.

Department of Statistics. (2014). Retrieved from www.dos.gov.jo

Diewert, W. E. (1978). Superlative Index Numbers and Consistency in Aggregation. *Econometrica*, *46*(4), 883–900. doi:10.2307/1909755

Fulginiti, L., & Perrin, R. K. (1993). Perrin R. Prices and Productivity in Agriculture. *The Review of Economics and Statistics*, *75*(3), 471–482. doi:10.2307/2109461

Fulginiti, L. E., & Perrin, R. K. (1997). LDC agriculture: Nonparametric Malmquist productivity indexes. *Journal of Agricultural Economics*, *53*, 373–390.

Fulginiti, L. E., & Perrin, R. K. (1998). Agricultural productivity in developing countries. *Journal of Agricultural Economics*, *19*(1-2), 45–51. doi:10.1016/S0169-5150(98)00045-0

Fulginiti, L. E., & Perrin, R. K. (1999). Have Price Policies Damaged LDC Agricultural Productivity? *Contemporary Economic Policy*, *17*(4), 469–475. doi:10.1111/j.1465-7287.1999.tb00697.x

Hendry, D. F. (1995). *Dynamic Econometrics*. Oxford: Oxford University Press. doi:10.1093/0198283164.001.0001

James, A., & Carles, A. B. (1996). Measuring the Productivity of Grazing and Foraging Livestock. *Agricultural Systems*, *52*(2-3), 271–291. doi:10.1016/0308-521X(96)00006-6

Jud, D. G., & Joseph, H. (1974). International Demand for Latin American Tourism. *Growth and Change*, *5*(1), 25–31. doi:10.1111/j.1468-2257.1974.tb00278.x

Kathuria, V., Raj R.S.N., & Sen K. (2013). Productivity measurement in Indian manufacturing: A comparison of alternative methods. *Journal of Quantitative Economics*, 11(1&2) (Combined).

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Kawagoe, T., & Hayami, Y. (1985). An Intercountry Comparison of Agricultural Production Efficiency. *American Journal of Agricultural Economics*, *67*(1), 87–92. doi:10.2307/1240827

Lau, L., & Yotopoulos, P. (1989). The Meta-Production Function Approach to Technological Change in World Agriculture. *Journal of Development Economics*, *31*(2), 241–269. doi:10.1016/0304-3878(89)90014-X

MOA Directorate of Studies and Policies. (2012). Annual report.

Nin, A., Arndt, C., & Preckel, P. V. (2003). Is agricultural productivity in developing countries really shrinking? New evidence using a modified non-parametric approach. *Journal of Development Economics*, *71*(2), 395–415. doi:10.1016/S0304-3878(03)00034-8

Qualset, C. O., McGuire, P. E., & Warburton, M. L. (1995). Agrobiodiversity: Key to agricultural productivity. *California Agriculture*, *49*(6), 45–49. doi:10.3733/ca.v049n06p45

Telleria, R., & Aw-Hassan, A. (2011). Agricultural Productivity in the WANA Region. *The Journal of Comparative Asian Development*, *10*(1), 157–185. doi:10.1080/15339114.2011.578490

The Central Bank of Jordan. (2011). Retrieved from: www.CBJ.gov.jo

Tornqvist, L. (1936). The Bank of Finland's Consumption Price Index. *Bank of Finland Monthly Bulletin*, 10, 1-8.

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Chapter 80
Human Overpopulation:
Impact on Environment

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ABSTRACT

Overpopulation has recognized as a global environmental problem since few decades, as it has caused a number of adverse effects on environment. Modern medical facilities and illiteracy in some interior regions of developing countries are the major reasons for development of this inverted pyramid demographic structure. Overpopulation has resulted in a series of catastrophic consequences by causing increased pressure on existing natural resources. Deforestation, effect on welfare, climate change, decline in biocapacity, urban sprawl, food security, increase in energy demand and effect on marine ecosystem are amongst most severe impacts of overpopulation. Concrete steps need to be taken on national and international level to combat the adverse effects of overpopulation, so that sustainability of natural resources can be ensured for future generations.

INTRODUCTION

The world's population has touched a mark of 7.3 billion in 2015 and could attain growth level of 9-12 billion before the year 2050 which suggest that the impact of overpopulation can increase the pace of ecological changes and impose a burden on biodiversity (Sala et al., 2000; UN, 2015). The 49 least developed countries have shown a growth rate of 2.3% annually, which was nearly twice as compared to the developing world i.e. 1.2% per year in the year 2009 (UN, 2009). Increases in human population

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size have caused an increased risk of synergies among impacts with resultant accelerated environmental degradation (Harte, 2007). This increase in population size has fastened the agricultural activities and technological development up to the extent, which is catastrophic to environmental health. The negative effect of an agriculture or technological society on the abiotic and biotic components of the environment can be expressed in the simplest terms, by the relation,

$I = P.F$

where P and F denotes the population and function, respectively which measures impact per capita (Ehrlich and Holdren, 1971). Thus, to reduce environmental degradation and to ensure sustainability of natural resources, better understanding of potential impacts of overpopulation on environmental and human health are required.

BACKGROUND

An exponential growth of human population over the last few centuries has caused encroachment in the wild habitats and their consequent destruction, posing a potential threat to biodiversity components (Vinod, 2012). Growth rate of world population was approximately 2% per annum from 1960-2000, which indicted potential population doubling every 35 years thus could cause ecological unsustainability (Bloom, 2011). Projected world population growth for the major regions is presented in Table 1. Improved agriculture practices, modern medical facilities and illiteracy in rural regions caused demographic transition with more natality rate and decline in mortality rate. From 1980–81 until 1999–2000, agriculture showed a growth rate of 3.2% per annum, which exceeds the population growth rate of 2.0% annually over the period, while annual growth rate of per capita income was 3.1% between 1980 and 1991 and 4.3% since there forms of 1991 (Lal, 2006). According to the Inter Academy Panel Statement on Population Growth, several environmental concerns such as, elevated level of greenhouse gases, threat to biodiversity, climate change and environmental pollution are arisen as a result of rapid population growth (Coleman, 2011; Edet et al., 2014). This chapter reviews the impacts of overpopulation on environment, indicates future perspectives and provides some recommendation to combat the adverse impact of overpopulation.

IMPACTS OF OVERPOPULATION

Overpopulation has severe environmental implications. Although it has contributed in the nation's economy at global level, but has caused some adverse impacts on environment, which need to be addressed (Figure 1). Table 2 summarizes evolution of environmental concern, associated with population explosion.

Deforestation

Increasing urbanization has triggered deforestation at a very fast pace, in order to fulfill infrastructure demand of increasing population. Lands with high canopy covers are being subjected to deforestation and people are continuing to migrate from rural areas to urban areas. According to World Migration Report

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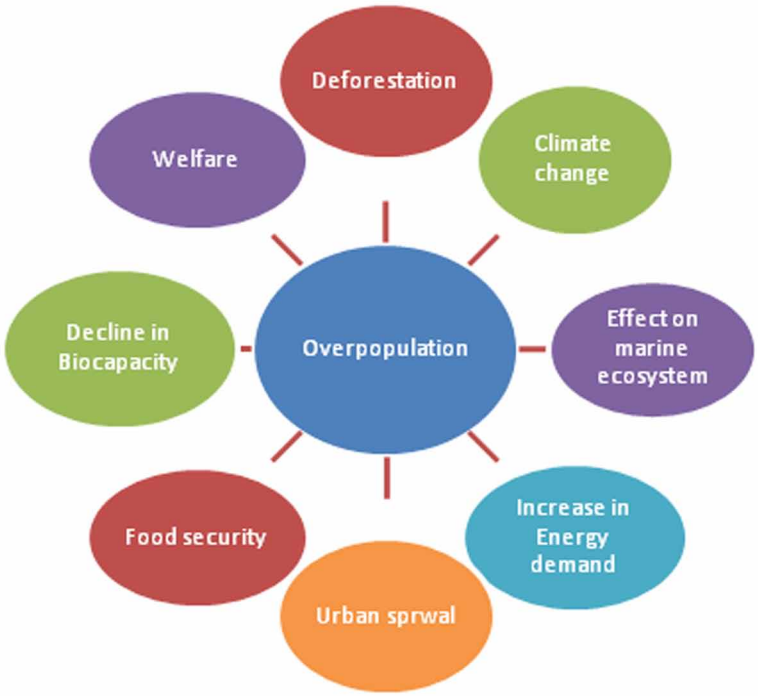
Table 1. Projected World Population Growth for Major Regions

Regions	2010 Population (millions)	2050 population Projections (millions)		
		Low fertility	Medium fertility	High fertility
Africa	1,022	1,932	2,192	2,470
Asia	4,164	4,458	5,142	5,898
Latin America and Caribbean	590	646	751	869
Europe	738	632	719	814
Northern America	345	396	447	501
Oceania	37	49	55	62
More developed regions	1,236	1,158	1,312	1,478
Less developed regions	5,660	6,955	7,994	9,136
World	6,896	8,112	9,306	10,614

Source: United Nations, Department of Economic and Social Affairs, Population Division. (2010). *World Population Prospects: The 2010 Revision.*

Figure 1. Effect of overpopulation on Environment



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(2015), net migration from rural to urban area during 1981–1991 was 11 million which has risen during 2001-2011 to 19 million, in India. Population growth caused an exponential increase in the alternation of the land utilization patterns to supplements economic needs in the form of agricultural products, fuel wood, timber etc. However, to control conversion of forest area to agricultural, industrial and residential area, Forest (Conservation) Act was enacted in the year 1980 in India as a result of which conversion of forest area to other land use practices was reduced with the annual diversion rate of 16,000 hectare (Economic Survey of India, 1998-99; Nagdeve, 2002).

Welfare

Overpopulation has severely affected the quality of life in recent years. Quality of life (QOL) of individuals is an approach used to determine their satisfaction in:

- Life,
- Financial status,
- Education,
- Social life,
- Family life,
- Health and
- Employment.

According to Quality-of-Life Index, 2005, Ireland ranks first in the quality of life, with comparatively low population in comparison with countries such as China and India which ranks 60 and 73, respectively. Increasing population has imposed a burden on existing recourses to fulfill the basic needs of such huge population, which resulted in elevated poverty percentage. According to Planning Commission, India, below poverty line population living in the rural area showed a sharp increase from 27.09% in 1999 to 41.79% in the year 2005. This increase is subsequently accelerating lack of education in a mass of poor population. It tends to increase fertility rate in illiterate and poor population, which is not much aware about degrading environmental quality due to increasing population. Table 3 represents general fertility rate of women by their education level in different states of India. Kerala showed lowest i.e. 1.3% of illiterate women, while Bihar represents highest illiteracy i.e. 51.1% of illiterate women. General fertility rate was found to be lower for literate women as compare to illiterate women in all states of India. However, states showed lower value of general fertility rate for illiterate population than the literate population which was ascribed to the fact that sample size in illiterate category was quite small as theses states have significantly high literacy level (Census of India, 2011). In addition, government of developing countries like India is not able to manage medical facilities to such huge amount of population.

Climate Change

Recent reports on climate change indicated more frequency and catastrophe in the weather extremes, leading to costly damage of infrastructure and loss of human life (Intergovernmental Panel on Climate Change, 2007). Increased use of fossil fuels since the mid-19th century in overpopulated regions around the globe caused release of over 1100Gt CO_2 into the atmosphere (IPCC, 2001). Furthermore, overpopulation accelerated agricultural practices, leading to enhanced emission of greenhouse gases. For

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example, methane is produced from rice agriculture practices and livestock. For emission of greenhouse gases, agriculture sources in 2014 accounted for 24% of 2010 global emission (IPCC, 2014). Population reduction in high-income countries might act as a possible solution. Any reduction in population growth in high-income countries, even starting from zero or negative rates, will have much more impact on reducing climate change than the same size reduction in low-income countries, because of the much higher per capita consumption and emission of greenhouse gases in the high-income countries (Rosnick, 2014). In addition, switch to alternative energy options (solar energy, tidal energy, wind energy etc) and improved agricultural practices could help in combating the problem of climate change resulting from increased population.

Decline in Biocapacity

Increasing global population has accelerated resource consumption, which subsequently increased pressure on existing natural resources to unprecedented levels. Biocapacity is the area available as productive land and available water to produce resources or absorb carbon dioxide waste, given current management practices (Ecological Footprint Atlas, 2010). Biocapacity seems to decline sharply with increased pressure on ecological resources, as existing resources could not support consumption need of such a wide world population. Biocapacity per head decreased from 3.2 global hectares (gha) in 1961 to 1.8 gha per capita in 2008, even though total global biocapacity increased over this time (WWF Living Planet Report, 2012). The Ecological footprint denotes the land area required to meet the consumption and waste absorption needs of a population (Wackernagel & Rees, 1995). It can be used to track the availability and consumption of ecological resources and thus can aid in sustainable utilization of resources. According to Ecological Footprint accounts, demand for renewable resources has increased from 7.6 billion global hectares in 1961 to 18.1 billion global hectares in 2010. Similarly, global bioproductive area showed an increase from 9.9 billion global hectares in 1961 to 12 billion global hectares in 2010, indicating its unsustainable status (Global Footprint Network, 2015).

Urban Sprawl

Urban sprawl is one of the several consequences of rapid population growth. Sprawl is a large scale development process of real estate, producing low density, scattered, discontinuous car-dependent construction, usually on the periphery of the declining older suburbs and shrinking city centers (Hayden, 2004). Urban global population will grow to 4.9 billion by 2030, while, the global rural population is predicted to decline by approximately 28 million during 2005 to 2030 (Bhatta, 2010). In the United States, urban growth is expected to utilize about 19 million acres of farmland, environmentally sensitive and other lands during 2000–2025 (Burchell et al., 2005). Urban sprawl can be caused either by increased natality rate or by increased immigration. Better living facilities and need employment of employment are the major factors, which caused migration of population from rural area to urban area. Governmental organizations cannot deliver all basic services and quality life to huge urban population and thus, resulting massive sprawl may cause severe environmental degradation.

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Food Security

Overpopulation has worsened the local and global food security by synergistic impacts of climate change. Emission from agriculture sources elevated from 4.7 billion tonnes to over 5.3 billion tonnes of carbon dioxide equivalents (CO_2 eq) during 2001-2011 (Food and Agriculture Organization, 2014). Climate change resulting from the enhanced emission of greenhouse gases has posed a severe threat on food security by affecting agricultural crop production and biodiversity. Food security is linked with food availability, accessibility and utilization. Increasing urbanization has limited the growth of agricultural sectors by encouraging industrial development in rural regions. Current food production is becoming limited along with the hasty growth in human population numbers. Technological development in the field of agriculture depends on availability of natural resources like water, land and energy. For instance, 1 kcal of food production requires about 10 kcal of fossil energy, which is present in limited amount and thus restrict the progress in agriculture production (Pimentel, 2011). Currently, agricultural land suitable for irrigation is 50% of the world's land. This land area is continuously being shrinking due to soil erosion, nutrient depletion, soil acidification and soil salination (Horizon, 2009).

Increase in Energy Demand

Growing global population has caused rapid inflation in energy requirement and consumption. According to Energy Information Administration (2001), use of energy, mostly for fossil fuels has boosted by nearly 85 percent globally during past 30 years, while for Asia, it is more than 300%. Sustainability for energy resources can be assured by the increased use of renewable resources, utilizing energy conserving devices for household purposes and development of advanced technologies for generating energy from biological sources.

Effect on Marine Ecosystem

Overpopulation in coastlines has mainly resulted from migration activities and caused severe environmental degradation. Mangroves, fisheries and beaches used commercially for tourism purposes are among the coastal resources, which are severely damaged by consumption practices (Naylor et al., 2002). Coral reefs are being rapidly degraded both due to direct impact of climate change and by human induced marine pollution, overfishing etc. Out of the 19,210 km^2 of coral reefs in South Asia, 45% of have been destroyed, while 10%, 25% and 20% are critically threatened, threatened and at low risk, respectively (Tun et al., 2004). In Mesoamerican Barrier Reef, coral cover is declining at an average rate of about 11% since 2004, with more than 50% cover loss for some reefs (Wilkinson, 2008). International agreements for conserving marine biodiversity have however caused a significant increase in several biodiversity rich marine regions but increasing population is still a hurdle for their successful implementations.

ISSUES, CONTROVERSIES, PROBLEMS

Several efforts are being taken to ensure reduction of adverse impacts of overpopulation on environment but these are associated with serious issues. For example, developing countries are being funded under clean development mechanism to increase plantation practices, but simultaneous deforestation, has

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Table 2. Evolution of environmental concerns from 1940s to the present (modified)

Decade	Environmental effect	Source
1940-1950	Depletion of natural resources	United Nations report on population and resources
1960-1970	Air Pollution, Water pollution, Radioactive pollution, Disposal of waste	Declaration of the United Nations Conference on the Human Environment World Population Plan of Action of the United Nations World Population Conference
1980-1990	Climate change, Ozone depletion, Acid rain	Reports of the United States National Academy of Sciences Agenda 21 adopted by the United Nations Conference on Environment and Development Recommendations of the International Conference on Population
1990-1993	Deforestation, Water management. Control of emergence and re-emergence of diseases, Biodiversity loss	Globalization Programme of Action of the International Conference on Population and Development Resolution S-21/2 on key actions for the further implementation of the Programme of Action adopted by the General Assembly at its twenty-first special session

Source: (Ruttan, 1993)

Table 3. General fertility rate by level of education of women in India and bigger States, 2011

India and bigger States	General fertility rate	
	Illiterate	Total literate
India	86.7	78.7
Andhra Pradesh	43.4	71.5
Assam	103.0	76.8
Bihar	144.7	83.0
Chhattisgarh	62.9	107.8
Delhi	76.3	60.2
Gujarat	82.4	78.5
Haryana	61.7	87.9
Himachal Pradesh	18.4	62.8
Jammu & Kashmir	79.7	53.6
Jharkhand	109.7	83.7
Karnataka	41.5	75.2
Kerala	15.3	54.7
Madhya Pradesh	93.9	109.2
Maharashtra	34.0	68.8
Odisha	72.3	72.8
Punjab	52.4	62.2
Rajasthan	104.6	99.8
Tamil Nadu	11.1	62.2
Uttar Pradesh	115.4	105.4
West Bengal	46.9	61.4

Source: (Census of India, 2011)

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checked the advantages emerging out of the strategy. Huge population in rural regions is still dependent on fossil fuels for energy needs. Although renewable energy programmes are being initiated in rural regions by various governmental organizations but the success of these programmes always remains on question. No maintainers are provided for the solar panels after their installment. As a result, most of such renewable energy devices remain in non-working condition. Several schemes are being hurled by government of India to provide employment in the rural areas so that the massive urban sprawl can be checked. Government of India inducted a scheme for self-employment in 1980-81 namely, Integrated Rural Development Programme (IRDP), which was further remodeled as the Swarnjayanti Gram Swarozgar Yojana (SGSY). In 1989, Jawahar Rozgar Yojana (JRY) was initiated by amalgamating National Rural Employment Programme (NREP) and Rural Landless Employment Guarantee Programme (RLEGP). The main goal of the scheme was generating more employment opportunities for people living in rural areas, advancing rural infrastructure and quality of life (Planning Commission, Government of India). However, it turns out to be a very time consuming process for procuring actual financial gain by rural people due to red tapism involved in governmental procedures especially in developing nations. In addition, to ensure food security, use of enormous quantity of chemical fertilizers further worsened the environmental health by reducing soil fertility.

POSITIVE EFFECTS OF OVERPOPULATION

As a major problem many scientists agreed that human population may reach the point at which the earth will no more able to sustain life. However, many believe that ever increasing population have some advantages such as:

- Economic benefits,
- Increased human resources,
- Higher demand in industries,
- Innovative, cheaper and
- More readily available products etc.

A nation with high population and/or increasing number of youth can add more people to developmental activities. An increasing population can boost the economic growth of a country only if the demand for better services grows. Therefore, to yield positive effects from growing population a nation must have sound policies. Keeping the pace with population growth, countries that utilize their human resources efficiently in developing better health care and medicine, food production,

SOLUTIONS AND RECOMMENDATIONS

The impact of overpopulation on food security can be reduced by raising food production, improving food distribution and by increasing economic access to food (Gregory et al., 2005). Similarly, deforestation can be reduced by proper management of forest. For the management of forest, an effective strategy should be developed to harmonize conservation priorities and development goals i.e. by including native people in decision making procedures regarding utilization and conservation of forest resources

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(Chakravarty et al., 2008). Similarly, for the efficient utilization of renewable energy, regular employment of maintainers and operators for each installed renewable energy plant should be ensured. In addition, Transparency in funding mechanisms of governmental procedures must be ensured, so that urban sprawl can be reduced. Population explosion awareness programs in developing nations need to be conducted, so that problem can be solved at grass root level. Some countries like China, had taken strong steps to combat problems of overpopulation but the scheme (One child policy) has failed due to several reasons. The scheme has encouraged people for increasing incidents of feticides, tending to gender inequality. A large mass of population is now entered in an old age and only a small proportion of young generation is there to support economic growth of country. Thus any scheme must be viewed with its possible pros and cons, before implementation.

FUTURE RESEARCH DIRECTIONS

Demographic structure of different countries needs to be evaluated and the reasons behind the inverted demographic pyramid should be assessed for each country. In addition, research needs to be conducted on the effective ways to maintain impartial sharing of resources, so that carrying capacity of ecosystem could be increased. Effective ways for awareness of people about programs related to family planning must be determined and implemented.

CONCLUSION

Overpopulation has posed severe threat to environment with regard to deforestation, ecosystem degradation, climate change and adverse impact of human welfare. Several measures were adopted by developed and developing nations in order to reduce the damage caused by overpopulation. These measures proved inefficient to curb population growth, as were associated with some serious drawbacks. Therefore, effective awareness programs about population control, education in rural regions and impartial sharing of resources must be ensured, so that population explosion could be controlled.

REFERENCES

Bhatta, B. (2010). Causes and consequences of urban growth and sprawl. In *Analysis of Urban Growth and Sprawl from Remote Sensing Data* (pp. 17–36). Berlin: Springer-Verlag Publishing. doi:10.1007/978-3-642-05299-6_2

Bloom, D. E. (2011). *Population dynamics in India and implications for economic growth.* Retrieved on December 23, 2015, from: www.hsph.harvard.edu/pgda/working.htm

Burchell, R. W., Downs, A., McCann, B., & Mukherji, S. (2005). *Sprawl costs: Economic impacts of unchecked development*. Washington, DC: Island Press.

Chakravarty, S., Shukla, G., Malla, S., & Suresh, C. P. (2008). Farmer's rights in conserving plant biodiversity with special reference to North-east India. *Journal of Intellectual Property Rights*, *13*, 225–233.

EBSCOhost - printed on 2/14/2023 11:28 AM via . All use subject to https://www.ebsco.com/terms-of-use

Coleman, J. (2011). World's 'seven billionth baby' is born. *The Guardian*. Retrieved on December 23 from: www.theguardian.com/world/2011/oct/31/seven-billionth-baby-born philippines? newsfeed=true

Edet, S. I., Samuel, N. E., Etim, A. E., & Titus, E. E. (2014). Impact of overpopulation on the biological diversity conservation in Boki local government Area of Cross River State, Nigeria. *American Journal of Environmental Engineering*, *4*(5), 94–98.

Ehrlich, P. R., & Holdren, J. P. (1971). Impact of population growth. *Science*. *New Series*, *171*(3977), 1212–1217.

Gregory, P. J., Ingram, J. S. I., & Brklacich, M. (2005). Climate change and food security. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *360*(1463), 2139–2148. doi:10.1098/rstb.2005.1745

Harte, J. (2007). Human population as a dynamic factor in environmental degradation. *Population and Environment*, *28*(4–5), 223–236. doi:10.100711111-007-0048-3

Hayden, D. (2004). *A field guide to sprawl*. New York: W.W. Norton and Company.

Horizon: Future issues for development. (2009). *Population growth, environment and food security: What does the future hold?* Author.

Intergovernmental Panel on Climate Change (IPCC). (2001). *Climate change 2001: Synthesis report*. Retrieved July 5, 2016, from https://www.ipcc.ch/ipccreports/tar/vol4/english/

Intergovernmental Panel on Climate Change (IPCC). (2007). *Climate change 2007: Synthesis report*. Retrieved December 16, 2015, from http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm>

Intergovernmental Panel on Climate Change (IPCC). (2014). *Climate change 2014: Synthesis report*. Retrieved July 5, 2016, from https://www.ipcc.ch/report/ar5/syr/

Lal, D. (2006). India: Population change and its consequences. *Population and Development Review*, *32*(1), 145–182. doi:10.1111/j.1728-4457.2006.tb00006.x

Nagdeve, D. A. (2002, June). *Environment and health in India.* Paper presented at the IUSSP Regional Population Conference on 'Southeast Asia's Population in a Changing Asian Context, Bangkok, Thailand.

Naylor, R. L., Bonine, K. M., Ewel, K. C., & Waguk, E. (2002). Migration, markets, and mangrove resource use on Kosrae, Federated States of Micronesia. *Ambio*, *31*(4), 340–350. doi:10.1579/0044-7447-31.4.340

Pimentel, D. (2011). World overpopulation. *Environment, Development and Sustainability*, *14*(2), 151–152. doi:10.100710668-011-9336-2

Rosnick, D. (2014). *The consequences of increased population growth for climate change. CEPR Reports and Issue Briefs 2014-18. Center for Economic and Policy Research*. CEPR.

Ruttan, V. W. (1993). Population growth, environmental change and innovation: Implications for sustainable growth in agriculture. In C. L. Jolly & B. B. Torrey (Eds.), *Population and Land Use in Developing Countries*. Washington, DC: National Academy Press.

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Sala, O. E., Chapin, F. S. III, Armesto, J. J., Berlow, E., Bloomfield, J., Dirzo, R., & ... (2000). Global biodiversity scenarios for the year 2100. *Science*, *287*(5459), 1770–1774. doi:10.1126cience.287.5459.1770

Tun, K., Chou, L. M., Cabanban, A., Tuan, V. S., Philreefs, Y. T., Suharsono, S. K., & Lane, D. (2004). Status of coral reefs, reef monitoring and management in Southeast Asia. In C. Wilkinson (Ed.), Status of Coral Reefs of the World (Vol. 1, pp. 235-275). Townsville, Australia: Australian Institute of Marine Science.

United Nations, Department of Economic and Social Affairs, Population Division. (2009). *World population prospects: The 2008 revision population database*. Retrieved December 23, 2015, from: esa.un.org/unpp

United Nations, Department of Economic and Social Affairs, Population Division. (2010). *World population prospects: The 2010 revision*. Retrieved from http://esa.un.org/unpd/wpp/index.htm

United Nations, Department of Economic and Social Affairs, Population Division. (2015). *World population prospects: The 2015 revision*. New York: United Nations.

Vinod, H. D. (2013). Newborn sex selection and India's overpopulation problem. *Modern Economy*, *4*, 102–108. doi:10.4236/me.2013.42013

Wackernagel, M., & Rees, W. (1995). *Our ecological footprint: Reducing human impact on the Earth*. New Society Publishers Philadelphia.

Wilkinson, C. (2008). *Status of coral reefs of the world: 2008*. Townsville, Australia: Global Coral Reef Monitoring Network and Reef and Rainforest Research Centre.

WWF/ZSL. (2012). *Living planet report.* WWF and the Zoological Society of London. Retrieved on December 23, 2015, from: wwf.panda.org/about_our_earth/all_publications/living_planet_report/2012_lpr/

KEY TERMS AND DEFINITIONS

Mortality Rate: It denotes the death of individuals per unit time.

Natality Rate: It represents the birth of individuals per female per unit time.

Red Tapism: It denotes the requirement of excessive paperwork for any work, that usually prevent or delay decision making process in bureaucracy.

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