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Opportunities and Strategic Use of Agribusiness Information Systems

Ferdinand Ndifor Che, Kenneth David Strang,
and Narasimha Rao Vajjhala

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This chapter provides an introduction to agricultural and farm management information systems. This chapter provides an overview of the components, subsystems, processes, and operations in agricultural information systems. This chapter also covers the impact of these systems in improving the efficiency, and productivity of farm output. This chapter introduces several technologies related to the use of information systems in agriculture, including agricultural information systems (AIS), farm management information systems (FMIS), e-agriculture, and precision agriculture. This chapter introduces state-of-the-art technologies used in agriculture in the current context apart from providing an introduction to the use and adoption rates of these information systems. This chapter concludes with a brief discussion on the issues facing the adoption and implementation of agricultural information systems and presents some of the key issues that decision makers need to take to improve the acceptance and use of these information systems.

Lower agricultural productivity levels in Africa calls for transformation of the sector from its historical level to a high potential, sustainable, and ecologically business-oriented sector. This chapter reviews the relevant literature on agribusiness in relation to use of innovation and value addition approach. The review first gives a background of conceptual understanding of the main terms and presents some case studies and efforts done until now. Transformation is happening across the globe through value addition, agribusiness principles and application of knowledge, innovation-driven solutions, and digitalization. Research for development and efficient advisory services are among the key factor of success.

The oil boom of the 1970s in Nigeria has negatively impacted the young generation's psychology about agriculture. This has led to a continued drain of workforces. The general view on agriculture is of a 'murky' business, as such always relegated within choices. Myriad programs and projects are being rolled out to revamp agriculture and attract youth in Nigeria. However, they remain largely with insignificant positive results and most of them with little or no deliberate appeal strategy towards enchanting youth. This research analyses the level of youth involvement in agribusinesses in Jigawa, describes and analyses ICTs landscape, then presents innovative approaches towards enchanting youth for agri-preneurial enterprises. Purposive sampling was used to select locations of data collection while convenient sampling was employed to elicit data. Results reveal that the youth entrepreneurial involvement is towards marketing, while a robust ICTs platform exist for supporting enterprises. Also, three packages were drawn and presented for the promotion of agri-prenuership in Nigeria.

The absence of well-developed agricultural information systems (AGRIS) has continued to hinder agricultural development in Africa. Efforts designed to modernize agriculture through AGRIS by the public and private sectors have been hindered by administrative bottlenecks, weak political will from governments, display of ineptitude by farmers/associations, and institutional corruption. In view of the foregoing, this chapter discusses AGRIS as a catalyst for SDGs in Africa. An effective AGRIS will strengthen decisions on the general management of the agricultural sector. Deploying the AGRIS for the management of agriculture will boost food production, increase the GDPs and directly strengthen the actualization of SDG 1, SDG 2, SDG 3, SDG 8, SDG 9, SDG 10, SDG 11, SDG 12, SDG 14, SDG 15, SDG 17, and indirectly impact other SDGs. Ultimately, this chapter suggests leveraging AGRIS for mitigating all the identified challenges to agricultural development in the continent.

India's agri-food value chains have been evolving over the last few decades to cater to the growing consumer demand for healthy, safe, and nutritious food. These value chains are increasingly getting integrated from production to marketing to cater to such demand. While large and/or commercial farmers have easy access to such modern food value chains, small and marginal farmers in India and other developing countries alike are unable to take advantage of the same. Focusing on improving the agri-food value chains, particularly for perishables, makes a strong case in India given most Indian farmers are small and marginal farmers and are unable to take advantage of economies of scale. It is encouraging that both public and private sector entities are getting engaged in connecting Indian farmers directly to the supply chains of various crops. However, more needs to be done to make the processes, particularly in the public sector, the least bureaucratic and more farmer-focused so that small and marginal farmers in particular, benefit widely.

The use of portable applications in the primary sector is undoubtedly an innovation that offers a truly important tool that helps farmers to utilize their farms and an approach to enhance agricultural entrepreneurship systematically and effectively. The chapter examined 10 agribusiness in the region of Western Greece and their owners were asked to manage their farms with the help of a "farm management" application for a period of 4-6 months. This case study focuses on assessment of mobile application usability. It examines the matter of evaluating the usability of mobile applications and is mainly aimed at evaluating a "proposal" to systematically record the technical and financial data of a farm using a farm management system. The results show that users find that the most important feature of mobile applications is the ease of use and utility.

The aim of this work is to discuss the ways risk may affect farm investments in ICT-based technology such as precision agriculture (PA) technologies and to establish how to better incorporate risk and uncertainty into cost-benefit analyses, in order to calibrate the estimated expected net present value from farmers' investments. To properly measure the factors underlying risk in agriculture it is essential to collect a proper piece of data and information from technology, market, and institutions. However, it is somehow hard to rely on historical information about PA technologies as they have appeared on the market in a recent time. Thus, in this work an ad hoc methodology useful to aid risk-averse farmers is developed, dealing with the estimation of financial parameters like discount rates, economic life of technology, and residual values at the end of the period for which benefits are considered.

Preface

This book was inspired by the desire to generate sound and relevant insights, frameworks, and tools to aid agricultural industry practitioners, smallholder farmers, managers of agricultural extension systems, academic researchers, and other stakeholders, towards making more effective and responsible decisions in the quest to achieve food security and poverty reduction in developing countries. Agriculture has a massive social and economic footprint in developing countries because it is the main source of employment, livelihood, and income for between 50 and 90% of the population. Over 70% of the farming population in some developing countries are smallholder farmers. In Sub-Saharan Africa, smallholder farmers make up more than 60% of the population, and the agriculture sector's contribution to the region's GDP is about 23%. Africa's agricultural potential is still untapped. Realizing Africa's agricultural potential will require significant investment, primarily to increase smallholder farmers' productivity, provide basic infrastructure, improve markets and cost competitiveness for local food crops, and to develop agribusinesses that are more attractive to the younger educated population.

The world population continues to grow, and most of that growth is in developing countries. In Sub-Saharan Africa, hunger and poverty remain major concerns. These problems are largely attributed to a multitude of factors, including poor economic conditions, conflict, climate variability, drought, floods, lack of technology adoption, terrorism, and or corruption. To have a fighting chance of overcoming hunger and malnutrition by 2030, nutritious food production must grow to match Sub-Saharan Africa's population growth. At the same time, agriculture is becoming increasingly knowledge intensive. The information needs of farmers in developing countries have increased and it important for these farmers to make effective and responsible decisions about crop planning, inputs, farm operations, and markets. But smallholder farmers in developing countries must face up to some challenges such as low levels of human capital, poor access to education, low levels of skill, poor infrastructure and limited access to markets and financial services.

The contributing chapters examine the role of agribusiness information systems in advancing sustainable growth in the agricultural sector, overcoming the food insecurity, and other problems in Africa. The authors explore the challenges that hinder the effective adoption of agricultural information systems and evaluate opportunities for the strategic deployment of ICTs and information systems to drive agricultural development for the benefit of agricultural sector stakeholders in developing countries. The authors provide helpful insights, relevant frameworks, and tools to aid agricultural industry practitioners, smallholder farmers, managers of agricultural extension systems, academic researchers, and other stakeholders concerned with exploiting a variety of ICTs and information systems to tackle food insecurity.

In Chapter 1, Narasimha Vajjhala introduces agricultural information systems and explores the components, subsystems, processes, and operations involved in agricultural information systems and the impact of these systems in improving the efficiency, and productivity of farm output. He provides an overview of several state-of-the-art technologies related to the use of information systems in agriculture, including agricultural information systems (AIS), Farm Management Information Systems (FMIS), e-Agriculture, and precision agriculture. Vajjhala also provides a brief discussion of the issues facing the adoption and implementation of agricultural information systems and presents some of the key issues that decision-makers need to take to improve the acceptance and use of these information systems.

In Chapter 2, Osman Babikir provides an overview of agribusinesses, agribusiness innovation systems, and the digitization of agriculture in Africa and the linkages with sustainable development. He examines agricultural value chains in Africa and discusses the justification for leveraging agribusiness innovation systems to transform Africa's agricultural sector through increasing agricultural productivity as a catalyst for economic growth and sustainable development.

In Chapter 3, Kenneth Strang, Ferdinand Che, and Narasimha Vajjhala present an empirical analysis of the factors underlying the agribusiness adoption barriers and food insecurity. The authors put forward possible remedies and what is needed to resolve the agriculture problems which could be of interest to other scholars. They offer several conceptual models to assist future agriculture research scholars, including keyword thematic diagrams, cross-case subject analysis, topic contingency analysis, and literature topic synthesis.

In Chapter 4, Rajasekhara Potluri and Narasimha Vajjhala explore the significance of ICTs and the e-readiness situation of Nigeria in the field of agri-business. The authors discuss the e-readiness challenges faced by the farmers and extension worker communities in North-East Nigeria, including lack of electricity, training facilities, lower literacy rates, language and cultural restrictions, lack of awareness campaigns, expensive telecom services. They also highlight the opportunities to attract youth in agriculture because they more readily adopt ICTs.

In Chapter 5, Hashmi Sakib, Safiul Afrad, Ahmed Harun-Al-Rashid, and Golam Kausar provide an overview of the role that agribusinesses play in the sustainable social and economic development of rural poor in South Asia. The authors discuss the challenges facing the agricultural sectors in South Asian countries and how agribusinesses provide opportunities for improvements in agricultural production, income generation for rural farmers, and support of rural farmers' livelihoods. They provide insights that could be helpful for policymakers and other agricultural stakeholders, including the private and public sectors, as they come together to overcome agricultural sector challenges.

In Chapter 6, Bashir Muktar, Norsida Man, and Martins Orifah discuss the challenges hindering the success of programs aimed at attracting the youth to the agricultural sector in developing countries. The authors identify a myriad of programs and projects that are being rolled out to revamp the agriculture sector and to attract the youth in Nigeria. The analyze the level of youth involvement in agribusinesses and the ICTs landscape in Jigawa State. They explore some innovative approaches that have the potential to attract the youth or agripreneurs to agribusiness.

In Chapter 7, Lukman Raimi, Ferdinand Che, and Mutiu Rufai explore the nature and components of agricultural information systems and related multidimensional benefits. The authors dissect the challenges of agricultural information systems, some practical decision-making frameworks, and explore how agricultural information systems can be used as a catalyst for sustainable development (SDGs) in Africa. They argue that the deployment of ICTs and agricultural information systems is crucial in ushering in the innovation necessary for the continent to achieve its agricultural potential and strengthen decisions regarding land use, labor force utilization, livestock, capital resources, and general management in the agricultural sector.

In Chapter 8, Dipanjan Kashyap and Sanjib Bhuyan discuss how the agri-food value chains in developing countries such as India have evolved to cater to the growing consumer demand for healthy, safe, and nutritious food. The authors highlight how the agri-food value chains are becoming more and more integrated from production to marketing to cater to demand that is driven by urban consumers whose income has been rising over the years and who are willing to pay a premium for quality and safe food. They argue that while large farmers and/or commercial farms and farmers have easy access to such a modern food value chain, because of economies of scale, small and marginal farmers in India and other developing countries are unlikely or unable to benefit from such growing high-value agri-food food chains. They assert that there is a golden opportunity to transform the Indian agri-food system to satisfy the needs of the consumers and benefit the farmers, particularly small and marginal farmers.

In Chapter 9, Alexandra Pliakoura, Grigorios Beligiannis, and Achilleas Kontogeorgos present an assessment of mobile applications for enhancing agricultural entrepreneurship as an innovation to help farmers optimize farm productivity. The authors evaluate the usability of mobile applications that systematically record technical and financial farm data used by a farm management system. Their findings indicate that the most important feature of mobile applications for farm users is the ease of use and usefulness.

In Chapter 10, Marco Medici and Maurizio Canavari discuss how risk affects farm investments in ICT-based technology such as precision agriculture (PA) technologies and elaborate on how to incorporate risk and uncertainty into cost-benefit analyses in order to calibrate the expected net present value from farmers' investments. The authors identify several types of risks and uncertainties in agricultural production, the value chain, markets, and technology. They also provide helpful insights on how farmers may be able to effectively factor risks associated with technologies or agricultural information systems into farm investment decisions.

In Chapter 11, Samwel Chege and Daoping Wang discuss the concepts of innovation and technology transfer as the main driver of agribusiness performance and economic development in developing countries. The authors dissect various economic strategies aimed at strengthening the flow of information and technology between innovators, national institutions, and industries. They also analyze the impact of transferring technology and innovation from the research and development sector to the industry and the challenges facing agribusinesses in developing countries. They make the case that linkages between research institutions and agribusinesses are critical for economic development and to guarantee food security, and that more financial support is needed to forge stronger linkages between research institutes and agribusiness enterprises.

In Chapter 12, Sreekantha Karanam and Anantha Achar propose the establishment of a Digital Kissan Hub to promote digitization in agriculture and the agribusiness sector. Kissan is a Hindi word for farmer. The authors discuss some key advantages of the proposed digital hub, including reducing the impact of middlemen in agribusiness and allowing the farmers direct access to markets. The authors further assert that the adoption of digital and modern technologies can bring many benefits to farmers, such as increased crop yield, enhanced profitability, reduced environmental footprint, and access to new markets without too high an investment.

In Chapter 13, Jibril Bala, Olayemi Olaniyi, Taliha Folorunso, and Emmanuel Daniya present the design of an autonomous robot system for chemical weed control, which relies on control theory, artificial intelligence, and image processing to navigate a farm environment, effectively identify weeds, and apply herbicides. The authors assert that the system has the potential to increase agricultural productivity with minimal human input, and lead to an increase in revenue and profit for agribusinesses.

In Chapter 14, Bamigboye Funmilayo and Emmanuel Ademola present the role of the Internet of Things (IoT) and modern improved farming practices in large-scale production of crops and animals. The authors discuss how the utilization of IoT sensors can improve agricultural productivity and crop yield and that IoTs play a critical role in smart agriculture and farming. The authors argue that IoTs can be used to facilitate crop and animal health assessment and monitoring, agricultural drone services, crop and livestock production and management, digital information platforms, marketing, and online trading of agricultural products. They also argue that IoTs can make agriculture more attractive to or draw young agripreneurs to the agriculture sector.

The themes explored in the chapters range from exploring the context and controversies associated with the deployment of agricultural information systems to develop the agricultural sector in developing countries, examining the key challenges that hinder the adoption of agricultural information systems, dissecting decision-making frameworks and process improvements, to evaluating various opportunities for the strategic deployment of ICTs and information systems to drive sustainable agricultural development in developing countries. The topics and themes explored provide sound and relevant frameworks and tools to aid agricultural industry practitioners, smallholder farmers, managers of agricultural extension systems, academic researchers, and other stakeholders in making more effective and responsible decisions when selecting, planning, deploying and managing agribusiness information systems.

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Chapter 1
Introduction to Agricultural Information Systems

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ABSTRACT

This chapter provides an introduction to agricultural and farm management information systems. This chapter provides an overview of the components, subsystems, processes, and operations in agricultural information systems. This chapter also covers the impact of these systems in improving the efficiency, and productivity of farm output. This chapter introduces several technologies related to the use of information systems in agriculture, including agricultural information systems (AIS), farm management information systems (FMIS), e-agriculture, and precision agriculture. This chapter introduces state-of-the-art technologies used in agriculture in the current context apart from providing an introduction to the use and adoption rates of these information systems. This chapter concludes with a brief discussion on the issues facing the adoption and implementation of agricultural information systems and presents some of the key issues that decision makers need to take to improve the acceptance and use of these information systems.

INTRODUCTION

Agricultural activity has evolved over the years from being a simple production activity to a multi-functional sector. Apart from following governmental regulations and guidelines on the use of agrochemicals, food safety, and animal welfare requirements, agricultural sector is now influenced by liberalization of international markets (Husemann & Novković, 2014). According to Okediran (2019), agriculture is an information-intensive industry where there is a continual need for updated information about the agricultural inputs, market information, and logistics. Farmers need updated and accurate information to make informed decisions that can enhance their agricultural productivity (Okediran, 2019).

Agricultural innovation can lead to reduction in poverty through direct and indirect effects (Berdegue & Escobar, 2001). Agricultural Information Systems (AIS) can help meet farmers' information needs,

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including agricultural inputs, education on extension programs, knowledge on agricultural technology, credit programs, and marketing information (Lu, Pan, Lu, Qin, & Wang, 2015). One of the examples of direct effects is through the adoption of new technologies, which can improve the income of the farmers when they reduce the marginal cos of producing one unit of output (Berdegue & Escobar, 2001). Indirect effects of technology on poverty reduction include the benefits of lower food prices because of higher agricultural productivity, and the increased employment (Berdegue & Escobar, 2001).

Agricultural information systems can help in disseminating information to farmers to enable them make better decisions and leverage market opportunities. Agricultural productivity can also be improved through relevant and reliable data as well as knowledge. In this chapter, an introduction to various information systems used in agriculture is provided. The next section in the chapter is the background of the various agricultural information systems, followed by a discussion on the issues influencing the adoption and use of various information systems in agriculture sector.

BACKGROUND

Agricultural information systems have been defined as an information system in which agricultural information is generated, transformed, and consolidated with the intention of underpinning knowledge utilization by agricultural producers (de Oliveira, Painho, Santos, Sian, & Barriguinha, 2014). The AIS consists of subsystems, processes, mechanisms and system operations (Vidanapathirana, 2012). The users of AIS could include the government decision makers, policy makers, universities, researchers, extension workers, and farmers (Vidanapathirana, 2012).

In the late nineties, the term precision agriculture or wired farms came into existence. These terms grouped several technologies, including Global Positioning Systems (GPS), Geographical Information Systems (GIS), and other state of the art technologies (Husemann & Novković, 2014). The advent of precision agriculture led to increasing amount of data being generated leading to the development of several Decision Support Systems (DSS), that were helping farmers make informed decisions. Some of the examples of specialized agricultural DSS, include Dairy Comp 305 - for herd management of milking cows, and DSSAT - tool for land cultivation etc. (Husemann & Novković, 2014). Precision agriculture as well as the use of AIS can help reduce the cost of agricultural production, minimize the pre-cultivation time, and increase the agricultural productivity (Santoso & Delima, 2017).

Another term that is often used in conjunction with AIS is Farm Management Information Systems (FMIS). Farmers often do not have access to tools to help them in financial management of their business. FMIS are information systems that facilitate the storing and processing of farm-related data providing farmers support in decision making in daily farm management (de Oliveira et al., 2014). FMIS could be a part of AIS, or could also be considered as an extension to AIS as these systems provide information required not just for agricultural activities but also some of the supporting activities. Some of the available commercial FMIS, include Agworld, FarmWorks, and 365FarmNet (de Oliveira et al., 2014).

Sørensen et al. (2010) defined Farm Management Information Systems (FMIS) as a planned system of collecting, processing, storing, and disseminating data in a form needed to carry out farm-related operational functions. FMIS are essential parts of farming enterprises because farming has evolved from simple production tasks to businesses with multifunctional sectors (Paraforos et al., 2017). FMIS assist in the storage and processing of farm data for everyday farm management. Some of the popular FMIS, include 365FarmNet, AgriWebb, AgWorld, and FarmWorks (Paraforos et al., 2017).

FMIS support the various domains of the agricultural sector, including dairy farming, crop management, field management, and financial management (Tummers, Kassahun, & Tekinerdogan, 2019). FMIS have evolved in the last decade from simple farm record-keeping into advanced complex systems helping in strategic decision making and handling several essential aspects, including managing production costs, compliance with agricultural standards, offering simulation, and decision-making tools, as well as weather forecasting capabilities (Rupnik et al., 2019).

Another important term is an extension of AIS, also referred to as Agricultural Knowledge and Information Systems (AKIS). This term, initially coined by Roling (1988) refers to information systems linking people and institutions and promoting the generation and sharing of agriculture-related technology, information, and knowledge (Gichamba & Lukandu, 2012). Several countries in Africa developed AKIS meeting their localized needs, as these systems are more accessible when the content is offered in local languages and at an appropriate technical level for the rural community to understand and use (Semeon, Garfield, Meshesha, & David, 2013). The success of AKIS depends on the ability of these systems to motivate farmers to trust and use these systems (Semeon et al., 2013).

Another term often used to refer to the use of ICT in agriculture is e-agriculture. E-Agriculture refers to the need to transfer knowledge and experience in the use of ICT in agriculture (Novković, Vasiljević, & Matković, 2013). Kumar et al. (2019) defined e-agriculture as the use of information and communication technology and processes to improve agricultural and rural development. This also includes the processes of conceptualization, design, development, evaluation as well as application of ICT in agriculture (Novković et al., 2013). E-agriculture is more of a philosophy or methodology rather than a set of technologies. E-Agriculture is encouragingly used to promote this way of thinking, especially among the farming communities in Asia and Africa that are yet to use ICT in the farming activities.

AIS can also be a contributing factor towards the use of information and communication technologies for development (ICT4D) (Okewu & Okewu, 2015). The ICT4D philosophy is essential to the development and growth of developing and emerging economies in Asia and Africa. Okewu and Okewu (2015) suggest four key areas integral to the ICT4D philosophy, namely, agriculture, education, health, and social security. E-Agriculture is an essential component of the larger ICT4D philosophy. The next section in this chapter will elaborate various agricultural information systems as well as introduce some of the factors influencing the adoption and use of these information systems among the farming communities.

Agricultural Information Systems

Ahmadvand and Karami (2011) state that there are three main elements of an AIS, namely, research, extension, and user subsystems. They also emphasize on two major dimensions of AIS, namely, the creative dimension and the interactive dimension. The creative dimension dealt with how the agricultural problems are identified and the interactive dimension dealt with the role of various actors in the AIS. Both these dimensions must be identified and addressed to avoid any break in linkages in an AIS and also for the successful adoption and use of AIS by the farming community (Ahmadvand & Karami, 2011).

Successful implementation of AIS would require both access and usage of these information systems by the farming communities (Bitrus, Strang, & Vajjhala, 2019). Access to the systems is influenced partly by the requirement of adequate infrastructure, especially in the case of developing countries with infrastructural problems. Farmers would need adequate training and knowledge to operate most of these technologically sophisticated information systems. Bitrus et al. (2019) point out that while governments in developing countries invest on supporting the initial implementation of AIS, these programs may not succeed unless the continued use intention of the farmers' is assessed.

FMIS can help provide farm holders access agricultural information using digital technologies with a potential for increasing farm yield by 4% and also increase the chances of adopting the recommended farm yield by over 22% (Fabregas, Kremer, & Schilbach, 2019). The use of FMIS is more prevalent in large-scale farms as compared to small to medium sized farms. This is because of several reasons, including the lack of knowledge and the complexity of the existing FMIS (Husemann & Novković, 2014). The management aspect of FMIS, includes planning, organization, monitoring, and controlling of activities in farms (Husemann & Novković, 2014). FMIS, which initially emerged as simple record keeping systems that helped farmers, track their basic farming and accounting needs have gradually evolved with the emergence of smart farming and precision agriculture. Modern FMISs now offer advanced systems with modules supporting features, such as agricultural yield monitoring, automated information gathering, and farm management (Köksal & Tekinerdogan, 2019).

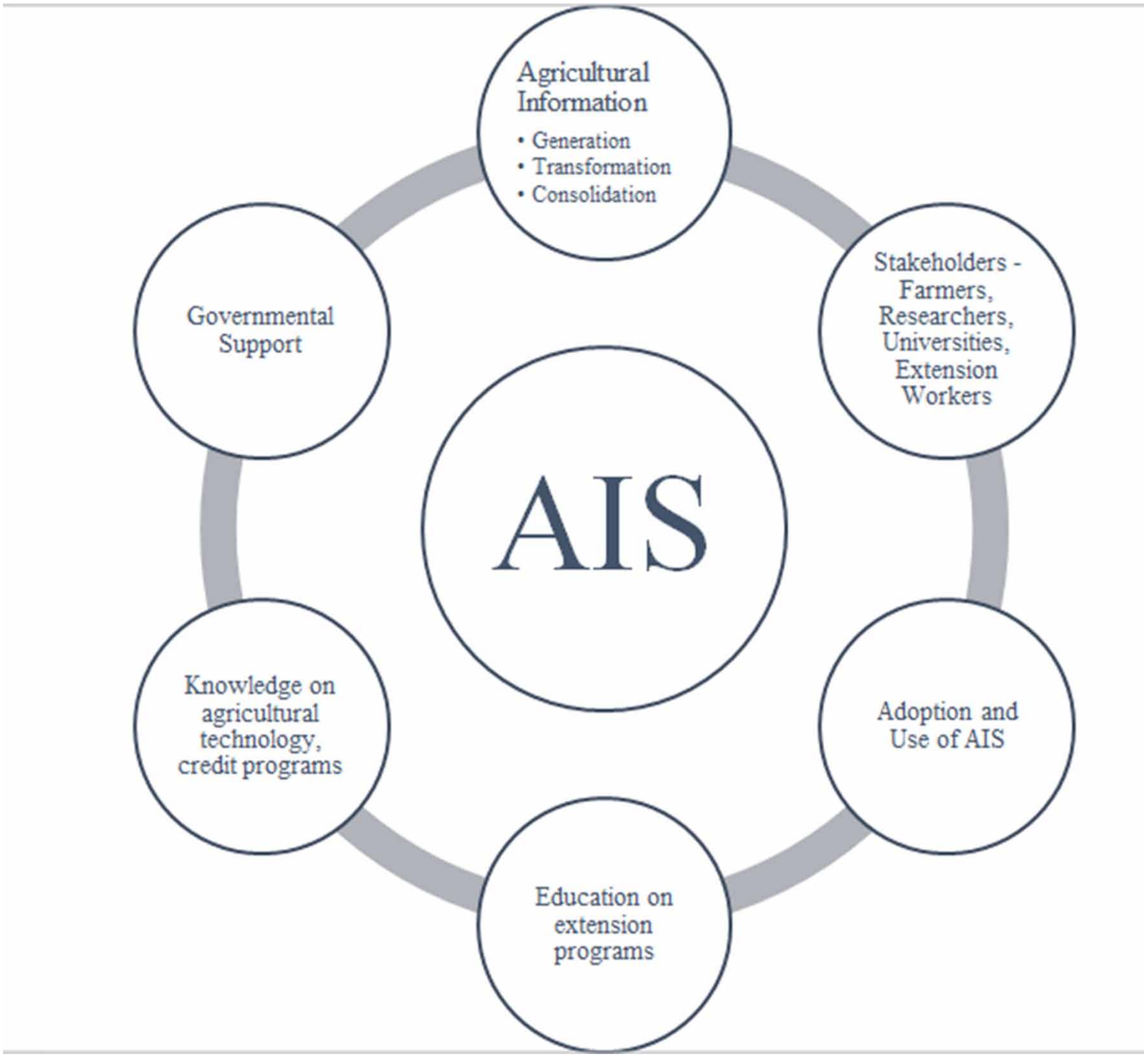
The AIS ecosystem is described in Figure 1. The primary component of the AIS ecosystem is the agricultural information. AIS primarily deals with the generation, transformation, and consolidation of the agricultural information needed to help the users of these systems. The next important actor in this ecosystem is the stakeholders, including the farmers, researchers, universities, academics, and extension workers. These information systems are not just used by the farming communities but also by universities and training institutions for training the users as well as researchers seeking to improve these systems.

Köksal and Tekinerdogan (2019) refer to the application of modern information and communication technologies (ICT), such as cloud computing, remote sensing, and Internet of Things (IoT) in agriculture to increase agricultural productivity as "smart farming". Precision farming can offer significant benefits to farmers. As an example, Erbschloe (2014) describes how precision farming can benefit farmers from the planting phase to the end of harvesting. Precision farming equipment and technology can help farmers in planting the seeds by controlling the amount of seed dispensed based on prior yield from a specific part of the field (Erbschloe, 2014). During harvesting, precision farming equipment, such as yield monitors can be used to record the harvest for each foot of the field (Erbschloe, 2014). Such vital information can provide the basis for future plantation as well as fertilizing activities. Miller, Grifn, Ciampitti, and Sharda (2019) classify the precision technologies into two categories, namely, embodied technologies and information intensive technologies. Farmers would not generally need any additional training for using the embodied knowledge technologies but would need additional skills and training for information intensive technologies, for instance precision soil sampling (Miller et al., 2019).

FMIS can help farmers by providing useful information on inputs, including land cost, labor work, fertilizers, pesticides, irrigation etc. The use of ICT tools can provide valuable information to farmers on the farm inputs and help them make informed decisions on activities, including which crops to plant well as which inputs to utilize based on farming as well as financial considerations.

Several international organizations, including the European Commission (EC) are focusing on creating software components and ICT tools that developers can use to create applications that can be used by the farming community (de Oliveira et al., 2014). For instance, EC launched the Future Internet Public-Private Partnership Program (FI-PPP) in 2011. The purpose of FI-PPP was to create a library of software components, referred to as Generic Enablers (GEs) to allow developers create applications. These applications use innovative technologies, including Internet of Things (IoT), big data analytics, and cloud computing (de Oliveira et al., 2014).

Figure 1. Agricultural Information Systems Ecosystem



One of the examples for innovative FMIS is the cloud-based FMIS called iFarma, which was developed by Agrotis Agricultural Information Systems in Greece (de Oliveira et al., 2014). iFarma was an integrated farm management application for individual as well as farmer cooperatives interested in performing precision agriculture through the use of mobile phones and modern technology (de Oliveira et al., 2014). These were some of the technologies and terms often used in the context of agricultural information systems. In the next section of the chapter, the issues involved in the adoption and use of agricultural information systems are discussed.

Issues With Adoption of Agricultural Information Systems

Although AIS and FMIS have been in existence and have evolved over the last three decades, the use and adoption of these information systems has not been uniform. There is a significant difference in the adoption and usage rates between developed and developing countries because of obvious infrastructural and financial issues. However, there are several other factors as well that are influencing the lower rates of adoption of these information systems. In this section of the chapter, the major issues and factors influencing the adoption rates are discussed.

The adoption of new agricultural technologies is often very slow by farmers as the research is often not focusing on the actual needs of the farmers and the link between the research and advisory services is also very poor (Vidanapathirana, 2012). Some of these information systems are developed in developed countries and address country-specific and region-specific issues. These issues are not applicable in several developing countries in Asia and Africa. Hence, the rates of adoption are low as the farming communities do not relate to these issues.

The slow adoption rates are also partly because of the ineffective technology delivery systems and poor methodologies adopted that do not meet the actual needs of the local farming community (Vidanapathirana, 2012). For instance, in Africa and Asia, the role of agricultural extension workers is quite important and farmers prefer face-to-face interaction with the extension workers. Hence, the extension workers need to be extensively trained and their feedback must be taken into consideration before implementing the information systems. Prior research has also indicated that agricultural information systems in agricultural fields have exhibited lower performance as compared to industrialized fields and industries (Lee & Park, 2017).

Governmental support is essential for the success of AIS as information about a number of public resources, including climate, weather, soil, and water apart from information about national policies on labor laws, ownership, and insurance is involved (Lu et al., 2015). Governmental support, especially from the higher echelons of the government is quite essential to motivate and ensure that the level of implementation is supported at the remaining medium- and lower-levels of the public administration. Adequate budgetary allocation and oversight will only be possible if there is a proper buy-in from the administrators in the higher levels of the government. Also, there should be adequate support from the international organizations funding these initiatives in the developing countries. The issue of digital divide comes up in the implementation and use of AIS. Digital divide is higher especially, in the developing and emerging economies where the farming community does not have either the resources or knowledge needed to access the AIS (Lu et al., 2015).

The adoption of the agricultural information technologies is usually a two-part decision-making process (Tambo & Abdoulaye, 2012), namely, the decision on whether to accept technology, and if yes, then how much technology to adopt? Several factors influence the adoption of technology by farmers, including education of farmers, access to agricultural extension, and exposure to the explanation on change in productivity (Shiferaw, Kebede, Kassie, & Fisher, 2015). The Technology-Organization-Environment (TOE) framework suggests that the individual behavior on the adoption of a technology depends on three factors, namely, technological, organizational, and environmental (DePietro, Wiarda, & Fleischer, 1990). Technological factors include both the internal as well as external tools and technologies as well as processes (Junior, Oliveira, & Yanaze, 2019). The environmental factors include the size and industry composition, competition, and governmental rules (Junior et al., 2019). The organizational context includes the resources and assets of the company, including the administrative structure of the company as well as the resources in the company.

A key issue in the use and adoption of AIS is that farmers often do not send data to the systems as they do not believe that there is any benefit for them in doing so (Lombardelli et al., 2020; Sutoyo & Sensuse, 2018). This is because of several reasons including lack of computers, smartphones and other technologies apart from lack of proper implementation incentives by the government. Sutoyo and Sensuse (2018) suggest the use of a gamification approach involving game-thinking and game mechanics to engage users in solving problems. The purpose of gamification in this case is to promote intrinsic motivation toward various activities for the farmers and motivate them in participation in adoption and use of the information systems. The gamification approach also addresses the issue of lack of education among farmers about the best practices in the industry in the context of AIS and FMIS (Markopoulos, Chan, & Ming, 2019). Markopoulos et al. (2019) give the example of Riceville which is a simulation game intended to promote the use of effective best practices introduced by international organizations. Gamification could be a potential solution for policy makers and organizational leaders in improving the acceptance and usage rates of both AIS and FMIS.

The prior experience of an individual in using technology is an integral part of technology acceptance, adoption, and use. Carrer, Filho, Batalha, and Rossi (2015) state that while there may be initial benefits for farm owners using information systems as compared to their counterparts who are not using information systems, these benefits may not continue in the long-term unless the adoption and usage of these information systems are continual. The adoption and continued usage of FMIS depend on several factors, including the farmers' training and proper processing of farm information using these systems. Kazeem, Dare, Olalekan, Abiodun, and Komolafe (2017) state that training of farmers is quite essential for ensuring higher levels of adoption and usage of agricultural technological innovations. Kazeem et al. (2017) emphasize that apart from training, the farmers' attitude towards training is equally important; in particular, the perception of farmers about the constraints to training on technologies.

Another factor that could influence the decision of a user to use a particular technology is the belief of the user in using a particular technology, also referred to as self-efficacy. Tarhini, Elyas, Akour, and Al-Salti (2016) categorize self-efficacy into two categories, namely, general computer self-efficacy and task-specific computer self-efficacy. Self-efficacy is important as higher levels of self-efficacy are likely to lead to better user experience in using a technology contributing to higher chances of acceptance and adoption of the technology. Higher self-efficacy will lead to higher levels of confidence in using technology, and users should be more willing to adopt and use technology (Tarhini et al., 2016). Hence, if farmers are provided with adequate training in the use of technology before they are exposed to FMIS, they are likely to react positively to these technologies as they would be familiar with the basics of general and specific technology use.

Tambo and Abdoulaye (2012) suggest that the understanding of the incentives and constraints of the adoption of the technology are essential to understand the factors impacting the adoption of agricultural and farm technology. In order to motivate the farming community to adopt agricultural technology, the efforts should be complemented with corresponding attempts to improve the contact with extension agents, access to credit facilities, and educational background as well as training. Zhang, Wang, and Duan (2016) identified several barrier factors hindering the deployment and utilization of information technology-based systems in agriculture including lack of technical support staff, limited knowledge sources, poor infrastructure, and lack of adequate quality controls.

Considering the benefits of using AIS, the use of AIS is still low in developing countries in Asia and Africa (Santoso & Delima, 2017). Some of the reasons include the lack of willingness of the farmers to change the way they cultivate and process their fields (Santoso & Delima, 2017). This is partly because of the high cost in accessing the required equipment and technology apart from infrastructural issues.

Land administration and evaluation is one of the key aspects of agricultural information systems. Land administration helps in providing key information about the land, including the property address and transportation network while land evaluation deals with the process of assessing the potential production for various land uses (de Oliveira et al., 2014).

Other factors influencing the decision to adopt and use AIS also include demographic factors, such as the age, income level, and educational level of the farmers apart from operational and technical skills (Lu et al., 2015). The link between research institutions, extension workers, and the farming community needs to be strong for any new agricultural technology to be accepted and used (Vidanapathirana, 2012). The evolving nature of agricultural information systems and technology also requires researchers to continually explore and identify the factors influencing the adoption and the use of these information systems. Shah and Soror (2019) emphasize on the need for replicating established research in new contexts to establish the boundaries of the work as well as explore the possible avenues for extension of the work. Hence, further work is required in the field of AIS and FMIS to validated some of the established literature and also explore further avenues for extension of the work in these fields. This section of the chapter dealt with some of the major issues influencing the adoption and the use of the information systems in agriculture.

CONCLUSION

This chapter was an introduction to agricultural and farm management information systems. There are several terms that are often interchangeably used, including precision agriculture, e-agriculture, AIS, FMIS, and smart farming. There are subtle to major differences in these terms which were elaborated in this chapter. This chapter also covered how AIS and FMIS can be used to improve the efficiency and productivity of farm output. Several examples were provided in this chapter about various AIS and FMIS that are currently in use. This chapter also included a discussion on the adoption and use of these information systems and the factors contributing to the varying levels of adoption and use across different geographical regions. This chapter also included several recommendations for decision and policy makers on how to improve the implementation and acceptance of these information systems across the agricultural sector. This introductory chapter forms the basis for the remaining chapters of this book focusing on various key issues involving agricultural information systems.

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KEY TERMS AND DEFINITIONS

Agricultural Information Systems: Information system in which agricultural information is generated, transformed, and consolidated with the intention of underpinning knowledge utilization by agricultural producers.

Agricultural Knowledge and Information Systems: Information systems linking people and institutions and promoting the generation and sharing of agriculture-related technology, information, and knowledge.

E-Agriculture: The philosophy emphasizing on the need to transfer knowledge and experience in the use of ICT in agriculture.

Extension Worker: An experienced farmer, selected and hired by the government to mentor and train local farmers, using their credibility as a farmer to approach their clients.

Farm Management Information Systems: A planned system of collecting, processing, storing, and disseminating data in a form needed to carry out farm-related operational functions.

Precision Agriculture: Group of several technologies, including Global Positioning Systems (GPS), Geographical Information Systems (GIS), and other state of the art technologies.

Chapter 2
Agribusiness and Innovation Systems in Africa:
A Survey of Evidence

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ABSTRACT

Lower agricultural productivity levels in Africa calls for transformation of the sector from its historical level to a high potential, sustainable, and ecologically business-oriented sector. This chapter reviews the relevant literature on agribusiness in relation to use of innovation and value addition approach. The review first gives a background of conceptual understanding of the main terms and presents some case studies and efforts done until now. Transformation is happening across the globe through value addition, agribusiness principles and application of knowledge, innovation-driven solutions, and digitalization. Research for development and efficient advisory services are among the key factor of success.

INTRODUCTION

In his book ''Why Africa is Poor and What Africa Can Do About It'', Greg Mills (2010) argued that the main reason why Africa's people are poor is that their leaders have made this choice. Despite many African states possessing natural advantages, 35 of 48 Sub-Saharan economies were net food importers at the end of the 2000s. While agricultural yields have tripled in East Asian countries and doubled in Latin American countries since the 1970s, Africa has lagged well behind (Mills, 2010).

In Africa, more than 60% of the people living in rural areas depend on agriculture as their mainstay; however, agricultural productivity often remains very low compared to international standards. These low productivity levels, among other factors, are the main reason why researchers, development practitioners, and policymakers call for the transformation of the sector from a historical subsistence level of production to a high potential business-oriented sector to drive and achieve sustainable levels of socio-economic development.

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In industrialized economies, such as the US, EU, Australia, and New Zealand, agriculture usually accounts for less than 10% of GDP and less than 15% of the workforce. Markets are domestically and internationally oriented; output mixes are highly diversified with a well-developed processing sector providing opportunities for value addition. The agricultural systems are highly mechanized and scale economies are quite pronounced. Differentiated products flow through well-organized value chains, and commodity markets maintain basic safety standards through regulation (Kinsey and Senauer, 1996).

In modern economies (Asia, Latin America, and Central and Eastern Europe), the agricultural sector accounts for a 10-30 percent share of the economy and a 15-50 percent share in the workforce. In these countries, the majority of farmers produce for domestic markets; but both subsistence and export-oriented systems are present. Food systems are neither traditional nor industrialized but somewhere in between (McCullough et al. 2008). In Africa, there is a high degree of dualism between traditional domestic food chains and organized chains, whether domestic or export-oriented. Food safety standards for poor consumers are quite low. Another major problem is the vicious cycle of low surplus volumes constraining market development, which then reinforces the subsistence nature of low input production systems. In Sub-Saharan Africa, continued underinvestment of public goods supporting smallholder agriculture is likely to further widen the gap between traditional domestic markets and the formal processing and retail sector. Urban demand is increasingly met with imports rather than by domestic producers (Jayne, 2008).

Development is dependent on improving productivity. This is usually the result of a better combination of capital, labor and technology. Without investment in people, equipment and technology labor potential can be underutilized (Mills, 2010). There was an old common view about the markets for land, labor, and capital in Africa that they remain incomplete and imperfect. A very recent update has shown that factor markets generally are not missing, but they regularly fail the farmers which impede productivity growth and poverty reduction. The pattern of market failure is general and structural, not related to the gender of the household head or geographic characteristics and in some countries, it can vary with agro-climatic zones (Dillion and Barret, 2018). This finding indicates that we need to work on the root causes of the failures not trying to approve whether these factor markets are existing or not, as this will help us to affect the productivity levels and the efforts of reducing poverty levels.

However, McCullough (2018), with recent data from Sub-Saharan Africa, proved that agricultural labor is not so unproductive in Africa. Agriculture continues to be the predominant income-earning activity for most households and most non-farm agricultural work is closely linked to agriculture. Productivity gaps are about half as large when measured from the household perspective rather than the perspective of the national accounts. And gaps are half as large again when measured in hours worked rather than annual output per worker. According to the World Bank, compared to the other regions, productivity levels in Sub-Saharan Africa for many food products are extremely low and yet food imports are very high (World Bank, 2007). Higher agricultural productivity levels are thus a precondition for growth and development and increasing yields is a key to raising incomes and reduce poverty in rural areas.

Agriculture innovation is potentially a powerful means to address the relatively low production and add value (World Bank, 2009). In Sub-Saharan Africa, the capital intensive mining sector, though considered the major engine of growth, does not create wealth for domestic economies and it employs less than 10% of the labor force and grows at over 10% per year. In contrast, agriculture manufacturing and services industries grew less than 2.5% annually, but they employ 80% of the labor force (ECA, 2011). Such contradictions necessitate the need for agribusiness and value addition approaches supported by innovations to lift the sector from its backwardness and hence contribute to wealth and employment creation, growth and poverty reduction. In recognition of the low productivity puzzle in Africa, African governments adopted in 2002, a Comprehensive Africa Agriculture Development Programme (CAADP) under the auspices of their New Partnership for African Development (NEPAD).

Agribusiness encompasses a wide range of activities that generate economic value and includes agricultural input industry, agro-industry products, equipment for processing, financing, marketing, distribution, and services (Yumkella et al., 2011). The suitable definition for Africa was proposed by the World Bank as organized firms, from small and medium enterprises to multinational corporations, involved in input supply or in downstream transformation. It includes commercial agriculture that involves some transformation activities (even if they are basic). It includes smallholders and micro-enterprises in food processing and retail to the extent that they are market-oriented, indeed these producers and enterprises make up the bulk of agribusiness activity in Africa today.

An Agriculture Innovation System (AIS) is a network of organizations, enterprises, and individuals focused on bringing new products, new processes, and new forms of organization into economic use, together with the institutions and policies that affect their behavior and performance (World Bank, 2006). Thus agricultural innovation system is about people, linkages, infrastructure and institutions. In SSA, innovation in agriculture is a powerful means to address relatively low production and add value. Higher agricultural productivity is a precondition for growth and development, and higher yields are a way to raise incomes and reduce poverty, particularly in rural areas. Understanding what innovations work, how to promote them and what are the supported policies and institutions are key issues in creating an innovatively driven agriculture.

However, it is crucial to highlight the link between agribusiness and development theory in general. McMichael (2016) critically described the social, political and economic transformations of the world since the Post-world War II era through the present. He summarized the story of development in four parts, colonialism, developmentalism, globalization and sustainability. These parts represent the historical stages of the development process or project as he named it and then he further, (2018) used an ecological development approach to emphasize the issue of sustainability amid of what he called the ecological crisis, as the world is increasingly challenged by structural unemployment, environmental degradation and climate emergency. We need to avoid the type of development that comes at the expense of the world's majority of peoples and planetary health concerns.

To this end, this chapter and in the light of the link between agribusiness, agro-ecological concerns, and principles of sustainability, revises the relevant literature on the topic in the context of Africa, with an aim to see whether the transformation of the agricultural sector that is supported by innovations and guided by principles of sustainability can provide answers to the challenges of the sector. More specifically, the first section covers an overview of agribusiness in general, the second section reviews agricultural innovations in general, system approach, research for development, and agricultural advisory services. The third section tackles value chains briefly in relation to agribusiness and finally, the last section covers the solution and recommendations.

AGRIBUSINESS IN AFRICA: AN OVERVIEW AND REALITIES ON THE GROUND

In Africa, agriculture remains the single largest source of employment and income, especially in rural areas. It contributes about a quarter of the GDP but employs about half of the labor force and even can play a significant role in poverty reduction especially for the rural poor (World Bank, 2007). Average yields are low compared with average yields in other regions. Improved knowledge and management practices can significantly increase land and labor productivity, thereby generating economic growth (Brooks et al., 2012).

Agriculture and agribusiness in Africa are projected to be a US$ 1 trillion industry in Sub-Saharan Africa by 2030 compared to US$ 313 billion in 2010. Agribusiness through agro-based industries can play a key role in economic transformation and, if it succeeds, can stimulate agricultural growth through the provision of new markets and the development of a vibrant input supply sector (World Bank, 2013). Traditional agriculture is expected to fail in contributing to output growth and poverty reduction, hence this contribution can be enhanced through strengthening linkages with industry through agro-processing and value addition.

Africa's agriculture and agribusiness are under-performing. Many developing countries such as Brazil, Indonesia, and Thailand export more food products than all of Sub-Saharan Africa combined. Africa has more than half the world's fertile yet unused land, it has used only 2% of its renewable water resources, compared to the global average of 5%. Post-harvest losses run 15 to 20 percent of cereals and are higher for perishable crops (World Bank, 2013). In a general sense, the empirical evidence had shown that the ratio of GDP generated by agribusiness to that generated by farming increases from 0.57 for a sample of nine agriculturally-based countries in Sub-Saharan Africa to 1.98 for a set of eleven transforming Asian countries and to 3.32 for twelve urbanized countries, and for the United States, the ratio stands at 13 (Wilkinson and Rocha, 2009). In terms of its size and contribution to the GDP, agribusiness according to FAO (2014), lacks data and still rudimentary in some countries. However, according to the World Bank, agricultural production averages 24% of the GDP for Sub-Saharan Africa and agribusiness is about 20%.

At the global level, agribusiness is about 78% of value-added in the agricultural value chain, but this share varies across income levels. It is 0.6% in agriculture-based countries (mostly in Africa), 2% for transforming countries (Asia), 3.3% in urbanized countries (Latin America), and 13% in the United States (World Bank, 2013). In terms of structure, agribusiness in Africa is made up of micro, small, and medium enterprises, and semi-industrial and industrial enterprises, distinguished not only by size but by their sources of labor, capital intensity and the type of market they reach. In West Africa, 75% of the agriculture-related firms are micro or small enterprises, 20% are semi-industrial, and 5% are industrial (Staatz, 2011). In Ghana, the last industrial survey was done in 1995 which covered only medium and large scale enterprises. The extracted data on agro-industries showed a total of 250 companies with about 48,914 employees. In Uganda, the sector is in its infant stage of development. Agriculture is dominated by smallholder farmers with limited interaction with both product and input markets. There is some growth in horticulture fish export sectors but no official statistics. In Kenya, the agro-processing sector contributed about 10% to GDP and 31% to total employment. In Nigeria, the sector is organized along three main clusters covering production, processing, distribution and consumption. The South African agro-food complex, which consists of primary production plus the input and agro-processing sectors, accounts for around 14 percent of the GDP and about 40% of the country's population depends on agriculture and its related industries (FAO, 2014).

According to FAO (2017), the relevance of agribusiness is underlined by the fact that they:

- Are often the main source of off-farm employment in rural areas of poor countries
- Have positive effects on poverty reduction and women's empowerment in countries where high-value agri-food exports are produced
- Create off-farm employment opportunities in agro-industrial firms, increase productivity through increased liquidity, and increase capacity to adopt technology

- Help to forge the necessary link between the agriculture and manufacturing sector, which in turn can catalyze the development of broader manufacturing industries

AGRICULTURAL INNOVATION SYSTEMS: A CONCEPTUAL REVIEW

General Overview of Innovation

According to Spilman (2005), studying innovation is not something new, and very earlier thinking about it can be traced back to Adam Smith (1776) when he talked about the influence of new production techniques and new divisions of labor on output and society.

The literature review defining innovation had shown that this term has multiple definitions. There is overlap among them; also, they are multidiscipline covering economics, business and management, innovation and entrepreneurship, technology and science, knowledge management, and organization study (Baregheh et al., 2009). Table 1 shows different definitions covering different disciplines and attributes and how all of them show how innovation process add value and sustain competitiveness. In relation to its multiplicity of definitions, Baregheh et al. (2009) had reviewed the literature collecting about 60 definitions of innovation with the aim of identifying the attributes of innovation and propose one simple textual definition that summarizes the essence of innovation (Table 1, the last definition).

Innovation and System Approach

For several decades, neoclassical economists have been criticized for their failure to integrate institutions into their theories and econometric models (Nelson, 1981). These concerns were partially addressed when scholars in the field of science, technology and innovation studies invented the concept of the national innovation system with its emphasis on the ways institutions behave and relate to each other (Godin, 2007).

The term innovation system was first used by Freeman (1987) in the context of Japan to describe the government institutions involved in defining and implementing research and innovation policies. Then from there, it has spread to be used in the context of institutions dealing with research activities and dissemination of knowledge for technological innovation. Then according to Godin (2007) and based on the new growth theory where knowledge was considered another factor of production, it has elaborated by OECD during the 1990s together with the concept of a knowledge-based economy.

An innovation system is defined as a network of organizations, enterprises, and individuals that focuses on bringing new products, new processes, and new forms of organization into economic use, together with the institutions and policies that affect their behavior and performance (World Bank, 2006). An innovation system is comprised of the agents involved in the innovation process, their actions and interactions, and the formal and informal rules that regulate this system (Ekboir and Parellada, 2002). Agents interact with each other knowingly or unknowingly, directly or indirectly, through formal or informal networks (Berdegue, 2005). These interactions between agents are very important as they entail according to Speilman (2005) social learning. Those formal and informal rules that regulate human behavior are so-called institutions. So according to Spielman (2005) institutions matter in determining the speed, magnitude and quality of innovation processes.

Table 1. How innovation is defined by different authors/organizations

Oslo Manual (OECD, 2005)	Introduction of a new or significantly improved product (goods or services); a new or significantly improved process; a new marketing method; or a new organizational method in terms of business practice, organization of the workplace or relationship with the external environment
Schumpeter (1961)	any addition to the existing body of technical knowledge or know-how that results in an outward shift of the production function and the downward shift of the associated cost curves.
World Bank (2006)	Innovation is the process by which individuals or organizations master and implement the design and production of goods and services that are new to them, irrespective of whether they are new to their competitors, their country, or the world
Thompson (1962)	Innovation is the generation, acceptance, and implementation of new ideas, processes products or services
Dosi (1990)	Innovation concerns processes of learning and discovery about new products, new production processes and new forms of economic organization, about which, ex-ante, economic actors often possess only rather unstructured beliefs on some unexploited opportunities, and which, ex-post, are generally checked and selected, in non-centrally planned economies, by some competitive interactions, of whatever form in the product
Wong et al. (2008)	Innovation can be defined as the effective application of processes and products new to the organization and designed to benefit it and its stakeholders
Damanpour (1996)	Innovation is conceived as a means of changing an organization, either as a response to changes in the external environment or as a pre-emptive action to influence the environment. Hence, innovation is here broadly defined to encompass a range of types, including new product or service, new process technology, new organization structure or administrative systems, or new plans or program pertaining to organization members.
Plessis (2007)	Innovation as the creation of new knowledge and ideas to facilitate new business outcomes, to improve internal business processes and structures and to create market-driven products and services. Innovation encompasses both radical and incremental innovation.
Baregheh et al. (2009)	Innovation is the multi-stage process whereby organizations transform ideas into new/improved products, service, or processes, in order to advance, compete and differentiate themselves successfully in their marketplace.

Sources: Schumpeter (1961), OECD (1997), Oslo Manual (2005), Thompson (1962), Dosi (1990), World Bank (2006), Wong et al. (2008), Damanpour (1996), Plessis (2007), Baregheh et al. (2009)

Two basic principles define innovation system theory, namely, that innovation is context-specific and that innovation occurs within an interacting system of diverse actors, where value chains are a particularly important organizational form (Elliot 2008). The private sector in SSA increasingly drives innovation, although the public sector and NGOs support innovation through research on public goods, whereby market conditions, policies, and institutional arrangements provide the incentives and the competitive pressures to drive private sector investment (World Bank, 2009). The recent thinking about innovation now turned out to be a new branch of economics called the economics of innovation. This has emerged in the last 40 years; according to Antonelli (2008), it is a distinctive area of specialization within economics, with a well-defined set of competencies about the origins, causes, characteristics and consequences of the introduction of technological and organizational changes in the economic system. At the same time, however, the economics of innovation pretends to be one of the main pillars of the emerging economics of complexity.

Four wide-ranging frameworks were identified in providing an economic explanation for technological change. These are the classical legacies of Adam Smith and Karl Marx, the Schumpeterian legacy, the Arrovian legacy, and the Marshallian legacy. Each of the four approached has a clear focus and a distinctive area of investigation. The classical legacy provided the basic inputs to elaborate a theory of economic growth based on technological innovations. The Schumpeterian legacy analysed the role of innovation within oligopolistic rivalry and made it possible to appreciate the role of entrepreneurship as a basic engine for the continual introduction of new technologies. The Arrovian legacy provided the first elements eventually enriched in a fully-fledged analysis of the economic characteristics of knowledge from an economic viewpoint. Finally, the Marshallian legacy has led to the emergence of an evolutionary approach, eventually articulated in new complexity theory, that makes it possible to understand the process of specialization and structural change, based on the interplay between heterogeneity, complementarity and competition that characterizes the innovation process (Antonelli, 2008).

Table 2. Historical development of innovation theory

Pre-1950	The first effort was tried by Joseph Schumpeter, who identified three stages of the process, invention, innovation and diffusion. For him, invention is the first demonstration of an idea; innovation is the first commercial application of an invention in the market; diffusing is the spreading of the technology or process throughout the market. This was what is called the linear model of innovation
1950s-1960s	Two main issues: ● Technology push versus demand-pull: technology push ignored prices and other changes in economic conditions that affect the profitability of innovations. In the case of demand-pull, it is economic factors that drive the rate and direction of innovation (Nemet, 2007). ● Organizational and national level research: it focused on how to promote innovation in organizations through effective management of research and development (R&D) departments and their activities (Xu, 2007). Robert Slow (1957) and others explored the macro-economic importance of innovation to the growth of national economies.
1970s -1990s	Innovation theory was furthered by three approaches: induced innovation, evolutionary approaches, and path-dependent models (Ruttan, 2001). The evolutionary and path dependency stress the importance of past decisions which may constrain the present innovation whilst the induced innovation emphasizes the importance of changes in relative prices in driving the direction of technical change (Foxon, 2003). Then additional concepts contributed towards a systems approach
1980s -2000s	The older linear model was evolved into several further approaches, i.e., the innovation system frame at the level of the firm, national, regional and sectoral perspective. Freeman and Perez (1988) defined a national system of innovation as the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies.
1990s – to present	The systems perspective of innovation: a more systematic, dynamic, non-linear process involving a range of interacting actors. Examples include technological innovation systems, technological transitions, and a multi-level perspective. Recently, there is a specific concept of eco-innovation which is defined by Kemp and Foxen (2007) as the production, application or exploitation of good, service, production process, organizational structure or management or business method that is novel to the firm or user and which results, throughout its life cycle, in a reduction of environmental risk, pollution, and the negative impacts of resources use compared to relative alternatives. Eco-efficient technology means all technologies which directly or indirectly improve the environment. A lot of work on innovations was done by the Organization for Economic Cooperation and Development (OECD), the United Nations Commission on Trade and Development, the European Commission, the World Bank and the International Monetary Fund (Spielman, 2005)

Source: Compiled from Schumpeter (1934, 1961), Ruttan (2001), Kemp and Foxen (2007), Spielman (2005), Nemet (2007), Freeman and Perez (1988), Xu (2007)

Agricultural Innovation Systems

Agricultural development depends on innovation, which is considered the major source of improved productivity, competitiveness, and economic growth and plays an important role in job creation, generating incomes, alleviating poverty, and driving social development (World Bank, 2011).

Historically, there are different approaches to promoting agricultural innovation since the 1980s. The period before the mid-1980s emphasized the creation of national agricultural research systems (NARS) to strengthen research at the national level and encourage technology transfer and invention. In the 1990s, this approach changed to pluralistic agricultural knowledge and information systems (AKIS). More recently, the AIS approach incorporates major agents such as universities, firms, and other organizations that can tap into the growing stock of global knowledge, assimilate and adapt knowledge to local needs, and create new technology and products (World Bank, 2009).

An agricultural innovation system can be defined as the set of agents (individuals, organizations, and institutions) that contribute to development, diffusion and use of new agricultural technologies, and that directly or indirectly influence the process of change in agriculture (Temel et al., 2003).

To answer the question of why innovation system thinking is needed for agriculture, according to the World Bank (2008), there are six major changes heighten the need to re-examine how innovation occurs in agriculture:

1. Markets, not production, increasingly drive agricultural development
2. The production, trade, and consumption environment for agriculture and agricultural products is growing more dynamic and evolving in unpredictable ways
3. Knowledge, information, and technology increasingly are generated, diffused, and applied through the private sector
4. Exponential growth of information and communications technology (ICT) has transformed the ability to take advantage of knowledge developed in other places or for other purposes
5. The knowledge structure of the agricultural sector in many countries is changing markedly
6. Agricultural development increasingly takes place in a globalized setting

Speilman (2005) argued that innovation system perspective on agriculture is critical to shifting socio-economic research beyond technological change "induced" by the relative prices of land, labor and other production factors in agriculture; beyond the concept of

linear technology transfers from industrialized to developing countries, from advanced and international research centers to national systems as an engine of change. However, it was observed that the first efforts were looking into the building of the institutions that can lead the change through innovation. This was highlighted by Spielman (2005) who mentioned that the application of innovation system analytical framework to agriculture is embedded within the wider context of institutional change, change process and answers certain questions that the linear conventional research and systems are not able to address. The government institutions need to build bridges to work collaboratively with the private sector, farmers and all other relevant stakeholders that can help in making innovation work for the desired transformation of the agricultural sector. As well, there is a need to strengthen extension services and technology transfer departments through favorable policies and financial support to support in diffusion and adoption of the new technology and research outputs.

Agricultural Research for Development

This will look into the role of research within the agricultural innovation system framework where the application of science, research outputs, and technology is crucial to create a shift from subsistence-oriented to business-oriented farming systems.

Innovation in relation to agricultural research covers the activities and processes associated with the production, distribution, adaptation, and use of new technical, institutional, organizational, managerial knowledge and service delivery (Hall et al., 2005). According to Bennett (2008) research converts money into knowledge, and innovation converts knowledge into money. The transformation of knowledge into products and processes does not follow a linear path, but rather is characterized by complicated feedback mechanisms and interactive relations involving science, technology, learning, production, policy, and demand. The growing competitiveness of the agricultural sector in emerging economies is partly attributable to investments in agricultural research and extension.

In agriculture, the innovation system, according to the World Bank (2006), is a collaborative arrangement bringing together several organizations working toward technological, managerial, organizational, and institutional change in agriculture. These organizations include the traditional sources of innovation (indigenous technical knowledge), the modern actors (National and International Agricultural Research Institutes, and advanced research institutes), private sectors (local, national and multi-national), agro-industrial firms and entrepreneurs; civil society organizations (NGOs, farmers and consumer organizations and pressure groups) and those institutions (laws, regulations, beliefs, customs, and norms) that affect the process by which innovations are developed and delivered. Three critical elements are important according to Blackswan (2010) for a role for research for development in the innovation process:

1. education or knowledge generated through basic and strategic research
2. an ability to translate the knowledge into real products and services through strategic, applied, and adaptive research;
3. the ability to communicate/market the ideas to the world through commercialization, communication, and service delivery

Table 3. Examples of best practices on the linkages between science, technology, and research and agribusiness

Example	Description
Home-grown Ltd.: A Kenyan market champion in the horticulture sector Steglich *et al.* (2009); Nyikuli (2008)	Some companies in African agro-industry grow successfully despite unfavorable policy and infrastructure environments. Home-grown Ltd, being part of Flamingo Holdings, which was taken over by rival James Finlay's Limited, established in 1986, has invested over $100 million in Kenya and employs over 8,000 people; it has become a multinational enterprise with its own in-house farmer training and extension services. Home-grown is a vertically-integrated business connected to the final markets in Europe, mainly the UK, and is operating an explicit value addition strategy in Kenya. Homerun's practiced internalization ('do it yourself') strategy was adopted because of dissatisfaction with public authorities and public research institutions. It has a training and technology sister company, Dudutech, which supplies its research and technology requirements while also exporting services to South Africa. The company is also strong in environmental protection services and is sharing an increasingly 'sustainable development' philosophy in its production. These do-it-yourself strategies, however, have limits in terms of scale, domestic linkages, and long-term sustainability. Both short-term public action and long-term public action may be needed to facilitate broad-based private sector development. A greater role of the government, especially through supplying public goods like research and extension services and learning how to deal with the private sector in a collaborative way, is therefore recommended.
Rooibos Ltd: Turning Indigenous Products into Business Opportunities Vink et al., 2014	Rooibos Ltd is the largest processor of Rooibos tea, and currently has a turnover of more than R250 million per year, experiencing strong turnover and export growth over the past few years. The production of tea is a cyclical process, which creates unique challenges for the company. Key success factors include strong upstream and downstream contractual relationships, ethical stewardship of the product, employees and the environment, and technological leadership. Key lessons are to protect your intellectual property; decide whether you have the potential to be a large business, or to remain a medium-sized business; understand your industry and your strengths and weaknesses; strive to be the best supplier of the product and the best service provider.
Harnessing the Power of Africa's Sun to Produce Healthy Products for International Markets: The Case of Fruits of the Nile (FON), Uganda Yamoah et al., 2014	Fruits of the Nile (FON), Ugandan Company, buy Fairtrade Organic sun-dried pineapple and banana from 5 farmers groups in Southern and Central Uganda who together form the Fruits of the Nile Growers Association. FONA has about 700 members, about a third of whom are pineapple farmers and two-thirds of whom are banana farmers. About a tenth of the farmers also run small businesses solar drying their fresh fruits. The farmers' group sell their solar dried fruits to Fruits of the Nile who grade and pack all fruit ready for export at their purpose-built factory in Njeru, near Jinja Uganda. Producer groups are given hygiene, drying and business training, and farmers are given cultivation training. The company's current challenge is to improve production quality in the context of ever-rising competition and requirements from European buyers
Wild Fruits of Africa: Commercializing Natural Products to Improve Rural Livelihoods in Southern Africa Mabaya et al., 2014	Wild Fruits of Africa is an emerging agribusiness based outside Gaborone, the capital of Botswana. Frank Taylor, the CEO, has spent much of his life researching indigenous plants and is currently commercializing natural food products made from local fruits. Wild Fruits collects wild fruits harvested by rural villagers who have limited income-generating opportunities. Wild Fruits processes the fruit to make healthy snacks targeting the country's growing tourism industry. The company is currently marketing and distributing its products to airlines, supermarkets, and safari lodges in Botswana, and is now seeking expansion into regional markets. This case illustrates the challenges and opportunities facing entrepreneurs in a niche market, as well as issues surrounding blended-value businesses in Southern Africa

Source: Compiled from different sources as in the table

Agricultural Advisory Services

The term extension was first used to describe adult education programs in England in the second half of the 19th century. It was later adopted in the United States with the establishment of land grant universities that included research activities as part of their official university mandate, in addition to the teaching function. During this same period, Britain transferred responsibility for extension activities to the Ministry of Agriculture, and the terminology for this new responsibility was changed to advisory services in the 20th century. This same term (in English) was then used in most European countries as they developed similar advisory services within their respective ministries of agriculture. In most developing countries, the terminology used to establish agricultural extension or advisory services was generally associated with the donor agency that helped establish the service. The U.S. Agency for International Development (USAID) played an active role in establishing agricultural universities and extension systems during the 1960s and 1970s.

In terms of definition, according to the Global Forum for Rural Advisory Services (GFRAS), an extension is all the institutions from different sectors that facilitate farmers' access to knowledge, information, and technologies; their interaction with markets, research, and education; and the development of technical, organizational, and management skills and practices. Thus, extension includes not only technical knowledge, but also functional elements such as communication, facilitation, and empowerment.

Extension Approaches and Methods

There are many approaches and methods of extension, or as is also called rural/ agricultural advisory services that are developed, tried, and used across the globe. The original thinking was a service to extend research-based knowledge to the rural sector to improve farmers' lives. It includes components of technology transfer, rural development goals, and non-formal education. The traditional view of extension in developing countries was focused on increasing production, improving yields, training, and transferring technology. Today's understanding of extension goes beyond technology transfer to facilitation, beyond training to education, and includes assisting farmer groups to form, dealing with marketing issues, and partnering with a broad range of service providers (Davis, 2008).

The dominant paradigm in the 1970s and 1980s (which still exists today) was the transfer of technology, a linear approach that aims to persuade farmers to adopt new technologies. This was seen not meeting the farmers' needs, hence replaced by system approaches such as farming systems research and extension. A spin-off of this was the agricultural knowledge and information systems approach emphasizing links between research, education, extension and farmers (Davis et al., 2018). During the 2000s, these systems approaches evolved into the agricultural innovation systems approach. An innovation system includes all the actors that bring new products, processes, and forms of organization into economic use (Hall et al., 2006). Extension methods can be divided into individual approaches (one-on-one advisory services either face-to-face, by telephone, or via the internet) and group approaches. These methods include mass media, demonstration, training and visit system, farmers field schools, theatre, videos and information, communication and technology, and innovation platforms.

Apart from the government-led extension services, this service can be provided by the private sector, cooperatives, or non-governmental organizations and producers organizations. However, it is widely documented that government-led services always face a shortage of funds and poor management styles. As highlighted by Davis et al. (2018) private sector agribusinesses such as input companies, service providers, and offtakes exist to create value by offering products and services demanded by the agricultural community. The report also retreated that, to overcome the constraints of both the public and market-driven extension services, the involvement of the producers' organizations can be a solution.

On the other hand, and in the spirit of agribusiness or commercialization, particularly in the rural setting, it is also recommended for extension services to consider building up of agripreneurship and value addition. Production agriculture must be linked to agribusiness and agripreneurship. Extension forms part of a set of supporting institutions, which has a critical role to play in supporting farmers to become more entrepreneurial through deliberate innovative actions. Entrepreneurs usually operate in a complex and dynamic environment.

Digitalization for Agricultural Transformation in Africa:

According to a recent report by CTA (2019), the strategic use of digital technologies, data, and innovative digitally-enabled business models can and have already begun to accelerate sustainable agricultural transformation in Africa. Digitalization for agricultural solutions already reaches up to 13% of Africa's smallholder farmers and generate up to USD$ 144 million in earned revenue annually with growing evidence of positive impact on smallholder farmers.

Famers, especially young people, need to be engaged and trained in agribusiness to ensure the sector is successfully developed for the coming bulge of young people in the population. From the point of view of farmers, producers and other actors in the value chain, there are opportunities to build agribusinesses through skills and training, technology and finance in order to improve productivity and add value to products. It is now possible to use evidence-based results to inform future action plans and propose measures to help young people make the transition into the labor market (Koira, 2014). Adapted from CTA report, the following table shows the historical development of the digitalization of agriculture at the global level:

Table 4. The historical development of the use of information and technology in agriculture

Period	Interventions/actions
2003-2005	Recognition of the concept of e-agriculture by the World Summit on the information society
2007	Web2ForDev International Conference promotes adoption and dissemination of low-cost application for development
2011	World Bank releases report on ICTs in agriculture
2011- to present	The Global System for Mobile Communication Association(GSMA) starts partnerships between Mobile Network Operators (MNOs) and agricultural organizations
2013	Centre for Technical Cooperation (CTA) host ICT for agriculture International Conference in Kigali
2014 – to present	Dutch Ministry of Foreign Affairs establishes the Geo-data for Agriculture and Water facility Global Open Data for Agriculture and Nutrition launched USAID forms new alliance ICT Agriculture Extension Challenges Fund
2016 – to present	World Bank Africa Disruptive Agricultural Technology Challenge and Conference
2019	CTA released its report on digitalization of African agriculture report

Source: adapted from CTA, African agriculture report, 2019

AGRICULTURAL VALUE CHAIN, INNOVATION AND AGRIBUSINESS

Equally important as innovations to the development of the agricultural sector is value addition or creation. Value creation is widely documented as a critical element for agribusiness success, and as indicated by Sirmon et al. (2007), the main objective of business has been to continuously create value. Therefore, understanding the concept of value creation or addition is critical for the realization of the objective of a business.

The linkage and dynamic integration of agriculture to other important sectors such as business and trade sectors open value-added opportunities and increased performance. Agriculture needs to link with commercial principles and business models focused on the access, generation, and practical use of and deployment of innovations to improve productivity (Payumo et al., 2017). This link in Africa still very weak while at the global level, it is very strong with a real and significant transformation. Thinking about transforming the agricultural sector needs to think and institutionalize the value chain approach as well as thinking about innovations and integrated solutions.

Value creation or value-adding in agribusiness is defined as the change of the product's current place, time, and form to characteristics more preferred in the marketplace (Anderson and Hanselka, 2009). More specifically, it has been defined by Coltrain et al. (2000) as to economically add value to an agricultural product (wheat) by processing it into a product (such as flour) desired by customers (bread).

Value addition is in itself a transformation process within each agricultural product from its primary stage to a profitable one, and that is why it is always defined as a series of value-adding processes which flows across many companies and creates products and services which are suitable to fulfill the needs of the consumers. The importance of the value chain approach in agribusiness is very critical because agribusiness comprises a set of activities start from the farm to the end consumers and along this path, many employment opportunities will be created as well, food security and nutrition improved and thus contributing to poverty reduction. Therefore, the creation of a conducive environment in terms of supportive policies and strategies is vital for the success of such transformation.

Another critical factor will be the need to foster the engagement of the private sector, including fostering public-private partnerships. However, the role of development practitioners is also needed to raise awareness and to support smallholder producers and the formation of small and medium-scale agricultural enterprises. Innovations and research for development are major elements in the success of value addition and hence agribusiness development. It is also essential to think beyond the national context when thinking about value addition as it is very important to strategize diversification of the economy through the support of regional policies to foster engagement in regional and global value chains.

SOLUTIONS AND RECOMMENDATIONS

In Africa, agriculture faces many challenges, among which low productivity levels and inadequate efforts in value addition are widely reported in research and policy debate circles. To address such constraints, innovation is expected to be one of the key drivers for higher productivity levels and vibrant value addition.

Therefore, understanding how agricultural innovation systems work and how they are affected by the supportive policies and institutions is very critical for the transformation of the sector from the current level of subsistence to a one based on business principles to contribute to real gains from economic growth and hence lowering rates of poverty levels.

The documented evidence in this chapter had furnished the way of how we can think about agricultural transformation and changing the sector from inefficiency to better productivity gains. In summary, the following points will cover all related aspects with the issue of agribusiness, innovations and value addition as an inter-connected chain to address the structural transformation of the agricultural sector:

1. Since the 1950s, the debate about agriculture in Africa is about agricultural productivity to accelerate economic growth, and the evaluation is that agriculture is underperforming in Africa. However, the remaining fact is that we still need to think about how to raise productivity levels sustainably.
2. Another optimistic type of debate is about Africa making significant progress in agriculture, and the Sub-Saharan African countries have made significant progress in fighting poverty, however, still, we remain the net importer of food and that is why we have the current debate on agricultural transformation through value addition, innovations and macro-economic enabling policies among others.
3. Within the agenda of transformation, agriculture is expected to compete globally, inclusive and business-oriented sector and not the traditional way we learned from our ancestors, and for this to happen, we need our governments to encourage business-oriented principles through supportive policies, finance, smart information and technologies, infrastructure development, among others. Equally important is the role of the private sector where actually the private sector is expected to play a leading role in the transformation and developing the agribusiness sector
4. Within the context of increasing productivity levels and transforming the agricultural sector, technological innovations and value addition are key drivers. Universities and research institutions as well as the extension and advisory bodies are now generally working in isolation from other sectors. Hence we need to bring them on board to accelerate the use of innovations and to service agricultural development. Promotion of interactions and connections between governments, business, farmers, extension agents, researchers, academia and civil society remain vital for sustainable agriculture
5. Thinking about sustainable agriculture and engagement of youth in agriculture, the issue of using digital technology can help to solve many problems in agriculture and as well foster agribusiness, and contribute to improved food security, increased farmers' incomes and equitable and inclusive value chains
6. Linking agribusiness with climate change, it is clear that climate-smart solutions which are a combination of mitigation, adaptation, and food security concerns, have many benefits to farmers especially the smallholder producers. At the global level, there is a growing demand for these solutions and in Africa, they are still at the pilot level which means we need to take up these solutions into adoption and upscaling levels.

Based on surveyed evidence in this chapter, the following recommendations can be suggested:

1. Given the fact that in Africa, agricultural productivity is very low there is need to increase it through science, research, value addition and innovations for increased yields, incomes and benefits to all involved actors Efforts are needed to enhance efficient use of agricultural inputs for production and consider sustainable management practices, extension services and disseminate knowledge and information to producers and other stakeholders.

2. Funding for research from government and development partners need to be increased to address all challenges facing agriculture. However, selection of research areas or themes need to be based on wide consultation among all concerned stakeholders
3. To support the growth of the agribusiness sector, governments should support the sector of small and medium enterprises through effective policies and strategies for the realization of increased growth and productivity gains
4. To enhance value addition in agriculture, there is a need to harness technologies including digital and climate-smart solutions, to contribute to enhanced yields, scaling up and adoption. That might also need to share and disseminate knowledge and support in capacity building especially for the smallholder sub-sector
5. Despite the significant growth in the knowledge base about climate-smart agriculture either in the form of evidence, successful stories, lessons and experiences, there is a need for these fruitful insights to be widely disseminated and made available for all relevant stakeholders to support the on-going efforts in promoting these techniques.
6. More focused research for development is required to look for innovative ways of engaging smallholder producers and develop for them value chain opportunities that enhance increased productivity and higher incomes. This can include local, national, regional and global value chains
7. Governments and development partners need to collaborate on documenting, publishing and disseminating good practices on agricultural innovations and facilitate tools, information, and knowledge used by all stakeholders including smallholder producers
8. Research and extension services can play significant roles in agricultural transformation, and through them, agricultural innovations can be harnessed to the benefit of the sector. However, in the context of the African countries, research and extension institutions are under-resourced with limitations in finance, lacking the supportive policies and strategies, and they also lacking updated methodologies and approaches. These necessitate considering all that when designing our transformative policies and strategies.

FUTURE RESEARCH DIRECTIONS

Given the limitations faced by this study, and the importance of the various issues tackled in the different sections reviewed in this chapter, the following recommendations for future research could be suggested:

a. More research can be done in regard to the identification of successful stories and opportunities at different contexts on agribusinesses for showcasing and upscaling
b. As agricultural innovations are key in driving agribusiness, it could be important to look into gaps and challenges that can help in bringing them up to the level of supporting the development of the sector
c. Research is needed for the promotion of innovative ways of financial support to research and extension institutions

CONCLUSION

In Africa, agriculture is considered the primary source of food, income, and employment for a significant portion of the continent population.

The current thinking in the continent is about agricultural transformation, which is simply defined as a process that leads to higher productivity on farms, commercially oriented farming, and strengthens the link between farming and other sectors of the economy. This transformation is perceived to contribute to job creations, increased incomes, reduced malnutrition and contribute as well in enhancing the economic growth rates. Across the globe, many countries came out as strong industrialized economies after they had managed to transform their agricultural sectors through value addition and agribusiness principles. For this transformation, the application of knowledge, innovations and research for development is vital to enhance agricultural development particularly in Africa where the countries are still lagging behind in the adoption of these critical elements.

The current debate is about digitalized solutions to help in transforing traditional agriculture into a modern, vibrant and business-oriented sector. This digitalization is simply the use of digital technologies, innovations and data to work along the value chain to solve the problems constraining productivity levels and other agriculture-related processes such as finance, marketing and other aspects for the sake of helping producers solving their problems of food and income sources and at the same time creating an enabling environment for transformation. The value chain perspective is a critical link in the business cycle as it involves a chain of activities from the production phase up to the end-user or the final consumer. As well, the value chain is always linked with research, extension, education and innovations led institutions, and actually, value chain development and continual improvement depend basically on an integrated effort of many all actors. One of the hot issues in Africa is its youthful population. Therefore, we need to make agriculture an attractive business for them through the use of technology, innovations and showcasing of successful stories.

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Chapter 3
Agriculture Business Problems:
Analysis of Research and Probable Solutions in Africa

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ABSTRACT

Researchers need to investigate global life-threatening problems tied to agriculture such as food insecurity and malnutrition pandemics. This chapter reviews empirical fact-based state-of-the-art literature underlying the agri-business adoption barriers and the agriculture food insecurity crises. The authors focus their effort on identifying the hot spots of global agriculture problems, in developing nations. They use critical analysis to identify the most pressing issues and controversies surrounding West Africa. They then explore empirical literature suggesting possible remedies and future research needs to resolve the agriculture problems, in a way that these concepts would generalize globally and be of interest to other scholars. They produce several conceptual models to assist future agriculture research scholars including keyword thematic diagrams, cross-case subject analysis, topic contingency analysis, and literature topic synthesis. They then focus on probable solutions and they create several conceptual models to summarize those. They close with recommendations for future research.

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INTRODUCTION

The objective of this chapter is to examine the key challenges which hinder effective agriculture advancement and in particular to identify the reasons farmers are not adopting information systems to improve the agricultural sector productivity in West Africa. West Africa is the focus here for two reasons. First, the world is too large a scope to address in a single chapter. Second, Nigeria was the specific focus for this chapter since it has the largest population in Africa, it is located in West Africa, and the citizens are relatively high technology-literature at least with mobile phones (Adetimehin, Okunlola, & Owolabi, 2018). Thus the aim of this chapter is to develop a framework and a current literature review to inform key stakeholders namely, agriculture software developers, agricultural industry practitioners, agricultural extension professionals, academic researchers, and government researchers.

Agriculture is an important world-wide contributing factor towards economic growth (Adesiji et al., 2014), but most African countries significantly lag developed countries in effective food production - and the outlook is worsening (Lamboll et al., 2018; Michalscheck et al., 2018). Empirical studies completed in Western Africa identified numerous causal factors which constrained agriculture productivity improvement, including government, industry and farm-related problems such inadequate training (Che, Strang, & Vajjhala, 2020). More than one researcher found that West African farmers need better information technology in order to improve the agriculture value chain efficiency (Omotayo, 2017). Some researchers studied the problems underlying government funding to promote agricultural socio-economic benefits in developing countries (Olowogbon, Yoder, Fakayode, & Falola, 2019). Terrorism, lack of training, and other systemic issues were found to negatively impact agriculture in West Africa (Adelaja & George, 2019; Strang, Bitrus, & Vajjhala, 2019). Another researcher claimed a critical agriculture problem was that farmers do not adopt modern software or technology (Soeparno, Perbangsa, & Pardamean, 2018). Yet other researchers have identified dozens of problems underlying the poorly performing agriculture industry (Fasona et al., 2016; Lamboll et al., 2018; Olowogbon et al., 2019; Omotayo, 2017; Ukpong & Obok, 2018).

Effective agriculture production is an essential requirement for developing nations especially in Africa because with differences in currency along with import-export trade, it is too costly to not domestically produce food (AGAR, 2018; FAO, 2017). In fact, many African countries, especially Nigeria, have been in a food security crisis during the last 10 years without resolution (Strang, Che, & Vajjhala, 2019). Food supply insecurity and lack of self-sufficiency continue to be major issues for African countries (AGAR, 2018; Azih, 2008; FAO, 2017). For example, African countries met 89% of food production requirements in the 1960s but dropped to 75% by 2000 and continues to decline in some West African countries (Takeshima, 2018). This drop in self-sufficiency was caused by political, economic and environmental issues (AGAR, 2018; Olorunfemi, Olorunfemi, Oladele, & Adekunle, 2018). Many developing countries are now focusing on improving agricultural productivity through the use of information technology hardware and application software (Oyegoke & Dabai, 2018; Usman & Ahmad, 2018; Wongsim, Sonthiprasat, & Surinta, 2018)along with training and mentoring from extension workers (Adetimehin, Okunlola, & Owolabi, 2018; Kazeem, Dare, Olalekan, Abiodun, & Komolafe, 2017; Michael, Giroh, Polycarp, & Ashindo, 2018).

By 2020, the Covid-19 ‘corona virus’ world-wide pandemic declared by the World Health Organization (2020), and global market volatility, further exacerbated the agriculture productivity problems and food insecurity crisis, especially in African regions. With global supply chain import-export and international travel practically shut down for months, agriculture practitioners and scholars need some direction about what to do next in this research field. No comprehensive research has been published to address this topic since the pandemic.

To address this gap in the literature, review the state-of-the-art empirical studies of agriculture business from the perspective of agriculture problems and probable solutions, with a focus on West Africa since that is where the most serious problem was documented. In this chapter we present a conceptual outline and then we review the empirical literature surrounding the modern agriculture industry. We then objectively analyze the literature to identify key issues and probable solution areas. We close with emerging recommendations for future research.

BACKGROUND

We collected empirical studies of agriculture or food security problems from peer-reviewed journals with a date range of 2015-2020, and we supplemented that with older articles identified through the primary search. Before we began our paper by paper analysis, we analyzed the abstract and keywords to organize the literature review. We developed the following agriculture problems state-of-the-art conceptual outline to guide our chapter, as graphically illustrated in figure 1. Our goal was to use this conceptual model to group related papers, and then discuss the findings by common agriculture industry theme, which we felt would facilitate further quantitative analysis of the underlying issues, controversies and probable solutions.

Figure 1. Conceptual outline for state-of-the-art in agriculture problems
(source: authors)

Figure 1 identifies only the top 20% of phrases from the state-of-the-art literature we reviewed which accounted for at least 80% of the quantity (a type of Pareto analysis). In this way we could quickly identify the most common and most serious topics at least according to the empirical literature (e.g., not government reports or web sites). The size of the phrase indicates the relative frequency of citation. For example, the most important keywords from the literature were associated with economics fields, such as macro, micro, industry, business, planning and government. In the agri-business body of knowledge, these levels of analysis correspond to strategic planning in the business science literature, starting with the macro environment, then the industry (including cooperatives or supply chain partnerships), and finally the lowest layer of detail is micro referring to the individual farmer.

We then observed important subjects emerging in the typology, starting with behavioral attitude change, training, social culture (socio-culture), facilities infrastructure, knowledge sharing, income diversification, project management, technology use, financial, corruption and to some degree demographics like gender or age.

We then re-analyze the abstract and keyword data to partition the state-of-the-art agriculture literature by what seemed like the theoretical subject focus (e.g., attitude change) across the levels of analysis (e.g., macro to industry). We added 'generic' to include those less than 1% such as executing or if there was not a clear subject focus. The results are summarized in table 1. This contingency table shows the relative frequencies of each theoretical subject across the levels of analysis. We consider government and society to be the macro level. All factors controlled outside the firm or farmer would be considered macro in our nomenclature. Note we use the term industry to refer to the task environment which is also known as other businesses in the industry (e.g., competition, partners, supply chain, and so on). The micro level is intended to be the individual farm, logistics firm or manufacturing company. The last level of analysis was mixed or a combination of the other three. It can be seen that approximately half the literature (51%) had multiple levels of analysis.

Table 1. Contingency analysis of agriculture problem literature by level of analysis and subject

Key Subject Focus	Macro	Industry	Micro	Combination	Total
Attitude Change	0.00%	0.00%	1.61%	20.97%	22.58%
Training	1.61%	7.26%	2.42%	5.65%	16.94%
Social Culture	0.81%	1.61%	4.03%	3.23%	9.68%
Infrastructure	6.45%	1.61%	0.00%	0.81%	8.87%
Knowledge Sharing	0.81%	1.61%	0.81%	5.65%	8.87%
Income Diversification	0.00%	0.00%	3.23%	4.84%	8.06%
Project Management	2.42%	1.61%	0.00%	3.23%	7.26%
Information Technology	0.00%	3.23%	0.81%	3.23%	7.26%
Financial	0.00%	3.23%	0.00%	2.42%	5.65%
Corruption	2.42%	0.81%	0.00%	0.00%	3.23%
Generic	0.00%	0.00%	0.00%	0.81%	0.81%
Demographic	0.00%	0.00%	0.81%	0.00%	0.81%
Grand Total	**14.52%**	**20.97%**	**13.71%**	**50.81%**	**100.00%**

In table 1 we can see a natural structure emerging for the state-of-the-art literature, with the majority being mixed levels of analysis, followed by an approximate balanced distribution between macro, industry and micro (farm-level). We calculated that approximately 40% of the papers discussed subjects within the psychology domain, which fell into two categories of attitude change and training (educational psychology). We should note that frequency of a subject does not necessarily indicate the significance of the problem or value of the research. In this table the percentage merely shows the popularity of the subject in the state-of-the-art empirical literature, or in another perspective, the quantity of the research (not the quality). Nonetheless, this affords a relevant typology for organizing our literature review.

A critical problem at the macro environment level is that Nigeria is importing significantly more wheat, rice and sugar at unfavorable currency exchange rates than what farmers could grow (Fawole & Ozkan, 2018). According to the Nigeria Ministry of Agriculture and Rural Development the essential bulk wheat import to export ratio is growing at an unsustainable 11% annual rate (Omeje, Arene, & Okpukpara, 2019). A further complicating factor is that many male farmers were lost due to terrorism not to mention that some women were captured and mistreated (Abraham, 2018). The loss of men and women in the farming industry has had an unknown impact on agricultural production and software acceptance (Bitrus, Strang, & Vajjhala, 2019).

Nigeria as a West Africa Focus

Several modern empirical studies have identified Nigeria as one of the most important West African countries to examine as a carrier-pigeon for agriculture productivity (Adelaja & George, 2019; Awotide, Abdoulaye, Alene, & Manyong, 2019; Chukwuji, Aliyu, Sule, Yusuf, & Zakariya, 2019; Famakinwa, Adisa, & Alabi, 2019; Obayelu, Adepoju, & Omirin, 2019; Ojo, Saleh, Coker, & Ojo, 2019; Olawuyi & Mushunje, 2019; Olowogbon et al., 2019; Omeje et al., 2019; Oparinde, 2019; Strang, Che et al., 2019; Sule, Kayode, & Emmanuel, 2019; Uduji, Okolo-Obasi, & Asongu, 2019; Urama, Eboh, & Onyekuru, 2019). This is likely due to its large economic footprint in Africa, the advanced ecommerce infrastructure and the combination of perplexing problems that plague other African countries, all seem to occur in Nigeria.

The key agri-business problem in Nigeria is that agriculture production is too low to sustain the national demand (Omeje et al., 2019; Osa-Afiana & Kelikume, 2016; Owutuamor & Arene, 2018; Tall, Koroma, & Burgeon, 2018, August) and there is a food insecurity crisis (Fawole & Ozkan, 2018; Obayelu et al., 2019; Olawuyi & Mushunje, 2019; Omotayo, Ogunniyi, Tchereni, & Nkonki-Mandleni, 2018; Oparinde, 2019; Sule et al., 2019). Secondary agri-business problems include the lack of labour resources due to Boko Haram terrorism (Lamboll et al., 2018), climate change impacts on farm land (Bosello, Campagnolo, Cervigni, & Eboli, 2018; Chukwuji et al., 2019; Urama et al., 2019) and widespread corruption (Azih, 2008; CISLAC, 2017). There are many other problems in Nigeria's agriculture industry which are common to other African countries, as discussed below.

Macro Agriculture Problems

The macro level is generally the government, either local or global such as the World Bank. Clearly, the downstream market-related macro factors impede Nigerian agriculture success. The main issue here is most Nigerian farmers and local value chain partners have limited transport options to external markets beyond the country borders (AfDB, 2013). The cost to transport products to sea ports for export is expensive due to long distances across treacherous terrorist controlled areas and poor infrastructure on the routes between (AfDB, 2013). The transport route problems include inadequate roads, lacking routine periodic maintenance coupled with poor initial design and construction (AfDB, 2013). The rehabilitation cost outlay for the existing federal and state road network was beyond budgets (AfDB, 2013).

One of the most promising initiatives was the Vision 20:2020 infrastructure program which was supposed to update transportation networks and logistics but many projects failed (AfDB, 2013). As a result, outside of major cities, the rural road network is usually dilapidated (AfDB, 2013). Furthermore, even if the agriculture goods could be cheaply moved around the country, there is inadequate deep sea port capacity and the moribund railway sub-sector is limited (AfDB, 2013). Getting to and from supply chain points can be problematic in Nigeria due to inefficient urban mass transit, which also suffers from occasional terrorism intervention (Adelaja & George, 2019) and high pollution emissions, which presents a negative marketing image to international stakeholders (AfDB, 2013). We could describe these factors as infrastructure logistics.

The Nigerian national and regional agriculture ministries have weak agriculture policies and poor coordination between the levels of government (AfDB, 2013; FAO, 2017). From an administrative standpoint, there is a low quality of agri-business analysis and not surprisingly a corresponding lack of National Bureau of Statistics data or estimates about farm activities (AfDB, 2013). The result is a weak capacity for agriculture policy formulation and non-strategic choices made for project implementation (AfDB, 2013). This further exacerbates the transportation problems because there is no comprehensive national infrastructure development plan (AfDB, 2013). Some infrastructure plans exist but they have been criticized due to inconsistent application of regulations and standards (AfDB, 2013). These factors could be summarized as strategic planning.

Perhaps the more serious issue is corruption at all levels of government, as well as at non-government organizations, combined with a weak institutional capacity to fight corruption (AfDB, 2013; CISLAC, 2017). The root of this problem seems to be poor non-competitive government policies for procurement during the awarding of contracts (Azih, 2008; CISLAC, 2017). Additionally, there are negligible ineffective parliamentary over-sight responsibilities mainly due to the underlying corruption (AfDB, 2013). It seems logical that unethical public financial management practices dovetail the corruption problem (AfDB, 2013; FAO, 2017). Corruption would be a suitable label for this sub-problem.

Industry Level Problems

At the industry level of analysis, agri-businesses have insufficient administrative or management staff to strategically improve their operations (AfDB, 2013). This translates into a lack of time to research or become aware of strategy information, market data, and best-practices documentation (Azih, 2008; FAO, 2017). The problem of insufficient human resources means there is too little time to understand regulations, rules and funding policies (AfDB, 2013), so often agri-businesses miss opportunities to win grants they would be eligible for. An insightful idea was the introduction of agricultural extension workers, where experienced well-educated practitioners from other regions or countries were hired through government funds to mentor farmers (Alabi & Ajayi, 2018; Otene, Okwu, & Agene, 2018). To some degree this mitigated this problem but it has not been examined through a scholarly study in the North-East Nigeria region. Overall, this might be described as a lack of strategic resource planning capacity.

Paradoxically, the above lack of resource planning problem could be overcome using information systems technology to facilitate access to marketing data and agricultural production information but software does not seem to be accepted by farmers (Asenso-Okyere & Mekonnen, 2018; Fatusin & Oladehinde, 2018). Perhaps this problem stems from the limited awareness of special-purpose agriculture information systems (Barnes et al., 2018; FAO, 2017), or the lack of exposure to the latest technologies (Asenso-Okyere & Mekonnen, 2018; Fatusin & Oladehinde, 2018). Some researchers assert there is a lack of agri-business software applications available at household level (Barnes et al., 2018; Wongsim et al., 2018) or a lack of awareness of what is possible (Asenso-Okyere & Mekonnen, 2018; Fatusin & Oladehinde, 2018). Ironically, when relevant agri-business software exists it often originates outside of the country which makes it expensive (due to low Nigeria international currency exchange rates) or sometimes it is prohibited for import (Uduji & Okolo-Obasi, 2018; Wongsim et al., 2018). There is insufficient research about the potential for farmers to adopt and customize agriculture software in the public domain, either for desktop systems of as mobile phone apps (Wongsim et al., 2018). An apt term for this factor would be agriculture software or agri-business applications.

There is a lack of training being provided to farmers and other stakeholders in the industry although recent government programs have initiated youth training projects (Ayinde, Olatunji, & Ajala, 2018; Koledoye & Olagunju, 2017). Nonetheless it comes as no surprise that farmers are using outdated farming methods, they lack knowledge of modern methods, and they employ ineffective farming practices (Olomola & Nwafor, 2018). The domino effect is that when farmers use older ineffective methods, these lead to poor sanitary conditions thereby lowering quality and profits (Azih, 2008). The lack of training goes hand in hand with the aforementioned industry factors of no resource planning capacity and missing agri-business software. Oddly enough, if a free agri-business application could be used, there will likely be no way to teach farmers to install it, maintain it and apply it for strategic planning (Olomola & Nwafor, 2018). Some of the medium to larger sized organizations have agriculture information systems but there is a lack of small farm holder training to effectively and strategically use agri-business applications (Strang, Bitrus et al., 2019; Wongsim et al., 2018). Other researchers have included public materials like government brochures, training guides and libraries as a type of training method or knowledge source (Adetimehin et al., 2018). Lack of farmer knowledge training seems appropriate to define this problem.

There is an overall lack of cooperation between Nigerian agri-businesses and their value chain partners including the construction and maintenance of road networks (AfDB, 2013). Most large projects require subcontractor partnerships but there are delays responding to government requests for proposals or opportunities due to cultural expectations, terrorism concerns and other risks (AfDB, 2013). Expansion projects are poorly designed due to ineffective communication between stakeholders and the relationships are not sustainable across initiatives (AfDB, 2013). The limited professional business capacity and poor cooperation results in inefficient or no services in some areas (AfDB, 2013). There is infrequent informal communication between large industry companies and small farm holders (AfDB, 2013). There is negligible agricultural information sharing or knowledge diffusion (Azih, 2008; FAO, 2017). Furthermore, there is minimal agricultural information system hosted applications or service delivery environments available to farmers because cooperation is needed to establish these (Azih, 2008). The lack of industry cooperation would encapsulate these issues.

There is problem finding adequate warehouse storage logistics facilities combined with delays of distributing harvested supply to the export market (Olomola & Nwafor, 2018). This is different than the macro level logistics problem as it relates to the industry supply chain partners – someone needs to provide storage, logistics, and distribution for farmers who specialize in growing. The lack of value chain cooperation reduces export competitiveness (Azih, 2008). Often farmers do not have sufficient fertilizer or seed supply especially the improved modern mixes (Olomola & Nwafor, 2018). These issues are different than the cooperation problem because they are upstream. Therefore an adequate term to represent this factor would be upstream supply chain. Farmers who are willing to start or expand their own ventures may quickly run up against the metaphoric brick wall if they do not have cash because there are few if any long term borrowing institutions or allowances for agriculture credit (Azih, 2008). In particular, there is a lack of financial support or credit for small farm holders (Olomola & Nwafor, 2018). The issue can be expressed as the lack of agriculture financing.

Micro, Farm or Logistics Firm Problems

The micro level refers to the individual farmer or the farm employee but it could also mean the individual in any part of the agriculture supply chain. Global agriculture researchers have determined several common physical demographic factors impact farm productivity. Each of these factors is usually independent of one another in predictive models. The age of farmer is often a significant factor, whereas younger farmers are more likely to adopt agriculture information systems as well as learn better methods (Barnes et al., 2018). Gender of farmer has also been found to be significant (Nwagu, 2017), meaning generally that males were expected to run farms leaving women to have other duties, and therefore males receive any available training (Agbo & Isa, 2017; Doss, 2018).

The other demographic factors are often interdependent to some degree on age and or one another. Educational attainment, literacy, primary, secondary, above secondary education, impact farm productivity (Awotide et al., 2019). Interestingly, the higher the farmer education the more likely they will be to adopt agriculture information systems, modern methods or try agri-business applications (Barnes et al., 2018). Many of these issues are interrelated such as age, gender, experience and education – older males have more experience and they receive more training but up to the point of not being willing to change (Adepoju & Osunbor, 2018).

Several researchers have noted that female farmers lack competencies because there was no knowledge transfer from males before they disappeared due to terrorism or other violent conflicts (Olomola & Nwafor, 2018; Strang et al., 2019). Therefore each of these factors may be independent or related, but all would need to be considered even if only to serve as a statistical control variable. Since these two factors imply a handicap for a certain status, they may be coded age-handicap to reflect youth may are more adaptable and gender-disadvantage meaning females have the odds against them.

The size of land holding especially the arable portion, can affect farm productivity, with larger plots offering more revenue along with increased productivity (Awotide et al., 2019; Barnes et al., 2018; Odudu & Omirin, 2012). The farm ownership structure may be important, which may be coded as individual, husband-wife, family, LLC, company, franchise, multinational (Barnes et al., 2018). Additionally, the farm tenancy status could be relevant, whether it is leased or financed or owned (Barnes et al., 2018).

It is possible that some farmers are employed in more than one discipline so occupation other than agriculture is a factor (Barnes et al., 2018), which we can signify as multiple employment. Somewhat related to this concept is that membership in a farmer cooperative or community of practice may impact productivity (Barnes et al., 2018). Some researchers have noted that farmer productivity can be enhanced through advisors or mentors from university (Barnes et al., 2018) or through extension workers (Otene et al., 2018). This has also been referred to as exploitation of agricultural middlemen (extension workers) or exploiting the information gap (Otene et al., 2018).

The next micro level factors are tacit or cognitive in nature, as exist in the mind of the farmer. There may be cultural and subcultural influence from nearby farmers or community cooperatives on farmer which impacts attitude as well as decision making (Barnes et al., 2018). The subcultural influence can extend throughout the supplier value chain network (Barnes et al., 2018). Socio-cultural factors include the national culture of farmer and farm owners, meaning if they were born and raised in North-East Nigeria, and whether they are Christian or Muslim, which in turn impacts their spoken languages through the socialization processes (Strang et al., 2019). Socio-cultural dimension seems to be the best term to capture these variations. Terrorism and civic turmoil have caused food insecurity and poverty (Strang et al., 2019; Tall et al., 2018, August). Violence and terrorism is an important independent factor.

There are several studies about the willingness of individual farmers to adopt information systems technology including hardware like cell phones as well as agriculture software and agri-business applications (Ayinde et al., 2018; Barnes et al., 2018; Dyck & Silvestre, 2019; FAO, 2017). The most interesting research concerns the software adoption psychological critical success factors. These cognitive software adoption factors are based on reasoned action decision making theory at the micro level of analysis, they were originally founded in the consumer behavior literature, and these variables can predict planned as well as actual software adoption (Strang, 2019; Strang & Vajjhala, 2019). The popular software adoption factors include satisfaction, perceived ease of use, perceived effectiveness, perceived trust of the product and perceived confidence or competence in using it (Vajjhala & Strang, 2020). A key limitation of the software adoption factors is they cannot accurately predict planned or actual behavior of unique African cultures such as Nigeria because those theories were developed in western cultures like USA with vastly different social, linguistic and economic contexts (Strang & Shimer, 2017; Vajjhala & Strang, 2019).

Nevertheless, a few researchers replicated the American software adoption models in Nigeria but with limited success mainly because the theoretical constructs did not translate well from a technology-literature society and the linguistic-cultural context was not comparable (Barnes et al., 2018; Strang et al., 2019). In one Nigerian study Strang, Bitrus and Vajjhala (Strang et al., 2019) found that popular software adoption models do not function well in rural agricultural settings due to language barriers, socio-cultural differences, perceived limited choices and lack of best-practice knowledge. Although the American software adoption models do not work well in Nigeria research, one basic factor does manifest, namely an overall behavioral attitude towards the acceptance or resistance of software (Kassali, Oyewale, & Yesufu, 2018; Strang et al., 2019; Yahaya & Abdulrahman, 2018).

Interestingly, some researchers noted that measuring the attitude towards resisting agricultural software can predict using function-specific information systems such as crop planning, weather forecasting, or drought prediction applications but in comparison there may be resistance towards using accounting products (Adeola, Ayodeji, & Olamide, 2018; Barnes et al., 2018; Kassali et al., 2018; Ojo et al., 2019; Yahaya & Abdulrahman, 2018). The underlying problem of the software resistance attitude is that it is difficult to measure perceptions when the participant has limited exposure to alternatives, a limited understanding of the application, and a difficulty understanding the interviewer's language or the translated questions. We refer to these multiple issues as software resistance attitude (generic disposition) and agri-business application resistance (for specific functions like crop planning).

There may be attitude differences for using certain types of hardware or information technology communications systems – the basic categories reported in the literature were smartphones, email hardware-software, scanners, weather radio, satellite TV, desktop/tablet Internet-browsers and special purpose technology with built-in software like computer controlled irrigation systems (Barnes et al., 2018). Many researchers describe this as information communications technology (ICT) which is used for market analysis and planning. Primarily the Internet or web is used on desktop computers of mobile cell phones, but it could extend to using ICT services at public libraries (Dyck & Silvestre, 2019; Kazeem et al., 2017; Orr, 2018).

The frequency of ICT use is another consideration because most of these products are becoming common place much like automobiles, notably email communication systems and desktop Internet browser platforms, but not every farmer will use them frequently although if they did agriculture productivity could increase (Elijah, Orikumhi, Rahman, Babale, & Ifeoma Orakwue, 2017; FAO, 2017; Ojo et al., 2019; Osa-Afiana & Kelikume, 2016; Otene et al., 2018). These factors could be classified as ICT use frequency (not agriculture specific software or software resistance), although ICT resistance or ICT adoption or technology resistance would also be possible phrases to represent this.

CONCEPTUAL ANALYSIS OF EMPIRICAL AGRICULTURE PROBLEMS

Agriculture Issues, Controversies and Problems

A key problem from the literature was that many farmers do not know the modern farming methods. Strang, Che and Vajjhala (2019) found that Nigerian farmers did not use up to date methods such as crop spacing to improve yield, planting to encourage maturity, nor did they know how to apply fertilizer mixes and alternative weed chemicals. They asserted that farmers needed training to find and apply the relevant information to cultivate corn, maize, beans, groundnuts as well as cattle (since this provides them with free organic fertilizer). Furthermore, they argued that farmers needed assistance from the federal government, non-governmental organizations, and private institutions like universities. A third party, preferably one of the above needs to develop and organize training programs near the field sites so farmers can acquire modern knowledge about farming methods and start the information sharing processes (Strang et al., 2019).

Che, Strang and Vajjhala (2020) found a key underlying agriculture production problem was that farmers have not been using modern fertilizers or good seeds because they are too expensive in the marketplace. They claimed the quality of seeds from local marketers or the dealers is thought to be adulterated or not good. The issue is that farmers cannot identify good seed varieties and the price is too high even if they could identify them. In their study they found another problem was that good quality seeds and fertilizers were not available because the government does not provide these inputs directly to rural farmers at affordable or subsidized prices.

According to Che, Strang and Vajjhala (2020), the same problem exists for fertilizers and herbicides. They noted some farmers complained that fake chemicals were being sold as fertilizers or herbicides. Fake fertilizers and fake herbicide chemicals were described by them as inputs brought into the market due to corrupt politicians. Apparently the politicians intercepted farm inputs then sold them off to earn profits for themselves while in parallel they regularly facilitated the introduction of fake products into the marketplace.

Roads and public infrastructure such as buildings, canals, trains, and other transportation systems were an often cited problem in the literature. Strang, Che and Vajjhala (2019) determined that farmers do not know how transport their products to the market and if they did know where to go, they often had no reliable means of transporting the goods other than bicycles or mopeds. Interestingly, what occurs is that intermediaries buy from farmers on site or from small local markets, but this puts rural farmers at a significant disadvantage because there is no government-regulated buyer competition (Strang et al., 2019). Additionally, local farmers cannot sell their products to markets outside of their local areas because of logistics problems due to poor roads, lack of affordable transportation, and lack of downstream marketing knowledge about where to send the product (Strang et al., 2019).

From a strategic planning standpoint, there is very little being done. According to Strang, Che and Vajjhala (2019), farmers produce crops without knowing if and where they will be sold. They complained that farmers have few if any local processing facilities and equipment. As a case in their study, milling machines, which would allow farmers to add value to what they grow, were neither available nor affordable (Strang et al., 2019). They argued if there were local processing facilities, this would alleviate the logistics problems and potentially draw buyers from outside the local markets into regional areas, strategically transferring the burden of transportation from farmer to buyer Strang, Che and Vajjhala (2019).

Regarding the agriculture logistics value chain, there were other problems cited in the literature. Idowu, Ayanwale, Rabirou and Williams (2012) explained that the middlemen have a monopoly on the farmers' produce because they are the only buyers, so they have total control of the prices. So, the middle men (we could call them logistics firms) buy the farmers' produce at very low prices, but they take them to distant markets and sell them at substantially higher prices (Jackson-Obot, 2018). Often the middlemen manipulate the weights or bag sizes to cheat the farmers (Che et al., 2020). The middlemen make the situation worse for the farmers as they usually mix good quality products with bad quality produce thereby ruining the reputation of good farmers and eliminating any bargaining opportunities the farmers could have (Che et al., 2020).

Further to this, Strang, Che and Vajjhala (2019) argued there were few if any farmer associations or government regulators to protect the genuine interests of well-intended farmers. Apparently farmers' produce associations which have been successful in the past in addressing the bargaining position of the farmers but these are no longer being used (Azih, 2008). Che, Strang and Vajjhala (2020) asserted that farmers produce associations could control commodity prices, and regulate the farmer-buyer middlemen exchange market to reduce corruption.

A somewhat related issue to the above agriculture problem is the logistics and mobility issue. In the past, farmers depended on motorbikes to carry their farm inputs, and farm produces around. This worked well when there was sufficient local demand, but over the last 10 years safety and terrorism have become issues (Adelaja & George, 2019). Due to the Boko Haram insurgency and increased kidnapping risk, allegedly it is no longer feasible to carry the farm produce to distant markers in countries like Nigeria (Strang et al., 2019).

Che, Strang and Vajjhala (2020) elaborated on this issue. Allegedly, in the past, extension, workers relied on motorbikes or push-bikes as a cheap transportation mode to get around. Due to the Boko Haram insurgency motorbikes were banned by the government in many regions such as Mubi North and Mubi South. Thus, farmers could not travel to export their products, and agricultural extension workers cannot easily travel to advice local farmers. Unfortunately, the government has not resolved this issue.

Surprisingly, some farmers have explosions in their house because they store dangerous chemicals at home (Zhang et al., 2018). According to Che, Strang and Vajjhala (2020), farmers store harmful chemicals in the same room where they live and sleep, thereby exposing their families to these harmful chemicals. Apparently farmers they lack safe storage facilities for agro-chemicals or other chemical inputs as well as lack knowledge about how to handle agro-chemicals (Che et al., 2020). Some chemicals contain Dichlorodiphenyltrichloroethane (DDT) or other toxic ingredients which the farmers and marketers use for preserving beans (Obi, 2015). Farmers use old methods of storing and handling hazardous chemicals that can result in dangerous burns, fires, or other damage (Okeke & Oluka, 2017).

Generating income is a problem for rural farmers because farmers may earn only the equivalent of $1 USD per day in local currency (Strang et al., 2019). The price of fertilizer is often higher than the selling price for a bag of corn (Che et al., 2020). The prices of agricultural inputs are often higher than the total output value in a season. Thus, the local prices for selling agricultural products are so low that rural farmers cannot get enough money to maintain a good standard of living, let alone to invest in improving their growing operations (Che et al., 2020). There is a domino effect taking place. Farmers cannot easily afford to purchase modern hardware and technologies like wireless smartphones, contemporary technologies like automated irrigation systems, or agricultural software for crop planning and others (Strang et al., 2019). On a positive note, Che, Strang and Vajjhala (Che et al., 2020) found that despite being constrained by their low incomes, some farmers have pooled resources to acquire technologies such as smartphones and even laptops. However, farmers were often unaware they can freely access information through Internet searches, live stream weather, SMS messaging outside their area, and to obtain reduced-price special purpose agriculture software like crop planning applications Che, Strang and Vajjhala (Che et al., 2020). Additionally, farmers did not realize there are free educational radio and TV channels available that could be beneficial to them (Adetimehin et al., 2018; Badiru & Akpabio, 2018).

There is a lack of technological equipment for storing or processing farm produce, especially for perishable crops like tomatoes, onions, and others (Che et al., 2020). Often farmers must take their crops to the market to sell them on the same day of the harvest otherwise the crops will spoil, especially because of the high temperatures in the area, and as such, they cannot make enough money from their produce (Che et al., 2020). There is no access to climate-controlled storage or at least equipment for processing that alleviate this major constraint and help to improve the farmers' bargaining position in the marketplace (Faborode & Ajayi, 2018).

Cultural barriers exist for rural farmers (Strang et al., 2019). Many farmers believe in traditional farming techniques, and they do not wish to change or learn other methods (Strang et al., 2019). In some places, the women and men do not mingle together because that is how it has always been (Che et al., 2020). However, some of these barriers are driven by the lack of access to information and knowledge in a way that helps the farmers to understand and to buy-in to the strategy (Che et al., 2020). Che, Strang and Vajjhala (Che et al., 2020) asserted that farmers would easily assimilate information that is presented to them in such a way as to demonstrate practical improvements or ways it can add value to their lives. Thus, the issue is not religion or operationally driven, but instead, it seems simply to be an issue of lack of knowledge about what may work better, such as practical labor sharing (Che et al., 2020).

African farmers need to take advantage of gender-neutral best-practices emerging from developed nations which would help them with farm workload distribution and productivity (Adesiji et al., 2014; Babatunde, Omoniwa, & Ukemenam, 2018; Dzanku, 2018). A related socio-cultural problem is linked to the collectivist nature of farmers especially in West Africa (Olawuyi & Mushunje, 2019; Sule et al., 2019). Another socio-cultural issue is that people in the community do not complain or protest so no one individual is comfortable standing out alone without support against any questionable behavior whether it is a farmer, middle man, or government (Olorunfemi et al., 2018; Otene et al., 2018). In a practical sense, farmers tend to have difficulty accessing tractors, especially those who have large acreages (Okeke & Oluka, 2017). Sometimes, farmers have sufficient money to hire or lease tractors, but there are not enough tractors available from either the local government or private individuals (Okeke & Oluka, 2017).

Climate change has also impacted rural farmers (Adepoju & Osunbor, 2018; Bosello et al., 2018). The climatic changes are unpredictable, and the rains are unreliable as compared to past years (Bosello et al., 2018). This means rural farmers cannot plan very well. A shortage of rainfall coupled with droughts limits the quantity and quality of crops that farmers can produce (Bosello et al., 2018). To add to that, there are increased amounts of pests and diseases affecting farm yields (Bamigboye, 2016; Imoloame & Ahmed, 2018; Zhang et al., 2018). Increased disruptive weeds go hand in hand with the climatic change phenomenon. There are problems with Striga or Witchweed, a parasitic plant that contaminates crops and reduces crops yield which is like a flower, and it adapts better to disruptive climatic changes than the crops Zhang (2018). There is also a kind of stubborn grass that the farmers must weed manually, which also ends up reducing their yield (Bamigboye, 2016). The farmers have to uproot these Striga and stubborn grass, but this is a very manual activity that requires a lot of labor which farmers cannot ill-afford (Imoloame & Ahmed, 2018).

As noted earlier, global terrorism has impacted West African farmers (Adelaja & George, 2019). Security challenges and kidnappings have affected farmer attitudes as well as behavior (Adelaja & George, 2019). Farmers are afraid to go out too far away farms since they are afraid of being kidnapped or killed, and they fear for family members when they are not there to protect them (Adelaja & George, 2019). The root cause of the insecurity in West Africa is often the Boko Haram terrorists or opportunistic criminals (Che et al., 2020). Che, Strang and Vajjhala (2020) reported that the brother of one of the extension worker participants was kidnapped during their study but was returned after a ransom was paid. This is somewhat a cause of the lack of motorbikes and lack of fertilizers because transportation is constrained due to terrorism. Sometimes, there are violent conflicts between farmers and nomadic Fulani herdsmen (Fasona et al., 2016; Oli, Ibekwe, & Nwankwo, 2018). The Fulani herdsmen sometimes graze their cattle on the farms, often eating entire crops, so this creates conflicts with farmers (Fasona et al., 2016). Conflicts with Fulani herdsmen are relatively uncommon but crop damage can occur during the night, so while there may be no conflict, there is still a loss of crops (Oli et al., 2018).

Money or line of credit is a problem with farmers and the entire agriculture logistics supply chain (Awotide et al., 2019; Michael et al., 2018; Ndubueze-Ogaraku & Andamadi, 2017; Osa-Afiana & Kelikume, 2016; Urama et al., 2019). There are few loan facilities to boost rural farmer productivity so farmers cannot afford to acquire new technologies to improve their productivity (Osa-Afiana & Kelikume, 2016). The issues of lack of credit have hampered farmers' ability to treat agriculture as a business and to strategically plan their farms, which are often located in disparate locations, exacerbated by the issues of poor transportation (Michael et al., 2018; Ndubueze-Ogaraku & Andamadi, 2017).

The farmers also experience land-hunger, a situation that arises because the land is owned or controlled by individuals or distributed by privileged individuals, and so property rights can become an issue (Smith, 2018). Farmers often need to do crop rotation, but they face challenges if they do not have access to another land on which they can cultivate particular crops (Odudu & Omirin, 2012). At the same time, it is difficult for others to enter the farming industry because they cannot secure access to suitable land to start cultivation (Barnes et al., 2018; Obayelu et al., 2019). These problems are interrelated. Individuals often do not have money to purchase land, but there is no suitable land in the area to rent (Barnes et al., 2018; Obayelu et al., 2019). Additionally, there is a lack of credit available to rent or purchase land (Ndubueze-Ogaraku & Andamadi, 2017). Che, Strang and Vajjhala (2020) posited that land swaps (owned or rented) may be an option to overcome the proximity issue, such as having farmers in different regions swap land for seasons making it easier for each party to cultivate due to a reduction in overall travel distances for operations and marketing functions.

A serious issue is that farmers lack strategic planning capacity and knowledge (Strang, Che et al., 2019). Farmers do not treat farming as a business, farmers lack business knowledge, and so they do farming basically to survive (Strang et al., 2019). Fawole and Ozkan (Fawole & Ozkan, 2018) insisted that farmers do not need business degrees, but at least they need strategic planning mentoring and advising from experienced, trusted sources. Somewhat related to the lack of strategic planning is the fact that there is a lack of agricultural extension workers (Otene et al., 2018). There are not enough well-qualified extension workers to properly support farmers, or in many cases, the extension workers are not able to get to the farm or vice-versa (Olawuyi, 2019; Otene et al., 2018). The evidence of this is that sometimes the farmers make long trips to a regional government office because they desperately need assistance, but there are no extension workers available to visit them at their farms (Che et al., 2020). Strang, Che and Vajjhala (Strang, Che et al., 2019) argued the root cause of this issue may be that extension workers have limited incentives or allowances because the government has stopped providing these allowances. According to them, in the past, the government supported extension workers by providing salaries and allowances, which enabled the extension workers to provide training to farms via demonstration plots. Without these incentives, the extension workers cannot maintain themselves and cannot continue with the demonstration plots (Strang et al., 2019).

Training and learning is a problem (Ettah, Chima, Celine, & F.Okorie, 2018; Kazeem et al., 2017). Some governments use demonstration plots for training and learning. These are particularly valuable for facilitating experiential or applied learning because the farmers can easily see and assimilate the modern applied methods and the production results Kazeem (2017). Farmers may be willing to adopt new methods if they could readily confirm the new methods would be better (Che et al., 2020). Inadequate incentives for extension workers hinder their ability to support the farmers and themselves adequately, where in some cases the extension worker salaries have not been paid regularly, or they are not paid at all (Kazeem et al., 2017). Overall, with extension worker pay cuts and the unreliable salary payments, the extension workers face tremendous challenges providing any level of support to the farmers (Che et al., 2020). Strang, Che and Vajjhala (Strang, Che et al., 2019) argued there was a clear need for the government to address the situation, to fix the broken support for the extension system so that the farmers can be better supported to improve their productivity.

On a related issue, Strang, Che and Vajjhala (2019) found there were inadequate training programs available to extension workers and farmers from agricultural research centers or stations. The research centers are sponsored by the government, and extension workers used to receive training from these centers, but they no longer get this training (Strang et al., 2019). Furthermore, information, knowledge, and messages used to be disseminated from the research centers to the extension workers who in turn shared the data with the farmers Strang, Che and Vajjhala (Strang et al., 2019). Similarly, the feedback and lessons from the farms used to be channeled through the extension system back to the research centers, with the offices coordinating activities in each region (Strang et al., 2019). This system of training and communication has since stopped, and the extension workers and farmers are suffering because of this breakdown (Che et al., 2020). The farmers' problems are not being adequately captured, not being addressed, and often it takes far too long to get a resolution for their problem. The infrastructure in terms of training facilities is neglected (Che et al., 2020). For example, according to Che, Strang and Vajjhala (Che et al., 2020) one training center building lost its roof because of the rains, but it was never replaced, and there is no longer furniture to hold any training for the extension workers – this was evident across all their case study sites.

There is a corruption problem, originating with politicians, who operate without impartiality (Azih, 2008; CISLAC, 2017). Politicians tend to cater to the needs of local special interests, which often leaves most of the people with little to no access to critical resources (CISLAC, 2017). The situation is that politicians tend to adopt strong political affiliations and have control of the resources and assets that farmers need (Dyck & Silvestre, 2019; Takeshima, 2018). What this means is that some farmers are unjustifiably favored and are showered with access to farming inputs, access to credit facilities, and other resources, while the others who are disliked are left to their own devices.

Olorunfemi, Olorunfemi, Oladele and Adekunle (2018) discussed a valuable training facility that called Agricultural Development Program (ADP) which was side-lined in the current government process for disseminating agricultural inputs (fertilizers and improved inputs). They complained that farmers found it too complex. According to them, the inputs are dispatched from the central government to the region then to the local government wards or ward chairman. From there, the inputs are inexplicably diverted to the markets or political favorites, but often none reaches to the farmers directly as intended. Allegedly corruption takes place by opportunistic politicians in the federal and local government apparatus has led to a hijacking of the inputs dissemination process to the disadvantage of rural farmers (Olorunfemi et al., 2018).

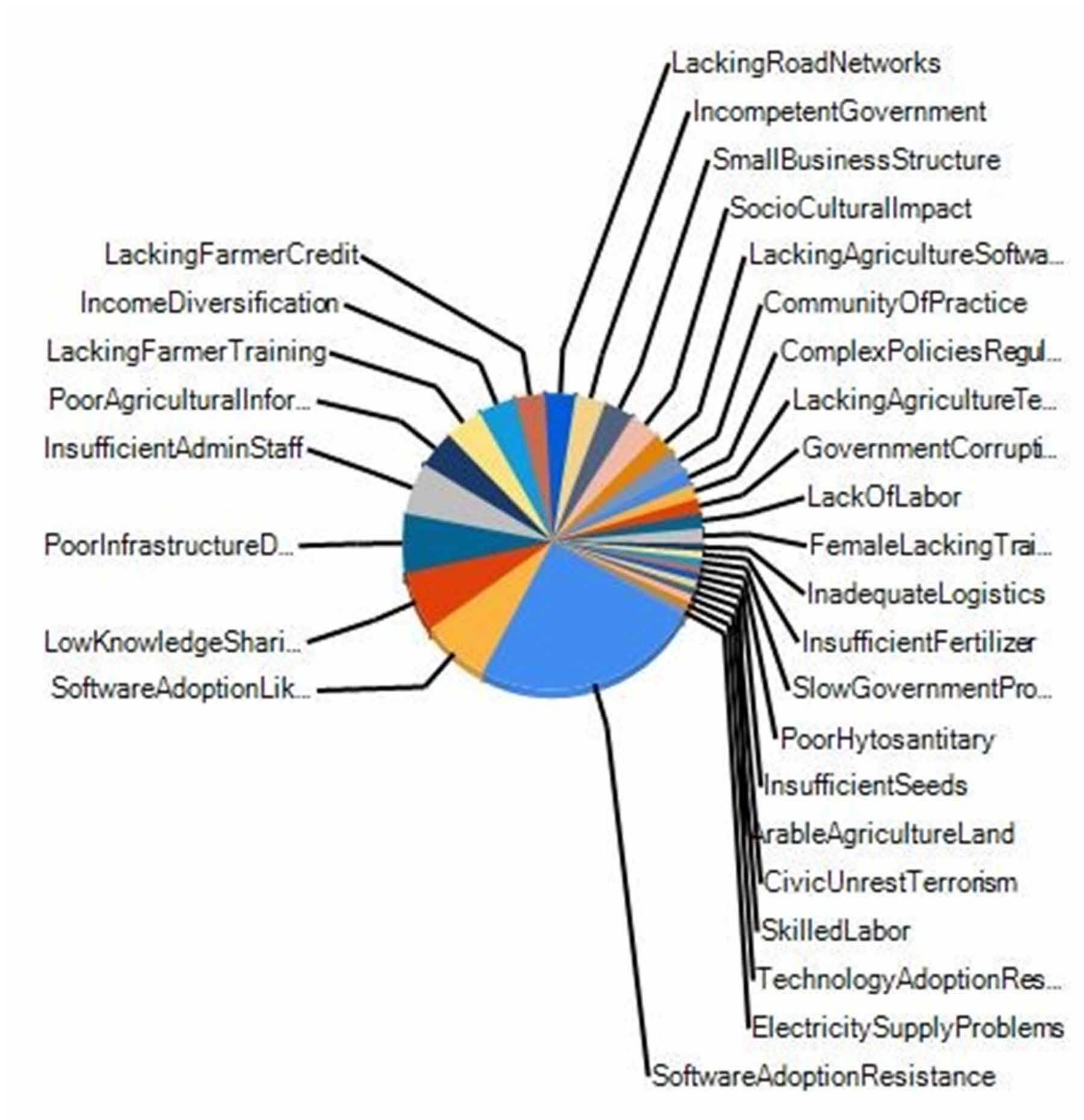
In the past, the previous Growth Enhancement Scheme (GES) program effectively delivered inputs to farmers across Nigeria through the ADP extension system, often free of charge or significantly subsidized (Omorinre, Osanyinlusi, Amoke, Olusola, & Isaiah, 2018). The GES was replaced with a new process requiring farmers to acquire raw agriculture inputs from unregulated dealers whose interests are limited to generating profits for themselves without genuine concern for farmers or quality (Uduji & Okolo-Obasi, 2018). The perception of farmers and extension workers is that the current system of inputs dissemination is severely broken, and they are powerless over the cost, quantity, and quality of the agricultural inputs they obtain (Omorinre et al., 2018).

In their empirical study, Che, Strang and Vajjhala (2020) illustrated how farmers often must make do with less than three bags of fertilizer in situations where they used to deploy ten bags, due to the increased costs and lack of subsidies. According to the authors, the inputs dispatched by the Ministry of Agriculture ends up in the hands of local politicians who turn around and sell the inputs to make profits for themselves. They noted that individual farmers are afraid to protest against these corrupt practices, but they have been unable to organize as a group to mount an effective protest because there is no united farmers' association or a farmers' cooperative union to handle such grievances or advocate for farmers. Che, Strang and Vajjhala (2020) stated that farmers would welcome support from NGOs or private businesses who could also advocate for them. Their idea was the government could assist in launching and funding farmers' cooperative unions to be located in the regions, then the farmers' cooperatives could take on a coordination function to handle both agriculture input regulation and output export market promotion, possibly, at nominal self-sustaining fees.

Synthesis of Agriculture Issues and Controversies

We analyzed our detailed review of specific agriculture issues and controversies. As we noted earlier, topics such as lack of strategic planning, terrorism, corruption and lack of education were several of the critical issues in the empirical literature. Figure 2 is a conceptual model summarizing and synthesizing the agriculture issues and controversies that we determined through our critical analysis of the literature, which was heavily weighted by Nigeria. This is subject in as far as we focused on issues or controversies that were discussed more often in the literature. However, we feel it is a valid representation of the state-of-the-art highlighting the most serious contemporary agriculture issues and controversies in West Africa.

Figure 2. Conceptual model of agriculture issues controversies



SOLUTIONS AND RECOMMENDATIONS

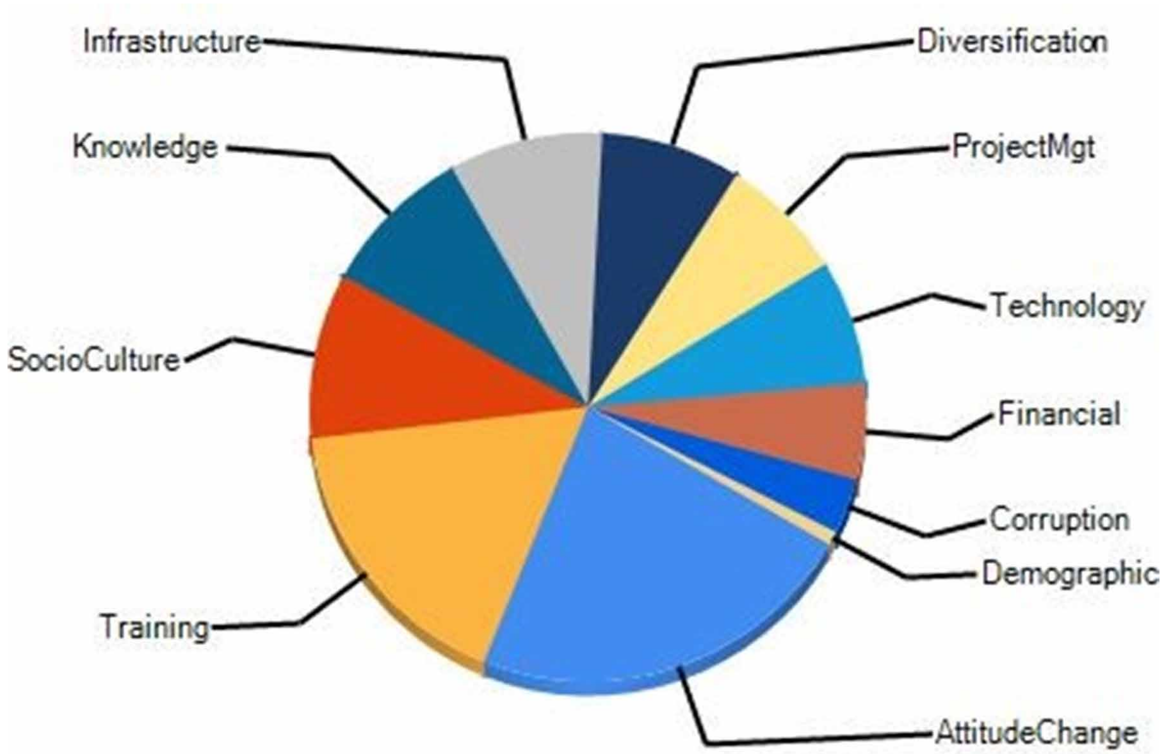
In this section, we revisit the issues and controversies discussed earlier, but here we attempt to highlight probable solutions for the agriculture problems. By probable solutions we mean topics and subjects that are forward-looking, data-driven ideas and strategies designed to overcome the root cause. We begin with a visual model as shown in figure 3 and then we discuss each probable solution.

The most promising empirical research focused on a combination of training, knowledge and attitude change, together. Albeit we labeled these as separate probable solutions, we feel they can be integrated.

We argue more training and knowledge sharing are needed, through face-to-face and distance (internet) modalities, to bring farmers and logistics firms up to date on modern techniques practiced in well performing countries. We also suggest to use social media for training, knowledge sharing and attitude change. This is an integrative approach, a valuable technique, to achieve multiple goals using the same related dissemination strategy.

Several other factors can be addressed and delivered through the training channels, perhaps through social media. Social culture takes time to change. This may involve sharing the knowledge that religion is not a barrier, it is just different. Most religions have a god, and we argue, everyone ought to be free to believe in their own version of religion. Religion rarely comes into conflict with agriculture (we cannot think of an example). Even the herdsmen who have different religions as compared with many farmers, so exist and respect the fact that religions and cultures differ. The demographic stigma of a female not working in agriculture is gradually being lifted. Also, age is not a barrier, since older farmers can train younger farmers, and more importantly, vice versa, young farmers returning with an education can practice train-the-trainer, spreading knowledge from regional centers into the farming cooperatives and community. This can be promoted through best practice sharing, again, disseminated through training or social media. Expanding and changing norms can be shared so that everyone realizes this is a moving target and not change but evolution, towards a better society with the same goal of food security.

Figure 3. Conceptual model of probable agriculture solution topics



Financial credit and income diversification are also related. Government must assist in providing better regulations and access to credit. Farmers must be cautioned to consider developing alternative sources of legal income to offset unknowns such as drought, climate change and terrorism.

Infrastructure, information systems technology and the fight against corruption could be combined as a probable solution. The government is ultimately responsible to improving buildings, potable water, irrigation canals road and transportation services. Why not add in technology provision as well? Governments ought to provide basic technology through schools and extension workers, to make access to technology more equitable and pervasive. Furthermore, government ought to investigate and identify free (or low cost) but safe software and technology to share with farmers. Good project management will be needed, to ensure agriculture improvement initiatives are successful. The government can use project management best-practices, credibility and knowledge to research mature software solutions, and purchase good quality but older year technology, and then make that available free or at low cost to farmers and logistics firms. Government could not accomplish this without fighting and eventually eliminating corruption. Corruption is a difficult social cultural norm to change. External assistance may be needed to fight corruption. For example, the European Union are fighting corruption with good practices and entry/maintenance criteria that requires a nation prove they are addressing and reducing corruption as was the case of Albania (Vajjhala & Strang, 2014).

FUTURE RESEARCH DIRECTIONS

We believe researchers are taking the global agriculture problems and food insecurity crisis seriously, and since this has gone on for decades without resolution, we condone the choice of empirical data-driven studies to identify the root causes and then involve local subject matter experts to form solutions.

For this reason we recommend mixed methods studies be attempted to address this large global problem. We assert that data-driven empirical studies are useful to authentically identify the issues along with their magnitude, but practical solutions must then be developed. The practical solutions require input from subject matter experts, those practitioners on-the-ground who have knowledge of the problem and resources available to solve the problems.

CONCLUSION

The objective of this chapter was to examine the key root causes which seemed to hinder the advancement of the agriculture section in West Africa, with a focus on Nigeria as a national case study. The goal was to identify opportunities to adopt information systems to improve the agricultural sector productivity in West Africa as well as specifically in Nigeria. West Africa was the focus here for two reasons. First, the world was too large a scope to address in a single chapter. Second, Nigeria, was the specific focus for this chapter since it has the largest population in Africa, it is located in West Africa, and the citizens are relatively high technology-literature at least with mobile phones.

In this chapter we applied the critical analysis method to review the state-of-the-art empirical literature about agriculture problems in West Africa. We took several complimentary perspectives to identify the relevant root cause issues, controversies and probable solutions. We used a table and four conceptual diagrams to convey our findings. However, since our chapter was a retrospective literature review critical analysis, we did not collect new data. We also found only week evidence of significant information system use for the agriculture sector. We felt this was due to the lack of training provided to farmers, and secondly, the lack of time available to farmers to use for strategic planning or information system use. The implications are that farmers do not have sufficient knowledge about the potential ability for small information systems which may be useful for agriculture planning, particularly on smart phones, such as weather apps and community forums. Also we feel this was in the early lifecycle of the use of information systems for agriculture in Nigeria – if we were to conduct this review in a few years we hypothesize the results will be significantly different, with prevalent use of mobile systems for agriculture.

We feel the literature theme keywords developed in this chapter from the extant literature review will be useful to key stakeholders namely, agriculture software developers, agricultural industry practitioners, agricultural extension professionals, academic researchers, and government researchers. We recognize our literature review was only the beginning step in identifying the underlying constraints of information system adoption in Nigeria and West Africa for improving the agriculture section. Therefore we recommend further studies be conducted. We recommend other scholars conduct empirical studies using a mixed method to collect and analyze evidence to be accompanied by problem solving using localized subject matter experts.

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KEY TERMS AND DEFINITIONS

Extension Worker: An experienced farmer, selected and hired by the government to mentor and train local farmers, using their credibility as a farmer to approach their clients.

Chapter 4
Assessment of E-Readiness Challenges of Farmers and Extension Workers in North-East Nigeria

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ABSTRACT

The grounded theory study-based chapter comprehensively presents information about the significance of information and communication technology, the e-readiness situation of Nigeria in the field of agribusiness. The core purpose of this chapter is to discuss the e-readiness challenges faced by the farmers and extension workers communities of the north-east region of Nigeria. While introducing and application of information technology (IT), numerous challenges like infrastructural constraints including electricity, training facilities, lower literacy rates, language and cultural restrictions, lack of awareness campaigns, expensive telecom services have been facing by farmers and extension workers of the targeted region. The significant adoption of technology in agriculture by the young generation when compared to the older age, also highlighted in the chapter. The authors highlighted the dot.com boom in Africa, particularly in Nigeria, along with stakeholder's role in creating awareness of agricultural information systems.

INTRODUCTION

Globalization has carried a unique prominence on knowledge innovation and transfer as the crucial driver of economic development and competitiveness with information technologies playing an ever-escalating role. The catalyst for the kind of knowledge innovations and transfer is only the Information

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and Communications Technologies (ICTs). It has, therefore, become imperative for countries to introduce advances in information technology (IT) to influence the organization and the success of all sectors of the economy as well as agriculture. The strategic application and administration of information technology confidently yield enormous benefits to all stakeholders of the government. Even though only five African countries had Internet connectivity in the year 1996, by 2001, all the nations in Africa had logged on to the Internet. During the first decade of the 21st century, Internet access in Africa has further increased (Hellsten, 2010), and as per the International Telecommunications Union (2019), Africa the second largest continent after Asia by size and population has 28.2 percent of the Internet accessibility. The kind of extensive expansion of information technology enhances the scope to avail of the benefits for all sectors comprising agriculture and its allied businesses. The situation of this kind raises the question of whether agriculture and its allied businesses are ready to invite the benefits of information technology or not? The reason is that most of the farmers and extension workers are illiterates and doing farming and other related activities by using traditional practices without the support of any type of technology. The existing sorry state of affairs in the agriculture and its businesses triggers the idea to the authors to study the e-readiness of the farmers and extension workers in north-east Nigeria. Notably, farmers and agriculture are the backbones to most of the developing and underdeveloped economies where most of the people are engaged in producing a variety of Agri-based products.

Agribusiness is the business of agricultural production. The term is a portmanteau of agriculture and business and is widely believed to have been coined in 1957 by John Davis and Ray Goldberg (Davis & Goldberg, 1957). The agribusiness comprises crop production, distribution, agrichemicals, breeding, farm machinery, processing, and seed supply along with marketing of all varieties of agri-based products. Agribusiness includes a broad range of activities and processes involved in the production, processing, marketing, and distribution of food products (Molla, Peszynski, & Pittayachawan, 2010). Extension workers play a critical role as information intermediary in the agricultural information services chain between the various governmental, non-governmental agencies, and the farmers (Mavhunduse & Holmner, 2019). Extension workers are individuals who are working with small farmers to improve farm productivity from initial sowing to get the maximum yields of the crops. The extension is the two-way method of transmitting information, knowledge, or skills that can help persons, families, neighborhoods, companies, or industries attain enhanced economic, social, and environmental outcomes and establish constructive transformation. Information and Communication Technologies (ICTs) include all products that can store, retrieve, manipulate, transmit, and receive information in digital form (Alabi, 2016; Das, 2018). UNESCO comprehensively defined the term ICT as types of technology that are applied to spread, progression, accumulate, generate, exhibit, distribute, or swap information by electronic means by using radio, TV, video, DVD, telecom satellite systems, and computer software and hardware along with the apparatus and services linked with the above technologies viz., video conferencing, emails, and blogs, etc. (UNESCO, 2007). ICT, as defined in the Information & Communication Technology Sector Strategy Paper of the World Bank Group consists of hardware, software, networks, and media for collection, storage, processing, transmission, and presentation of information (voice, data, text, images) (World Bank, 2003). In a nutshell, ICT means “dispensation and passing of information in a scientific manner”, which covers lengthy above-mentioned activities (World Bank, 2011). The term e-readiness is defined by Jukic et al. (2009) in a more comprehensive manner as the maturity of citizens, businesses, NGOs and governments for participating in the electronic world (e-commerce, e-government etc.) Hellsten (2010) defined e-readiness as a country’s capacity and ability to provide services through the Internet.

ICT facilitates in escalating demand for new methodologies. It also eases in energizing the rural communities by offering improved access to biological resources, expanded agricultural technologies, efficient production strategies, markets, banking, and financial services. ICTs have been evolving at a rapid pace, especially over the last decade, with the emergence of smartphones and enhanced internet connectivity. However, the successful adoption of ICTs by farmers would depend on the e-readiness of these agricultural extension workers. If the extension workers are ready and are convinced about the effectiveness of using the technology to improve agricultural productivity, they would be motivated to convince the farmers to adopt these technologies. While several researchers have investigated the role of ICT on agribusiness, the rapid pace of technology development requires continual evaluation and validation of the extent of the impact by examining the readiness of the intended users of these technologies. Higher levels of e-readiness by farmers lead to higher adoption rates coupled together with the development of sustainable agriculture as well as in improving agricultural productivity (Ashraf, Shurjeel, & Iqbal, 2018; Gavai, Musungwini, & Mugoniwa, 2018). In most of the developed countries, technology is entirely intertwined with agribusiness, and further studies on e-readiness may not be required for validation. Several researchers have confirmed the advantages and success of intermediation offered by agricultural extension services in developed countries in improving farming productivity and performance (Álvarez-Coque, Ramos-Sandoval, & Mas-Verdú, 2018; Lapple & Hennessy, 2015). However, in the case of developing and emerging countries in Asia and Africa, there are significant economic, social, and technological challenges because of which the fusion of technology and agribusiness is still limited, especially in the context of agricultural extension workers (Lapple & Hennessy, 2015). The World Bank report has indicated that the poverty rates globally have been showing a decreasing pattern, except for the countries in Sub-Saharan Africa (Asongu & Nwachukwu, 2016). There is a need for studies assessing the e-readiness of extension workers to use the ICTs used in agribusiness by the farming community, especially in sub-Saharan African countries, which are facing several economic challenges. The rationale of this grounded theory study is to examine the e-readiness of farmers and extension workers and the challenges they face in North-East Nigeria.

BACKGROUND

African agricultural performance has improved over the last two decades, even though it is still quite low in the context of yield and productivity as compared to other parts of the world (Bachewe, Berhane, Minten, & Taffesse, 2018). Agricultural growth and productivity are important issues for African countries that have been facing several problems, including political, economic, and environmental issues (Bachewe et al., 2018). Food insecurity is a major global issue, especially in Sub-Saharan Africa, with inadequate nutrition resulting in an aggregate shortfall between 0.64 and 4.04 percentage points in annual GDP across Sub-Saharan Africa (Wantchekon & Riaz, 2019). The shortfall in production has been attributed to several factors, including lack of proper agricultural inputs, lower levels of awareness of agricultural technology, lack of governmental initiatives, lack of adequate agricultural extension services, and lack of distribution and storage facilities. The performance of small farmers is often hindered by the inability to access capital and technology (Álvarez-Coque et al., 2018). Agricultural extension services are critical in such instances in disseminating Information to millions of farmers and providing them with Information about advances in farming technologies and practices. There is a significant difference in agricultural productivity in the farming sector in developed and developing countries (Nordin &

Höjgård, 2017). Developed countries have significantly higher farm productivity as compared to developing countries. Some of the factors for this disparity include technology adoption, learning failures, and the under-adoption of new technologies. Extension workers could help in farm management by helping farmers adopt better fertilizer technologies, and provide vital information on rainfall, soil conditions, and application of fertilizers and other agricultural inputs (Nordin & Höjgård, 2017).

Most of the developed countries are gradually moving toward smart farming, which is based on using information and communication technologies in the cyber-physical farm management cycle (Wolfert, Ge, Verdouw, & Bogaardt, 2017). As part of smart farming practices, trending technologies, including big data, the Internet of things (IoT), and artificial intelligence, will be an integral part of technology assisting in farming (Wolfert et al., 2017). While developing countries in Asia and Africa are way behind schedule in adopting and implementing smart farms technology, there is a need to get the underlying infrastructure and Information in systems in place so that they can adapt to the rapidly evolving pace at which technology is moving forward. The critical challenge for governments in developing countries is disseminating the Information to the farming community to ensure higher rates of ICT adoption. The agricultural extension services are vital in ensuring that the Information is transmitted promptly to the farmers. Hence, the adoption of ICTs by farmers is dependent on the e-readiness of the extension workers. However, few studies are investigating the factors influencing the e-readiness of agricultural extension workers in developing countries, and in particular countries in Sub-Saharan Africa.

ICTs can play an essential role in helping information dissemination among farmers by the extension workers, especially on crucial farming issues requiring technical and expert assistance, including cropping pattern, use of high-yielding seeds, application of fertilizers and pesticides (Das, 2014). Several studies have demonstrated a positive change in income, quality of farm produce, and crop diversification because of the use of various agricultural information systems (Sousa, Nicolay, & Home, 2016). Tumbo et al. (2018) categorized ICTs into two categories, namely, traditional and modern. Traditional forms of ICT are less interactive, for instance, radio and television are a couple of examples of traditional ICTs. Modern ICTs are considerably more interactive and allow two-way communication, for instance, web-based systems and mobile telephony. Considering that farming communities in developing countries often depend on indigenous farming techniques, access to complex Information related to climate patterns and high-yielding seeds can be easily be made available and accessible through the use of ICTs.

Developed countries have been prosperous in integrating information systems not just for farm management but also for managing agribusiness and for providing timely assistance to farmers on a range of issues, including weather, farm inputs, and farm outputs. The Food and Agricultural Education Information System (FAEIS) is maintained by the United States Department of Agriculture (USADA). The said information system is a comprehensive nationwide system that provides empirical data as well as analysis. The principal aim of this system was to provide support for higher education in the food, human, agricultural, and natural resource sciences (Marchant et al., 2010). The data generated from this information system benefits not only academics and researchers, but can also form the basis for policy-makers framing legislations (Marchant et al., 2010). Similar information systems have the potential to make an impact in the agricultural sector in Sub-Saharan African countries. However, the adoption of these ICTs needs to be investigated.

Extension workers face several challenges while using ICTs, including poor interconnectivity, power outages, poor ICT infrastructure, lack of computer literacy skills, and lack of user-driven information (Mavhunduse & Holmner, 2019). More research about the e-readiness of extension workers is needed. Strang, Bitrus, and Vajjhala (2019) found that traditional ICT adoption factors could not predict the behavior of

Sub-Saharan African farmers on the Jos plateau in Nigeria, and they recommended in-depth qualitative research be conducted to investigate the phenomenon further. Similarly, other researchers recommended more in-depth studies be completed to identify which factors actually influence the e-readiness of agricultural extension workers (Mavhunduse & Holmner, 2019). The expanding internet connectivity and e-readiness are especially crucial in many African countries that face significant economic and political challenges. These contain, for instance: (1) the elevation of sustainable development and the eradication of poverty; (2) delivering equal and fair access to the natural resources; (3) the prevention, management, and resolution of ethnic conflicts and reinforcement of peace, security and stability; (4) the endorsement of inclusive popular participation in the development processes of democracy and "good governance"; and, (5) the promotion of human rights and civil society activities (Hellsten, 2010). Based on the above background of the study, the researchers had taken-up the study to know the e-readiness challenges of farmers and extension workers in the North-East part of Nigeria.

Provision of Agricultural Information Through ICTs

The high failure-rate of ICT for development (ICT4D) projects in African countries is partly because of the highly techno-centric nature of the projects, which often tend to ignore the social context of the implementation environment (Mavhunduse & Holmner, 2019). The agricultural extension services are a vital component of this social context as farmers in developing countries prefer face-to-face communication with the extension workers. Governments in developing countries need to train extension workers in ICT and ensure their e-readiness before embarking on techno-centric ICT4D projects. The agriculture sector is information-dependent, particularly on scientific and technical information for effective decision-making (Prakash, Philip, & Sriram, 2017). Despite the recent technological advances, including the higher penetration rates of mobile telephony, agricultural extension services are still the primary source of agricultural information in developing countries, and in particular, the Sub-Saharan African countries (Mavhunduse & Holmner, 2019). Agricultural extension workers use several ICT tools for disseminating information to the farmers, including radio, telephones, mobile telephony services, computers, email, newspapers, and televisions (Kintoki, 2018). Several studies have provided evidence of the role of information technology in increasing agricultural productivity and income (Das, 2018). One of the key benefits of integrating technology in agriculture is information dissemination and knowledge sharing through the setting up of incubation and research centers (Das, 2018). ICTs can help improve food security as these can be used as vehicles to inform farmers about new technologies, improved input management, and raise awareness about modern farming technologies (Nakasone & Torero, 2016). ICTs can help farmers in accessing Information about farm inputs, including new seeds, fertilizers, demand patterns, government schemes, weather information, and selling input at the right prices (Das, 2018). ICTs can also be critical in increasing awareness among farming communities about better sales opportunities as well as the sales opportunities available to farmers (Nakasone & Torero, 2016). Jain, Kumar, and Singla (2015) emphasize that ICTs can play a significant role in agriculture as farming is a knowledge-intensive industry, and farmers can benefit from expert advice about financial, climatic, and regulatory Information.

Factors Influencing Adoption of ICTs/Farmers' Readiness to use of ICTs in Agriculture

The successful adoption of technology is usually dependent on the ability of technology to meet the needs of its users Lubell and McRoberts (2018). E-Readiness refers to the readiness for using new technologies and is mainly determined by critical factors, including connectivity, content, community, commerce, capacity, culture, cooperation, and capital (Oreku, Li, Kimeli, & Mtenzi, 2009). Tumbo et al. (2018) suggest that contrary to the belief that users do not use technology because of lack of knowledge or skill, the primary reason for not adopting technology is the perception that the technologies do not contribute towards improvements. If the farmers perceive that the technologies are not beneficial or are prone to high risk, they are unlikely to use and adopt these technologies. Alabi (2016) identified several issues leading to lower ICT readiness and adoption and usage rates among the farming community in Sub-Saharan African countries, including lack of training and ICT education, access issues, cultural issues, and lack of proper infrastructure. For the extension workers to achieve higher levels of e-readiness, a clear understanding of the objectives of using the new technology is essential (Oreku et al., 2009).

Infrastructural constraints, including lack of electricity, was also identified as a significant factor leading to lower levels of ICT use by farming communities. In their study on the factors influencing ICT readiness in commercial agriculture in Zimbabwe, Gavai et al. (2018) found three key factors, namely, training, government policy, and awareness campaigns. The level of education is also likely to influence the adoption of ICTs as the farmers need a variety of ICTs for pest control, post-harvesting, irrigation, and weather forecasting. According to Sousa et al. (2016), the readiness for the new technologies tends to be quite low because of several factors, including sparse information networks, lack of awareness, and absence of financial incentives. The early adopters of innovations are usually equipped with better information networks. Hence, a significant factor in encouraging the e-readiness of extension workers is to build up a reliable information network so that the users of the technology are aware of the tangible benefits of using the new technology (Sousa et al., 2016).

Jain et al. (2015) state that the successful implementation of ICTs in agriculture requires a complex set of policy, investment, and capacity-building measures. Some of the critical constraints influencing the adoption of the ICTs by the farming community include connectivity, content, and capacity.

The adoption of ICTs in agriculture depends on addressing various issues, including lack of awareness, lower literacy levels, lack of infrastructure, language, and cultural restrictions (Sousa et al., 2016). Lubell and McRoberts (2018) investigate the adoption of ICT by agricultural extension workers using the diffusion of innovation theory. The main argument of this theory is that the probability of an innovation being adopted by its users is related to five primary attributes of the innovation, namely, relative advantage, compatibility, complexity, trialability, and observability. The advantages of using technology over the available alternatives would indicate the level of the relative advantage of an innovation. Innovation can be considered as compatible if it fits within the professional and social norms where the innovation is applied. An innovation may not be easily used and adopted if the users struggle in using the innovation, taking into consideration that not all the users of the innovation have the required level of technical expertise. Observability and trialability features require that the effectiveness of the innovation can not only be tried but also should be readily observable by the users.

The content and relevance of the information provided by the ICTs are also quite crucial for the adoption and application of this information. The content made available through the ICTs should provide quality and provide value to the farming community. The farming community is likely to adopt and use

ICTs if the Information is relevant in context to the needs of the farming community (Nakasone & Torero, 2016). While some information may be generic and useful for farming communities across all the developing countries, most of the Information is likely to be region-specific and community-specific. The mode of delivery and timing is also an essential factor in the context of delivery through ICT. For instance, Nakasone and Torero (2016) suggest that the use of SMS may not be useful as the initial vehicle for disseminating information about new farming techniques but might be more relevant in reinforcing training given to farmers. Also, pull-content may be more effective as compared to push-content, as pull-content if reflective of the information demands of the farming community (Nakasone & Torero, 2016).

Demographic factors may also play a role in influencing the behavior towards adopting new technologies. The younger generation dominates the number of ICT users in developing countries. Nakasone and Torero (2016) give the example of the internet users in developing countries in Asia, Africa, and Latin America where the number of users in the age group of 10-25 years is around 4 to 12 times higher than those in the age group of 50 years or older. A large proportion of the farmers are likely to be in a higher age group. Hence age may influence the adoption and usage rates of technology by the farmers. Another strategy could be to identify the pre-adoption attitudes of the users as this would be an early indicator of the success of the implementation of the new information systems (Schedler, Guenduez, & Frischknecht, 2019). During the initial stages of the implementation of information systems, there could be gaps between the rhetoric and reality, resulting in a gap between expected outcomes and achieved results (Schedler et al., 2019). Finally, as said by the researchers Potluri, R.M. & Potluri, L.S. (2015), governments can swiftly review their existing IT policies and identify loopholes in penetrating to rural to accurately organize those deficiencies for the quality delivery of services like education and telecom and highlighted the widespread application ICT to procure candid information about latest practices and methods related to agriculture and artisans,

There is no exception to the field of agriculture and its allied businesses. In the last two to three decades of dot com boom propagate in Africa in general and Nigeria, in particular, has positively driven the economy into new strides. The e-boom also relates to human capacity development in the direction of mistake-free gathering, application, and use of information through ICT aggressively multiply all kinds of skills of people who, in turn, increase their belief in exploring for their employment.

Awareness of Agricultural Information Systems

ICTs can play an essential role in Information and knowledge sharing between and among the various stakeholders in agriculture. Farmers need timely expert advice to remain competitive and engage in sustainable agricultural practices. ICTs can help farmers leverage and access timely expert advice and engage in knowledge sharing. Awareness of ICTs is an essential factor in determining the successful adoption of technologies by users. Lack of awareness was also identified as one of the reasons for lower levels of investment and adoption of ICTs in agriculture (Gavai et al., 2018). Access to ICTs can lead to a reduction in transaction costs by lowering search costs as well as reducing knowledge and information asymmetries (Gavai et al., 2018). The lack of proper comprehensive national IT policy in the context of content and coverage was also identified as a significant reason for the low awareness rates of ICT in Sub-Saharan African countries (Alabi, 2016). In a study carried out in India, Prakash et al. (2017) found medium levels of awareness in the farming community about the availability and use of ICT initiatives, including the use of social networking, mobile telephony, and email services. Kumar and Babu (2017) give the example of successful implementation of ICT initiatives in India through the setting up of village information centers that provided the local farming communities with web-based agro-advisories, subject-matter literacy training programs, weather data, and computer literacy training programs for youth and women.

Ashraf et al. (2018) emphasize the role of extension workers in training and increasing awareness among the farming community. The governments in developing countries often seek the assistance of extension programs and workers to disseminate Information about improved farming management practices. However, there is a lack of sufficient information on the actual impact of these extension programs on actual agricultural productivity (Nakasone & Torero, 2016). There is also criticism of the implementation of the extension workers program, including poor infrastructure, lack of follow-up information, and the lack of accountability among extension workers (Nakasone & Torero, 2016). In several developing countries, especially in Sub-Saharan Africa, the lack of proper infrastructure, in particular roads, makes visits by the extension workers to remote farming areas very costly and challenging. This factor also leads to extension workers conducting only one time visits and avoiding follow-up visits, which are quite essential to ensure complete implementation of the program objectives—also the lack of financial incentives and training results in lower levels of accountability among the extension workers. ICTs can help address some of these criticisms of agricultural extension programs by facilitating access to remote areas through ICTs, eliminating high transportation costs, and enabling frequent two-way communication between the extension workers and the farmers (Nakasone & Torero, 2016). ICTs can also help in ensuring the accountability of the extension workers through improved transparency and availability of information.

Constraints/ Barriers to using ICTs or modern methods

The global mobile telephony penetration rate was at an average of 63%, with Europe at a high of 85% and Sub-Saharan Africa at the lowest of 43% (Danquah & Iddrisu, 2018). While the low penetration rate is an area of concern, the positive aspect is the surge in contact with mobile phones in the last few years. Sub-Saharan countries, including Nigeria, suffer from poor infrastructure, but there has been a rapid increase in access to mobile phones in both rural and urban communities in the last few years (Wantchekon & Riaz, 2019). This rapid increase in the availability of mobile technology has contributed to improved information availability as well as information flow. The physical availability of extension workers is also a significant challenge in developing countries, with the extensions staff to farmers ratio as high as 1:2000 in some areas in India (Mavhunduse & Holmner, 2019). The situation would, in turn, affect the rate of information delivery as the farmers may not receive timely information.

METHODS

Grounded theory is a qualitative design that allows researchers to develop substantive theory in a stage-wise manner (Leino, Mattila, & Kaunonen, 2012). Grounded theory was suitable for this research study as the focus group in this study involved interaction with extension workers who were key stakeholders. The purpose of constructivist grounded theory is to inductively build a new theory that is sensitive to social conditions when the existing theories have been generated in alternative conditions (Hense & McFerran, 2016). The design of the research question in a constructivist grounded theory should address the cause, conditions, consequences, covariances, context, and contingencies of the study (Moore, 2010).

Grounded theory research does not involve any testing of preconceived hypotheses, and instead, a theory is allowed to emerge by examining the content of the raw data. Researchers conducting a grounded theory study should also refrain from a rigid focus and should frame a flexible and broad research question (Hense & McFerran, 2016; Moore, 2010). The researchers in this study also refrained from any bias or preconceived notions about the issues facing the farming community, The researchers moderated the focus group and let the participants, i.e., the agricultural extension workers discuss openly about the issues facing the farming community in the two local government areas in North-Eastern Nigeria. We had used a purposive sampling technique for this study. Purposive sampling technique is suitable for constructivist grounded theory studies because the knowledge of the researchers is a key determinant in picking cases to be included in a sample (Moore, 2010). The guidelines of a grounded theory are applied in a flexible manner as compared to strict rules in some of the other research designs (Sutcliffe, 2016). A constructivist grounded theory allows the researchers to move from a description of what is happening to an understanding of the process by which it is happening (Boadu & Sorour, 2015). The researchers did not seek to test any hypothesis, and instead, the focus was on understanding the phenomenon. Boadu and Sorour (2015) further state that grounded theory is suitable when the researchers are seeking to understand what lies behind a particular phenomenon about which much is not known. The objective of the researchers in this study was also to understand the factors influencing the acceptance and adoption of agricultural information systems and ICTs by the farming community in north-eastern Nigeria. The researchers conducted the literature review after the analysis and theory generate to ensure that the pre-existing theories do not bias the researchers (Sutcliffe, 2016). The researchers had adopted an inductive coding approach in this study. The iterative inductive coding process resulted in the comparison of emerging categories to the data extracted from the interviews.

Six themes were identified from the inductive coding of the raw interview and focus group data collected from the extension workers. These six themes were: the high cost of new technologies, lack of government subsidies, lack of technology skills, lack of training, shortage of extension workers, and unavailability of technological infrastructure. In this study, qualitative data were collected employing interviews and focus group sessions, which involved making field notes. The qualitative data were analyzed using qualitative techniques, which consisted of assigning codes to the phrases (known as keywords in context), and then analyzing the keywords in context using visual pattern comparisons to identify and group similar words with the help of NVivo (Version 12.0) content analysis software. The objective of the coding process is to divide the text into segments, label the segments with codes, examine the codes for redundancy, and collapse the codes into broad themes. The transcripts were transcribed verbatim from the audio-recorded interviews, and key phrases were recorded. Redundant codes were then removed from the list of code words. The process of reduction in the number of codes continued until the six themes were identified. A word cloud illustrating the key terms from the word count frequency is shown in Figure 1. Partially, quantitative techniques were also be used to analyze the qualitative data because, once the phrases were coded and organized into thematic keyword hierarchies, groups of words in the hierarchy could be counted and grouped with totals, as shown in Table 1.

Figure 1. Word Cloud – Technology Readiness Obstacles

Table 1. Word Frequency Count

Word	Length	Count	Weighted Percent
information	11	6	4.17%
technologies	12	6	4.17%
knowledge	9	5	3.47%
lack	4	5	3.47%
extension	9	4	2.78%
methods	7	4	2.78%
modern	6	4	2.78%
new	3	4	2.78%
training	8	4	2.78%

CONCLUSION

Information and Communication Technology (ICT) can transform the agriculture sector in most of the developing countries and can benefit all farmers and extension workers in the frontline. Effective introduction and application of ICTs into the agriculture and its allied businesses have the potential to engage the entire farming community. All the stakeholders related to agriculture have to show a high degree of commitment and responsibility to introduce primary ICT tools for the agricultural sector include personal computers, telephones, the Internet, and other telecommunication devices. Agriculture and its allied businesses are the most crucial and vital sector with most of the rural populace in developing countries depending on it. Even in the new millennium and widespread dot.com boom, including Nigeria, most of the developing countries farmers still following pragmatic approaches of agriculture because of numerous challenges in terms of production, marketing, profit. The challenges of traditional agriculture are addressed prominently by the application of Information and Communication Technologies (ICT) that play a significant role in improving the livelihoods of farmers and extension workers, for which first the e-readiness of the said communities is an imperative situation. The chapter elaborately discussed various e-readiness challenges faced and urged to resolve those with the support of diverse stakeholders of the agri-business to make the rural communities confidently prosperous. Even with an endless number of problems like low literacy rate, language, and cultural restrictions, the farmers and extension workers in the study region has received great support and cooperation from the federal, state, and local governments in providing better access to natural resources, improved agricultural practices, effective production strategies, persistent training facilities, awareness programs on technology adoption, latest techniques of farming, markets, banking, and financial services by addressing the numerous infrastructure constraints.

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Chapter 5
Agribusiness in South Asia:
Current Status, Obstacles, and Policy Options

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ABSTRACT

Agribusiness plays a key role in the sustainable economic development of rural poor by fulfilling daily needs. In South Asia, all the countries have a similar pattern of societies, resources, climates, practices, and people located close to each other. Crop cultivation, dairy production, fishery, and forestry are the main agribusiness sectors for trading agricultural produce in markets. In contrast, factors (i.e., global warming due to climate change, natural calamity, environmental pollution, unsafe foodstuff, labor unavailability, marketing limitations, and financial crisis) are responsible for a serious fatal to agribusiness activities. Unless we uproot challenges, agribusiness cannot contribute effectively to the economy of developing nations in South Asia. Thus, future strategies may be standing on contemporary scientific research approaches on crop science, restoring resources, controlling food quality, introducing modern types of machinery, best marketing practices, and inclusive financing.

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INTRODUCTION

UN (United Nations) has planned to alleviate hunger by increasing agricultural productivity and sustainable production of food (UN, 2020). Agro-ecological approaches and advanced technologies could be used to achieve sustainable agricultural development in small and large income countries (Adenle et al., 2019). Transferring technology is a promoting factor for smallholders to have fruitful access to international markets. If governments develop strategies for transferring technologies to the smallholders, food security could be enhanced (Chege & Wang, 2020). For instance, technological development in Nigeria now gives support in ensuring food security without importing any food items through government policies for promoting agriculture (Gil et al., 2019). However, food security can be failed due to wastage of food products during sorting, processing and handling in the farms (Lawrence et al., 2013).

Large agribusiness has got success in making huge profits in the South African agriculture sector. Small agribusiness still has opportunities to successfully compete in the market with the larger ones in the retailing of foods. However, limited access to credit from banks is the core barrier to small business (Ramabulana, 2011). Moreover, rural farmers suffer from the scarcity of fair subsidy in inputs form the government in North-East Nigeria (Che et al., 2020). Africa, South America and Russia have shown interest in investing in agriculture. Thus, International Finance Corporation (IFC) announced to increase investment for strengthening agribusiness due to get informed about the interest of the new private sector in dealing with food industries in Africa (Tandon, 2010). The generation of employment is influenced by using land properly for agribusiness purposes in Peru (Delgado, 2015). Smallholder communities are usually privileged by getting water supply as a prime input for cultivating food (Mena-Vásconez et al., 2016).

Developing nations have a similar situation in terms of agribusiness. Like South America and Africa, South Asia shows identical attributes of agricultural technologies, production, marketing and retailing. The adoption of new technologies depends on knowledge, education level and annual income of the farmers (Sakib & Afrad, 2014). The broadcasting of information through popular channels can improve the knowledge level of farmers by getting information on the latest agricultural innovations (Sakib et al., 2014). Young agriculture professionals are likely to be sharing the newly released technologies over the internet for distributing mass clients for making them skilled enough within the existing Indian culture (Strang & Vajjhala, 2020). Mass media covers a wide area of clients to aware of the new technology for a large production (Sakib et al., 2015). Improvement of agricultural production can keep alive the agribusiness. Therefore, it is necessary to unearth the main hindrances of agricultural production, finances, marketing and consumption. In view of these drawbacks, this chapter will reveal the core challenges and opportunities of agribusiness in South Asia. Besides, it will also put forward some clues to policymakers for addressing present barriers. Moreover, it will guide the researchers to investigate more for the advancement of agribusiness in this region.

BACKGROUND

Generally, agribusiness involves producing, processing, marketing, and trading of agricultural goods (Antonio & Ioris, 2016; Kumar et al., 2013). It encompasses the whole chain of agricultural activities such as supplying seeds, processing foods and using machinery to meet food demand (Jin & Kim, 2008). Nowadays, development seeks agribusiness to bring notable changes in society by promoting small and micro agribusiness enterprises (Olowa & Olowa, 2015). In rural areas, many unemployed migrant laborers can take shelter under the canopy of agribusiness for their daily livelihoods (Findlay & McCollum, 2013). Globally, agribusiness takes attention to the private and public investors for large scale economic benefit and development. Moreover, it helps to ensure food security for pro-poor in rural areas (van Westen et al., 2019).

The satisfaction of customers is very important for the grand success of a company. Nowadays, proper steps are very important to increase customers' satisfaction for a market system (Pishbahar et al., 2019). Customer satisfaction is the primary indicator of the past, present, and future performance of a business (Zhang et al., 2005). Therefore, businessmen need to offer agro-products according to the preference of the customers. Usually, customers are convinced to pay a higher price to purchase a fresh product for the attainment of safe food (Yin et al., 2018). Furthermore, it is found that food safety measures increase both yield and profit to some smallholders (Kumar, 2020). Thus, changing the necessities of customers must be considered by agribusiness companies in order to attain their target business goals (Son et al., 2019). At present, the customer demands environmentally friendly products to keep the world free from threats or at least to lessen the threats. Logos indicating the eco-friendly contexts of products get more customer preference and influence to pick them as fresh at once (Rihn et al., 2019). Nowadays, customers try to stay with satisfaction in deciding to purchase a single food item by giving priority in terms of healthy and safe food (Pham et al., 2018).

South Asia consists of eight countries, namely Bangladesh, India, Pakistan, Afghanistan, Nepal, Bhutan, Maldives, and Sri Lanka (Ray et al., 2019). These countries are involved in different wings of agricultural production for continuing their economic development. Agriculture, fisheries, forestry, and livestock are the prime sources of raw materials for a food product in this territory. Basic needs are fulfilled from the earnings of agribusiness. Therefore, the agribusiness concept is being modernized to cope up with the changing desires of customers for establishing a suitable agribusiness environment in coming future. Still, this sector is facing many direct and indirect challenges to adapt to unexpected problems and unavoidable situations. Frequent droughts, floods, heat waves and cyclones are potential threats to the stakeholders in different agricultural sub-sectors (Ahmed et al., 2019). Some other direct limiting factors of agribusiness are pollutions, unlawful food additives, laborer unavailability, and improper financing (Karmaker et al., 2020; Siddiquee et al., 2019b; Singh, 2000; Tiwari et al., 2020). However, these constraints thrust agribusiness allied stakeholders, especially, company owners, to decide the way to fight against upcoming future challenges. It is high time to establish some new rules to regulate the agribusiness activities in South Asia for a quick recovery of latent losses. Now the stakeholders must know the reasons for these losses in agribusiness and pick up some good strategies to mitigate these losses. The story then turns to investigate the current situation of agribusiness with some relevant evidence and the factors playing a role as significant barriers for sound agribusiness in this Sub-continent.

METHODOLOGY

This chapter accessed the relevant secondary data for concluding comprehensive qualitative research. Secondary data were extracted in a systematic way to get useful information from published scholarly works on agribusiness in South Asia. The selection of scholarly works was made very carefully to fulfill the objectives. Significant issues on agribusiness were picked up from recently published literature on agribusiness in South Asian countries. Scholarly published scientific articles, annual reports of various agricultural organizations as well as online databases in English ranging from 2000 to 2020 were sampled for preparing this chapter by summarizing the agribusiness situation, challenges, and future plans for South Asia. Procured data were analyzed to extract core messages by conducting a critical literature review (CLR) method. The CLR evaluates scholarly articles on a specific subject matter by analyzing in a systematic way according to the objective for the purpose of apprehending the trends, enhancing understanding, and getting insights into relevant studies about a subject of inquiry (Saunders et al., 2003). This method also assists a researcher to ensure the quality of the content in a manuscript by identifying the most related and important topics to include in the findings (Saunders & Rojon, 2011).

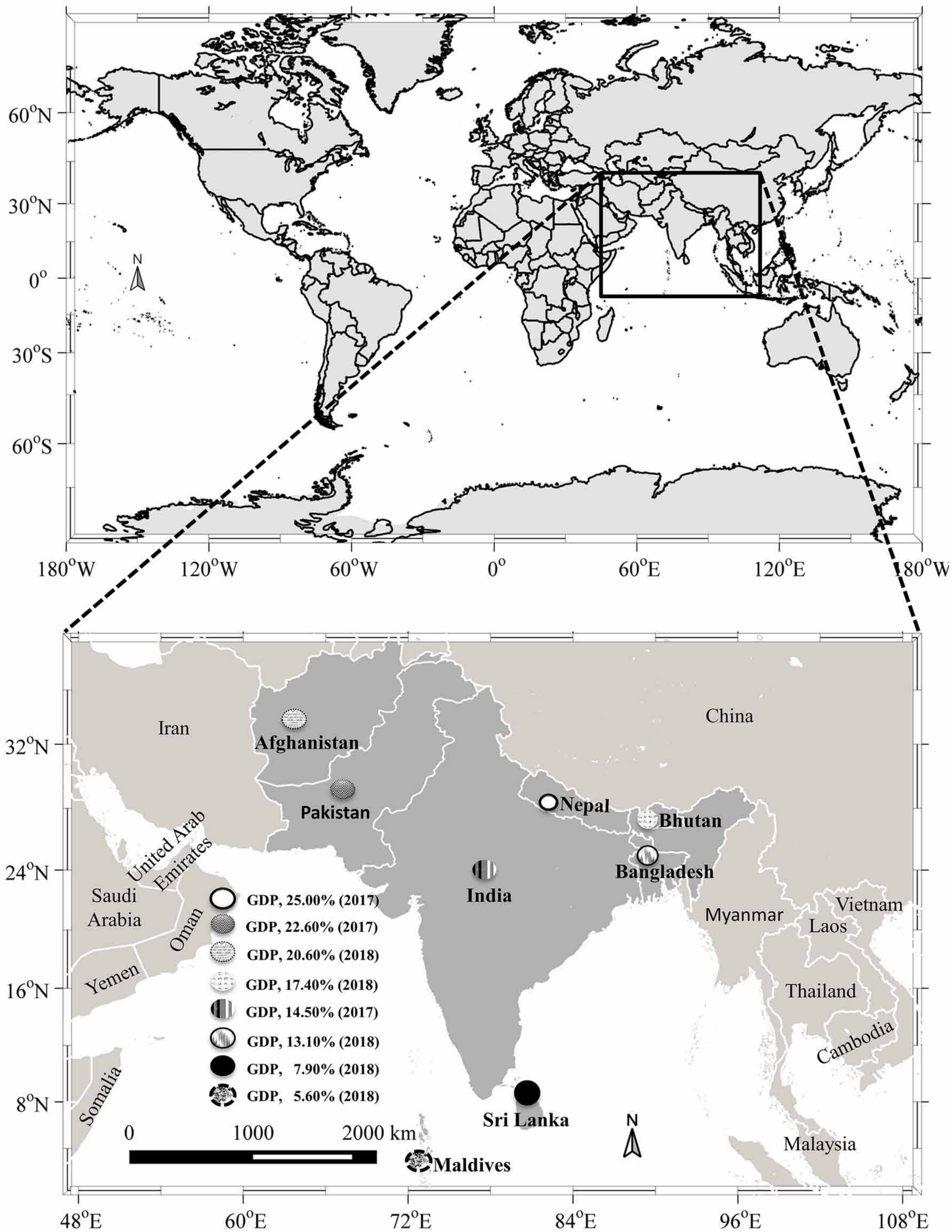
SCOPE OF AGRIBUSINESS

South Asia has a potential marine resource, the Indian Ocean, to the south from where Bangladesh, India, Pakistan, Sri Lanka, and the Maldives are extracting direct advantages in terms of agricultural production, processing, and trade. Figure 1 displays the agricultural share of the gross domestic product (GDP) in eight countries in South Asia. It indicates the suitability of this location for agribusiness.

Developing nations are attributed to underprivileged people with ample possibilities but limited technologies. Even they always fight against so many natural calamities like drought, cyclone, earthquake, landslide, flood, etc. retarding insufficient access to pertinent innovations, tools, and kits. Besides, poor economic conditions force them to take loans for short or long term to continue their agricultural activities. However, inclusive financing to the marginal peasants can be a possible way to strengthen agrarian societies because most formal financial institutions are not interested in providing financial services to the poor farmers in remote places (Oostendorp et al., 2019). However, providing long-term climate-smart financing to the same group of people may bring a remarkable change in socio-economic conditions and agricultural production status in the near future.

Bangladesh has a wide array of natural resources, including huge freshwater and marine wild fisheries stocks to meet the local and international food market demand. Excessive harvesting always pushes unbearable pressure to nature without considering the renewable capacity of resources. Indeed, by decreasing wild harvests such as Hilsha (*Tenualosa Ilisha*) fishery, Ecosystem-Based Fisheries Management plays a crucial role in making sustainable profits at different level value chain actors (Khan et al., in press). There are ample opportunities for rearing fish in different wetlands in this riverine country since a sufficient workforce can be engaged in aqua-farming (Dhar et al., 2017). In aquaculture, Bangladesh is one of the leading producers in South Asia since 1995 (FAO, 2018). Cattle farming is also a popular sector in these deltaic plains of South Asia including Bangladesh due to the advantage of getting all inputs and supplies for production. Huge labor force, availability of sophisticated technologies, high local market demands and consumer preference can give privilege for advancing in the meat processing sector (Sarma, 2014). As documented, new modern rice varieties make a good amount of profits which can encourage poor farmers to cultivate the same crop(s) in the next seasons (Gaffney et al., 2019). Nowadays, improving the way of procurement according to the demand of agro-processing companies is well-known to some extent to the farmers. The digital procurement system from farmers can reduce uncertainty, unreliability and cost. Almost all crops can be procured in a digitized procurement system to make the system faster and transparent through proper channels like sugarcane (Alam & Wagner, 2013). Some commercial medicinal crops can be cultivated within a regular schedule of cropping since it can increase the annual income of growers (Saiyem et al., 2020).

Figure 1. Map of South Asian countries representing agriculture share of GDP in recent years
(Source: World Bank, 2019)



Growth of India's agribusiness helps in employing rural people for generating income in the remote areas in its large territory in South Asia. Based on the dairy sector, the county took privilege and became the second-largest exporting nation in the globe. It can be assumed that in the coming years, agrarian societies of India will step forward towards enlarging agribusiness to improve employment status by exporting dairy products (Singh, 2019). In India, however, corporate social responsibility brings some beautiful examples to operate agribusiness smoothly and to mobilize resources sustainably (Raj et al., 2019). These plans work satisfactorily and thus can also be applied for improving the livelihood of poor societies in other South Asian countries. Besides, Agri-clinic and Agribusiness Centers (ACABC) becomes popular to the agro entrepreneur as a graduate training scheme to improve agricultural extension sectors in this country so far. Considering the public extension system Government of India took the initiative for improving the existing extension service system (Dumpala & Thomas, 2020). Such an initiative in other countries can make more skilled agro practitioner in this sector to improve annual crop production.

Sri Lanka is located just on the south of India in the Indian Ocean. In particular, this territory also a potential for agribusiness, having a wide range of scope for fisheries, livestock, and agriculture. Like other South Asian countries, Sri Lankan agrarian society tries to continue conventional ideas regarding agribusiness. Most families do not support an agriculture graduate to work in his own farmland. People expect that agriculture graduate will render their services through different public or private jobs only. However, entrepreneurship brought higher profits for a new investor in a couple of cases (Sachitra, 2019).

Village-based forage seed enterprises were developed to produce berseem clover (*Trifolium alexandrinum*) for dairy farmers in Pakistan (Tufail et al., 2018). As a result, on-farm profitability and productivity increase incredibly in a sustainable manner. One of the profitable businesses is natural rubber in Nepal, but the initial cost is high (Pandey et al., 2020). Therefore, such profitable crops can be introduced to some other similar geographic locations to check their feasibility and output (Mishra et al., 2018). Management attributes are different from place to place in terms of farming, but contact farming has already gained popularity for its higher profits from increased yields in Nepal. Mandarin is one of the important crops in Bhutan. Here, an interesting relationship exists between middlemen and producers in Mandarin based agro-business. Producers sell the crop thudding the flowering stage to the contractor to take care until harvest (World Bank, 2016). Similar practices are found in mango orchards in Bangladesh. In the recent past, the agriculture sector of Afghanistan contributed 73.3% of total export earnings (Rahimi & Artukoğlu, 2019). Collectively, South Asian people stand on agriculture which leads agribusiness here.

PREVAILING CHALLENGES

Likewise, any other field agri-business also engulfed with some encounters which need to be identified and unfold for the stakeholders for their skillful reduction to make agri-business smooth and profitable as well.

Climate Change and Natural Disasters

Climate change is a global issue to be faced by all over the world. However, South Asia has the possibility of seeing the major consequences of climate change. People have to be ready to get victimized more for their livelihoods because of frequent droughts, floods, heat waves and cyclones (Ahmed et al., 2019). Greenhouse gasses (GHGs) form agriculture sectors also contribute to maintain the rapid pace of climate change (Aryal et al., 2020). Moreover, groundwater recharge faces uncertainty for increasing water demand in agriculture and industrial activities over many parts of India (Chattopadhyay et al., 2019). Impacts on crop production will get worsen for changes in temperature and precipitation patterns in South Asia (Aryal et al., 2019). Thus, climate change factors involved in leading to a considerable decline in crop productivity at agricultural farms. In the markets of India, the price of the important agricultural crops like rice and wheat could hike due to a decline in the yields for climate change (Palanisami et al., 2019).

Environmental Pollution and Degradation

The agricultural environment includes soil, water, and air for desired and safe production. A variety of reasons are responsible for deteriorating this agricultural environment (Li et al., 2019). Urbanization growth is considered as a prime contributor to environmental damage from some experiences in Bangladesh, India and Sri Lanka (Azam & Khan, 2015). Environmental pollution shows some incredible and bad stories from India. Similarly, livelihood and health complaints often come due to environmental issues in this country (Chopra, 2016). In recent years, injudicious use of chemicals and pesticides triggers soil degradation to make conditional think for living beings. Soil degradation from waterlogging, salinity, and alkalinity have also occurred over the large geographical area (Singh, 2000). However, in Nepal, the main threats to poultry enterprises are environmental pollution and disease outbreak (Dhakal, 2019). Likewise, the water quality of the Karnaphuli River of Bangladesh became unsafe for drinking and aquaculture as the pollution dispersed across the waterbody (Hossen et al., 2019). Thus, agribusiness is assumed as a low profitable sector by investors for remaining some environmental threats to some sub-sectors of agriculture.

Food Safety

Consumption of safe food has become a challenge in South Asian countries, especially in Bangladesh (Saha & Wu, 2019). It is because of ranges of issues like food adulteration, unsafe preservation, unsafe value addition, some cases of genetic modifications, etc. (Alam & Alfnes, 2019; Okumus & Sonmez, 2019; Rahman et al., 2020b). Nowadays, a number of customers are reluctant to purchase genetically modified (GM) food products as they feel unsecured in terms of food safety and the environment (Alam & Alfnes, 2019). Infrastructural deficiencies for processing meat affect health gains due to failure to maintain a standard of animal-source food (Schwaba & Armah, 2019). Consumers also notice features like freshness, color, and taste in case of taking the decision to purchase fish (Uddin et al., 2019). Moreover, food safety risk has a great power to change a consumer's purchase behavior (Uddin et al., 2019; Yeung & Morris, 2001). In Bangladesh, sugar was used to add as an adulterant with ultra-high temperature (UHT) and pasteurized milk in local markets (Karmaker et al., 2020).

Labor Issues

Human labor is one of the most important issues for agricultural production, processing, preservation due to their increased involvement in industrial sectors especially in readymade garments and also for time demanding mechanization of agriculture (Mia & Akter, 2019). In this connection, major issues raised are laborer shortage, low productivity, and high input cost of conventional cropping systems are well documented as important challenges of agribusiness (Weerakkody & Mawalagedera, 2020).

In Bangladesh, during the harvesting period of paddy, shortage of skilled labor and family labor often emerges as a hurdle for reaping the crop (Siddiquee et al., 2019a). Like other countrymen, laborer shortage compels Nepalese farmers to use chemical fertilizers instead of organic fertilizer for crop production since the transporting of organic manure is a labor-intensive practice (Tiwari et al., 2020). In Sri Lanka, production costs and labor shortage were mentioned as potential barriers in the tea sector due to having some limitations in technological developments for harvesting (Jayasinghe et al., 2019; Herath & Weersink, 2009). In contrast, higher-wage has been demanded by men rather than women workers due to agricultural mechanization in the Global South (Rai, 2020).

Marketing Limitations

Marketing of any products is the key determinant of its growth, extension, intake behavior, and profitability (Chen, 2019). Price fluctuation, delayed payment, low price, inadequate storage facilities, and absence of grading facility were found as the notable marketing problems for trading rubber as a profitable business in Nepal (Pandey et al., 2020). In the local vegetable markets of Bangladesh, there are some deficiencies of market information to the vendors for marketing the product in due time to get a higher price for sale. Thus, by selling their goods at the proper time, they can get big profits from the market (Rahman et al., 2020a). International trade faces some marketing problems regarding commissions, transportation and storage facilities in India (Remya, 2019). Some wholesalers face problems in transporting, storing and low prices of products in the market (Siddiquee et al., 2019b). Similar problems were also noticed in different countries in South Asia.

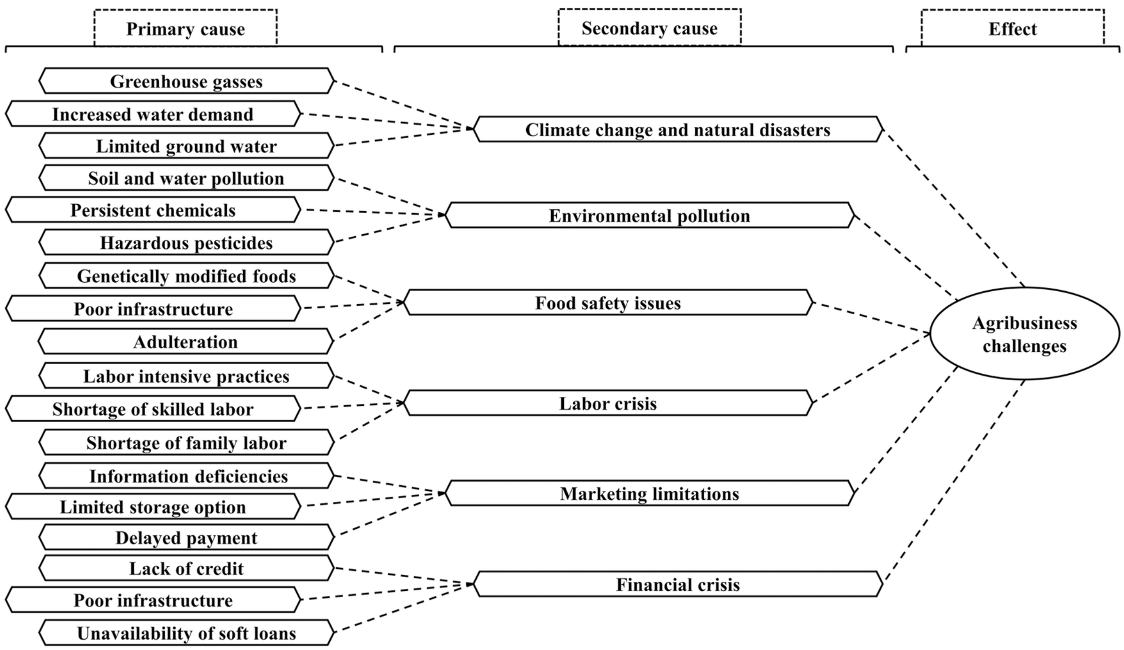
Financial Crisis

Credit is one of the major inputs in playing a vital role in any sector and agribusiness, is similarly important for production, processing, preservation, marketing and distribution as well (Sneyd & Enns, 2019). In Bangladesh, agribusiness desires soft loan policies for active participation in the sector. From rice millers to retailers, lack of credit facilities is predominantly a crisis for marketing rice on time (Siddiquee et al., 2019b). Similarly, the unavailability of soft loans discourages investors since existing incentive plans from private sectors are inadequate for infrastructure facilities in Nepal. Moreover, the facilities in the public sector are also inadequate, inefficient, underutilized, and outdated in the country (Gauchan, 2019). Without timely investing, the expected profit cannot be made by an entrepreneur since the price of a product fluctuates with time.

There are some primary causes that formulate some secondary causes which affect the agribusiness to a great extent (Figure 2). Climate change and natural disasters are the effects of increasing greenhouse gases, higher demand for agricultural water, etc. Environmental pollution occurs due to indiscriminate production and overuse of agrochemicals; food safety for genetically modified food, food adulteration and poor infrastructures for food processing and storage; labor crisis arises for the increasing demand for labor in the industrial sector, incentive agricultural practices, lack of skilled labor and decreasing family labor; marketing anomalies occur because of limited product and market channel information, lack of trust in payment and for the lack of sufficient credit in all spheres.

Therefore, secondary causes originated from primary sources including but not limited to climate change, and natural disasters, environmental pollution, food safety, labor crisis marketing anomalies, and credit insufficiency are responsible for imbalanced agribusiness in this region (Figure 2).

Figure 2. Conceptual model showing primary and secondary causes affecting agribusiness



EMBRACING POLICIES

In view of the aforesaid circumstances, it is obvious to put forward some policy issues to overcome the same for sustainable agribusiness in South Asia. It is often said that problems are the opportunity to deal with the difficulties for better withstand.

Research and Predict

At present, remote sensing is considered as one of the cheapest tools to estimate crops on farmlands to forecast the expected yield (Weiss et al., 2020). Free satellite products are available to monitor precipitation and soil moisture for predicting and improving sudden flooding in the croplands to avoid the risk of huge loss in agribusiness (Camici et al., 2019). Temperature can also be measured from optical satellite data to get an accurate idea of diversification of land use in particular farmland (Vadrevu et al., 2019). The identification of abandoned agricultural land can be made successfully by many remote sensing methods (Visockiene et al., 2019). Other disturbances like fire, pest control and vegetation removal treatments can be managed through remote sensing approaches (Monroe et al., 2020). South Asian agribusiness seeks stated policies for conducting research to predict the total yield for fulfilling the future food demand of the globe.

Restoration Measures

GHGs can be mitigated by either reduction in CH_4 and N_2O emissions or an increase in the amount of CO_2 sequestration (Aryal et al., 2019b). Well-designed pilot programs must be introduced to build awareness on soil pollution management for a fruitful remedy of contaminated farmland. (Li et al., 2019a). Among the adopted policies in different countries in the world, China opted for the general polluter pays principle to get rid of the proliferation of contaminations. People who involved in polluting soil are obliged to conduct remediation through the risk control actions (Li et al., 2019b). Suitable mitigation needs to use agricultural residues i.e., feedstock for producing renewable energy (Martinho, 2019). It seems that the utilization and production of renewable energies will be popular in the coming days to eliminate the pollution in South Asia.

Quality Control

Near-infrared spectroscopy is a simple and fast analytical technique to maintain the quality of a product. This is one of the leading approaches to determine authenticity, adulteration and composition of milk to control its quality (Asaduzzaman et al., 2020). Contemporary formaldehyde detection technique has opened a new window for fruit lovers to get fresh fruits such as mango and orange (Kundu et al., 2019). Food fraud is a punishable crime and it should be stopped by implementing some effective food fraud policies (e.g., define food fraud as a food agency issue, establish the definition and scope, fund and support to execute the policies, and circulate a government official notice about the laws). Moreover, at the beginning phase of the development food fraud policy should be developed to get a successful outcome in controlling the quality of food (Spink et al., 2019).

Contemporary Mechanization

Overall, food production has increased due to enlist modern machinery as a vital input in the farms for saving the precious time of farmers. Consequently, food security status and crop production can be improved by applying automated machines in the farmland (Nasrin et al., 2019). Today a new concept is smart agriculture with modern machine and sensors to get updated data on the physical and chemical properties of soil and environment. This technology helps to decide about the shortage of any inputs such as fuel, labor, and fertilizer, pesticides to achieve quality products and sustainable yield (Nidhi, 2020). Multiple applications of modern, powerful machinery can reduce production costs to make a provision for making a higher profit in farms (Meinel et al., 2020).

Marketing Strategies

Marketing issues like uncertainty, unreliability, and cost can be managed easily by procuring crops from farmers in a digital mobile messaging system for better marketing facilities (Alam & Wagner, 2013). Some key strategies (i.e., planning for a crop, time management, crop diversification, processing of products for better prices, making crop insurance, and sell a product within farmers' locality) can reduce the major marketing risks (Rahman et al., 2020a). Overall marketing may be solved by introducing technical training on high yielding cultivation to procedures for getting advantages in processing and marketing of agricultural products. In addition, the government can start some facilities such as storage and transport agricultural produce in rural markets (Quddus & Kropp, 2020).

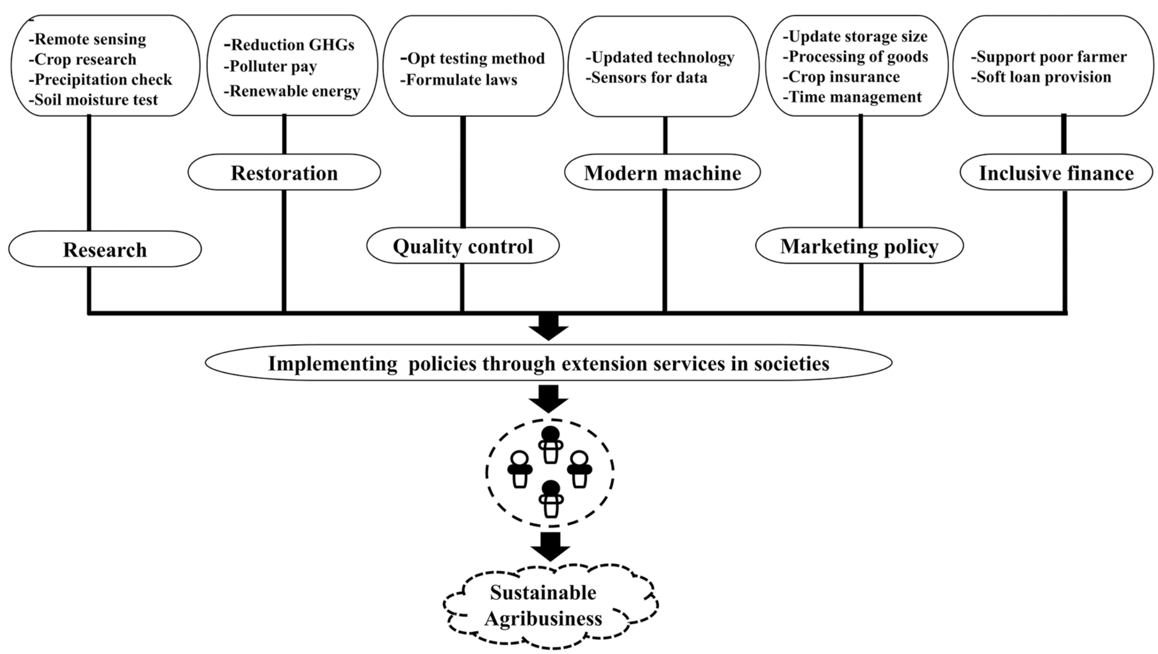
Inclusive Financing

In small agribusinesses, some factors such as cash flow constraints, limited access to capital, and lack of resilience to revenue hamper to a great extent in continuing trading. The inclusive financing model should be owned by banks and related financial companies for better service to poor farmers (Kalkan, 2019). Intermediaries face a common problem to purchase goods from producers due to lack of credit. Soft loans can be a solution for agribusiness stakeholders at different levels to run uninterrupted trading by undertaking some fruitful financial policies in the agriculture sector (Siddiquee et al., 2019b).

POLICY OPTIONS FOR SUSTAINABLE AGRIBUSINESS

In view of the foregoing discussions, it is imperative to pinpoint that for sustainable agribusiness in South Asia some policy issues but not limited to pragmatic research, environmental restoration, quality control of foodstuffs, contemporary application of machineries, crystal clear marketing channel, well-accepted guidelines and ensuring credit in easy terms and conditions are deemed to be important (Figure 3).

Figure 3. Proposed conceptual framework for implementing policy options towards sustainable agribusiness



Researches can be undertaken for understanding the suitability of crops grown, sunlight sufficiency, rainfall forecasting, edaphic condition, and maximizing the use of remote sensing mechanisms. There should have activities for reducing greenhouse gases, minimizing industrial and other pollutants and at the same time increasing the use of renewable energy sources leading to environmental restoration. Foodstuffs as a basic element of agribusiness must be in standard quality which needs to be maintained through instant determination and stringent rules and regulations. Contemporary mechanization is essential both for production and processing of agro-products. Well accepted marketing policy can make a provision for an equitable share of profit among the producers, value-added companies, wholesalers, retailers and consumers as well. A financially friendly environment ensuring well-accepted guidelines may safeguard the worth survival of the even marginal producers at the grassroots level for all the stakeholders of agribusiness. Agricultural extension service providers can play a pivotal role in implementing this process from starting to the end.

FUTURE RESEARCH DIRECTIONS

Always developing countries face the scarcity of capital to invest in contemporary research for upgrading technologies in agriculture. Productivity can merely be improved if there is a scope to improve existing technology. Imported technology is somewhat pricy to tackle down the price-gap in the international market. Information and communication technology is also a weapon to make aware of updated methods and technology. Besides, proper market monitoring may be possible with the active introduction of mobile technology to rural areas. Strengthening agricultural extension programs combats by raising peoples' awareness so that they can refrain from any adverse actions against the environment by using information and communication technology. Efficient technology will provide more production at a cheap input cost. It means that the producers will make more profit by investing less. In contrast, native scientists have to aware of the environment while releasing new but cheap technology. Renewable energy can be a solution to avoid pollution which may have a negative role in decreasing crop production. Studies may be undertaken on the role of information and communication technologies to modern agricultural marketing system to get a fruitful outcome in pursuing sustainable agribusiness. Mobile technology will also give a meaningful way to do teleshopping in both urban and rural sites by reducing the tier between producer and consumer. In this regard, the uninterrupted power supply is required in the remote place of any developing nations. Native graduates may take part in developing new technology to ensure cheap power supply for better agribusiness in a sustainable way. Future generations will have huge prospects to study in technology development having a direct or indirect impact on agribusiness for aiming at food supply to hunger.

CONCLUSION

Agribusiness is an avenue for farmers, intermediaries, whole-sellers, retailers, and vendors to carry on livelihood for ensuring their every meal of a day. It can be the main weapon for economic development in developing nations since people primarily depend on this sector for livelihood. South Asian countries belong to similar features in terms of resource possession, climatic condition, societal structure, community practice, and people due to get adjacent locations.

Hence, there are ample opportunities to earn money from crop cultivation, dairy production, fishery, and forestry in rural areas. Climate change, natural calamity, environmental pollution, unsafe foodstuff, labor unavailability, marketing limitations, and financial crisis are found as significant factors to limit agribusiness activities. Global warming will be the main threat to agriculture for making the weather unpredictable. A similar limiting factor is a hazardous chemical acting as a potential pollutant in soil and water to spread animal disease and to make water inappropriate for aquatic organisms. Production will be hampered due to the active influence of climate change and pollution. Moreover, people are quite conscious of the adulteration and other food safety issues to get rid of health risks. The retail market, unhealthy foodstuffs are being ignored by the customers to reduce the possibilities of foodborne disease. In fact, there are some common challenges in South Asian agribusiness viz., shortage of labor, lack of storage facilities, inadequate information about selling price in the markets, improper transport facilities, delayed payment between vendor and customer, and very poor access to the soft loans for rural farmers.

Future policies for agriculture and agribusiness should rely on more scientific research on crop science, resource restoration, food quality control, the introduction of updated machines, best marketing practice, and inclusive financing. In South Asia, agriculture demands contemporary remote sensing approaches for conducting research to predict the future yield in supplying foods to local and global markets. The utilization and production of renewable energies can be a permanent solution to the pollution in SAARC (South Asian Association for Regional Cooperation) countries. Indeed, potential issues of food quality are addressed by establishing some strict rules in all over the world. Besides, powerful modern machinery can act as a panacea to combat the shortage of labor and higher production cost. A government may take long-term policies to improve the facilities such as transportation and storage to help retailers by reducing uncertainties in remote places. It is advised to consider the uncertainties of small enterprises in terms of soft loan distributions through an inclusive financing system.

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Chapter 6
Agricultural Information Systems and Sustainable Food Value Chain Development:
Strategies Towards Innovative Application of ICTs

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ABSTRACT

The oil boom of the 1970s in Nigeria has negatively impacted the young generation's psychology about agriculture. This has led to a continued drain of workforces. The general view on agriculture is of a 'murky' business, as such always relegated within choices. Myriad programs and projects are being rolled out to revamp agriculture and attract youth in Nigeria. However, they remain largely with insignificant positive results and most of them with little or no deliberate appeal strategy towards enchanting youth. This research analyses the level of youth involvement in agribusinesses in Jigawa, describes and analyses ICTs landscape, then presents innovative approaches towards enchanting youth for agri-preneurial enterprises. Purposive sampling was used to select locations of data collection while convenient sampling was employed to elicit data. Results reveal that the youth entrepreneurial involvement is towards marketing, while a robust ICTs platform exist for supporting enterprises. Also, three packages were drawn and presented for the promotion of agri-prenuership in Nigeria.

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BACKGROUND

The oil boom of the 70s and rudimentary, static nature of agricultural systems in Nigeria have entrenched a general view of agriculture as a murky business and, thus a vocation of the backwards. Hence, most youth and graduates prefer white collared jobs to agricultural ventures, resulting in a myriad of problems amongst which are rural-urban migration, increased unemployment rate, poverty and neglect of agricultural production. Lack or absence of efficient and effective information in the country has further aggravated this outflow of youth, where potentials and prospects are not disseminated enough to attract them and the little workforce enjoyed by the sector is continuously drained out. Previously, before the discovery of oil, agricultural enterprises and ventures across the agricultural value chain not only ensured able employment but sufficient income and economic prosperity within a functioning food system. Northern Nigeria had a booming agricultural production and other dependent enterprises like oil mills, textiles to small traditional confectionaries of making snacks, candies *(alawa),* sweet syrups *(madi)* etc.* However, since the discovery of oil, the sector has witnessed a continuous drain of its workforce and key actors to white-collared and menial jobs within cities. This has always lessened the food sources which are produced in most cases through smallholder families from rural areas. The food system is thus faced with the problem of demand-supply imbalance in the face of the expected herculean task on it. The food system as alluded by FAO, is expected to feed an estimated excess of 9.5 billion people by the year 2050 (FAO, 2016b). A goal that is clearly agreed by the world as one of the Sustainable Development Goals (SDGs) of ending hunger.

In Nigeria, where the population is also rising and thus demand for food, the problems of aging farmers, disenchanted youth, and little access to information in terms of extension services is a glaring reality. Together with the economic recession occasioned by plummeting oil prices with attendant rising unemployment, poverty, hunger, malnutrition, the pressure has never been higher on the food system. In response, the Nigerian policymakers have rolled out numerous policies and implemented several programs for the sector's development as an avenue of ensuring constant supply for a healthy, prosperous population (Adegoke, Araba, & Ibe, 2014). In fact, globally, it is prescribed that if sustainable development is to be achieved in most developing nations, it must be through agriculture (FAO and AFDB, 2019). Nigeria has launched various programs to promote agriculture and agricultural value chain development hence agribusinesses have been especially focused on the agricultural transformation agenda of the country (Adegoke et al., 2014; Obiora, 2014). Although the focus is apt and is aimed to increase the profitability of the sector's activities, the agricultural information systems are faced with a shortage of professional extension service providers (Oladele, 2013). Extension agents are grossly inadequate and thus could not cover the more 70 million estimated agricultural value chain actors; therefore, participation is mostly not of genuinely stimulated interest but for access to funds which are always diverted outside the sector (Muktar, Mukhtar, & Ahungwa, 2015). Usually, these lots are mostly compelled by their poor demography to partake as such the enthusiasm to innovate, add value and enter into agriprenuerial exploits is minimal.

Obviously, if the agricultural sector is focused on resuscitating itself, a lot more has to be done in the area of repositioning the information system, especially in the face of other challenges of climate change and its extremes events of the flood, drought and other shocks (FAO, 2016a). The agricultural value chain activities are heavily dependent on information through extension services, where agronomical activities, market information, value addition and stimulation of innovations are all dependents on how much information is accessed and utilized by an individual actor.

Due to the limited number of extension personnel, ICTs are heavily used as part of the AIS in Nigeria and beyond. But, in Nigeria and most developing countries another problem is being faced which is lack of training and equipment that is impeding the dissemination of information through ICTs (Muktar, Ahungwa, & Ado, 2016; Premium Times, 2020 (Muktar, Man, Kamaruzzaman, Samah, & Umar, 2018). In Nigeria, the Agricultural Information System generation landscape is robust, judging by the scale of institutions serving it; however, access to such information can best be described as grossly inadequate. This is evident looking at the ratio of farmers to extension officers which is unacceptably wide, quoted at about 1:3500 (Knierim et al., 2017) and thus their activities grossly are in-effective. The extension workers are also mentioned as having the low capacity to perform extension services through the ubiquitous ICTs, thus the danger of scuttling the potentials of ICTs in bridging the problem of unbalanced client- extension agent ratio.

A need, therefore to train and retrain is imminent but beyond that, there is a need for innovative and intentional design of policies and approaches aimed at attracting agile stakeholders, especially youth to agribusinesses. The ubiquitous ICTs are identified as capable of not only providing linkages to both financial and extension institutions but could also fancify the agricultural commodities value chain and enchanting youth to the sector (Muktar, Mukhtar, & Ahungwa, 2015). This study seeks to present ICTs based strategies and ways of captivating the farming communities towards venturing into agribusinesses for sustainable food value chains. As such, it seeks to:

- Assess the ICTs' use and access within agricultural enterprise actors.
- Analyze the farmers' perceived level of agricultural information for food value chain development,
- Determine the relationship between demographics and perceived adequacy of information on FVC
- Present Innovative strategies towards enchanting the youth through ICTs

LITERATURE REVIEW

Sustainable Food Value Chains Panacea for Food Security and Achievement of SDGs

The Food Value Chains (FVCs) as a concept is rapidly gaining increasing attention in the world, especially as it directly relates to the Sustainable Development Goals (SDGs) goals 2 of '*ending hunger*'. *SDGs Goal 2* demands high expectations on the global food systems to meet the food demand of the rising population (FAO, 2017), and not only provide food but to ensure the provision of nutritionally rich diets to fight malnutrition (FAO, 2013). Impliedly, the need for the FVCs to be ever more productive, more profitable and importantly, self-sustaining cannot be overemphasized. The FVCs refer to the entire stakeholders that are involved in the production, processing, selling, and even consumption of food that is from farm to table (Deloitte, 2013; Food and Agricultural Organization, 2017). As an approach, the FVCs approach to agriculture is espoused as an ensured avenue of reaping more gain from farming-related labor, but this understanding is opined as too economic centric which suggests un-sustainability. However, it is posited that FVCs must be all-encompassing to achieve the set-out goals but without compromising the future generations' chances (IFAD, FAO, WFP, & Bioversity, 2018). This ushers in the concept of sustainability, where the triple bottom line is engrained as a principle within FVCs, where it is adjudged that it must focus on not only the economic but also ecological and social principles

(Ikerd, 2011). Food systems if at all, are aimed at achieving the SDGs, must focus on the sustainability approach while performing its function of food provision.

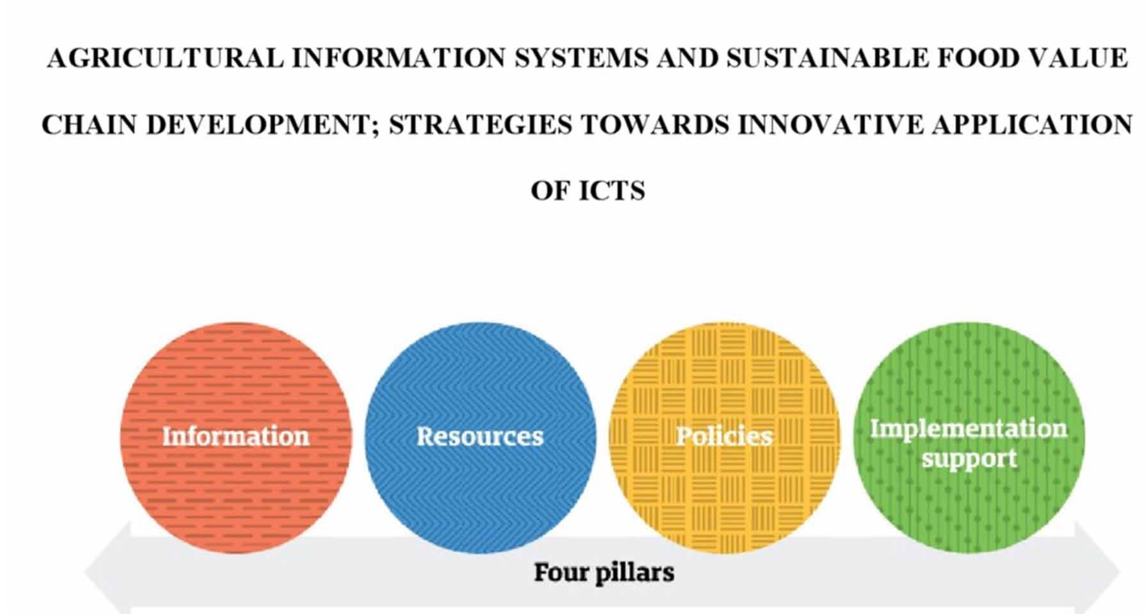
Sustainable Food Value Chains (SFVCc) are those farms and firms and their value-adding activities that produce a particular raw material, transforms them into a particular improved product (s) for increased profitability in a socially and environmentally responsible manner (FAO, 2014; IFAD et al., 2018). The SFVCs are by this definition, supposed to be linked in a way to ensure responsiveness and regeneration (Ikerd, 2011). The SFVCs has at its core two basic items flowing through them at all time, which are services (information, Knowledge) and goods (products). These two functions are the bloodline or livewires as every action is determined by them. This is especially with regards to information, where they facilitate activities, from production to different value addition activities and flows of the products to the markets and eventually consumers. The success or otherwise is therefore heavily dependent upon how much information and or knowledge is disseminated or otherwise to the actors at a particular time.

Agricultural Information System and Effective Communication Roles in Sustainable Food Value Chains

The place of communication within agriculture has long been established and recognized as a veritable tool in agricultural and rural community development across the world (B.G Muktar, Man, Saleh, & Daneji, 2018). This has made extension services as one of the key inputs given to any meaningful agricultural intervention. Effective agricultural information relayed by the extension service providers is adjudged as stimulators of agricultural best practices that are knowledge-based as generated by institutions and experiences over time (Swanson & Davis, 2014). As such, information on good practices, vast existing opportunities, threats and agricultural linkages are accessed by farmers and other agro-related actors through such channels as ICTs and direct contacts with extension agents. Agricultural information is defined as any information and or services that are provided to farmers and agricultural units for increased efficiency. Agricultural information is adjudged as key and cardinal input that not only boost production but also stimulate growth in the sector in all its ramification including the practice of value addition. The absence or weakness of such services in the sector is capable of bringing inefficiency, lost opportunities, and markets. For example, the FAO reported that Nigeria is estimated to have lost US$ 10 billion in annual exports of agriculture and agro-processed commodities as a result of a drop in production and value addition exercise (PriceWaterCoopers, 2017). It has been realized that for the promotion of food security, socio-economic development and attainment of Sustainable Development in Africa, the agricultural value chain (FVC), approaches are non-negotiable and a key factor in agricultural information, which is unique in its requirement and nature to each and every node of the FVC. The dearth of the information or inefficiency of agricultural information system in Africa has been alluded to by a report of the PWC, where it was mentioned that although a lot has been achieved in generating knowledge on production techniques, there has been limited permeation of food system knowledge and agricultural value chain addition practices in the Sub-Saharan Africa. In Nigeria the post-harvest level of FVC has been especially mentioned as grossly having receiving less attention by the extension service providers (PriceWaterCoopers, 2017). Recent realization has shown the existing extension service has always focus more on raising productivity, paying less attention to post harvest extension services where most of the losses and or value addition exercises occurs.

Typically, FVCs typically represent connective linkages of products, finances, social assets, knowledge within farming communities; the place of information is thus critical and apparent. This means that at every node of the FVC, the services of the information and advisory service providers are needed and close collaboration and cooperation among stakeholders for an efficient system to exist. It is this information that will guide all actors into satisfying the requirement of the last actor towards the satisfaction of the next consumer. The knowledge of the key requirement towards fulfilling the nutritional requirement of the consumer is essential in guiding the activities of the actors in the food value system. Food system also extends a salient role of being responsible to the environment; it is in this regards that four-pillar framework for action was charted towards sustainable food Value chains by UNDP & Global Environment Facility, (2017, where the pillars were highlighted as information, resources, policy and implementation support. It is noteworthy that in all these pillars, the role of information is unparalleled; as a stand-alone pillar, it ensures awareness creation, knowledge dissemination, and sharing among actors. Furthermore, policies, when formulated, the information system is thrust with the responsibility of awareness creation, public enlightenment etc. At the implementation stage, the training and technical assistance by experts are more effective when channeled through professional communicators who will relay it to the public appropriately. Overall, the sustainability of the FVCs, the behavioral change of the people towards an environmentally responsible utilization of resources, the act of nutritious feeding is by and large maintained by the agricultural information system. This is for the fact that it links up the stakeholders to all the four pillars of the sustainable food value chain.

Figure 1. Four Pillar Framewokr for Action for Susatainable food chain



ICTs Use and Access Among Agricultural Enterprises in Nigeria

The benevolence of ICTs has revolutionized the way things are done in every sector of the economy, including the agricultural sector. The ICTs are so ubiquitous that even the last mile farmers are found to be utilizing it in earnest and that it is adjudged to be capable of stimulating innovations in rural farming communities (B. G. Muktar et al., 2015). This was emphasized or buttressed by the report of Forbes magazine where it was reported as saying that by the year 2019 more than half of the worlds' population will be online (FAO and ITU, 2019), where already countries like Japan and other Asian tigers are taking the next leap into higher technologies of artificial intelligence (AI) and Internet of things (IoT) to agriculture. The ICTs coverage and access in by farming enterprises in Nigeria are reported to have been increasing and such inputs like information and extension services are now relayed mostly through the ICTs (Williams & Agbo, 2013). An example is where the Date Palm farmers in Dutse were reported to have admitted receiving a lot of information through the various forms of ICTs available (Sanusi, Omokhudu, & Fadeke, 2017). Various agricultural enterprises in Oyo state were reported to rely on the use of mobile to access both production and marketing information as the ratio of extension services to farmers is reported to be very wide (Bolarinwa, K. K. and Oyeyinka, 2011). A study conducted to ascertain the level of Facebook use by farmers and extension agents in Otukpo in Bayelsa state revealed that the farmers (56%) use Facebook to access information although hindered by poor network while most of the extension agents (50%) reported a high level of use of Facebook to source and relay information (Otene, Okwu, & Agene, 2018). Generally, it is known that the mobile phone has revolutionized businesses and ease up linkages to both market access, finances and other vital information for the survival of businesses. Similarly, FVCs actors are known to rely heavily on the services of ICTs like a mobile phone to source or contact potential consumers or their products, reach out to services and even solve imminent problems they perceive (Ifeanyi, Irene, Chiebonam, & Virginus, 2018; Mwombe, Mugivane, Adolwa, & Nderitu, 2014; Williams & Agbo, 2013).

Enchanting the Youth to Agripreneurship Through ICTS and Food Value Chains

The youth of developing countries like Nigeria are observed to be naturally disenchanted to the agricultural sector, at least at the level of practicing the actual production. The average youth views agricultural production as tedious and backward. Furthermore, the fact that a good number of farmers known to the youth are wallowing in poverty may have increased their resentment of the sector. Research that reviewed the behavior of youth in Nigeria towards agriculture asserts that although the youth may have shown little interest in the sector, the introduction of innovative and more organized approach may better attract the agile youth to the sector (Muktar et al., 2015). Recent developments in Nigeria have revealed how the level of exposure of opportunities have attracted a crop of innovative both physical and online agripreneurs amongst youth. An example is the Breakfast King that presents the traditional African breakfast typical of the country in a fancy way. Beans cake popularly known as *kosai in Hausa and Koko* which is a palp made from sorghum, is packaged and can be conveniently taken away in a fancy package. Also, another set of innovators is a group of youth that are leveraging on the ICTs to crowdsource funding for farming. In an investment approach that is win-win for both farmers, investors and the company exist in this setup. It is typical in Nigeria for farmers to have little or no startup capital while there are many willing investors willing to farm but had no time and expertise. Farm crowdy is a company that offers a solution to this situation by linking the two parties online and the investor is linked to a farmer. This and many other initiatives by the youth is heralding a new paradigm in the utilization of ICTs towards agripreneurship.

METHODOLOGY

Study Area

The study was carried out in Dutse Metropolis of Jigawa State, the state capital of Jigawa State. The state is situated in the northwestern part of Nigeria and has a population of 5,189,835 (National Population Commission, 2010). The state is located on latitudes 11.00^0N to 13.00^0N and longitudes 8.00^0E to 10.15^0E. A mean temperature ranges within the month of October to about 35^0c to 50^0c in May. The months of November to December is usually characterized by cold harmattan wind (Oladipo et al., 2020). The state is purely agrarian with more than 80 percent of inhabitants engaged in agriculture and related activities.

Population, Sampling, and Analytical Techniques

Dutse Metropolis was used as the population of the study, and the city has a total population of 335,600 inhabitants. A multi-stage sampling technique was adopted for the study; at first, a purposive selection of two market places within the metropolis was made. Secondly, the use of a convenience sample was followed to select of ninety respondents who are engaged in any agricultural enterprise within two market places, which are the Dutse old market and new markets. The sample of 90 respondents was determined and approached; the condition set is for the entrepreneur is to be off in the marketing of agricultural-related products like grains, vegetables and fruits that have not mechanically processed. A total of ninety respondents were targeted and information was elicited from them. The use of descriptive and inferential statistics was made to analyze the collected data.

RESULTS AND DISCUSSIONS

Socio-economic Characteristics of Respondents

The **majority of the** respondents, as shown in Table 1, are between the young age of 16 to 28 years (31.1%) and between the age of 29 to 41 years (30.0%). This reveals that agricultural trading enterprises are mainly dominated by young, agile men. This suggests that perhaps, the youth are mostly more attracted to the marketing aspect of agriculture than the more rigorous production aspect (Muktar et al., 2015). The Income reveals the majority (27.6%) made a monthly return of between N50,000 to 69,999. The education level of the respondents presents a fairly educated lot at the basic level, with 46.7 percent having passed through the primary education level. This is finding is in contrast to the findings of Dutse, Atala, Umar, Duniya, & Dodo, (2015), who found that the farmers in the same north are mostly educated up to secondary level, perhaps this may be due to the status of Jigawa State being an educationally backward state. The enterprise respondents are engaged in is mostly retailing of grains, fruits & vegetables and tubers of potato (Irish & sweet) yam and cassava. The majority (45.6%) of the respondents are found to be mainly of being within their 1st to 5th year of being engaged in these enterprises, this suggests that the enterprises may be just used as a transitionary business for the youth to generate capital, which present sustainability issues in the value chains.

Figure 2. Map of Duse Metropolis

Access to ICTs by the Respondents

Table 2 reveals access to basic ICTs by the respondents; it was discovered that the majority have access to one form of ICTs or another or a combination of ICTs as revealed by the multiple responses received. The highest ICTs accessed by all the respondents is the radio, which is a common feature of the average Hausa community in the country. Research by (Oladipo et al., 2020) also revealed the radio as being ranked 2nd in preference and access to farmers in the same state. This is being followed closely by the mobile phone with 29.6% indicating having good access to it. The average northern Nigerian farmer is adjudged to have access to at least one form of Information and Communication Technologies (ICTs) or the other. Many empirical studies have established this, for example, research conducted by (B. G. Muktar et al., 2015) asserted that the last mile farmer is now in possession and utilization of the mobile phone, while Sanusi, Omokhudu, & Fadeke, (2017) reported over 50 percent of date palm farmers have access to radio in Dutse local government of Jigawa State

Table 1. Socio economic Characteristic of respondents

Variable	Frequency	Percentage
Age		
16 -28	28	31.1
29-41	27	30.0
42-54	21	23.3
55-67	14	15.6
Monthly income		
0 -29999		
30000-49999	24	26.7
50000-69999	25	27.8
70000 Above	19	21.1
Education Level		
Primary	42	46.7
Secondary	18	20.0
Tertiary	2	2.2
Islamic	28	31.1
Gender		
Male	68	75.6
Female	22	24.4
Years of engaging in agricultural enterprises activities		
1-5 years	41	45.6
6-10 years	34	37.8
11 Years and above	15	16.6
Type of agricultural Enterprise		
Grains	51	56,7
Fruits & Vegetables	26	28.9
Tubers	13	14.4

Source: Field Survey 2019

Perceived Level of Advisory Services and Adequacy of Information

Table 3 also reveals that the level of general advisory service aired on the radio; the respondents were able to access perceived very low with the majority (62.2%) perceiving it as low. Also, specific information on the food value system is ranked none existent by the majority (78.9%) of the marketers. When asked about the value addition they conduct on their products, and the respondents were found to be conducting simple value addition of sorting, processing and packaging.

Table 2. Access to ICTs and ranking of ICTs used for agricultural information by the respondents

Variables	Frequency	Percentage	Ranking
Access to ICTs			
Mobile Phone	83	29.6%	2nd
Television	86	28.5%	3rd
Radio	88	30.2%	1st
Computers	34	11.7%	4th
TOTAL*	**291**	**100.0%**	

Source: Field Survey *multiple responses apply

Table 3. Perceived Level of level Advisory services and availability of agricultural information accessed by agripreneurs

Perceived level of radio-based general entrepreneurial advisory services		
High	12	13.3
Low	56	62.2
None	22	24.5
Perceive Adequacy of Agricultural information on Food Value System		
No	71	78.9
Yes	19	21.1
Total	**90**	**100**

Value Addition Activities

The multiple responses in table 4 reveal that most of the respondents carry out both sorting and packaging off the products and the least activities carried is that of processing, this may have been due to the fact that most of the marketers have only means of simple tools that may not have support processing activities. The majority of them only involve in simple packaging (44.9%), and little processing (15.7%) reveals an untapped potential.

Table 4. Value addition activities taken by respondents

Value addition	Frequency	Percentage
Sorting	73	39.5%
Packaging	83	44.9%
Processing	29	15.7%
Total *	**185**	**100.0%**

*multiple response Source: Field Survey 2019

Relationship Between Perceive Adequacy of Information and Level of Education

Table 5 reveals Chi-square results between the perceive adequacy of information and level of education. Within the entrepreneurs, just over 71% of them stated that there is no adequacy of specific information on the food value chain system and 19% believe such information is given. In all, there exist a significant relationship between the level of education and perceive the adequacy of information (X^2=16.35, df=3, p<0.001). The null hypothesis thus is rejected which suggest that as the level of education of individual increases, so does his search for information (Kabiru, Abiodun, Gafaru, & Abdulrahman, 2016).

*Table 5. X2 between adequacy of Information * Educational level Crosstabulation*

		Educational Level				
		Primary	Secondary	Tertiary	Islamic	Total
Adequacy of Information	No	36[a] (50.7) [b]	10 (14.1)	0 (0.0)	25 (35.2)	71(100.0)
	Yes	6[a] (31.6) [b]	8 (42.1)	2 (10.5)	3 (15.8)	19 (100.0)
Total		42(46.7%)	18 (20.0)	2 (2.2)	28 (31.1)	90 (100.0)

Chi square =16.35 Degree of freedom= 3 observed significance level=0.001
* a=count frequency, b=percentage within phi=.426
H_o: There is no significant relationship between Perceived adequacy of information and Level of education of respondents

Presentation of ICTs Based Strategies for Agricultural Information System by Centre for Agricultural Research and Extension Services (CARES) in Outreach Villages

CARES is a research center in the Federal University Dutse in Jigawa State and the Centre was established in the year 2015 when two existing centers were merged together for increased efficiency, the centers were the center for agricultural research and food security and the Agricultural extension outreach center. The center is mandated to conduct agricultural research and disseminate findings across the northwestern part of Nigeria. The center has identified and adopted outreach villages around the university surroundings, and these villages are used as partners in the conduct of the center's activities. The Villages are Raju, Hausawa, Maja, Gurungu, Gombawa, Zareku and Sansani villages.

CARES is collaborating with government agencies like National I multinationals and Non-governmental organizations to achieve its objective.

Agricultural Information Systems for Sustainable Food Value Chain; The CARES, FUD Initiatives

The Nigerian agricultural Information System has tremendously suffered a major setback, hitherto the most reliable and efficient form with which agricultural information is passed to farmers was mainly through the extension agent, a lot of research findings adjudged that in most cases the preference of farmers has been the interactive communication sessions with the extension agents. Researches like that of (Muktar et al., 2016; Opara, 2008) highlighted the high preference for extension agents as sources of agricultural information. However, in recent times the Nigerian Agricultural sector has failed to recruit new hands into the sector as extension agents, as it is most of the existing extension agents are either too old or retired. It is popularly known that there is a very wide gap between the ratio of extension agent-farmer and what is obtainable in most states of the country. Jigawa state is particularly accused of paying lip service as nothing much is being done to bridge the gap, going by the minimal percentage given by the government. It is further highlighted that in the nearest future, about seventy percent of the aged extension workers will retire (Premium Times, 2020). From the foregoing, it became evident that the agricultural information source is yet going to receive another major setback. The Centre for Agricultural Research & Extension Service (CARES) has proposed what is referred to as CARES e-extension packages where it tries to reach the agricultural system's nodes with key information through the use of information and communication technologies (ICTs). The proposed strategies are aimed to provide both one-way relaying of agricultural information and also a two-way information exchange. Table 4 below shows the proposed e-strategies that are being implemented by CARES to augment the dearth of extensionist in the immediate university Community.

a. **CAREs Short Clips:** These are short clips that are being developed by the center, the clips contain a detailed explanation of some identified entrepreneurial opportunities across the value chains of some identified commodities. Commodities like sesame, cowpea, groundnut were selected due to the fact that the state is a recognized major producer of these commodities. The clips contain the list of enterprises that people can venture into across the production, procession and packaging nodes of each of the agricultural commodity and revealing unidentified markets in neighboring communities. The clips contain a detailed address and phone numbers that can be used to reach the center for further information as the need arises.
b. **CARES Anchor-person:** This initiative is based on the lead farmer initiative as well as train the trainer initiative. The center has identified fairly learned people within the outreach communities and is being trained regularly in the center on food value chain development. Then they are supplied with relevant clips and online video on a supplied e-tablet from the center. The anchor-persons will then take the information to the outreach villages and play the video to some targeted producers that are targeted to be enticed into value addition practices. The target is to mobilize some reasonable number of farmers with the identified potential to be engaged in sustainable food value chain activities towards sustainability.
c. **CARES street Shows:** The center in an effort to bring back the forgotten practice in extension which was entrenched in the agricultural information system of the 80s and part of the 90s where

street shows are played within towns and villages. The center is using the same approach in the outreach villages and thus showcasing agricultural best practices, entrepreneurial opportunities as well as information of market linkages etc.

d. **CARES Agripreneurs e- mentorship**: This is targeted to young, fairly educated farmers and agripreneurs, that have access to an android phone or active mobile line. The aim is to link up the potential agripreneurs to consenting established individuals that may not necessarily be within Jigawa but even neighboring Kano State. The aim is for the mentee to be guided and leveraged on useful information that will help him get established. This is alongside being closely in contact with the staff of CARES for technical information and services.

Table 7. CARES E-Extension Strategies

CARES e-extension Strategies	ICTs Platform	Target Audience	Nature of Communication
CARES Short Clips	Social Media	All social media users	One way in most cases
CARES Anchor-person	Tablets	CARES outreach farmers & youth	Feedback through Trained anchor-person
CARES Street shows	Computers Projector	Outreach Villages, youth, and invited entrepreneurs	Feedback possible as there is physical contact.
CARES entrepreneurship mentor	Social Media, email, etc.	Identified Youth Farmers & entrepreneurs	Feedback possible as they are trained and able to operate advanced platforms

Challenges of the CARES e-Extension Initiative

The major challenge being faced for a total rollout of these initiatives is the lack of sufficient funds.

CONCLUSION

The agricultural information system in Nigeria is continuously losing its vigor due to the inadequate extension personnel across the nation. Where they exist, they are adjudged to be old aged and lacking in ICTs expertise. The sector on its own is marred with a lot of problems that range from low productivity and lack of value chain system expertise; thus, the potentials are far from being tapped. The resultant effect is disenchanted youth that have a wrong view on the sector due to what they observe within communities. Innovative approaches are springing up from the leveraging of the ubiquitous ICTs to enlighten and attract a value chain approach to the sector that will ensure sustainable development. This piece of work adopts a mixed method of empirical approach and literature to analyze and describe the agricultural information roles and their motivating effect on the actors across the food value chain. The findings of the research reveal that the youth are engaged in most part of the marketing aspects if grains, fruits & vegetables where they carry basic value addition exercise of sorting, packaging etc. They are also discovered to have a relatively high level of access to ICTs but have alluded to having little access to information on the agricultural food system. The prescribed CARES packages advanced innovative approached towards improving or disseminating agricultural information as leveraged by the ubiquitous ICTs. The research has revealed the gap in the provision of basic information on agricultural value chains; it has also shown the level of use of ICTs by the respondents as well as the limited knowledge the respondents have on the process of food systems. The research was able to establish that with the amplification or revamping of the dissemination of information on agricultural markets linkages, value addition and other agricultural input like best practice technique, there will be increase participation and better return in investment. The spiraling effect is always a self-sustaining food system that is maintained or powered by the knowledge of opportunities to grasp. In conclusion, the CARES innovative packages advanced a promising package that will ensure the flow of information as leveraged by ICTs to meet a wider audience for sustainable production and increased agriprenuerial participation by the youth of developing countries like Nigeria.

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Chapter 7
Agricultural Information Systems (AGRIS) as a Catalyst for Sustainable Development Goals (SDGs) in Africa:
A Critical Literature Review

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ABSTRACT

The absence of well-developed agricultural information systems (AGRIS) has continued to hinder agricultural development in Africa. Efforts designed to modernize agriculture through AGRIS by the public and private sectors have been hindered by administrative bottlenecks, weak political will from governments, display of ineptitude by farmers/associations, and institutional corruption. In view of the foregoing, this chapter discusses AGRIS as a catalyst for SDGs in Africa. An effective AGRIS will strengthen decisions on the general management of the agricultural sector. Deploying the AGRIS for the management of agriculture will boost food production, increase the GDPs and directly strengthen the actualization of SDG 1, SDG 2, SDG 3, SDG 8, SDG 9, SDG 10, SDG 11, SDG 12, SDG 14, SDG 15, SDG 17, and indirectly impact other SDGs. Ultimately, this chapter suggests leveraging AGRIS for mitigating all the identified challenges to agricultural development in the continent.

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INTRODUCTION

The absence of well-developed agricultural information systems (AGRIS) has continued to hinder agricultural development in Africa. Efforts designed to modernize agriculture through AGRIS by the public and private sectors, including agricultural interventions from international organizations, have been hindered by administrative bottlenecks, weak political will from governments, display of ineptitude by farmers/associations, and institutional corruption. There is a need to strengthen the agriculture sector and increase the productivity of agribusinesses in the continent, leveraging AGRIS. The continent's low agricultural productivity is compounded by weak linkages of research findings and advisory services, inadequate basic infrastructure, ineffective information packaging and dissemination, limited commercial farming capability, and poor access to new agricultural technologies for the benefit of the farmers (Oluwole, Youdeowei, Ohiomoba, Adewale, & Yemi, 2016; Vidanapathirana, 2012). Unfortunately, for a continent with a population estimated at about 1.3 billion (WPR, 2020), it is also the most hit by food insufficiency, hunger, and abject poverty. Previous blueprints on sustainable development such as the green revolution, millennium development goals (MDGs) and sustainable development goals (SDGs) made food sufficiency and agricultural productivity across the globe a priority.

The food and agricultural organization (FAO) had long advised that the number of food-insecure people across the globe could be reduced to 675 million by 2015 because there are environmentally-sustainable technologies with the capacities to help double world food production without causing threats to ecosystems. However, the targeted reduction of the number of food-insecure people could not be achieved because of insufficient political will on the part of countries (FAO, 2017). The situation has worsened beyond the FAO 2015 estimates because the population of the world continues to grow with more frightening population growth rates coming from the developing countries. Therefore, developing countries must increase their food production in the agricultural sector to match their growing populations to ensure food security (FAO, 2017).

But, the quest to achieve food security for the hungry population of Sub-Sharan Africa will remain a tall order without higher levels of investments in AGRIS, water resource development, human capital development, basic infrastructure or transport systems, power grids, agricultural research and extension, and genuine political will from the governments of Sub-Saharan Africa. While other continents are making systematic efforts at boosting their agricultural systems leveraging technology and information systems, the African continent still heavily relies on aid and food importation to sustain its growing population.

Providing an enabling environment for the implementation of SDGs justifies investments in AGRIS to accelerate the progress towards achieving the SDGs in Africa. The viability of AGRIS-SDGs synergy has attracted the attention of the international community. The United Nations has appointed FAO as a 'custodian' for 21 of the 230 SDG indicators that cut across SDGs 2, 5, 6, 12, 14 and 15, and a contributing agency for six more (FAO, 2017). However, there is also a paucity of literature connecting AGRIS and the SDGs in the African context. Very few articles from FAO only reported the synergies between AGRIS and the SDGs. Since 2016, FAO and the US Agency for International Development (USAID) have been working to boost the capacity of developing countries to deploy AGRIS for tracking agricultural data, which would accelerate the realization of SDG 2 that aims to end hunger, achieve food security and improved nutrition and promote sustainable agriculture (Wahlen, 2016). There exists a knowledge gap to be filled with regards to the relevance of AGRIS to all 17 SDGs in Africa.

In view of the foregoing, this paper critically discusses AGRIS as a catalyst for sustainable development in Africa. Specifically, the chapter seeks to answer the following questions: (a) What are the components, benefits, workable framework, and operational challenges of AGRIS? (b) In what way can AGRIS serve as a catalyst for sustainable development in Africa? Following the introduction is the second section, which focuses on methods and analysis. The third section discusses the conceptual definition of AGRIS. The fourth section highlights the components of an information system. The fifth section analyses the multidimensional benefits of AGRIS. The sixth section presents a workable framework for AGRIS in Africa. The seventh section discusses the operational challenges of AGRIS. The eight section explains the relevance of AGRIS as a catalyst for sustainable development in Africa. The ninth section concludes with practical/managerial implications and policy suggestions.

METHODS AND ANALYSIS

This paper adopts a qualitative research method and relies on secondary data. The required qualitative data were extracted from scholarly works on AGRIS and SDGs in Sub-Saharan Africa. A rigorous and objective process was adopted in purposively selecting previous relevant scholarly works. This resulted in a sample of 54 relevant studies on AGRIS and SDGs that were selected from the Google Scholar database and private and public agricultural research and advisory services with a focus on Africa. A critical literature review (CLR) was conducted on the sample of scholarly works and thematic pieces of information on agricultural practices, AGRIS and SDGs were extracted and analyzed to distill some valuable insights. The CLR is the systematic and objective analysis and evaluation of scholarly articles on a specific subject matter for the purpose of developing new insights, richer findings, and enriching understanding about the subject of inquiry (Saunders and Rojon 2011; Saunders, Lewis and Thornhill, 2012).

Conceptual Definition of Agricultural Information Systems (AGRIS)

AGRIS is a category of information systems (IS) that is designed to improve the efficiency and effectiveness of agricultural knowledge systems - the generation, processing, dissemination, and use of agricultural information by agricultural stakeholders involved in the agricultural information chain. AGRIS is a critical part of IS-enabled interventions in the agricultural sector. AGRIS can play a critical role in eliminating or minimizing information deficiencies faced by smallholder farmers in Africa, who typically own less than five hectares of land and have limited access to basic infrastructure (such as power, road transportation, and railways), markets, and extension information (Goedde, Ooko-Ombaka, & Pais, 2019; Nakasone, Torero, & Minten, 2014). For example, ICTs can be used to support and sustain the generation of relevant local agricultural content, or to facilitate more frequent information sharing between farmers and agricultural agents, to reduce the cost of extension visits, and extension workers, and to enable better agent accountability, or to transform existing market structures that entrench inherent market inefficiencies (Cole & Fernando, 2013; Nakasone et al., 2014). This is not suggesting that AGRIS provides a panacea of solutions because there are also other factors beyond ICTs that hamper farmers' adoption of ICTs in developing countries. For example, if farmers do not have access to the necessary credit to adopt and sustain ICTs, they may not be able to do anything even when they are convinced about the potentially positive impact on farm productivity. Furthermore, farmers may not have access to the irrigation technologies or systems necessary to optimally deploy the ICTs (GAO, 2019). The adoption of some ICTs may require certain knowledge and skills to effectively deploy them, collect and process any relevant information involved, whereas the farmers may not possess or may not be able to acquire the knowledge and skills (Magne, Cerf, & Ingrand, 2010; Nakasone et al., 2014). Therefore, ICTs alone may not and cannot be expected to solve all the problems.

An AGRIS is usually deployed as part of an IS-enabled intervention by agricultural industry stakeholders, which include decision-makers, policymakers, researchers, extension personnel, public and private input providers, large commercial farmers, and smallholders. These agricultural industry stakeholders make decisions or take actions that are necessary to improve farming operations. At the tactical level, these decisions or actions are aimed at increasing agricultural productivity at the industry level or, at the national level and beyond, to address food security problems (Che, Strang, & Vajjhala, 2020; FAO, 2017; Oluwole, Youdeowei, Ohiomoba, Adewale, & Yemi, 2016). The success of an IS-enabled intervention is based on how well it achieves its intended objectives and goals. The intervention must be accepted by its intended users, and it must achieve the desired outcomes or meet stakeholder requirements (Solorzano, Sanzogni, & Houghton, 2017). Basically, the IS must make an impact in terms of generating tangible benefits over a period of time for its stakeholders (Solorzano et al., 2017). The IS will be considered a failure if it does not adequately address the needs of its users and stakeholders.

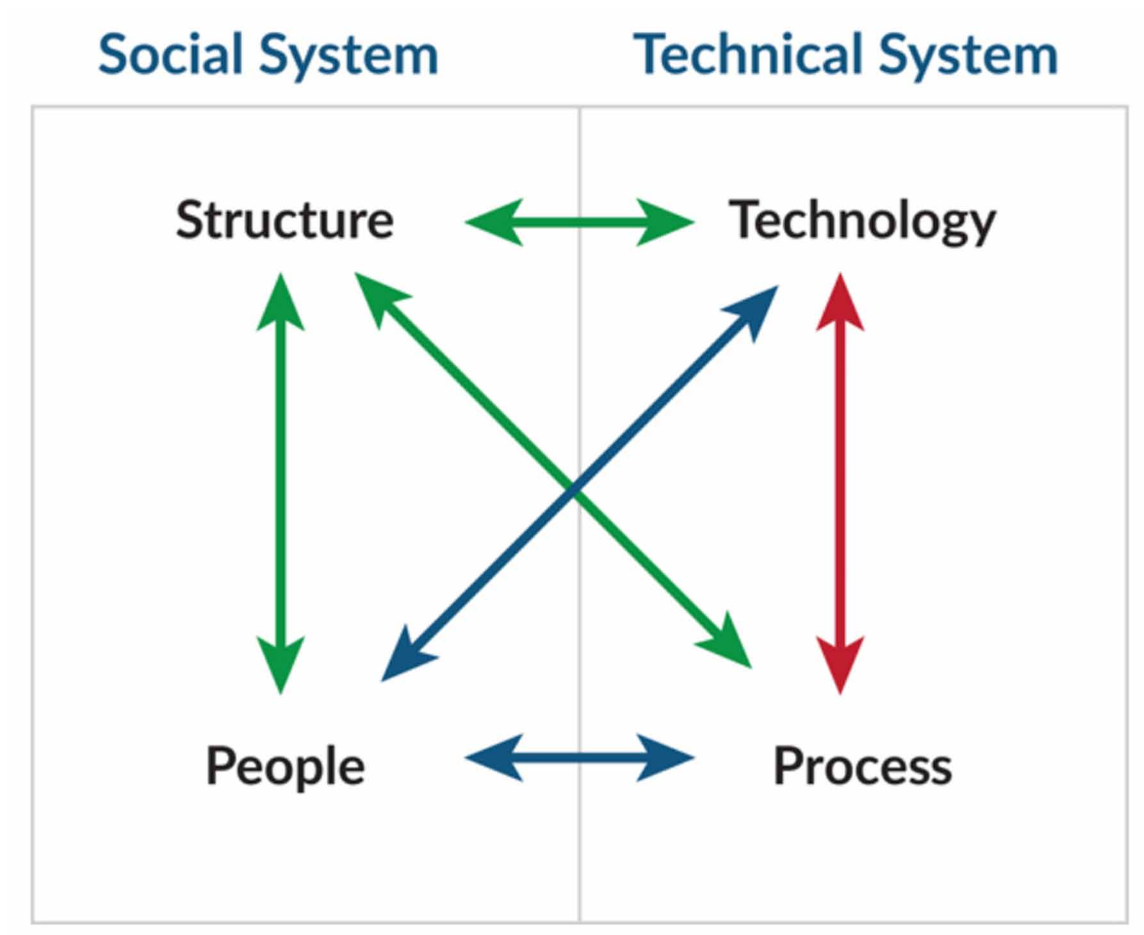
The success of AGRIS depends on whether it was designed to solve a relevant and meaningful problem and that the intended users adopt it. The task of clearly articulating the nature of the agricultural problem, and the strategies to address it, is critical and is neither an IT nor a business responsibility alone. Both IT and business experts work collaboratively to discover and articulate the business and user requirements (Robertson & Robertson, 2012; Tegarden, Dennis, & Wixom, 2012). Furthermore, at the heart of the most productive strategies for solving the problem is a recognition that IS-enabled interventions have a systemic or multidimensional impact. The discovery and articulation of requirements involve working with users, who often do not know or cannot be expected to know what needs to change. However, if an AGRIS intervention is to be successful, following a systematic requirements process to articulate the goals of the intervention, the benefits that are expected to be generated, should not be taken lightly (Robertson & Robertson, 2012). The overall goals of the AGRIS intervention ultimately provide an avenue for assessing its success or failure.

The Components of an Information System

The meaning of the information system (IS) is broader than that of the information technology (IT) even though both constructs are often used interchangeably or even confused. It is important to recognize that IT is a fundamental component of any modern IS (Piccoli & Pigni, 2018). IT is usually a part of any modern IS and so it is not unexpected that in most conversations about IS nowadays, the part that IT plays is taken almost for granted or assumed to be implicit that such systems are IT-based information systems. An IT-based information system is designed using a range of technologies, and the goal is usually to improve some processes and operations in some way so that people can interact more efficiently, communicate and share information more effectively, or coordinate operations more effectively, as people strive to accomplish some organizational objective(s) (de Vreede, Antunes, Vassileva, Gerosa, & Wu, 2016; Imre, 2017; Migdadi, Zaid, & Hujran, 2012; Piccoli & Pigni, 2018; Sneha & Straub, 2017). Henceforth, in this chapter, the focus shall be on the exploration of IT-enabled IS. An IT-enabled IS can be described as a socio-technical system that is comprised of two sub-systems: a technical sub-system and a social sub-system, which can be further broken down into four interdependent components (Piccoli & Pigni, 2018). The technology and process components make up the technical sub-system, whereas the people and structure components make up the social sub-system, as seen in Figure 1 (Piccoli & Pigni, 2018). The technology component, which is often referred to also as information communication technology (ICT) or the more general information communications technologies (ICTs), is a fundamental piece of the IT-enabled IS puzzle and its role opens the door to multidimensional benefits that will be explored in a later section.

An IS does not operate in isolation but usually plays a role, usually in the context of a greater intervention or initiative in an organization or other real-world context. Basically, the IS plays a role that contributes to or ultimately that drives the achievement of some objective for someone, organization, or some purpose. For any IS to be effective in its role, it is vital that all its four components are present and working together in a cohesive fashion (Imre, 2017; Piccoli & Pigni, 2018; Sabarguna, 2018; Solorzano et al., 2017).

Figure 1. Components of an Information System (extracted from Piccoli and Pigni, 2018, p. 29)



Modern organizations increasingly depend on IT as a central part of any IT-enabled intervention. The IT component, in Figure 1, can take a variety of forms, including hardware, software, and all communication equipment used to capture, process, store, and distribute information. ICTs encompass a range of technologies such as computers, mobile phones, tablet devices, the internet, radio, and television, to name just a few (Nakasone et al., 2014). In the situation where a farmer uses a mobile phone to check crop prices or information crop diseases or to order farm inputs, the obvious hardware technologies involved are the mobile phone device, the local cables, any inter-organizational channels of communication and the routing equipment necessary to disseminate the information (Adetimehin, Okunlola, & Owolabi, 2018; FAO, 2017; van Vark, 2012). The access portals or technology platforms that the farmer relies on or through which agricultural data is captured, processed, stored, and disseminated are driven by software (ESOKO, 2020; GSMA, 2012). ICTs are usually purpose-built and as such, they can enable as well as constrain the actions that are supported by or the functionality of the IS. It is also important to recognize that ICTs encompass a wide range of technologies and as such, the impact of ICTS can vary widely depending on the specific technology involved (Nakasone et al., 2014). Therefore, it is critically important that there is a good match between the technologies and the underlying business processes that they support or are used to drive.

The process component of IS refers to the methods, policies, the series of interrelated steps or activities that can be carried out by an individual, a group or an organization as a necessary part of doing business or business operations. With business processes, there is no such thing as one size fits all. Multiple or different business processes can be designed to accomplish a business operation (Alduraywish, Xu, & Salonitis, 2017; Piccoli & Pigni, 2018). Ultimately, it is people who execute the business processes, and people are not automatons – as no two people can be expected to accomplish a task in the exact same way that it is specified and do so repeatedly without fail time and time again. As a result, there is often a gap between what is specified as an official business process and the way that the process is performed (Piccoli & Pigni, 2018). Therefore, in designing or deploying an IS intervention it is critical to recognize that there needs to be a fit between not only the business process(es) and the IT component, but also the other components of IS that may need to be adjusted to achieve an optimal outcome. In Kenya, after completing a pilot program, Safaricom realized that training its network of agents was a critical determinant of the success of the service that delivered via the M-PESA platform, which is an SMS-based IS that enables users to deposit, send, withdraw, and save funds using their mobile phones (FAO, 2017; World Bank, 2017). In summary, all four components of an IS must be present and working together to produce optimal results. That completes the technology and process component or the technical sub-system of an information system, and an exploration of the social sub-system follows.

In the Safaricom example above, a focus on all four components of the IS, including people and structure, was what led to the recognition of the appropriate or successful strategies. The people and structure components make up the social sub-system of an IS. The people component refers to the individuals or groups who are directly involved with the IS. These people could be managers who define the goals of the system, or IT professionals, or end-users of the IS. The end-users of IS represent one of the most important categories of people because if they do not accept or cannot learn and use the IS, then the IS will undoubtedly fail (Bourgeois, 2014; Piccoli & Pigni, 2018). People are characterized by variability in terms of differences in knowledge, skills, attitudes, biases, personality traits, preferences in information channels (Alshawi, Elliman, & Paul, 2000; Wiredu, 2010). In addition, people are usually motivated by different interests, all of which can influence what they do or choose to do (Bipp & Demerouti, 2015; Kerse, 2018; Piccoli & Pigni, 2018; Robbins & Judge, 2018; Strang, Che, & Vajjhala, 2019; Yaw, Asuming-Brempong, & Mabe, 2013). For example, in a study that was conducted to establish how farmers access and exchange cocoa-based information in two key cocoa-growing areas of Ghana, it was found that farmers used a wide range of information channels and sources but sought information primarily from colleagues and other personal sources, and the farmers obtained relevant information from their radios and televisions much more than from extension agents, research institutes, or other public sources (Yaw et al., 2013). The lack of adequate provision for IS systems to support extension information dissemination meant that the farmers could not realistically have taken advantage of more modern or effective information alternatives that would be enabled as a result of an influx of telecommunications networks in the study areas (Yaw et al., 2013). Therefore, when designing an IS intervention it is critically important to account for the fact that the people involved, especially the end-users, may have diverse backgrounds, different set of skills, personality traits, attitudes, biases, information channel preferences, and interests (Che et al., 2014, 2020; Misaki, Apiola, Gaiani, & Tedre, 2018; Movarej, Hashemi, Hosseini, & Rezvanfar, 2012). Furthermore, people do not generally work alone, as there is often necessary to coordinate actions with others to achieve optimal outcomes. The IS structure component captures the essence of how people work together to enact processes whilst relying on technologies to accomplish their objectives efficiently and effectively.

The IS structure component refers to organizational resources and how the efforts of groups of people can be coordinated, facilitated by the relationships amongst the individuals in the groups, the hierarchical and reporting structures that they follow, and the incentive systems that are necessary to align peoples' and organizational interests. An aspect that is often overlooked, particularly for AGRIS, is the aspect of structure that extends beyond the organizational boundary, even though it has implications on the IS structure, and that is the broader structure of the market in which the IS-enabled intervention must operate – the number of buyers, sellers, and the degree of market or bargaining power, barriers to entry/exit, and any vertical coordination mechanisms (Chiatoh & Gyau, 2016). The structure component can determine whether an IS-enabled intervention succeeds or fails, depending on whether the intended users accept or resist the IS (Bourgeois, 2014; Piccoli & Pigni, 2018). Paying attention to the IS structure component, as well as the broader market structure, can reveal critical insights that open new avenues for how to effectively leverage IS, prevent IS failures, or to minimize the impact of any IS failures, and ultimately how to effectively fund and sustain the IS-enabled intervention (Chiatoh & Gyau, 2016; Piccoli & Pigni, 2018; Wiredu, 2010). The introduction of an IS intervention is an organizational change because it is often accompanied by broader changes. Thus it can involve changes in mentality, business processes, capacity building, role changes, and reporting structures, as well as changes in the support and incentive systems (Dyer, Godfrey, Jensen, & Bryce, 2015; FARA, 2014; Oluwole et al., 2016). For example, introducing new ways of work can unsettle individuals in an organization because of the perceived implications of the change (Alshawi et al., 2000; Robbins & Judge, 2018). Therefore, when designing or introducing a new IS intervention, it is imperative to recognize that it is a change that could have systemic impacts on individuals, groups of people, how information is shared, and the processes that the people enact. At the same time, the technology is not static as it should also be flexible enough to accommodate change through usage and knowledge sharing (Alemu, Jennex, & Assefa, 2018). For an IS-enabled intervention to succeed, the processes that are involved, the people involved, the reward systems must be aligned.

The Multidimensional Benefits of AGRIS

The case for investment in modern agricultural innovations to boost Africa's agricultural productivity has been made for quite some time. Africa's population is growing, and over 70% of the people make their living from agriculture (Oluwole et al., 2016). Even though a large proportion of Africa's population makes their living from agriculture, agriculture contributes only about 30% to its overall GDP because the vast majority of farmers are smallholders and because governments do not prioritize investment in the sector (Oluwole et al., 2016). Only about 23% of Sub-Saharan Africa's GDP comes from agriculture (Goedde et al., 2019). The potential of an average farm in Africa is hardly being tapped as each farm performs at no more than about 40% of its potential. If nothing is done to alter this situation, then it is estimated that Africa will only produce about 13% of its food needs by 2050 (Oluwole et al., 2016). Africa's leaders have long pledged to invest at 10% of their countries' annual budgets in agriculture, as they recognized the potential opportunities to lift about 85 million people out of extreme poverty and hunger if such investments resulted in the expected productivity gains (Oluwole et al., 2016).

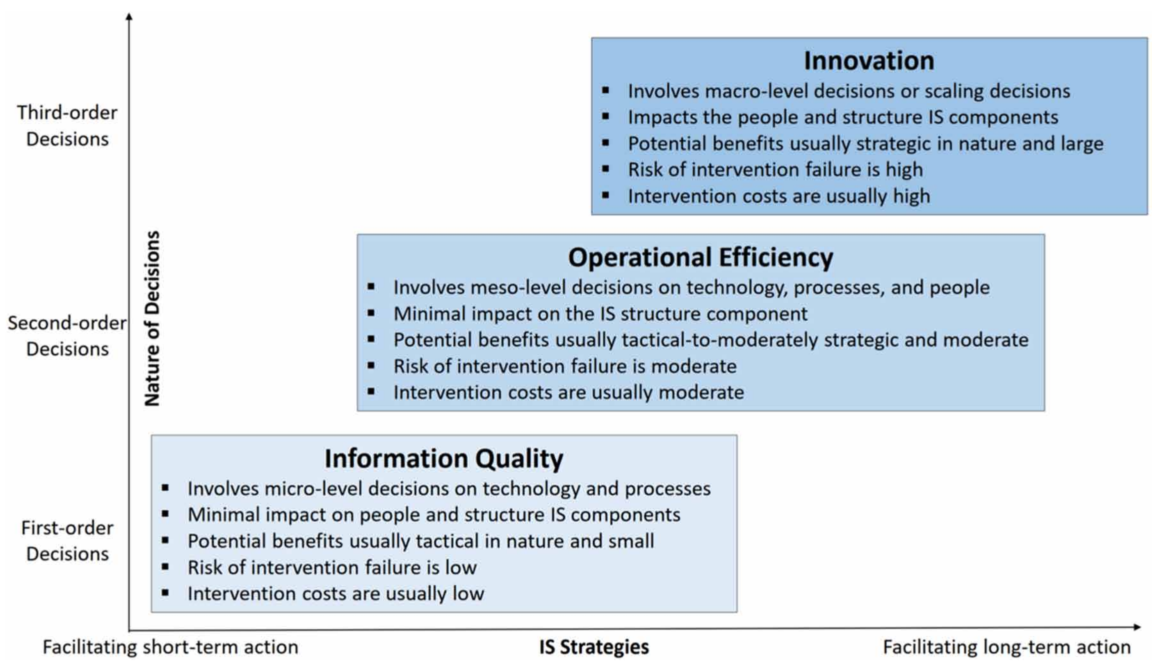
Africa's population is currently estimated at about 1.3 billion, expected to be about 2.4 billion by 2050 (Goedde et al., 2019; WPR, 2020). Africa is the only region in the world with a growing youth population, and more than 50% of the world's uncultivated arable land (Oluwole et al., 2016; Sow, 2018). It should be noted that most of the untapped arable land in Africa is mostly inaccessible because of a lack of basic infrastructure. Based on Sub-current land estimates, without additional investment in basic infrastructure, Saharan Africa could contribute only about an additional 10% to Africa's cultivated land (Goedde et al., 2019). Nevertheless, the potential of Africa's agricultural sector is still untapped, and productivity could be intensified two to three times more (Goedde et al., 2019). Africa's leaders must step up as only an estimated 8 out of the 54 countries have followed through with the promise to invest at least 10% of their annual budget in agriculture (Oluwole et al., 2016). Ultimately, with growing urbanization in Africa, more and more land is being consolidated in addition to ongoing smallholder aggregations through farmer cooperatives, presenting greater opportunities for more large-scale mechanized farming or an increase in the number of medium-sized farms (Goedde et al., 2019).

The biggest growth opportunities and drivers of agricultural productivity in Africa are expected to lie mainly in increasing smallholder productivity, improving cost competitiveness, but much less in expanding cultivated land (Goedde et al., 2019). To Africa's agricultural potential – raising productivity by up to three times – requires a significant investment in basic infrastructure, agricultural inputs, and market development (Goedde et al., 2019). That investment could account for about eight times more fertilizer, based on current application rates; six times more improved seed; at least $8 billion in basic storage, not including cold-chain investments for horticulture or animal products; and as much as $65 billion in irrigation (Goedde et al., 2019). Without investment in basic infrastructure such as roads, electricity, a haulage system, and with the high cost of production, Africa's farmers cannot compete in the marketplace. What will unlock the opportunities in Africa's agricultural sector is sustained investment in raising farmers' productivity and innovation by both public and private entities.

To unlock Africa's agricultural potential, companies should focus their investments in improving the route to market, on the supply-side, and farmer engagement, on the demand-side (Goedde et al., 2019). According to Goedde et al. (2019), the focus of the efforts on the supply-side should be on disrupting the very fragmented supply chains to reduce costs, providing value-added services to agro-dealers, and pursuing more flexible and innovative agro-dealer payments models. On the demand side, companies should focus their efforts on developing innovative farmer financing models, working collaboratively through sales and promoter networks, becoming more customer-sensing, and generally being market-driven (Aqmala & Ardyan, 2019; Goedde et al., 2019; Seiden, 2015). All such interventions could be more cost-effectively achieved by leveraging digital innovation. Africa's leaders, private companies, and non-governmental organizations (NGOs), and all stakeholders participating in the agricultural value chain should work independently or collaboratively to devise strategies to leverage IS to create and sustain the multidimensional benefits of AGRIS interventions.

For IS strategies to be successful in any organizational context, the IS must be aligned with the nature or dimensions of the decisions involved in the change. As discussed earlier, all four components of IS must be present and working in tandem to ensure success in any IS-enabled intervention. The illustrative framework in Figure 2 was developed as an attempt to simplify the complex intersection between the multidimensional benefits of IS, which include information quality improvement, operational efficiency, and innovation (Alshubaily & Altameem, 2017), and the nature of the decisions that can be expected to be involved in an IS-enabled intervention. The illustrative framework in Figure 2 shows strategies that span a spectrum from those that facilitate short-term actions to those that facilitate long-term actions. On the other hand, the nature of the decisions involved can range from relatively simple to complex. Simple or first-order decisions are generally encountered in change that involves the introduction of ICTs to automate or modify how existing processes are performed (Piccoli & Pigni, 2018). Second-order decisions are usually meso-level change decisions which are a level of complexity higher than first-order decisions, and the implications of the decisions impact not only the nature of the processes but also people involved whose roles may change or a different set of people may be required (Piccoli & Pigni, 2018). Finally, third-order decisions are usually macro-level change decisions and are the most complex and can have much broader implications beyond a single organization or even region (Piccoli & Pigni, 2018). Third-order change may involve significant disruption that can usher in novel ways of doing things and scaling proven solutions. All three levels of decisions are common in AGRIS interventions.

Figure 2. Illustrative IS strategies framework



The information generated by AGRIS needs to accurate, reliable, timely, and usable to ensure that good quality and effective decisions can be made from it. IS strategies that are aimed at improving the quality of information generation and dissemination typically involve first-order decisions, which means that the decisions can range from simple automation of existing processes to moderate process improvements with minimal impact on the people that enact the processes, as seen in Figure 2. For example, farmers in Burkina Faso, Côte d'Ivoire, Mali, and Senegal rely on accurate market information from N'kalô system, a commercial advisory service that leverages digital technologies to disseminate agri-food sector information, to negotiate fair prices for the produce (Ricau, Tossou, Senou, & Bappa Se, 2019).

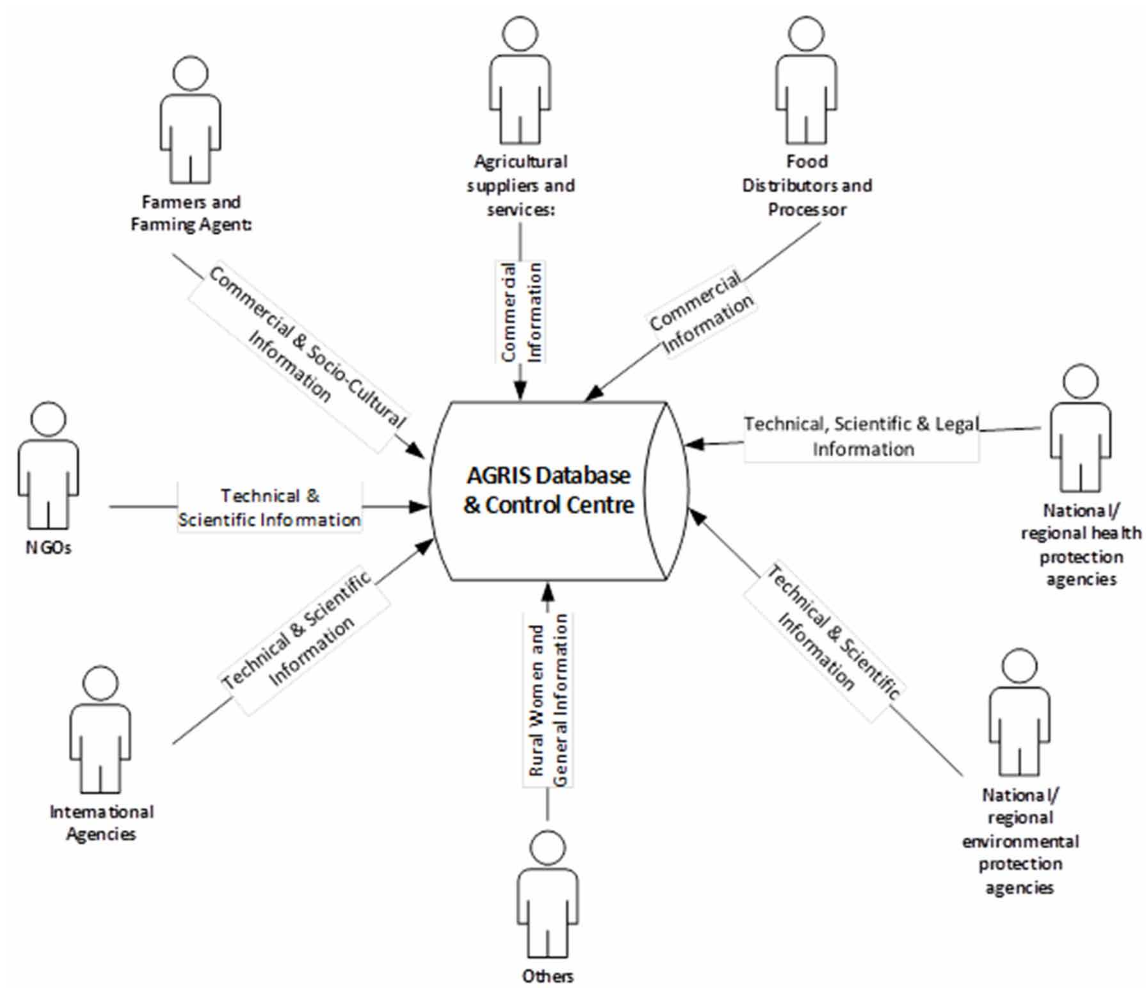
The generation and dissemination of quality information in the case of the N'kalô system can be considered a first-order decision. But there are also operational efficiencies that emerge from systems such as N'kalô. For the farmers, having accurate pricing and market information saves time, because negotiations become easier, increases their bargaining power, because of transparency, and reduces transportation costs as buyers must come to the farmers.

The strategies involved in coordinating the various agricultural value chain partners participating in a system such as N'kalô involve meso-level decisions. Finally, rolling out a platform such as N'kalô across multiple countries involves a collaborative effort from public agencies and private entities willing to leverage innovation to adapt solutions in one setting to make them work seamlessly in another, which involves macro-level decisions.

Workable Frameworks for AGRIS in Africa

This section presents a model framework for an AGRIS in Africa. There are several AGRIS models designed across the globe. For instance, Vidanapathirana (2012) presented an AGRIS concept map with a robust structure that comprised subsystems, components, processes, mechanisms, and operations. Similarly, Rathnayake (2019) discussed the llanga Agricultural Model in Sri Lanka which has enhanced the efficiency and the forecasting ability of the agricultural system in the areas of water management, tank capacity and capacity development, management of the agricultural area, crop and harvest, marketing as well as settlement capacity, forest growth, catchment shading and many other components of IT system. However, the AGRIS being an Information System is expected to have set objectives and functions. Figure 3 shows a model framework that incorporates the people and their respective contributions to the Agricultural Information Systems.

Figure 3. Model Framework showing People and contributions to AGRIS



The model framework identifies the following as essential components of an effective AGRIS

- The people in The Agricultural Information System
- Sources/Type of Agricultural Information System
- Means of Transmitting information in AGRIS
- The AGRIS Database and Control Centre
- Information Usage Policy

The People: These are the stakeholders in the agricultural sector. They consist of groups of individuals who play positive roles in the realization of the objective of the AGRIS system. Involving multiple stakeholders in the Agricultural Project improves the quality of decisions, promotes active participation, and gives the process credibility (Marielle & Gunther, 2006). Each person in the group share information in the interest of the overall objective of the AGRIS system.

- **Farmers and Farming Agent: -** These include landowners, farmworkers, unions, and farmers' associations. They are at the bedrock of agricultural produce.
- **Agricultural suppliers and services: -**They are responsible for making available items needed for effective agricultural product delivery - such as seed, pesticide, fertilizers. They also render services that aid food production, such as transport services.
- **Food Distributors and Processor: -** They are responsible for transforming the harvested agricultural product into processed food. They could be food manufacturers, wholesalers, retailers.
- **National/regional health protection agencies: -** They food regulatory agencies which include Public health institutions, food standards agencies, occupational health and safety agencies, local/regional health boards and environmental health departments
- **National/regional environmental protection agencies**: - They consist of Ministries of environment, environmental regulatory agencies, local authorities who ensure the preservation of the environment
- **NGOs**: Pesticide action groups, organic farming groups, animal welfare groups
- **International Agencies**: European Commission (Directorates for Agriculture, Environment, Health); WHO, FAO.
- **Others**: This consists of Rural residents, National and local media, scientists (epidemiologists, toxicologists, environmental scientists).

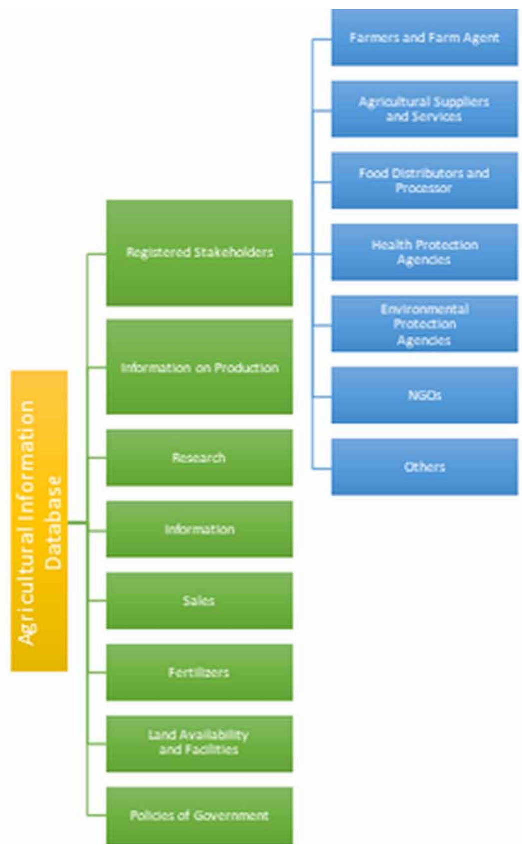
Each of the people discussed above has assigned roles in the effectiveness of an information system. Some contribute useful information while others make use of the information for decision making for the overall agricultural development in Africa.

Sources/Types of Information: AGRIS, as the name suggests, is information-driven. The sources of information in AGRIS are determined by the type of information available with the agricultural ecosystem. According to scholars, six types of information are very important for an IS, namely: Technical/scientific information, Commercial information, Socio/cultural information, Legal information, Information on rural people, and general information (Adio et al., 2016). Further explanations of the six types of information are discussed below.

- **Technical/scientific information:** These are information obtained from research which will aid production when applied. The source of this type of information is usually from research intuitions or higher institutions of learning. They are mostly used by farmers to boost production.
- **Commercial information:** This is related to information on agricultural products and services, availability of products, quantity available, and where cost and people in need of the products. Commercial information is usually generated by farmers, agricultural suppliers, food distributors, and processors.
- **Socio/cultural information**: This relates to information on the traditional agricultural practices, local cultures, norms/values, and background information and training done in different communities as well as on the availability of labor, etc.
- **Legal information**: This type of information educates all stakeholders in the agricultural sector on legislated laws and policies on the production and distribution of agricultural produce.
- **Information on rural people**: This type of information will be useful to train rural people on proven technology in agriculture, food production, processing, and preservation, storage, utilization, and marketing and how to improve their standard economically and socially.

- **General Information,** these are information of general interest to farmers, for example, handling of flood, fire, and other disasters. The idea behind the framework is to preserve all this information in a comprehensive database and make them easily available on request.

Figure 4. Content of an Agricultural Information System



Means of Transmitting Information in AGRIS

Useful information collected from various sources discussed above is shared through the following medium radio, television, extension workers, cooperative societies, friends and colleagues, newspapers and magazines, books/leaflets, phones, libraries, and institutes. Also, observation of people's organizations, speeches, documents, picture and artwork can also be described as information sources (Demiryurek et. Al., 2008).

AGRIS Database and Control Centre

There is an existing Agricultural Information System Database created in 1974 by the Food and Agriculture Organization (FAO) of the United Nations. It is an International bibliographic information system reservoir for agricultural science and technology. It has 2.6 million structured bibliographical records, out of which 75% are journal articles, 18% are monographs, 6% are conference papers and 1% are other literature (Raj & Kaushik, 2012). Furthermore, existing AGRIS has limited scope in relation to agricultural information because it handles only technical information that does not address in totality the needs of developing countries where Africa belongs. Other challenges associated with the international AGRIS are non-inclusion of regional language literature and non-inclusion of grey literature in AGRIS. Based on the aforementioned challenges associated with the existing AGRIS database, this paper advocate a comprehensive AGRIS database tailored to Africa specific needs with a network link to the Global AGRIS. Figure 4 shows the likely content of the proposed AGRIS database

Operational Challenges of AGRIS

The multidimensional benefits of AGRIS, especially modernization of agriculture and attainment of food sufficiency in Sub-Saharan Africa, have been discussed, but the process of meeting the information needs of rural farmers through agricultural information systems faces a number of challenges. Oladele, Koyoma & Sakagami (2004) had long reported that AGRIS in Africa is challenged by a weak response by the policymakers to local conditions and concerns of farmers and other stakeholders. Secondly, existing AGRIS is limited in its capacity to facilitate constructive inter-organizational collaboration through capacity-building and local institutional development. AGRIS in Africa has not addressed the financial insecurity of farmers and low educational levels of extension staff. Moreover, existing AGRIS failed to meet the specific interests of local farmers nor made an attempt to engage indigenous knowledge/inventiveness of local farmers and the age-long farmer-to-farmer communication systems.

Furthermore, Mbagwu, Benson & Onuoha (2017) identified inadequate ICT infrastructure/poor internet access as a major challenge to agricultural information systems. Inadequate ICT infrastructure prevents rural farmers in developing African countries from accessing and transmitting the necessary information to the end-users. Without strong internet connectivity, it will be difficult to connect the rural farmers and provide them with internet-based information services. Related to the above challenges is the low level of interest in utilizing AGRIS by the rural farmers because of preference for the traditional agricultural practices and information-sharing system, which in most cases are ineffective. Thirdly, inadequate knowledge by the rural farmers about the benefits of AGRIS poses another set of challenges to agricultural development. To these rural farmers, some information needs are personalized, while the generic should be shared. This misconception has largely affected the acceptance and adoption of the AGRIS in the continent. Other challenges include weak linkages of research findings and advisory services, inadequate communication, ineffective Some information packaging, and poor access to new agricultural technologies for the benefit of the farmers (Vidanapathirana, 2012). With specific reference to Ghana, Lamptey, Sambo and Hassan (2016) revealed that the effective functioning AGRIS is challenged by a high level of illiteracy, poor electricity supply, language constraints, funding inadequacy and technological barriers especially the paucity of technology experts to assist with the management of agricultural information systems.

AGRIS as a Catalyst for SDGs in Africa

It has been estimated that around 800 million people suffer from hunger, and malnutrition (one in three people on the plane), availability of data (through AGRIS) to rural actors on crops growing conditions, weather, and markets, will allow an estimated 500 million smallholder farmers to farm more profitably by using scarce resources efficiently, thereby accelerating the attainment of achieving zero hunger and sustainable development (FAO, 2017). Providing an enabling environment for the implementation of SDGs justifies investments in AGRIS to accelerate the progress towards achieving the SDGs in Africa. The deployment of AGRIS would directly boost food production and increase GDPs. The linkages of the agricultural sector to the SDGs are both direct and indirect. The positive outcomes of AGRIS-SDGs synergy would directly strengthen the actualization of SDGs as discussed below.

SDG 1: No poverty. Agriculture contributes immensely to the GDPs in Africa, employing about 60% of the workforce (SDGC|A & SwedBio, 2017). Deploying AGRIS to improve the way markets work for farmers and to encourage youth agribusinesses to flourish would boost food production, reduce poverty, and increase the GDPs across the continent.

SDG 2: Zero Hunger. Africa's vast agricultural potential remains largely untapped and major investment needed to unleash that potential (Goedde et al., 2019) and AGRIS present opportunities to achieve food sufficiency, reduce hunger, and eradicate poverty.

SDG 3: Good Health and Wellbeing. About 7.5% of children under five in the world are affected by stunting and wasting due to malnutrition, and about half of these live in South Asia and Sub-Saharan Africa (FAO, IFAD, UNICEF, WFP, & WHO, 2018). Low-income women in rural areas experience high levels of micronutrient deficiencies, diets low in dairy and eggs, which affects their health and can contribute to stunting and wasting and learning deficits in their children (Ansah, Aloys, & Cesari, 2017). AGRIS and other appropriate agricultural production technologies could be deployed to ensure the adequacy of nutritious food, more responsible food production, storage, and consumption.

SDG 4: Quality Education. Food insecurity and lack of nutritious food are linked to poor educational outcomes, particularly for children (Engler & Kretzer, 2014; FAO et al., 2018). AGRIS could be deployed to support agricultural extension and enable farmers to access to quality skills, tools, inputs, and knowledge they need.

SDG 5: Gender Equality. Women are not only deeply involved in all stages of agricultural production (Doss, 2015). In Sub-Saharan Africa, as economies grow, men increasingly move out of agricultural work and into other sectors. Rural women farmers produce as much as 80% of the food in some countries in Sub-Saharan Africa such as Nigeria (Adenugba & Raji-Mustapha, 2013). Women would be just as productive as men, given access to similar resources (Doss, 2015). Deploying AGRIS and other appropriate technologies to identify and address the gender differences in access to agricultural resources would close any productivity gap and enhance overall food security.

SDG 6: Clean Water and Sanitation. Irrigated agriculture represents 20% of the total cultivated land and contributes 40% of the total food produced worldwide (WB, 2020). By 2050, the global demand may be more than doubled, with agriculture alone requiring more than what can be sustained to feed the world (Boretti & Rosa, 2019). Appropriate AGRIS and other appropriate precision agricultural technologies could be deployed to improve the efficiency of water delivery and use.

SDG 7: Affordable and clean energy. Energy is central to all aspect of agriculture and human livelihood in a world where 1.5 billion people (20% of the world population) have no access to electricity supply, and almost 3 billion people rely on firewood, crop residues, cattle dung, coal and other solid fuels for cooking (Surendra et al., 2014). Since affordable energy is crucial industrial needs, leveraging AGRIS for planning and generating clean and renewable energy from biomass such as kitchen waste, cattle dung, crop residues, green wastes, and the organic wastes would further the realization of SDG.

SDG 8: Decent Work and Economic Growth. In developing countries, unemployment and deprivation have forced many people to accept non-standard employment with indecent terms and conditions of service (Shehu and Nilsson, 2014). Decent work is an effective means for poverty reduction and achieving equitable, inclusive, and sustainable development (ILO, 2013). AGRIS could attract young educated farmers and agripreneurs (YPARD, 2013) to the agricultural sector, and supported by appropriate labor policies could not only improve the agricultural productivity but also increase access to decent jobs on farms and agro-based industries, and ultimately stimulating economic growth.

SDG 9: Industry, innovation, and infrastructure. Innovative infrastructure assists the industrial and agricultural sectors to cope with operational challenges such as identifying innovation needs, contracting appropriate services for innovation projects, and executing these projects (Klerkx and Leeuwis,2008). Innovative infrastructure from science and engineering can produce high-yielding crops to feed 9 billion people (Leach et al., 2012). Therefore, investments in AGRIS infrastructure across Africa are expedient for achieving sustainable development in Sub-Saharan Africa.

SDG 10: Reduced Inequality. Inequality is caused by the exclusion of segments of society from economic opportunities and governance. To reduce inequality, there is a need to incorporate the disadvantaged and excluded groups into the mainstream, through a fundamental reform to the idea of development that allows for the identification of development needs of the people, addressing causes of inequality and preferring solutions for sustainable development (Freistein & Mahlert, 2016). An improved agricultural sector leveraging AGRIS has the tendency to reduce inequality in the society, as the needs of the disadvantaged and marginalized populations in terms of employment, food, and basic necessities will be taken care of by the wealth generated from the booming agricultural sectors in Sub-Saharan Africa.

SDG 11: Sustainable cities and communities. There has always been a trade-off between cities and agriculture; the cities require vast areas of land for infrastructural expansion, but when a large proportion of land is used for the development of cities, then, the cities have to depend on large amounts of food imported from outside the land area they occupy (Deelstra & Girardet, 2000). There is therefore a need to re-examine the use of land space for city development and food production (Ackerman et al., 2014). Deploying AGRIS and other urban planning policies could help achieve sustainable cities and communities through effective management of trade-off between cities and agriculture.

SDG 12: Responsible Production and Consumption. The world population is growing at a rate that outweighs the natural resources required for sustainable livelihood. At the same, the average consumption per capita is increasing (Berners-Lee, Kennelly, Watson, & Hewitt, 2018). This calls for responsible production and consumption - a perspective that cautions the world on the need to re-conceptualize, re-assess and reinvent the present production and consumption system for the purpose of developing a systemic change that is sustainable (Vergragt, Akenji & Dewick, 2014). AGRIS as an IS-driven framework, could provide a system for bringing together stakeholders within the agriculture value chain Sub-Saharan Africa for the applications of the ideals of sustainable production and consumption.

SDG 13: Climate Action. To manage the existential challenge of climate change and its adverse effects on earth, the world requires innovative infrastructure from advanced science and engineering to provide solutions to mitigate climate change (Leach et al., 2012). AGRIS could be effectively used for planning and forecasting all aspects of agricultural activities associated with climate action.

SDG 14: Life Below Water. To make oceans conducive for marine creatures, flora, and fauna, analysts advocate the sustainable management of oceans (Cormier & Elliott, 2017), adoption of green infrastructure, urban farms and community food gardens to reduce the quantity of urban heat island effects, mitigate urban stormwater impacts and lower the emission of poisonous energy from transportation (Ackerman et al., 2014). AGRIS supported by the UN Law of the Sea, the International Maritime

Organization agreements and Regional Seas Conventions could help "conserve and sustainably use the oceans, seas and marine resources" (Cormier & Elliott, 2017) for sustainable future.

SDG 15: Life on Land. Life on land is an SDG that is germane to human survival on earth. Land system change is the four critical boundaries of Earth system functioning that are continuously violated through unstainable human activities. Three other violations are climate change, biosphere integrity, and biogeochemical flows (nitrogen and phosphorus) (Steffen et al., 2015; Vanham et al., 2019). Deployment of AGRIS in the agricultural sector could be an effective way of managing the forests, combat desertification, halt and reverse land degradation, halt biodiversity loss, and other actions that threaten life on land.

SDG 16: Peace, Justice, and Strong Institutions. The ongoing crisis in Syria that forced 12 million people to become refugees underscored the fact that maintaining peace, justice and strong institutions is essential for sustainable development in the developed and developing countries (Kumar, Kumar & Vivekadhish, 2016). Deployment of AGRIS in peaceful regions in Africa with strong institutions for the enforcement of justice on ownership and use of land resources by farmers and agro-based companies could strengthen agricultural productivity and realization of the SDGs in Africa.

SDG 17: Partnerships for the Goals. The success of regional and global agenda depends on partnership for the actualization of goals. In the past, there had been several bio-economy concepts formulated by different countries and international organizations for socio-economic development (FAO, 2016; Heimann, 2019), but SDGs stands out because of a strong partnership among UN member states, and its implementation process interfaces with various existing regulations and initiatives at the regional, national, and supranational levels (Heimann, 2019) Therefore, the implementation of AGRIS in Africa through collaborative actions and strong partnerships would help actualize the 17 SDGs for sustainable development in Africa.

CONCLUSIONS, PRACTICAL/MANAGERIAL IMPLICATIONS, AND POLICY SUGGESTIONS

The chapter explored the nature of AGRIS and highlighted the importance of deploying AGRIS across the African continent to usher in innovation, improve the efficiency and effectiveness of the agricultural knowledge systems in the areas of information generation, processing, dissemination, and utilization by agricultural stakeholders in the agricultural information chain, and escalate the achievement of SDGs. The chapter provided a framework through which agricultural stakeholders, policymakers, and practitioners could view or evaluate AGRIS adoption decisions. An effective AGRIS could strengthen decisions on the general management of the agricultural sector. Providing an enabling environment for the implementation of SDGs justifies investments in AGRIS to accelerate the progress towards achieving the SDGs in Africa. The deploying the AGRIS would directly boost food production and increase GDPs. The linkages of the agricultural sector to the SDGs are both direct and indirect.

The positive outcomes would directly strengthen the actualization of SDG 1 (No poverty), SDG 2 (Zero Hunger), SDG 3 (Good Health and Wellbeing), SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, innovation and infrastructure), SDG 10 (Reduced Inequality), SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Production and Consumption), SDG 14 (Life Below Water) SDG 15 (Life on Land), SDG 17 (Partnerships for the Goals) and indirectly for other SDGs. Ultimately, this chapter suggests leveraging the workable framework of AGRIS for mitigating all the challenges to agricultural development and the actualization of the 17 SDGs. The suggestion for the future is for researchers to carry out an empirical investigation on the compatibility of SDGs with the AGRIS framework.

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KEY TERMS AND DEFINITIONS

Agricultural Information Systems (AGRIS): This refers to the applications of IT and IS in the field of agriculture, livestock production and farm management to improve the efficiency and effectiveness of agricultural knowledge systems especially the generation, processing, dissemination, and use of agricultural information by farmers and other stakeholders in the agriculture value chain.

Agriculture: This refers to the business of cultivating farmlands for growing food and cash crops, raising animals, and other related activities for commercial purposes.

Critical Literature Review: This refers to an analytical technique in the qualitative research method, which entails in-depth analysis and critical evaluation of information collected from many sources for the purpose of generating new and richer insights in research.

Enabling Environment: This refers to an effective institutional framework provided by the government or other authorities in the forms of regulations, economic infrastructure, financial incentives, friendly socio-cultural context and technology that allows agribusinesses to flourish and allows farmers/farm holders to progress.

Food Security: This refers to the condition where food is available, accessible, useful, affordable, and stable the citizens to foretell hunger, malnutrition and other deprivations associated with food poverty.

Information System: This refers to is an organized system with four components (task, people, structure, and technology) designed to enable users to collect, process, store, and distribute information.

Information Technology: This refers to the use of technologies such as computers, disruptive electronic devices, and telecommunications gadgets for collecting, processing, storing, retrieving, and sending information to diverse users in society.

Sustainable Development: This refers to a development that provides for the expectations and diverse needs of both the present and future generations.

Sustainable Development Goals (SDGs): This is the 17 Global Goals conceptualized and adopted by all United Nations Member States as a universal agenda for ending poverty, protect the planet and ensure that all people enjoy peace and prosperity by 2030.

Chapter 8
Role of Agri-Food Value Chains in Bolstering Small and Marginal Farmers in India

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ABSTRACT

India's agri-food value chains have been evolving over the last few decades to cater to the growing consumer demand for healthy, safe, and nutritious food. These value chains are increasingly getting integrated from production to marketing to cater to such demand. While large and/or commercial farmers have easy access to such modern food value chains, small and marginal farmers in India and other developing countries alike are unable to take advantage of the same. Focusing on improving the agri-food value chains, particularly for perishables, makes a strong case in India given most Indian farmers are small and marginal farmers and are unable to take advantage of economies of scale. It is encouraging that both public and private sector entities are getting engaged in connecting Indian farmers directly to the supply chains of various crops. However, more needs to be done to make the processes, particularly in the public sector, the least bureaucratic and more farmer-focused so that small and marginal farmers in particular, benefit widely.

INTRODUCTION

The Indian economy has been moving from an agrarian economy to a service economy over the last few decades. Agriculture's contribution to India's GDP fell from about 27% in 1990 to almost 15% in 2018, while the share of the service sector grew from 42% to over 58% during the same time (GOI, 2020). However, according to the latest population and agricultural census, almost 67% of India's 1.2 plus billion people still live in rural areas and most of them rely on agriculture as their principal source of

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income and livelihood (GOI, 2019). Such dependence on agriculture by the majority of India's population had not changed much since its independence in 1947 when more than half of the national income was contributed by agriculture and more than 70% of the total population was dependent on agriculture (Pandey, 2013). Thus, despite the reduced importance of the agricultural sector in India's economy, it remains the most important source of livelihood for hundreds of millions of people in India.

Agriculture has significant linkages to India's food and nutritional security (IFPRI, 2015). This sector also plays an important role in adaptation and mitigation strategies relating to climate change (IPCC, 2001 and 2007). Similarly, agricultural development is crucial for the reduction in poverty (World Bank, 2008). Not surprisingly, India has increased its annual budget outlay from Rs. 37,865 crores in 2001-02 (= USD 5.83B; 1 USD = Rs. 65) under the Tenth Plan[1] to Rs. 43,799 crores in 2013-14 (= USD 6.74B) under the Twelfth Plan, an increase of about 16% (GOI, 2020). Return to such investments in the agricultural sector resulted in higher output in food grain and other principal crops. In 2018-19, India registered record food grain production of 284.83 million tons (GOI, 2019b). India remains the largest producer (25% of world production) and consumer of pulses (27% of world consumption) as well as the highest net importer of pulses (Dev, 2018). India also became the largest milk producer in the world, hitting an annual high of 176.4 million tons in 2017-18 but it remained a milk deficit country (NDDB, 2019). India is the second-largest producer of rice, wheat, sugarcane, cotton and groundnuts, as well as the second-largest fruit and vegetable producer, accounting for 10.9 percent and 8.6 percent of the world fruit and vegetable production, respectively (FAO, 2017).

One of the major problems in the Indian agricultural sector is the fractured nature of agricultural holdings. The latest Indian Agricultural Census data shows that in 2015-16, out of a total of about 146 million agricultural holdings, almost 81% were small and marginal farmers.[2] The Agricultural Census data also shows that about 69% of the total land holdings belonged to marginal farmers (those with less than 1 ha). Such smallholdings and prevalence of it across the country also limit the adoption of certain agricultural production or harvesting technology which are not scale-neutral. Thus, the fractured nature of agricultural landholdings in India makes the economic viability a challenge for small and marginal landholders in the country.

As the Indian economy grew over the last few decades, consumers' spending power also grew along with their demand for safe and healthy food. To fulfill such rising consumer demand, the food production-marketing systems in India has evolved from mostly unorganized or itinerant sector to a more organized sector in which food supply chains are more aligned with what consumers want. Nowadays, one can find Western-style supermarkets not only in big cities but also in smaller population centers across India. Agri-food value chains that integrate various foods from their points of production (farms/ranches) to the points of consumption (retailers) and meet the changing consumer demand for healthy and safe food products may provide a solution to the growing challenge of addressing the economic viability of small and marginal farmers in India.

The generation and application of agriculture knowledge are important, particularly for small and marginal farmers, who require relevant information to improve, sustain and diversify their farm enterprises (Mathur and Goyal, 2014). The advent of information technology (IT)[3] in the agricultural sector has introduced new methods and ideas in food production and marketing, such as precision farming, optimal use of agricultural chemicals, and targeted selection of crops to suit the cultivable land. IT is also used to make production and marketing decisions of a vast array of agricultural products, from field crops to milking of dairy cows. It is needless to say that information technology has transformed the agricultural sector around the world and India is no exception.

In this chapter, we discuss where do small and marginal (and medium) farmers fit in the growing agri-food value chain in India and what has the private sector and the government agencies been undertaking to introduce and implement e-commerce at the farm level. We highlight a few e-commerce initiatives that include farmers as one of the market participants to show the role of IT in Indian agriculture and how it has and still could improve the overall standard of living of small and marginal farmers. We also discuss various policy issues that need addressing to support small and marginal farmers' access to the growing agri-food value chain.

OVERVIEW OF THE AGRI-FOOD VALUE CHAINS IN INDIA

Recognizing the Importance of Agri-food Value Chains

The value chain is loosely defined as a set of functional activities that a business in a specific industry performs to deliver products or services that have value to its customers. An efficient value chain, thus, brings together all market participants engaged in the production-marketing system of products or services with the common goal of satisfying their respective customers by delivering value to the customers. Efficient value chains successfully integrate a market-oriented philosophy in the production-marketing system rather than a production-oriented philosophy and thereby help the market participants improve their productivity, prices they receive, and their profitability.

Agricultural value chains include the input suppliers (including those who deliver technology and build capacity) and market intermediaries who are involved in the post-production activities such as collecting, grading, storage, transportation, processing, and retailing of agricultural and food products. Organizations and/or entities, both public and private, that facilitate producers delivering value to their customers are also a part of such a value chain. For example, financial institutions and market intelligence (information) agencies that facilitate the smooth functioning of the agri-food system are integral parts of the agri-food value chains in India (and elsewhere).

Over the last few decades, India has made notable advancements in economic restructuring leading to higher economic growth (CIA, 2019). As a result, consumers' spending power has increased considerably over the years and their demand for safe and healthy food (among other things) has increased. To fulfill such rising consumer demand, the food production-marketing systems in India has evolved from mostly unorganized or itinerant sectors to a more organized sector where food supply chains are more aligned with what consumers want. Nowadays, one can find Western-style supermarkets not only in big cities but also in smaller population centers across India. The agri-food value chains in India have evolved to cater to the growing need for high quality, fresh, safe, and better food; nonetheless, agri-food value chains in India remain underdeveloped and still have ample room for improvements.

The Government of India (GOI) has utilized a myriad of policy tools to uplift the agri-food sectors in India (Sekhar, 2014). As a result, Indian agriculture has experienced major transformations over the past few decades, particularly after the economic reforms of the 1990s (Kumar and Sharma, 2016). One of the most visible changes noticeable is the emergence of integrated supply chains that starts at the farm sector and extends up to the retailing sector (grocery and food service). The traditional way of food production is gradually replaced by vertically coordinated production-marketing stages characterized by IT-supported coordination among farmers, processors, wholesalers, retailers, exporters, and other stakeholders in the agri-food value chain (Kumar *et al.*, 2011).[4] Agricultural Gross Domestic Product

(GDP) increased at an annual rate of 3% between 1980 and 2012-13, making India the third-largest agricultural producer by value after China and the USA (Kumar and Sharma, 2016). However, India's agricultural sector has a long way to go before it can realize its full potential. For example, agricultural productivity remains around 60 percent for most crops and particularly for fruits and vegetables. Additionally, India lags in food processing facilities that can meet the domestic and global demand. Only four percent of the fruits are processed in India compared to 23% in China, 50% in Indonesia, and 70% in Brazil (Shivakumar, 2016).

Unlike field crops which require a large amount of land and other natural resources like water, and typically rely on the government for pricing, fruits, and vegetable cultivation does not require a large amount of land and other natural resources employ more agricultural laborers per unit of land, and provides up to 2-4 times higher incomes to farmers. These products also have a high-income elasticity of demand, i.e., demand for these products go up as the national income goes up, as has happened in India. However, a major issue in the fruits and vegetable sectors is the harvest and post-harvest loss, mainly due to a lack of proper storage (cold storage) and transportation (chilled trucking) facilities. In their study, Jha *et al.* (2015) assessed harvest and post-harvest losses of major fruits and vegetables and reported a wide range of losses in such produce, e.g., almost 16% overall loss in guava, or over 12% loss in tomatoes. Thus, an improved value chain for fruits and vegetables will improve the efficiency of the entire production-marketing chains for fruits and vegetables as well as connect farmers to the ultimate consumers and allow diversification in the farm sector leading to higher income, employment, and tapping into the value-added foreign markets.

The GOI efforts also include creating a sustainable agri-food system which requires new kind of planning around the natural resources needed for farming, proper implementation plans, and above all, the true commitment of farmers without whose participation, sustainable agriculture is not feasible. It is widely acknowledged that knowledge and related information, skills, technologies, and approaches will play a key role in creating sustainable agriculture (Serbulova, 2019). Similarly, it has been argued that the transition to sustainable agriculture and food systems requires innovative solutions and appropriate technologies, such as IT (Wolfert, 2015; Poppe, 2016). In this regard, the relevant IT includes mobile and/or cloud computing, the Internet of things, location-based monitoring (remote sensing, geo-information, drones, etc.), social media, and big data (data network, concatenated open data) (Serbulova, 2019). Various IT tools that have been deployed by the GOI for agricultural knowledge management include organizational web portals created for specific commodities, sectors, and enterprise and for e-commerce activities (Sulaiman *et al.*, 2012). One of the aims of the GOI's IT initiatives includes IT-based interventions, especially in the marketing of agricultural commodities (more on this in Section III).

Even after more than 70 years since independence and the implementation of a myriad of policies aimed at improving the agri-food sectors in India, these sectors are still behind compared to the agri-food sectors in many developing countries, such as Thailand and Indonesia, and the developed countries in Europe and North America. While the improved economic conditions in the country created a middle-class with different preferences and lifestyle that demands high-value commodities and products, such as fruits, vegetables, meat products which are also of high quality and safe to consume, the Indian agri-food value chain has not been well-developed yet to meet such a demand. Participants or actors in the agri-food value chain, starting with Indian farmers, must become more knowledgeable about the consumer-driven and consumer-oriented marketing philosophy and adjust their operations accordingly. The opportunity for growth and expansion of the agri-food value chain in India, particularly for high-value foods, therefore, is huge. To meet the growing needs of increasingly demanding Indian consumers, the agri-food value chains in India will require innovative technologies, including extensive use of IT, in all stages of the agri-food value chain, from harvesting to processing to retailing and in managing logistics which bind these various stages of the value chain.

Tapping Into the Value-added Supply Chains for Perishables: an Example From the Dairy Sector

The restructuring of the food value chains across India to meet growing consumer demand for food that is safe, has assured quality, and has a wide range of variety provides an opportunity to farmer cooperatives and other organized business entities to tap into the growing food supply chains serving various parts the country. Dairy cooperatives, for example, are in a good position to provide value-added milk products that carry a higher price premium (e.g., probiotic yogurt, cheese, health shakes, etc.). The role of the cooperatives for rural development in general and for strengthening smallholder farmers is immense. Producer cooperatives offer member-farmers market opportunities, provide them with services such as better training in resource management, better access to information and IT, inputs, technologies, and extension services. Through the support of their cooperatives, small and medium farmers can achieve sustainable livelihoods, improve food securities in their communities and collectively play a greater role in meeting the growing demand for food on local, national, and international markets.

The Sitajakhala Dugdha Utpadak Samabai Samiti Ltd. (Sitajakhala Dairy Cooperative Society), which is based in Jagiroad, Assam, India, provides an excellent example of the importance of the agri-food value chain and the role of modern technology, including IT, in the dairy sector.[5] As of spring 2020, it collected almost 20,000 liters of milk daily from its 1,000 plus members and produced high quality homogenized and pasteurized fluid milk and various milk products for both wholesale and retail markets. Through rigorous quality control that uses modern technology and starts at the point of collection of raw milk at the farm level, the cooperative assures consumers that its milk and milk products are of high quality and safe to consume. The cooperative also provides direct or indirect employment to more than 6,000 families in the region. Therefore, the Sitajakhala cooperative has made a tremendous positive impact on the dairy farmers in the region by tapping into the dairy value chain and reaching the final consumers.

However, this story of success by Sitajakhala did not exist just a few years ago because despite its growth in membership, the cooperative did not have a modern processing facility and about 20% of the milk collected from the farmers was sold at a lower price and thus, did not benefit its members as much. Such a situation led the Sitajakhala cooperative's management to develop strategies that would benefit its members, and one of the outcomes was its decision to produce and market value-added milk (processed and homogenized instead of raw milk) and milk products by establishing a modern automated processing plant to cater to the growing demand for high-quality milk and milk products in the region. As Table 1 shows, the production and marketing of processed milk (pasteurized and homogenized) and milk products have increased significantly since the new automated processing facility came into operation in November 2018.

Table 1. Processed milk and milk products produced by Sitajakhala cooperative

Year	Average milk procured per day (liters)	Milk used for processing per day (liters)	% of total milk used for processing
2016-17 (BEFORE the establishment of processing plant)	10,340	480	4.65
2018-19 (during the establishment of processing plant)	16,000	2,500	15.63
2019-20 (AFTER the establishment of processing plant)	17,000	8,000	47.06

(Source: Sitajakhala cooperative)

The recent modernization and expansion of Sitajakhala cooperative's processing facilities have not only reduced the challenge of handling the additional supply of raw milk from its members but also allowed the cooperative to directly participate in the value-added dairy supply chain. With consistent quality control and better brand management, aided by IT technology that monitors quality as well as quantity, Sitajakhala has successfully marketed itself as a producer of premium quality and safe products that increased its customer base and improved its customer loyalty. Marked improvements in labeling, bottling, and packaging of milk and milk products have helped the cooperative to tap into the value-added dairy supply chain and establish itself as a leader in dairy products supplier in Assam among bulk buyers as well as individual consumers.

ROLE OF INFORMATION TECHNOLOGY IN THE AGRI-FOOD VALUE CHAINS IN INDIA

There are many definitions of IT, but regardless of their origins, these definitions agree that IT is the study, design, development, implementation, support or management of computer-based information systems—particularly software applications and computer hardware, i.e., it is everything that businesses, institutions, and organizations use computers for to handle information. By definition, IT has a critical role to play in improving the decision-making processes across the agri-food sectors and particularly in the agri-food value chains in developing countries like India.

How Could IT Improve the Lives of Indian Farmers?

It is easy to envision the role of IT in all facets of Indian agriculture, including farming and all post-harvest activities, such as transportation, storage, processing, and retailing (Pavan *et al.*, 2019). Well-designed and delivered IT can help farmers make timely decisions regarding planting, harvesting, and marketing as well as help farmers prepare for the upcoming crop season and mitigate market uncertainty (Lahan, 2017). Information technology also has a role to play for those who provide facilitating services to the agricultural production-marketing systems, for instance, the agricultural extension system. Judicious use of IT in the Indian public agricultural extension system could greatly improve how the extension services design and deliver their technical advice and services to farmers; for example, farmers having IT-based tools at hand to communicate directly with their designated extension service personnel for technical advice greatly enhances farmers' ability to improve their efficiency and productivity. Thus, timely planning and implementation of IT at various stages of a vertical supply chain that starts in the farming sector can improve the efficiency and productivity of the farm sector and those downstream from farmers.

According to Nehra *et al.* (2018), the role of IT is becoming more important in India, particularly for small and marginal farmers who need information in a timely manner to improve, sustain, and diversify their farm operations. Lahan (2017) argues that the use of simple accounting software has allowed farmer-based organizations, such as farmer cooperatives to manage production, aggregation, and sales with increased accuracy and transparency. Below is a summary of the findings of a wide range of research on the role of IT on Indian agriculture and how it may improve the lives of Indian farmers:[6]

- **Removal of market intermediaries and increased transparency and traceability:** Information Technology can bring more transparency into transactions of *Mandis* and the Farmer Producer Organizations (FPOs). Better data maintenance and market connect can empower each stakeholder. Streamlining and traceability of business can improve farmers' income and exports.
- **Reduction in losses in the food chain:** Around 60 percent of food loss and waste in India happens between the field and the end consumer, and this is concentrated in a few crops, especially in fruits and vegetables. Information technology could help farmers and other stakeholders in reducing food loss in the whole value chain.
- **Increase in the overall efficiency of the farmers:** The sector is now looking forward to using a large number of digital technologies at the pre-production, production, and post-production stages. A large number of digital technologies must be scaled up, some of which have been done already.
- **Timely information for price realization:** Centralized platform integrating farmers and the wholesale markets can provide different market-related information in time which will surely help the farmers in better price realization.
- **Better access to inputs:** Provision of better access to agricultural inputs at the doorsteps by efficient use of IT will help the farmers in understanding the value of best inputs to increase yield and productivity.
- **Help in getting finance:** By and large, farmers struggle to get finance in time; but agri-tech based start-ups help such an underserved community of farmers to get the loan quickly.
- **Digital agriculture:** Digital/precision agriculture-based businesses offer an innovative technology solution to increase farm productivity and farming process efficiency.
- **Improving the supply chain:** IT-based market linkage provides a digital platform that connects farm output with the customers.
- **Farming as a service:** Information technology offers affordable technology solutions for the farmers by providing easy access to expensive equipment, connectivity with the manufacturing companies, and direct contact with the agricultural experts.
- **Create digital ecosystems for crop insurance:** IT-based interventions are very necessary to speed up the process of verification, approval, and release of insurance amount to the farmers during and immediately after natural calamities such as flood, drought etc.

IT Initiatives in the Indian Agri-food System

The importance of IT in the Indian agricultural production-marketing system has been understood by both the government (public sector) and the private sector. As a result, several IT initiatives geared toward the agri-food value chains have been undertaken by both the public and private sectors in India. We briefly discuss a few such IT initiatives here.

Agricultural Marketing Information Network (AGMARKNET)

Agricultural Marketing Information Network (AGMARKNET) is an information network that uses cell (mobile) phone technology to connect farmers with the markets (http://www.agmarknet.nic.in). AGMARKNET facilitates generation and transmission of prices, commodity arrival information from agricultural produce markets, and web-based dissemination to producers, consumers, traders, and policymakers transparently and quickly. It was launched in March 2000 by the Union Ministry of Agriculture (MOA), Government of India (GOI). The Directorate of Marketing and Inspection (DMI), which is a federal or central government agency under the MOA, links around 7,000 agricultural wholesale markets in India with the State Agricultural Marketing Boards and Directorates (these are state-level agencies) for effective information exchange. AGMARKNET is implemented by the National Informatics Centre (NIC).

The portal has helped to reach farmers who do not have sufficient resources to get adequate market information. It facilitates web-based information flow of the daily arrivals and prices of commodities in the agricultural produce markets spread across the country. The data transmitted from all the markets are available on the AGMARKNET portal in eight regional languages and in English. It displays commodity-wise, variety-wise daily prices and arrivals information from all wholesale markets. Various types of reports can be viewed in the portal including trend reports for prices and arrivals for important commodities. Currently, about 1,800 markets are connected and work is in progress for another 700 markets. The AGMARKNET portal has a database of about 300 commodities and 2,000 varieties (Jain, 2011).

e-Choupal

The e-Choupal initiative ("Choupal" means a meeting place or meeting place in a village) was launched in June 2000 by ITC Ltd. (an Indian conglomerate; https://www.itcportal.com/) to "..tackle the challenges posed by the unique features of Indian agriculture, characterized by fragmented farms, weak infrastructure and the involvement of numerous intermediaries, among others" (ITC, 2020a). According to the ITC, the e-Choupal service has reached over 4 million farmers who grow a wide range of crops, in over 40,000 villages linked through 6,500 'e-Choupals' across ten states (Madhya Pradesh, Haryana, Uttarakhand, Karnataka, Andhra Pradesh, Uttar Pradesh, Rajasthan, Maharashtra, Tamil Nadu, and Telangana) (ITC, 2007).

Real-time information and customized knowledge provided by 'e-Choupal' enhance the ability of farmers to make decisions and align their farm output with market demand and secure quality and productivity. The aggregation of the demand for farm inputs from individual farmers gives farmers access to high-quality inputs from established and reputed manufacturers at fair prices. As a direct marketing channel, virtually linked to the '*mandi*' system (traditional market places for food and agricultural commodities) for price discovery, 'e-Choupal' eliminates wasteful intermediation and multiple handling and significantly reduces transaction costs (Kaur *et al.*, 2014). Additionally, 'e-Choupal' ensures world-class quality in delivering these goods and services through several product/service specific partnerships with the leaders in the respective fields, in addition to ITC's own. While the farmers benefit through enhanced farm productivity and higher farm gate prices, ITC benefits from the lower net cost of procurement (despite offering better prices to the farmers) because through 'e-Choupal,' it is able to eliminate costs in its supply chain that did not add value (Kaur *et al.*, 2014). Not surprisingly, today 'e-Choupal' is the world's largest rural digital infrastructure, empowering 4 million farmers (ITC, 2020b).

National Agriculture Market (e-NAM)

The electronic National Agriculture Market (NAM) is a pan-India electronic trading portal. As a part of the reform agenda in the agricultural sector, with the objectives to create a barrier-free market, enhance competition and transparency in transactions and widen choices to farmers for the sale of their produce, the GOI has launched National Agriculture Market (e-NAM) on 14th April 2016. Only those States/ Union Territories (UTs) which have undertaken reforms in their Agricultural Produce Market Committee (APMC) Acts in respect of (i) e-trading; (ii) single point levy of market fee across the State; and (iii) single unified trading license valid across the State are eligible to participate. As of April 2020, only 17 out of 28 states and two out of eight UTs in India have become eligible to participate in the e-NAM program. The Small Farmers' Agribusiness Consortium (SFAC; http://sfacindia.com/), a MOA/GOI sponsored autonomous body, is in charge of implementing e-NAM. One of the goals of e-NAM is to double the farm income in participating states/UTs by 2022.

The principal goal of e-NAM is to offer unhindered trade between farmers and traders of different states, market areas, and different languages through a common electronic marketing platform; it is noteworthy here that e-Choupal, a private sector initiative and which was launched four years later than e-NAM, has already achieved something similar. The e-NAM is aimed at creating a unified market through an online trading platform, both at the state and at the national levels, and promotes uniformity, streamlining of procedures across the integrated markets, removes information asymmetry between buyers and sellers and promotes real-time price discovery, based on actual demand and supply, promotes transparency in the auction process, and access to a nationwide market for the farmer, with prices commensurate with the quality of the produce, and online payment and availability of better quality produce and at more reasonable prices to the consumer. According to Sajwan (2020), e-NAM is currently linked with 585 district level *mandis* in 17 states and two UTs, and hence only 8.42 percent of the total *mandis* (6,946 nos.) are connected through the e-NAM platform. Although there are 263.1 million agricultural workers in India, of which almost 119 million are farmers and slightly over 144 million are agricultural laborers, only 14 percent of these farmers can connect with e-NAM (Sajwan, 2020).

Kisan Call Centre (KCC)

To harness the potential of information and communication technology in agriculture, the MOA/GOI launched the scheme "Kisan Call Centres" (KCCs) on January 21, 2004. The principal aim of this program is to answer farmers' queries on a telephone call in their own language. A countrywide common toll-free number (1-800-180-1551) has been made available to farmers to call these KCCs. This toll-free number is accessible through both mobile phones and landlines across all telecom networks in India, including private service providers. Replies to the farmers' queries are given in 22 local languages (GOA, 2020). Currently, there are 21 KCCs in different locations across the country.

Kisan Call Centre services are available from 6.00 AM to 10.00 PM on all seven days of the week at each KCC location. These KCCs are manned by technical personnel who are called Farm Tele Advisors (FTAs); these FTAs typically have graduate degrees (masters or doctorate) in agriculture or allied sciences (Horticulture, Animal Husbandry, Fisheries, Poultry, Bee-Keeping, Sericulture, Agricultural Engineering, Agricultural Marketing, Bio-Technology, Home Science, etc.). These FTAs are responsible for addressing the queries of the farmers in respective local languages. Those queries which cannot be answered by FTAs are transferred to higher-level experts known as Subject Matter Specialists (SMSs) of State Departments of Agriculture (SDAs), Indian Council of Agricultural Research (ICAR) Institutes, Krishi Vigyan Kendras (KVKs) and State Agricultural Universities (SAUs) (GOI, 2020). Evaluative studies of the effectiveness and success of the KCC is currently not available but is highly warranted.

OVERCOMING CHALLENGES IN THE AGRI-FOOD VALUE CHAINS IN INDIA

Improvements in the agri-food value chains will benefit all market participants in India's agri-food value chains, particularly Indian farmers who are mostly small and marginal farmers who are unable to take advantage of the economies of scale. Well-developed agri-food value chains can offer a solution to the food-security problem through capacity building and knowledge-sharing across various stages of such value chains. As discussed earlier, efforts by both the public and private sectors are continuing to improve the functioning and efficiency of various agri-food value chains in India, particularly on the issue of giving farmers access to e-commerce. In some cases, these efforts are paying off dividends as evident from the e-Choupal beneficiaries.

However, India is a very large country with a very large population that is upwardly mobile (good news from the demand perspective) but with poor or inadequate economic and policy infrastructures to support the needs of the country's rapidly evolving agri-food production-marketing systems. For example, adequate cold storage and transportation facilities are lacking; the general transportation infrastructure is poor, bureaucracy is stifling, legal and financial infrastructures have not kept up with changing economic times, and so on. As in the case of any development efforts, Indian agri-food sectors and their related value chains have a long way to go before they come close to those we see in the developed countries in Europe and North America. Existing research in this area has shown us where the bottlenecks or barriers exist and options to overcome such bottlenecks or barriers. A summary of such findings is presented here.

Challenges Facing India's Agri-food Value Chains

Recent studies focusing on the challenges faced by the Indian agricultural sector in general and the agri-food value chains identify the following issues the major challenges:[7]

a) **Access to finance:** The agricultural value chain system in India is completely unorganized, and the local firms lack the required capacities to export agricultural products to external markets. Most of the Indian agricultural value chain firms focus on the local market and they need more resources and capacity to compete in the external markets. They need to be given relaxations in tax, institutional credit, and other monetary incentives.
b) **Non-tariff barriers:** In India, some agricultural value chains are oriented towards exports as the products find global markets, such as fruits, vegetables, coffee, tea, spices, cashew, etc. While the

export-based value chains might be similar to that of commodities for domestic markets, there are some parts of the value chain that are very different. The exportable products require improvement in quality and standard, mutual recognition of certificates and standards by other countries. Although, in the case of agriculture-based exportable products testing and health safety regulations and procedures are now mandatory but infrastructure (testing and certification laboratories at crucial custom ports equipped with trained and enough number of staff members) for these have not been created in India. Apart from these, exportable agricultural products are not being dealt with a clear export promotion policy, which has hindered the prospects of these products in overseas markets.

c) **Market access:** The improvement of the agriculture value chain in India continues to be a challenge. The existence of middlemen and agents, the absence of data and information about other links in the chain and the inability to invest in improving the performance in almost every part of the chain led to inefficiencies. Agricultural value chains are difficult to stabilize in India with many small and marginal farmers. The production, collection, storage, and delivery parts of value chains must be made efficient in order for the small farmers to realize higher returns.
d) **Capacity building:** To export agricultural products in external markets, it is necessary that the quality and safety of the product is maintained. Most of the small and marginal farmers do not realize how to produce, store, and preserve agricultural products in a modern and more sophisticated era and how to constantly check the quality. Even many cold storage and warehouse owners do not know the exact details to preserve and store agricultural products.
e) **Unpredictability about the supply of commodities:** With unpredictable commodity supply, it is very difficult to set up sophisticated processing and value addition plants throughout the country.
f) **High variation in quality:** Landholdings of Indian farmers are less and the majority of them prefer to cultivate individually. As a result, it is not possible to maintain the quality standards of the final products, with the application of varied inputs and their differentiated usage rate.
g) **Short shelf life and high wastages in the supply chain:** Lack of cold stores and processing plants at distant and remote places force the farmers either to sell the produce in nearby markets at a lesser price or to bring them to the urban areas. For better price realization, if the farmers bring the produce to urban areas, it leads to heavy wastage due to hazardous communication systems and mishandling of produce.
h) **High incidence of market charges:** Most of the agricultural markets are non-regulated in nature, and hence the charges to be paid by the farmers are not uniform. As a result, market committees (official or unofficial) exploit the farmers by fixing and collecting higher market charges.
i) **Exploitation by middlemen/traders:** It is a bitter truth that farmers realize un-remunerative value for their produce because of the exploitation by middlemen and traders involved at different stages of the marketing channels.
j) **Lack of logistics and scientific management of information:** Modern and sophisticated facilities and instruments cannot be installed in the traditional Indian markets, which is coming out as one of the major bottlenecks in the development of agricultural marketing at present.

Although the above list of challenges faced by India's agri-food value chains may not be exhaustive, it represents a common consensus among the researchers. A future research agenda of the authors is to assess the bottlenecks in the value chains for perishables and update the above list.

Recommendations to Improve Agri-food Value Chains

The Indian agri-food value chains have come a long way since the days of independence due mainly to the economic reform policies implemented by the Central government (GOI). Given the potential of these value chains to improve the entire agri-food systems, including benefitting small and marginal farmers, researchers have focused on how to develop agri-food value chains for various parts of the country and improve the existing value chains. Here we summarize the recommendations of some recent research on the topic:[8]

a) Given the fact that infrastructure is less developed in India and the public investments are very limited, it is appropriate to encourage investments by the private sector in agriculture. For example, testing laboratories, certification, and inspection mechanisms can be developed by either private companies or with their assistance. Small size food parks can also be developed at various center points with the facilities of packaging, semi processing, grading, better equipment for loading and unloading and machinery for value addition in fruits and vegetables. A coordinated mechanism for connecting infrastructure is also necessary.

b) In a large developing country like India, where infrastructure is not developed, tax and other related duties are often too high, and total costs are unbearable for small and marginal farmers and new entrepreneurs. It is necessary that the tax regime should be made innovator and entrepreneurs-friendly. Recently, the government announced several initiatives for 'startup IT companies'; such facilities and packages should also be given to the agriculture sector. Cooperatives could play a crucial role along with the government in bolstering small and medium farmers in India. In the developing and under-developed countries, the main aim of the cooperative is to get the poor and indebted farmers out of poverty and out from the clutches of moneylenders. Cooperatives have advantages in tackling the problems of food security and employment generation. It is considered to have immense potential to deliver goods and services in areas where both the public and private sectors may fail. Cold storage facilities may also be set up by the cooperative societies for the benefit of the farmers. By and large, cooperatives are 'local institutions', addressing 'local needs', employing 'local talent', and led by 'local leaders.'

c) Currently, India does not have a famous brand for crops/food products in external markets. This can be done by identifying few products and specific export destinations (for example, fruits to the South Asian countries) and by launching an aggressive marketing campaign similar to the Indian tourism campaign 'Atithi Devo Bhava'. Specific attention should also be given to such Agricultural Export Promotion Zones (AEPZs), where fruits and vegetable products are included in the list decided under the National Foreign Trade Policy 2015-2020.

d) Domestically, the agro-processing sector should be considered as an important component of agriculture and export policies. Thus, there is a need for a new initiative, such as 'Grow, Process and Export from India' similar to 'Make in India' campaign.

e) Farmers and entrepreneurs have little or no knowledge about the latest technologies and how to work effectively and efficiently. The role of information technology and communication in agriculture should be developed and advertised. Although there are initiatives, such as the launch of 'Kisan Channel' and 'farmers helpline', but need is to make them popular among the farmers and the entrepreneurs.

f) Attention should be focused not just on increasing productivity and improving extension services, but also on increasing advocacy efforts through other channels. It is observed that NGOs, self-help groups (SHGs), Micro, Small and Medium Enterprises (MSMEs), Farmer Producer Organizations (FPOs) and women associations in rural areas are very active in this role and increasingly becoming effective to deal with the local level agricultural issues. The government should scale up its support to these institutions through focused schemes. This can be done with assistance from existing organizations, such as the National Bank for Agriculture and Rural Development (NABARD) or Small Industries Development Bank of India (SIDBI). Apart from government banks, private and foreign banks should also be encouraged to open their branches in rural areas and provide financial support to farmers and new entrepreneurs.

CONCLUSIONS

The growth and development of agri-food value chains for domestic and external markets can be a powerful tool for poverty reduction and to fight against the challenge of food insecurity in developing countries like India. Emphasis to improve agri-food value chains, particularly for perishables, makes a strong case in India given most of its farmers are small and marginal farmers and who are unable to take advantage of economies of scale. Following the successful examples of agri-food value chains, such as e-Choupal, which are well-coordinated at various stages and strongly supported by well-developed IT backbones, small and marginal farmers could be targeted to produce and market high valued products, such as fruits and vegetables, dairy, livestock, and fish, etc. Agri-food value chain development efforts that duly address the structural weaknesses mentioned earlier (e.g., access to timely and transparent information, access to credit, transportation and storage, etc.) will help to link all farmers to high-value downstream markets, including value-added processing.

Fueled by the new strategic initiatives directed at improving the agricultural sector in India, the demand has risen substantially for technical assistance (including those related to IT), for access to improved production technologies and markets, and for business development services related to agri-food enterprises. The good news is that both the government and the private sector enterprises understand the importance of agri-food value chains in the Indian agri-food sectors. However, existing research has shown that numerous bottlenecks exist in the Indian agri-food value chains, and unless these impediments are properly addressed, most farmers will not benefit. Therefore, at this age of explosion of information technology which has become an integral part of everyday life in India, it is key that our understanding of the importance of modern agri-food value chains in India is translated into practical, feasible, less bureaucratic actions that are focused on assisting farmers as well as all market participant; otherwise, a golden opportunity to transform the Indian agri-food system to satisfy the needs of the consumers and benefit the farmers, particularly small and marginal farmers, will be lost.

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ENDNOTES

1 This is India's 10th five-year national development plan and called the Tenth Plan. Details of such development plans are available at: https://niti.gov.in/planningcommission.gov.in/docs/index_oldpc.php.

2 Marginal: less than 1 ha; Small: less than 2 ha; Semi-medium: 2-4 ha; Medium: 4-10 ha (GOI, 2019a).

3 Simply put, IT is the use of computers to store, retrieve, transmit and manipulate data or information.

4 An increase in the market concentration in various stages of these agri-food value chains (Kashyap, 2018) raises public policy concerns.

5 We select this particular cooperative to highlight the importance of farmers tapping into the value-chain because this cooperative is one of the oldest and the largest active cooperatives in the north-eastern region of India and one that uses modern technology, including IT, for plant automation (Outlook, 2020; The Hill Times, 2020).

6 This summary is based on work by Goyel *et al.*, 2017; Singh *et al.*, 2017; Lahan, 2017; Rebekka and Saravanan, 2015; Chhachhar *et al.*, 2014; and Shalendra *et al.*, 2011.

7 This list is summarized from the findings by Pavan *et al.*, 2019; Naik and Suresh, 2018; Kumar and Sharma, 2016; Negi and Anand, 2015; Raju, 2014; Srinivasan, 2012; Narula, 2011; and Rota, 2010.

8 This summary is based on work by Kumar and Sharma, 2016; Negi and Anand, 2015; Raju, 2014; Halder and Patil, 2011; Narula, 2011; Sharma and Singh, 2011; Veena *et al.*, 2011 Rathore *et al.*, 2010; and Rota, 2010.

Chapter 9
Enhancing Agricultural Entrepreneurship Through Mobile Applications in Greece:
The Case of a "Farm Management" Application

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ABSTRACT

The use of portable applications in the primary sector is undoubtedly an innovation that offers a truly important tool that helps farmers to utilize their farms and an approach to enhance agricultural entrepreneurship systematically and effectively. The chapter examined 10 agribusiness in the region of Western Greece and their owners were asked to manage their farms with the help of a "farm management" application for a period of 4-6 months. This case study focuses on assessment of mobile application usability. It examines the matter of evaluating the usability of mobile applications and is mainly aimed at evaluating a "proposal" to systematically record the technical and financial data of a farm using a farm management system. The results show that users find that the most important feature of mobile applications is the ease of use and utility.

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INTRODUCTION

Recent developments related to globalization and the technological revolution, mainly in the fields of information, and communication, has resulted in increased entrepreneurship and development in modern economies, significantly affecting the behavior of production units operating in the primary production sector. Entrepreneurship is one of the most important parts of agriculture, as it encourages innovation and preventive thinking about future trends (Drucker, 2000). The degree of difficulty of the decisions that managers/producers are called upon to make becomes increasingly complex, requiring their support from specialized tools. Particular emphasis should be placed on the promotion of information, but also on the development of systems that will support decision-making and management processes in the primary sector.

The advancement of digital technology and especially ICT creates many challenges for smart, sustainable and without exclusions growth, and therefore constitutes a crucial initiative to strengthen entrepreneurship in the agricultural sector. Agricultural enterprises seem to have a lot to gain from using Internet technology (Koehnen, 2011). ICT could help farmers in accessing market information, land records and services, accounting and farm management information, management of pests and diseases, and rural development programs(Purnomo & Kusnandar, 2019).

The importance of technology transfer as a driving force of innovative entrepreneurship in agriculture is highlighted by Carayannis et al., (2018) and has argued for the technological integration of the added value of the agricultural industry.

The complexity and the large amount of information used or required to solve problems of rural economy coupled with the need for quick decision-making have resulted in the interference of modern and often multifunctional computing units (portable devices computers) and individual devices which take place in different natural environments andcan be used in rural economy almost immediately after their introduction (Salampasis et al.,2006). According to Nakasone et al., (2014) data collection, monitoring and evaluation via mobile applications are quickly and impressively taking over traditional methods of information gathering and use. Building up human capacity, as well as, the infrastructureneeded to facilitate better connectivity is also critical.

Indeed, there is no better example of smart farming than with the mobile apps. It has become a game changer for on-the-go growers and retailers, allowing them to perform critical tasks wherever and whenever they need them. Farmers can achieve higher crop yields, as they get access to timelier and better-quality information on products and inputs as well as environmental and market conditions through ICTs (Torero,2014).

The diffusion and use of ICT is considered as an important factor in improving the productivity and competitiveness of Greek Agriculture. However, the degree of ICT penetration into the Greek Agriculture, compared to other European Union countries, is relatively low (Salampasis & Theodoridis, 2013; Michailidis et. al., 2010). Given the growth rate, information about mobile technology can quickly become obsolete. The information and skills gap that prevents the adoption of available technologies and management practices has been studied by many researchers (Brugger, 2011, Singh et al., 2016; Kante, et al. 2017, Chege et al. 2020) and in various countries. ICT, and especially mobile technologies, are often seen as a “game changer” in smallholder agriculture, facilitating the dissemination of information (Brugger, 2011). The insignificant contribution of ICT to accessing and using information on agricultural inflows in developing countries is limited by the low use of ICT caused by certain factors, such as farmers’ perceptions of ICT, the quality of information and the possibilities of use and utility provided.

(Kante, et al. 2017). This study seeks to fill this research gap by assessing user satisfaction with its interface with such applications. "Satisfaction is an evaluation process, which is based on whether the particular experience was as good as the user thought it would be" (Hunt, 1977).

Assessment leads to the creation of more user-friendly applications by enhancing the adoption of mobile technology by farmers in order to use innovative applications in "smart" mobile communication devices (smartphones) and tablets, since the usefulness of applications for mobile devices are one of the critical factors in increasing the spread of ICT (Batzios et al., 2001; Michailidis et al.,2010).

Therefore, it is important to evaluate mobile applications usability. However, the usability of mobile applications can be performed with different approaches (Rubin & Chisnel, 2008).Thus, both final users and developers can benefit from the evaluation once the product met users' needs and the developers have reduced the number of errors in the final version of the Application (Romani et al., 2015).

This study followed an exploratory approach to investigate the role of digital entrepreneurship among farmers. Discusses the use of ICT in Greece in terms of mobile apps and also evaluates a portable farm management application (agroFarm) for its usability as well as the effectiveness of the system on farms. The main objective was to evaluate the ease to use of a mobile farm management application so as to identify problems of use and satisfaction from the system interface.

The second objective was to clarify the factors that most affect the efficiency of the application on farms and to present a 'proposal' for the systematic recording of the technical and financial data of a farm, with the help of mobile devices. Understanding the barriers and factors that affect mostly the acceptance of such applications, it would be possible to design a way to overcome these barriers. In addition, this paper attempts to present the use of each evaluation method as well as the methodological framework used to make the results as reliable and valid as possible.

The remainder of this paper is organized as follows: The next section of the paper presents an extensive literature review that provides a theoretical background and a conceptual framework for this study. Then, the adopted methodology is presented, followed by a discussion of the findings. Finally, conclusions are drawn and suggestions are made for future research directions.

BACKGROUND

Use of ICTs and Applications for Entrepreneurial Agriculture

Economic growth depends on two key processes, accumulation and productivity growth (Grossman & Helpman 1991, Vivarelli 2018). Productivity growth in agriculture is essential. Information and communication technology services provide opportunities for structural change and can also contribute positively to productivity growth (Ssozi, & Bbaale, 2019). Purnomo and Kusnandar (2019) noted that as a result of the emerging new example of rural development, the old way of providing basic services to farmers needs to change. The creation of agricultural mobile applications will provide the prerequisites for a significant acceleration of the digitization of agriculture. According to Bai (2018), the introduction of a new generation of digital technologies in the agro-industrial sector is an effective way to reap the organizational benefits of the agricultural entrepreneurial model. Nambisan (2017) stated that digital entrepreneurship is about "*careful consideration of digital technologies and their unique characteristics in shaping business pursuits*". There is a growing demand for the development of new information technologies to modernize and optimize the agricultural sector, thereby creating a large volume of data to be stored and shared between different people, such as researchers, governments, institutions, farmers, etc. (Romani et al., 2015).

While other sectors use Internet services to a large extent, the agricultural sector is slightly behind the urban counterpart (Stenberg et al., 2009). Thus, the mobile applications in agriculture can be applied to simplify supply chain management as it allows access to very accurate and specific information about the products involved (Zhou & Zhou, 2012). Sulimin et al., (2019) studied the adoption of new generation digital technologies in small companies in developing countries. Farming was focused on the more mechanical development, e.g. the development of larger machines and equipment for them rather than digital precision farming (Linna et al, 2019).

In recent years, the availability and use of portable devices with significant computing power, such as computers, tablets, and smartphones, have increased (Johnson et al., 2010). According to Csótó (2015), the use of smartphone is basically determined by the personal characteristics and previous ICT experience of farmers and used as an extension of the current information management system.

Internet has been recognized as a tool that can be used to improve the efficiency of the agricultural sector (Gloy & Akridge, 2000) and multiple factors influence farmers' decisions to adopt agricultural technologies (Birthal et al. 2015; Asif et.al., 2017). Farmers obtain information about the technologies and farming practices from different sources such as other farmers, government extension services, information through mobile phones (Aryal et. al. 2018) and ICT in the agri-food sector. (Miranda et al.,2019). Aker (2011), indicated that agricultural extension, which depends to a large extent on information exchange between extension services providers and among farmers, has been identified as one area in which mobile phone technologies could have a particularly significant impact.

Mobile phone technology has been used widely in different ways: text messaging (Kachelriess-Matthess et al., 2011), market information, for example, prices for agricultural goods in local markets (Aker, 2010), animated educational videos for learning gains of knowledge around agricultural-related topics (Bello-Bravo et al.,2018) and other services, for example, as a tool for libraries (Thomas, 2012). Many studies predict the transformative potential of technologies, such as mobile devices, remote sensing, cloud computing, or used for precision agricultural (Karanasios & Slavova, 2019; Wanjohi, 2018; Yonazi et al., 2012; Ekekwe, 2017; Murugesan, 2013).

The critical review of the systematic literature review by Pongnumkul et al. (2015), reports the case of smartphones equipped with various types of physical sensors, which make them a promising tool to support a variety of agricultural tasks. The findings show that GPS and cameras are the most popular sensorsused.Studies have explored the use of e-commerce in agricultural enterprises (Liu et.al., 2013) and small rural businesses (Beley et. al., 2013). Mobile devices (cell phones, tablets and smartphones) and related services are powerful tools for farmers (large farms and small family farms) in the field. Applications can build collaborative knowledge as well as encourage interaction between their users, creating networks that can help in areas such as production and business planning. In addition, applications can also collect valuable information that can guide service delivery and automate processes (Romani et al., 2015).

Hansen & Hansen (2009) consider the theoretical exploration of the application of mobile learning (m-learning) in fields with practical orientation such as agriculture. In the agricultural sector (agriculture, livestock farming, fishing, etc.) during the last decade the applications of mobile learning (m-learning) increased more and more in rural education internationally (Denmark, Iran, USA, South America etc.).

Through ICT, agricultural Research & Development (R&D) processes can be made more comprehensive and communication between all stakeholders in agriculture is enhanced. Along with infrastructure investment and collaboration between e-sciences and rapid developments in digital devices and the interconnection in rural areas, the ways in which scientists, academics and development workers create, share and apply agricultural knowledge are transformed through the use of ICT (Ballantyne et al., 2010). Linna et al., (2019) focused on the study of machine learning techniques to develop harvest yield prediction and found out the correlation between many data sources.

Assessment Studies of the use of Mobile Applications

Usability assessment is an iterative process when developing a system to assess the extent to which the system can be used effectively by its typical users (Hornbæk & Stage 2006).

Moumane et.al., (2016) highlighted a set of usability issues related to hardware and software that should be taken into consideration by designers and developers in order to improve the usability of mobile applications.

Kjeldskov & Stage, (2014) in their related article presented and evaluated six techniques for evaluating the usefulness of mobile computer systems in laboratory environments. In this context, Romani et al. (2015) proposed an approach to mobile application design based on user-centered design concepts. They also argued that *"applications may generate collaborative knowledge, as well as encourage interaction among their users, creating networks that can assist in areas such as production and business planning"*.

Many researchers focus on evaluating systems development centered on the real needs of users (Vink et al., 2008; Holtzblatt & Beyer, 2014; Vredenburg et al., 2002). A study by Arhippainen & Tahti (2003) confirmed that different methods should be used to evaluate the user experience. Thus, in order to evaluate the use of a mobile application, user-related factors and application characteristics must be recorded, as well as the space where it is used. The Human-Computer Interaction (Cairns & Cox 2008) is based on the fields of computer science, psychology, cognitive science and organizational and social sciences, to understand how people use and test the interactive technology. Nielsen, (1993) in his book *Usability Engineering* devotes a whole chapter to explain the concept of usability. Shneiderman & Pleasant (2009) extensively argued on the concept of universal usability, which also includes factors related to accessibility of products and systems.

Lockner & Bonnardel (2015) in addition to the traditional approach of usability and efficiency, introduce the concepts of empathy and emotional design for user interfaces. According to Hassenzahl et al. (2010) User Experience (UX) is the emotional effect of human-computer interaction, in other words, how a person feels when using a product or service.

Moumane et al. (2016) present an empirical evaluation based on ISO 9241-11: 1998, ISO 25062: 2006 standards for evaluating the usability of applications running on existing mobile operating systems. Certain representative applications of the agro-industry on the Internet and some conclusions have led to the successful adoption of e-commerce in agriculture. (Ferentinos, 2006). According to Adamides et al. (2013) gender, age and education level of the principle farm owner, the annual income, the farm type (crop or livestock farming), the employment type (full-time or part-time), the participation in a Producers' Organization and the district, are factors that significantly influence the usage of Internet by farmers.

Stoyanov et.al. (2015) developed a mobile application appraisal scale to evaluate the usability of mobile health applications. Bohmer et al. (2011) evaluating the data collected through the Appazaar application point out that despite the variety of applications available, communication applications are almost always the first used on a device's waking from sleep.

Hegarty & Wusteman (2011) determined the usability of the services provided by EBSCO host Mobile, utilized the methodology that includes pre- and post-use test questionnaires and "think out-loud" usability tests. Bidit et al. (2011) attempts to identify how farmers integrate mobile telephony into their daily lives and what factors facilitate and limit the use of mobile telephony. The findings suggest that current understanding of usability must be combined with technological credits to better understand the use and subsequent incorporation of technology into daily life. They present an original conceptual diagram that combines the concept of usability and ownership.

Given the observed income gap between Internet users and non-users, Chang & Just (2009) used a multilevel econometric analysis to assess the impact of internet access by rural households in Taiwan. A study by Sarban et. al. (2015) discussed that people who have higher computer skills their use of ICT services in rural area has been in more rates. Kjeldskov & Graham (2003), through a review of 102 publications on mobile human-computer interaction research, concluded that 71% of these studies were conducted in laboratory conditions and only 19% in the real environment for which they were intended computer applications. According to Beck et al. 2003 there is also reference to cases in which studies take place in laboratories designed in such a way as to simulate the characteristics of the area in which the tested application is to be used. Zhang &Adipat (2005) present an innovative framework that incorporates four major perspectives. That is, the presentation of information, the data input methods, the user and the mobile interface.

RESEARCH METHODOLOGY

Evaluation research is an important tool used to identify weak points and improve the services provided by an application in terms of ease of use and content.

The list of possible benefits (McNamara, 2009) of the use of mobile applications in agriculture adopts a view of agricultural activities throughout their economic, social and institutional environment, tries to understand existing initiatives and experiences, and the potential of mobile technologies to enhance entrepreneurship. For example, impact achievements (e.g. improved performance or outreach); cost savings or increased operational effectiveness (e.g. where it is used to organize business processes), as in the case under study.

Study Procedure and Sample

The research was conducted in the first half of 2017 in the region of Western Greece.The researchers first approached the owners of 18 farms who used the agroFarm application to manage their farms for 4-6 months. Then we evaluated the application by asking the farmers to answer a usability questionnaire.

The usability assessment process involved ten (10) farmers-owners (9 males and 1 female), aged 25 to 45 years, with different agricultural holdings, having different familiarity with digital applications and were at least high school graduates.The other 8 were reluctant and unwilling to use the "agroFarm" application for the management of their holdings. Individual barriers such as confidence in the ability to use ICT,less preferences for mobile app use, lack of ICT skills and time management problems in learning to use mobile applications were the main reasons for their reluctance. Many researchers refer to the same problems with the adoption of ICTs (Bingimlas, 2009; Mungania, 2007; Purnomo & Kusnandar, 2019).

Purnomo & Lee (2010), observed that individual characteristics such as prior experience and computer anxiety played important roles in affecting users' beliefs as to the perceived usefulness of ICT.

The participants in this survey were asked to use "agroFarm" application for approximately six months in their farms. Given this, they were asked to evaluate their usefulness by responding to a user interface questionnaire. According to Rubin & Chisnel, (2008) a sample size of 10 to 12 participants per condition is appropriate, before considering the use of inferential statistics. Thus, the sample size of this study can be characterized as satisfactory.

Initially, agroFarm (available at google play) was evaluated using the heuristic evaluation method. The assessment process involved five experts, who have experience not only in designing software but in the application of the method and generally in the usability assessment of applications. The review was conducted at the laboratory of the School of Electrical and Computer Engineering of the Aristotle University of Thessaloniki and the experts used a simulation of the application in a desktop environment. The simulation environment was developed to meet the needs of the assessment experiment. Experts were asked to evaluate the 10-heuristics criterion of Nielsen (Nielsen, 1993) based on a numerical scale to indicate the degree of acceptance or rejection of the application's usability in the data being considered. Based on commonly accepted and well-established authorities, they examine whether they are implemented, the design rules and principles are respected. A Likert type scale ranging from 1 to 7 is chosen which is the simplest to create and the most widespread.

Subsequently, the questionnaire communicated in this study is one of the most commonly used standard usability questionnaires (for post-test use) and is the "Questionnaire for User Interface Satisfaction" (QUIS) (Chin et al, 1988).

The QUIS questionnaire consists of 26 questions, divided into five parts, and the answers are given on a Likert type scale of one (1) to seven (7) which corresponds to the extent to which they disagree or agree with each of the questionnaire proposals. The graded answers start with one (1 = Absolutely disagree) and end up in seven (7 = Absolutely agree). Do not know / do not answer = NA. All questions were closed-ended. However, the questionnaire was structured in such a way that it allowed users to comment briefly and to express their opinion at the end of each section. As a result, it helped to collect a larger volume of data (qualitative data) regarding the evaluation of the agroFarm application.

Methods and Data

The first aim of this paper is to provide an analysis of methods that evaluate the ease of application. Usability testing, the second aim of this paper, employs techniques to collect empirical data while giving significant weight to representative end-users who use the product to perform realistic tasks.

The study presents a combination of evaluation methods. The methodology includes two basic methods. (a) The analytical method in the laboratory (without user participation) of the Heuristic Evaluation and (b) the non-laboratory inquiry method (involving users) and the use of a questionnaire.

The literature discussed in the previous section provides support for the alignment of key usability features designed to expose usability gaps and to gradually modify or process the product in question.

The analysis was performed using the Statistical Package for Social Scientists (SPSS), version 20. The descriptive and exploratory results were summarized using tables to aid in drawing statistical conclusions.

Applications for Agriculture - The agroFarm app

This section focuses on suitable applications for management and farmers' data. At the very beginning of the project, it was unclear which application would be chosen and what requirements it would have. After a wide study, it appeared that there were many potential applications although it was not necessary to find all the applications.

Through the websites and agriculture sector companies' web pages, several Greek agricultural mobile applications running Android, Windows and iOS software were identified. The majority of the applications were commercial.

The ICT applications can be classified into several categories such as: E-Commerce Application Systems, Geographic information systems, Farm management Information systems, Precision agriculture applications systems, etc. Some of these platforms were paid and some were free. The purpose of this study was to evaluate a Farm Management Application. Farmers with such management applications can collect valuable information that can guide the provision of services and automate processes. After short tests (pilot tests on agribusiness owners selected by the researchers' personal network) of different kinds of farm management applications, more and more interest focused on agroFarm.

The selection of particular application was based on the following criteria:

1) Run on an android environment because it is the most popular software (https://en.wikipedia.org/)
2) Settling in a mobile device environment in the Greek language (language is an ICT problem, Mungania, 2007)
3) No email or password required for logging in. (Technological barriers have significantly affected the acceptance of mobile apps by farmers, Purnomo & Kusnandar, 2019)
4) To be free of charge
5) Have a help guide to direct the user when logging in. (This support was an incentive for farmers to use the application).

The agroFarm application is designed to work on mobile devices (smartphones and tablets) with Android software. This farm management system allows for the storage of all kinds of farming activity on crops, farms and farm machinery. At the same time, it calculates the income and expenses of each agricultural activity. It is a useful tool for farmers, especially small farmers, who do not have the financial resources to maintain an advisory service.

Figure 1 shows a snapshot of the agroFarm application with information recorded on the home screen and in the field "*Cultivations-Farms-Agricultural Machinery*".

Figure 1. Screenshot of "agroFarm" application

Farmers through the use of "agroFarm" application succeed:

- To manage the farm efficiently from anywhere.
- To save time by keeping records in the field, so when they get home, they have done most of the administrative work.
- To have real data and make better decisions.
- To gather all information in one note.
- To be more competitive by identifying which crops, fields, machines or workers have the best productivity.
- To make better decisions on inputs, crop planning, investment in machinery, leases, etc.

Thus, this app serves as a decision-making appliance, such as general information about on cultivation, start planting, the fuel cost and the maintenance program for all agricultural machineries, apply defensive or fertilizer etc., in order to enhance the productivity and competitively of holding.

Table 1. Heuristic criteria

Heuristics criteria	Short description
1. Visibility of system status	The system must at all time keep users informed of its status for what is happening on it. This must be done in an appropriate form of feedback and within a reasonable time.
2. Match between system and the real world	The system should speak the user's language, with words, phrases and home concepts to the user. Practices and conventions of the real world must be followed in order for information to appear in physical and logical form and order.
3. User control and freedom	There should be obvious options, the ability to cancel actions and the ability to recall or repeat operations.
4. Consistency and standards	Users should not be wondering if different words, situations or actions mean the same thing. Also, the system should follow well-known conventions in relation to similar systems.
5. Error prevention	Careful design that protects against errors before they occur is better than a good error message.
6. Recognition rather than recall)	The user should not constantly remember information from previous sections of the dialog. Instructions for using the system should be easily recoverable whenever required.
7. Flexibility and efficiency of use	Accelerators, invisible to the novice user, can speed up the interaction for the experienced user. Experienced users should be given the opportunity to properly configure frequent actions.
8. Aesthetic and minimalist design	Any additional information burdens the use (minimalist is not meant as a design style)
9. Help users recognize, diagnose and recover from errors	Error messages should be expressed in plain language (not difficult-to-understand codes). The error must be accurately described and the solution proposed constructively.
10. Help and documentation	The system must be used without the need for documentation (although it needs to be available). Any documentation should be easily searchable, user-focused, and non-bulky.

RESULTS AND DISCUSSION

The gender distribution showed that 90% of the respondents were men. Respondents are the age group of 25-40 years old and only one was 45 years old. The most common level of education was high school (50%), followed by a technical education degree (20%) and a university degree (30%).From the farms that participated in the research, seven were vegetable production and the remaining three were mixed (vegetable and animal production).

Heuristic Evaluation

One of the most important and widely used evaluation methods (in the lab without user participation) is heuristic evaluation (Nielsen & Molich, 1990; Nielsen, 1993; Nielsen & Mack, 1994). This method is a subjective method based on empirical rules and findings that are known and concern the good design of interaction environments. The evaluation is done by experienced ease of use evaluators who have not been involved in the system development process to ensure impartial judgment and a second view of design. Evaluators check the user interface of software with a set of heuristics. Evaluation by the heuristic method focuses mainly on the general design of the system screens and the flow of dialogues, messages and actions required performing a particular process.

Heuristic evaluation has the advantage that it can be applied to various purpose and relatively low cost software systems. It can also be performed in all phases of development but also after the completion phase of a system. Finally, the usual number of evaluators required and according to Nielsen can detect about 75% of the total usability problems are 3 to 5 evaluators.

A widespread set of heuristic evaluation rules that comprise the design principles of anthropocentric systems has been proposed by J.Nielsen and R.Molich (Nielsen & Molich 1990) and subsequently revised by Nielsen (Nielsen & Mack, 1994), shown in Table 1.

Experts who participated in the heuristic evaluation were asked to evaluate the application using the above 10 heuristic criteria. The results are shown in Table 2.

Table 2. Heuristic evaluation of the "agroFarm" application

Questions	Results
[1] Is the user aware of the changes that occur in the system constantly through his feedback?	Positive result: Data storage and deletion information is provided to the user.
[2] Does simple and understandable language be used and are the conventions of the real world followed?	Positive result: the user is given the content in a clear design
[3] Is the user able to cancel actions and revoke or repeat operations?	Positive result: User can navigate and control with device keys.
[4] There is consistency in the use of terminology, symbol semantics, etc. throughout the range of use?	Positive result: consistency in the use of terminology is sufficient and the system follows common contracts with similar systems
[5] Does the system protect the user from possible errors?	Negative result: no restrictions
[6] An attempt is made to minimize the user's memory load, is it possible to list information from previous screens?	Negative result: usage and execution information are not sufficient to navigate the user
[7] Is it possible to distinguish between experienced and inexperienced users?	Negative result: Does not provide navigation shortcuts
[8] From a design point of view, the system is characterized by elegance and proper flow of information to avoid confusion of the user.	Positive result: the same design is provided on all screens, but any additional information is burdened by the user.
[9] Are error messages clear and understandable and suggest a way out of the error?	Negative result: there are no error messages.
[10] Is the help provided and user manuals adequate and comprehensive and focused on user work	Positive result: There is user guidance at points defined as necessary.

Overall Evaluation Image: Positive results: 6
Negative results: 4

Analysis of Evaluation Data by Experts

Initially, with regard to system feedback and user information on the processes being performed, it was observed that there was information on storing and deleting data, but not on further invisible tasks.

The language used as well as the symbols are familiar to the user, are connected to reality and contribute to a logical sequence of actions. It is possible to undo, cancel or even correct actions, but not the repeat function in an existing pattern.

The user interface makes it possible to differentiate concepts through different words and situations. But there are similar options that lead to similar screens that can confuse the user.

The error prevention is not present in this application. The system does not impose any restrictions on the user. The correction can be done by the user, but not by the system itself, which is usually the main form of correction.

It was also noted that it is possible to go back to the previous state of retrieval of information, but presupposes interrupting the work with compulsory storage, returning to the previous page and further processing of the work for its complete and documented storage. This application has not given the user the right to interfere with the interface, nor the option to use a more flexible interface for more experienced users.

Finally,the design of the application helps to familiarize the user with the various screens, since a uniform image is maintained. At the same time, however, the options provided are inherent, resulting in confusion about which one is appropriate.

Evaluation With User Participation

The User Interaction Satisfaction Questionnaire is a usability testing tool designed to measure subjective user satisfaction with a computer interface. It was developed in 1987 by an interdisciplinary team of researchers at the Interaction Human Computer Interaction Laboratory at the University of Maryland (Chin et al., 1988).

The users - owners of agricultural holdings evaluated the features for the five individual dimensions of the application. The five parts of the QUIS questionnaire are; 1) General impression of the user, 2) Screen 3) Terminology and communication with the system, 4) Learning of use 5) System capabilities.

The present study uses a quantitative and qualitative approach using descriptive statistics. The following are the results of user evaluation in the form of tables and diagrams.

General Impression of the User

The first part includes five questions about the general reaction of the application in terms of user satisfaction, use and flexibility from their interface with the system.

Table 3. General impression of the user

	N	Min	Max	Mean	Std. Deviation
The overall reaction of the system was great	10	4.00	6.00	5.100	.567
The general reaction of the system satisfies	10	2.00	5.00	4.000	.942
The overall reaction of the system was pleasant	10	4.00	6.00	5.600	.699
The general reaction of the system was easy	10	2.00	6.00	3.900	1.100
The general reaction of the system was flexible	10	3.00	6.00	4.300	.948

Source: Based on data

By examining the user responses one can conclude that the users of the application were partially satisfied with the “general impression” of the application. The users felt that the application is quite pleasant and flexible, but less easy and with the general reaction of the system being confusing. In general, the scores were slightly fluctuating close to five with an average of 3.9 to 5.6.

Screen Content

The second part of the test includes questions about the design of the screens, the structure and the amount of information displayed.

Table 4. Screen content

	N	Min	Max	Mean	Std. Deviation
Screen design has always helped	10	3.00	6.00	5.000	.942
The amount of information displayed on the screen was sufficient	10	5.00	7.00	6.000	.816
The structure of information on the screen was organized	10	2.00	6.00	4.500	1.433
The sequence of screens was clear	10	3.00	6.00	4.600	.966
Next screen in the series was predictable	10	4.00	6.00	5.200	.918
Back to the previous screen was easy	10	3.00	7.00	5.800	1.135

Source: Based on data

The user responses showed satisfaction with elements such as ‘screen design’, ‘the amount of on-screen information’, ‘return to the previous screen’, and ‘next screen in the predictable order’, while they showed that they expected more from the ‘building information’ and ‘the sequence of screens’.Users’ comments about the same module argue that the information displayed on the screen is too much and consequently repetitive to the user’s chaotic perception.

Table 5. Terminology and communication with the System

	N	Min	Max	Mean	Std. Deviation
Messages appear consistently on the screen	10	5.00	6.00	5.600	.516
Messages that appear on the screen are clear	10	3.00	7.00	5.100	1.286
Your computer tells you what it’s always doing	10	1.00	7.00	3.700	2.110
Performing a move leads to a predictable result	10	4.00	7.00	5.400	1.074
Delays were admissible	10	4.00	7.00	5.700	1.159
The error messages were very helpful	10	3.00	5.00	3.700	.675

Source: Based on data

TERMINOLOGY AND COMMUNICATION WITH THE SYSTEM

In this section the questions are about the user's communication with the application and the messages that the application provides.

Generally, the users liked the way the app communicated and scored high in questions about the messages that appeared on the screen. High scores were also given to questions like 'if we conduct a move, we are led to a predictable outcome' and users were pleased with the possible 'delays' in the application response. In contrast, questions about whether the system "informs what it is doing" and "whether it helps with error messages" had the lowest score, with the first having the highest variance.

LEARNING OF USE

The questions that users are asked to answer in this section refer to the ease to use and the learning time required.

Table 6. Learning of use

	N	Min	Max	Mean	Std. Deviation
Learning to use the system is easy	10	2.00	7.00	4.200	1.549
User learning time is a few	10	2.00	7.00	3.900	1.595
Work is done in a logical sequence always	10	3.00	6.00	4.300	.948
The steps to complete always follow a logical sequence	10	4.00	600	5.100	.875
Feedback when the job is completed is clear	10	4.00	7.00	5.400	.966

Source: Based on data

The users argued that 'learning how to use the system' was not easy and the 'time to learn' was enough. Positive were their judgments about whether 'steps to complete the job follow a logical sequence' and about 'feedback' when a job is completed, while they were negative about whether 'work is done in a logical sequence'.

Users' comments indicate that using the system requires already existing usage knowledge in related applications as well as accounting and terminology knowledge.

SYSTEM CAPABILITIES

The fifth and final part of the questionnaire contains general questions about speed, stability, and reliability of the application.

Table 7. System capabilities

	N	Min	Max	Mean	Std. Deviation
The speed of the system is satisfactory	10	1.00	7.00	4.500	2.415
The system is always stable	10	3.00	7.00	5.300	1.494
Operations-functions are reliable	10	4.00	7.00	5.900	.875
The ease of handling depends on the user experience	10	5.00	7.00	6.400	.843

Source: Based on data

Finally, the users believe that the 'speed of the system' is satisfactory and the application 'stable' and that 'operations-functions' take place quite reliably. The user responses to whether 'user-friendliness depends on user experience' reached almost maximum with an average of 6.4.

Users' comments identified some weaknesses in the application and suggested changes that would improve the capabilities of the system such as: 1) Greece in the list e.g. "Suppliers" to be first in choice, 2) the calendar with the Greece option to be automatically activated, 3) adding a drop-down list for easier access to data and services where required and 4) finding a way to properly register product invoices that have a different tax rate (e.g. one product with 13% and another with 23%).

Generally according to the users' replies and their comments, they consider usability being the most important feature of mobile applications. The users want to get the information they are looking for following simple steps, and in the case of agroFarm, the relatively low rating on the question of organizing information on the screen clearly shows that almost everybody's attention was focused on this point. In general, the second and third sections, which were concerned with the presentation of the data on the screen and the communication with the System, had the lowest score from all other sections.

This indicates that users require of such an application (or generally a mobile app) to give more importance to functionality and usability rather than anything else.

DISCUSSION AND RECOMMENDATIONS

According to qualitative data, such as participants' specific comments, requests were made to improve the application with data and function such as: Timely information related to production, protection, post-harvest, weather forecasts and awareness to help in planning agricultural work. The users found it important to access market information so that, farmers, (buyers and sellers) can make informed choices of where, how and how much to buy or sell for. Some of the participants claimed that voice messages would help farmers with less literacy skills. Communication or even "live Interaction" with scientists (agronomists, veterinarians, etc.) would help to extend the interoperability of the existing version of the application and concerning the design similar farm management applications in the future.

The analysis of the evaluation data revealed the superiority of the experiment by experts in identifying problems related to the consistency and navigation of the system so that they can be corrected in the early stages of application development in general. Three to five evaluators identify 66-75% of usability problems (Nielsen & Molich, 1990).

On the other hand, the results of validation based on the proposed approach have shown that the involvement of the end user is fundamental to enhancing the quality of the end product.

The main advantage of developing applications for smartphones and tablets is the ability to access anywhere via a Wi-Fi network much greater than just desktop computers. (Rubin & Chisnel, 2008). However, development teams are facing new challenges, mainly due to the variety of devices and versions of operating systems used, as well as the different profiles of users accessing the application. It is therefore necessary to propose evaluation methods to improve the usability of such applications.

Finally, the study found that individual barriers, culture and technological barriers significantly influenced the acceptance of mobile apps by farmers in western Greece. These individual obstacles could be overcome by training in the use of computers and the Internet (Purnomo & Kusnandar, 2019).

According to Michels et al., (2019) the key behavioral elements of the technology acceptance model namely ease of use and perceived utility, have a positive influence on the intention to use such applications.

Because perceived ease of use and perceived utility positively influence the intention to use such applications, developers and providers should highlight the benefits of using management smartphone applications and keep the application interface as simple as possible. Data collection is often used to improve the services of expansion, research, policy making and market intelligence. According to Sulimin et al., (2019) the use of a systematic and rational state approach to the introduction of a new generation of digital technologies in agriculture should be an important and promising element of the strategic development of the agricultural industry. The government should not only improve access to ICT, but also develop policies with incentives aimed at developing farmers' skills and abilities so that they are able to adopt digital entrepreneurship. Adequate ICT skills and knowledge will allow farmers to use the technological innovation and digital tools they need to gain access to global markets for their products. Government policy should be aimed at improving ICT infrastructure, promoting the technological external activities of agricultural enterprises; and disseminating ICT innovation to promote agricultural entrepreneurship.

RESEARCH LIMITATIONS

This study has some limitations. First of all, many of those involved in usability tests are not sufficiently trained in the use and interpretation of statistical conclusions. Even with experienced professionals, there can often be a great deal of disagreement about which statistical test to use and what the results are later. Second, those who use the test results to make decisions about the product are rarely trained in their interpretation and can easily misinterpret the results. Third, and probably more relevant, the way the test is conducted varies greatly depending on the data provided to them (Rubin & Chisnel, 2008).

Due to the culture of the farmers (*I don't need application, I have everything in mind*) and the individual barriers it was difficult to find a larger sample, regarding the educational level of the participants, the age, the size and the type of farms.

The problem of farmers' technological infrastructure and familiarity with information technology is present. Many of those involved in the field of agriculture are old age, unfamiliar with the technology and do not have a smartphone. It results in, the creation of the "digital divide" phenomenon, which describes the separation between those who are knowledgeable in information technology and those who are completely ignorant. Thus, the familiarization of the rural world with mobile devices, the Internet and generally with contemporary technology is a significant obstacle to the use of agricultural management applications.

Limiting factor is also the access to the Internet of farms located in remote areas and the lack of high speeds, phenomenon known as "broadband".

In total, nine (9) of the respondents were men, reflecting the typical gender imbalance in farming communities in terms of management.

CONCLUSION

The use of information and communication technology, and especially the use of mobile applications in the primary sector, is undoubtedly an innovation that contributes to the integration of the two information spaces (physical and digital) by providing a truly important tool that helps farmers exploit their farms and an approach to enhancing agricultural entrepreneurship systematically and effectively. To this end the main factors affecting the acceptance and intention to use the new technology is the user experience of mobile applications, the expectation of improved performance, ease to use and utility, the expected personal benefits (e.g. less effort) and the suitability of technology for its intended purpose.

As an important contribution to the evaluation process, participants detect various aspects of the application that could be improved. The main problem found was the absence of frame restrictions to protect the user from possible errors.

Although the majority of users were experienced in using the Android system, all of them were concerned about the ease to use and the learning time. Thus, several suggestions were related to improving the usability of the interface to allow for a better and autonomous user interaction. Particularly regarding accounting data entry, participants reported some system failures to perform these tasks.

As a result, an evaluation process involving application specialists and end users in the evaluation team has brought many ideas that can be drawn from other similar experiences in specific areas of the agribusiness industry. Evaluation methods, especially for mobile devices, are still required to produce products that respond effectively to users' needs.

The acquisition of "analytical" skills, the expanded field of knowledge and the friendly functional environment of these systems for users who do not have programming knowledge is considered utmost importance. Many Greek farms are located in remote locations away from urban centers, which make digital forms of entrepreneurship an important way for farmers to promote their entrepreneurial activities.

Digital farm management is a way for farmers to use their time and space to diversify existing business practices. That said, digital technology offers opportunity for farmers to create new business ventures that are complementary to the knowledge economy.

This document, among others, contributed to the development of farm entrepreneurship by focusing on the use of mobile technology.

Moreover, it expands the established literature on entrepreneurship in rural areas, exploring deeper areas related to mobile applications that help agricultural enterprises. It is hoped to serve as a prelude to the growing body of research on the need for more digital applications for farm entrepreneurs.

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Chapter 10
Addressing Risk Associated to ICT-Based Technology:
Estimation of Financial Parameters

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ABSTRACT

The aim of this work is to discuss the ways risk may affect farm investments in ICT-based technology such as precision agriculture (PA) technologies and to establish how to better incorporate risk and uncertainty into cost-benefit analyses, in order to calibrate the estimated expected net present value from farmers' investments. To properly measure the factors underlying risk in agriculture it is essential to collect a proper piece of data and information from technology, market, and institutions. However, it is somehow hard to rely on historical information about PA technologies as they have appeared on the market in a recent time. Thus, in this work an ad hoc methodology useful to aid risk-averse farmers is developed, dealing with the estimation of financial parameters like discount rates, economic life of technology, and residual values at the end of the period for which benefits are considered.

INTRODUCTION

As the global population continues to grow, food demand has continuously been on an increasing trend (Alexandratos & Bruinsma, 2012). This aspect, coupled with the volatile commodity prices have continued to exert pressure on farmers to become more efficient, producing more at relatively lower input costs, even with more quality. Agricultural systems have to withstand the pressures of changing needs,

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demands and social and economic evolution and, as a consequence, agricultural infrastructure needs to be renewed or redesigned, in order to achieve improved sustainable production (De Wrachien et al., 2015).

In the last years there has been a rapid development and marketing of agricultural technologies and Precision Agriculture (PA) approaches aimed to increase farm efficiency, with pieces of literature reporting possible positive impacts associated with the adoption of ICTs (Buntin et al., 2011). However, to date it is uncertain about how much these technologies will impact food production since most studies conducted to show their effect on profitability have been undertaken on hypothetical farms and simulations (Castle, 2016). When farmers adopt novel technologies, potential benefits are limited to the efficient use of inputs and enhanced outputs in terms product quality (Reichardt & Jürgens, 2009). Also, PA is intrinsically information intensive, and farmers face many difficulties in efficiently managing the relevant amount of data they make available (Fountas et al., 2005).

Farmers live with risk and uncertainty and the daily farm operations are influenced by factors that cannot be predicted in time with high accuracy (Kahan, 2013). To name but a few conditions, unexpected weather phenomena may occur, prices could drop, agricultural equipment could break down and be unavailable for undetermined time, and government policies can change overtime (Hamada, 2017).

All these conditions can affect too, in varying degrees, farm profitability.

Farmers take decisions about what, how much and when to plant, thereby adjusting investments in new machinery and equipment, and for each of these decisions the outcome cannot be certain.

In this context, adequately explaining and quantifying economic benefits related to novel technology to farmers is a present issue. Perceived riskiness of the investment and low awareness of potential economic returns have been demonstrated as hindering factors for PA technology adoption by farmers (Holpp, 2008; Robertson et al., 2009).

Facing these issues, the purpose of this work is to discuss the ways risk may affect farm investments in PA technology and ICTs, and to provide a framework for incorporating risk and uncertainty into cost-benefit analyses, with practical benefit lying in improved calibration of estimated expected Net present value (NPV) associated to investments.

The rest of the chapter is organized as follows. A background regarding cost-benefit analysis for technology adoption is first explored. Then, the themes of risk and uncertainty are introduced in order to give an exhaustive overview of the factors that determine risk in agriculture. Following on, the theme of technology uncertainty is addressed in order to come up with decisions on technological investments. Last, a general framework to adjust costs and benefits and the related financial parameters such as discount rates, economic life of PA technologies, and residual values within a net present value analysis is discussed.

BACKGROUND

From the study of the impact that PA technologies have on farm economics it has become clear that technology affects farm economics through multiple channels (Pedersen et al., 2019; Schimmelpfennig, 2016; J. Shockley et al., 2012; J. M. Shockley et al., 2011). For instance, PA technology can reduce operating costs by preventing farmers from overapplying inputs, and even if input use and operating costs increase, yields can grow enough to increase operating profits. The use of ICT and PA technology can effectively lead to a decrease of input costs. Several works have investigated to which extent technology can nowadays contribute to increase economic -but also environmental benefits in agriculture. It is widely documented how lower rates of fertilizer carefully better distributed applied can reduce input up to 38% without affecting yield and crop quality (Aggelopoulou et al., 2011; Casa et al., 2011; Matson et al., 1998; Zaman et al., 2005; Schmidt et al., 2002). Moreover, Dobermann et al. (2002) and Wang et al. (2003) reported both increased yields (up to 11%) and cost benefits resulting from site-specific fertilization management. Similar benefits were highlighted also for real-time pesticide application (Chen et al., 2013; Dammer & Adamek, 2012), lime application (Bongiovanni & Lowenberg-Deboer, 2000) and weed control (Dammer & Wartenberg, 2007; Kunz et al., 2015).

PA technologies have the potentiality to effectively provide the agricultural inputs in the right place, with the right amount and at the right time, and they are therefore employed with the aim of maximizing productivity, minimizing both production costs and consequently the impact of agricultural activities on the environment. In this way, the use of innovative technology can potentially greatly affect the agronomic and economic results of a farm's business, being useful to mitigate specific risks that are inherent in the agricultural sector. However, ex-ante cost-benefit analyses need to rely on reasonable assumptions about the quantitative impact of the technology on the reduction of operating costs and on the increase of future crop yields over time in order to take into account risks and uncertainties.

RISK AND UNCERTAINTY IN AGRICULTURE

Uncertainty and risk represent an essential feature of the production environment in agriculture. The term risk is generally associated to undesirable effects. This is intuitively related with attributes that cannot be forecast with high accuracy within physical and economic environments characterized by relevant complexity. Decision making under uncertainty is characterized by risk, because not all possible consequences desirable in the same way.

As argued by Hardaker et al. (2015), uncertainty can be defined as imperfect knowledge and risk as uncertain consequences, and therefore it is not value-free; to take a risk means to expose oneself to a probability of harm or loss. It is also worth of mention the contribute of Knight et al. (1921), who interpreted risk as randomness that is measurable, described by a probability distribution, and uncertainty as a form of randomness unable to be measured by a probability distribution. In case of absence of sufficient amounts of precise information, one can hence refer to the term uncertainty. Risk is intuitively unimportant for many daily decisions but many farm management decisions, like investments in new technology, need to be taken with explicit account of the risks involved.

It is possible to identify several types of risks and uncertainties in agriculture with respect to production, price, technology and scope (Moschini & Hennessy, 2001). *Institutional risk* plays an important role in agriculture: changes in the rules that regulate farm production can affect profitability and, besides regulation, also taxes, interest rates, exchange rates, provision of public goods have impacts on agricultural practice. *Price risk* (also named *Market Risk*) is generally associated to the production lags mentioned above and to the volatility of agricultural markets too. In this regard, farm input prices and outputs are seldom known for certain at the time when farmers must make decisions. Price variability is mainly the result of developments in the commodity markets (supply and demand forces, market adjustment processes), and in this scenario farmers cannot influence it. Price variability makes planning difficult because of uncertainty and leads to income problems for farmers; these circumstances lead in turn to inefficient resource allocation (Ellis, 1998). *Production risks* derive from the fact that the production function is stochastic: in agriculture the output resulting from given inputs is not known in advance with certainty. Such uncertainty is determined by unpredictable and uncontrollable factors like climate change, the incidence of pests and diseases, and other biological processes underlying the production of crops. Components of the production risk in a field are variability in space and time. Temporal variability is due to climatic or seasonal factors, while spatial variability deals with changes in yield across the field. It was demonstrated how temporal variance over consecutive seasons is substantially larger than the yearly spatial variance (Whelan & McBratney, 2000); this fact emphasizes the importance of relying on large quantity of data in order to proper assess how investments in PA technology can affect production risks. Another marked feature of agricultural production is *Technological uncertainty*, especially when long-term economic problems are considered. This kind of uncertainty is associated with the evolution of production techniques that can make past investments in technology obsolete. Nevertheless, ICT-based technologies are still under a rapidly changing phase of experimentation and improvement which confers additional uncertainty regarding their effects on farm productivity in the years to come. In addition, it was highlighted the fact that technological innovations resulting from efforts made in adjacent sectors (ICT, for example) makes competitive farmers taking the role of captive players in the adoption process (Moschini & Hennessy, 2001). This aspect contributes to make farmers less updated about technological advances, and therefore less aware of the associated risks.

Given this framework, it is appropriate to point out if and how the possible adoption of PA technology can mitigate risks and thin the relative uncertainties. The adoption of technology in agriculture seems to be related to both production risks and technological uncertainty: on one hand PA technology can limit production risks in agriculture thanks to their ability in limiting yield variability, which anyhow is always subjected to natural causes; on the other hand, its adoption may entail a high degree of technological risk especially when it requires a relevant capital investment, with possible net benefits expected to come to light only after several years. To date, it is hard to assess production risks because these technologies are relatively recent and time-dependent data at operational level (crop yields and quality, input savings) are missing or owned by technology and service providers.

Perceived Risks and Barriers to Adoption

Risk is frequently used with the connotation that it can be assessed and calculated. It is associated with the stochastic performance of the investment, and results at macro level in unwillingness/slowness in the adoption of innovations (Ellis, 1998). In scientific research, risk in agriculture has been addressed in terms of farmers' perceptions and attitudes, and it is considered as a problem parameter treated within motivational profiles. Several survey-based studies have focused the individual perceptions associated to risk, like expected economic margins and individual risk preferences to name a few, with emphasis placed on the fact that risk-related measurements are directly affected by the rate of information acquisition and learning-by-doing phases in the adoption process of farmers. At the same time, academics recognized the necessity for a better understanding about the motivations and risk attitudes of farmers. In this context, examples of works investigating the adoption of innovations are related to 'best management practices' (BMPs) (Greiner et al., 2009), new-crop types (Ghadim et al., 2005), genetically modified (GM) seeds (Barham et al., 2015) and appropriate technology for rural smallholders (Guttormsen & Roll, 2014). Despite the potential benefits associated to PA technology are widely acknowledged in literature -part of which have been discussed above, there exists some perceived risks that slow down their adoption among farmers: initial cost, technology complexity and human capital-related issues.

The adoption of novel technology can entail a high degree of risk for the farmer, especially if the adoption of the technology requires a relevant capital investment. In this case the perceived risk may be high because the farmer has had no first-hand experience of the new method or equipment (Hardaker, 2015). A survey of Nebraska farmers in the US showed that the main barrier to the adoption of new technology is precisely the initial cost of investment, with acquisition cost considered by most of the farmers one of the leading issues concerning future technological advancements in agriculture production, as well as overall affordability (Castle et al., 2016).

Technology complexity of PA is another barrier that holds back the diffusion of ICT solutions in agriculture. Indeed, although the concepts of PA may be clear and easily understood by most farmers, the complex manipulation of mapping technologies data into functional and useful information at farm level decision making undoubtedly constitutes a deterrent to most farmers. In fact, the risk of lack of confidence among older farmers in their ability to effectively use precision farming techniques is high. For this portion of farmers, the time needed to learn and keep up to date with the changing technology can exceed what other farmers can be willing to surmount. Such technological barrier can easily prevent farmers from adopting novel technologies. ICT can be also related to an increased human capital risk. Indeed, the manpower required must be highly trained to operate machines and interpret the data collected, with need of specialization on particular sub-tasks of precision farming; this issue has become relevant particularly for guidance technology (Kahan, 2013; Lowenberg-DeBoer, 1999).

It has been argued how investing in novel technology under uncertainties can be difficult. Farmers may therefore tend to wait and clear the uncertainties before undertaking investment in technologies which demand relevant initial costs for the equipment and are generally characterized by steep learning curves (Della Seta et al., 2012). In addition, risks and uncertainties can potentially reduce the possibility of farmers of acquiring complete sets of technologies and equipment, leading them to partial adoption of some components and taking time before adopting the rest. This concept was demonstrated by Leathers & Smale (1991) who prove how rationality leads not fully informed farmers to adopt equipment one step at a time, as they slowly learn about the whole package instead of adopting the complete package all at once. More recently, the adoption based on sequential adoption has been enriched by Ma and Shi (2015) who acknowledged an additional dimension to the adoption analysis: the so-called forward-looking farmers tend to take into account the future effect of their learning by considering their own learning and that of their neighbours; such a 'myopic model' implies an underestimation of the value of early adoptions among forward-looking farmers, leading in the end to lower adoption rates for a given technology. Anyway, whatever the adoption pattern is, there is an 'adoption lag' until the farmer has accumulated enough evidence to make the perceived risk acceptable (Hardaker, 2015).

ASSESSMENT OF FINANCIAL PARAMETERS

To properly measure the factors determining risk it is essential to rely on a sufficient amount of information on risk factors and uncertainty within the analyzed context. In general, it is hard to rely on time-dependent data about PA technologies as they are relatively recent. We hence refer to uncertainty when addressing investments in ICT-based technology, bearing in mind the distinction between risk and uncertainty provided by Knight (1921): risk can be seen as randomness that is measurable, i.e. can be described by a probability distribution; differently, uncertainty is a form of randomness than cannot be measured by a probability distribution. It was previously noted how the randomness of new knowledge development can affect the technology adoption in agriculture. In this regard, uncertainty referred to ICT-based solutions includes the possibility of realizing increased crop yields for a number of years, cut significantly input costs, as well as the foresight to predict the invention within the next years of more advanced technology that makes the adopted equipment obsolete. In practice, uncertainty deals with the variability and the duration of future cash flows associated to the investment.

In this regard, a good methodology for cost-benefit evaluation should entail reasonable assumptions about the quantitative impact of the technology on the reduction of operating costs and on the increase of future yields, with uncertain costs and benefits adjusted upwards and downwards, respectively (Stæhr, 2006). A number of strategies are proposed to add caution to the decision-making process when risks and uncertainties are present.

Economic Life

First, a correct way to reduce technological risk and uncertainty of adopting ICT-based technology is to cut off the period of net benefit flows. This method implies that possible net benefits in distant future times are not considered in the net present value calculation. Generally, a good rule of thumb for investment in agricultural machines was to take an economic life of 10-12 years for most farm machines and a 15-year life for tractors (Edwards, 2015). The economic life can be defined as the number of years over which costs are to be estimated; generally, this value is less than the machine's service life because most farmers trade the equipment before it is completely worn out. Accordingly, considered that the evolution rate of ICT-based technology is very high, it is possible for the already existing equipment and techniques to become obsolete in a shorter time. For these reasons, we propose to refer to a cut off period of 6-8 years for most of the PA technologies including monitoring technology, sensor-based technology, variable-rate technology and guidance technology (*Table 1*).

Table 1. Proposed cut-off period for investments in ICT

ICT/PA technology	Cut off period
Monitoring technology ● LiDAR sensors ● Multi/Hyper-spectral cameras ● Soil EC sensors	6 years
Reacting technology ● Spraying UAV ● VR fertilizer application system ● VR pesticide application system – Map-based ● VR pesticide application system – Real-time	8 years
Guidance technology ● Auto-steer ● Section control	8 years

Residual Value

A null residual value can be considered for investments susceptible of technical obsolescence. Residual value is the estimate of the sale value of the machine/equipment at the end of its economic life. Estimates of the remaining value of conventional machines like tractors, combines and forage harvesters are often listed by published reports. However, since novel technology uses much more information technology than conventional agricultural equipment, one can expect that they will have a null sale value at the end of their economic life, constituting real discarded electronic devices.

Discount Rate

Another foresight that can be used to add caution and prudence in the calculation of expected net present values of investments is to adjust discount rates. In this regard, the rationale is that when novel technology is adopted it is easier to forecast cost and benefits developments in the very near future than in more distant years. However, in a context characterized by poor possibility to quantify risk-related variables, deterministic spreads varying from country to country over risk-free rates are definitely hard to determine. Surely the fact that much of the emphasis of PA research on ICT-based technology (VR applications are one example) is focused in lowering spatial variability of yields contributes to lower the risk, which can be taken into account by assuming relatively low discount rates. For the reasons above mentioned, we suggest to adopt a risk-free discount rate for investments in novel technology, and to consider risks and uncertainty in other financial parameters, like the recovery value (likely to be set as null) and the cut-off period over the investment. In this context, it is worth of mention that the metric of internal rate of return (IRR) can be considered itself as an implicit risk indicator: the closer to the applied discount rate it is, the more the investment will be likely to narrow its benefits down to make even a negative result, according to the given cash flows distribution.

Application example

NPV analysis can be performed with expected yearly benefits and costs and the two variables cut-off period T (years) and interest rate r (%) constituting respectively the investment lifespan of the project and the discount rate equal to the risk-free bond rate of similar duration, as shown in the following equation:

$$\text{NPV} = \sum_{t=0}^{\text{T}} \frac{1}{(1+r)^t} \left(\text{benefits}_t - \text{costs}_t\right)$$

In which benefits are possible additional yields as a consequence of PA technology adoption, and costs include investment costs, possible yearly costs (e.g. service fees) as well as costs reductions due to input savings (with a negative sign).

FUTURE RESEARCH DIRECTIONS

The non-clear perception of economic benefits when using ICT caused by the lack of appropriate criteria to define them is a present issue. As suggested by Lamb et al. (2008), a solution to augment the adoption rate of PA technologies may be the development of protocols and realistic performance criteria by technology providers, which should play a more effective role in supporting adoption (Lamb et al., 2008). Also, public bodies should encourage initiatives promoting sustainability in agriculture and food production as many PA technology are associated to a mitigation of negative environmental impacts associated to conventional agriculture (Medici et al., 2019). Future research should investigate the social impact related to the adoption of ICT in agriculture in order to further increase it. A number of themes are related to this issue, including farmer fatigue reduction, capacity development, workplace safety and promotion of food sovereignty (FAO, 2013).

CONCLUSION

The relatively high investment costs of certain PA technologies leads to sub-optimal adoption rates, and this is reinforced by farmers' low awareness and biased perception of the benefits. Any investment is accompanied by risks and uncertainty. In this work the way these circumstances may affect farm investments in PA technology have been discussed and a framework for incorporating them into cost-benefit analyses was proposed. Actors involved in food production need to be able to assess the economic viability of applying ICT to a farm before the actual investment. This is a clear direction for the future of PA.

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Chapter 11
Agribusiness Technology Transfer and Innovation as a Catalyst for Food Security in Developing Countries: Case of Kenya

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ABSTRACT

This study assesses the influence of agribusinesses technology transfer and innovation in developing countries, Kenya. The study used a sample framework of 300 enterprises and structural equation modeling for content analysis. The findings show that innovation and technology transfer have a positive impact on firm performance and rural development. However, the lack of effective agribusiness technology transfer from R&D institutions to the industry is the main challenge facing agribusiness performance and rural development in developing countries. Thus, the need for financial support for research and development institutes that would promote the linkages between the innovators and the agribusiness enterprises in rural areas. The study recommends that to encourage innovation and technology adoption across business sectors, a suitable policy linking agribusiness enterprises with R&D institutions is critical in promoting innovation transfer from these institutions.

INTRODUCTION

Technology transfer is a process that embraces the advancement of innovation and organizational performance (Bennett & Vaidya, 2005). The rapid changes in the global industrial environment act as

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a catalyst for companies to improve their competitive advantage by obtaining new technical skills by advancing their technologies. The majority of advanced and emerging countries depend on technology transfer and innovativeness of small agribusiness enterprises to speed their rural economic development (Ramanathan, 2011). Previous studies have shown that firms that have invested in new technology have experienced noticeable development in relation to their profitability (Ahmed et al., 2015; Huang, 2016).

Agriculture plays a key role in reducing global poverty. It is estimated that 75% of the population engaged in agriculture-related activities and lived in rural areas (Chan, Sipes, & Lee, 2017). It is estimated that 70% of the working population in sub-Saharan Africa and 67% of the working population in South Asia work in agriculture (GOK, 2016). In Kenya, agriculture is the mainstay for economic development and contributes 26 percent directly to the GDP and 27% indirectly via other sectors. The agribusiness industry provides employment for over 40% of the Kenyan population and 70% of Kenyans in rural areas. Additionally, it helps achieve the urban-rural balance; by creating job openings in rural areas and discouraging rural-urban migration.

According to FAO (2019), the number of malnourished populations in developing nations is about 870 million people. In Africa, the number of undernourished people has steadily increased since the early 1990s from 175 million to 239 million. FAO (2019) has also shown that 36 countries in the world require external food assistance. From the 36 countries requiring external food assistance, 28 countries come from Africa. According to Kaloi *et al*. (2005), fifteen million (approx. 50%) of Kenyans are faced with food insecurity; about 3 million were supplied with food relief throughout the year. Due to this food security concern, the government and lead agencies in the agricultural sector have come up with a number of agricultural technologies to boost food production (AGRA, 2017).

Despite decades of investment in agricultural technology, hunger and poverty continue to ravage many people in developing countries. The poverty situation in Kenya is changing and directly affects the country's agricultural sector. Currently, 46% of Kenya's population survives on less than $ 1 per day, while 37% are facing food insecurity, and 35% of children below five years are malnourished. The country's population has increased considerably and is expected to double over the next 27 years, reaching 81 million in 2039. As a result of this rapid growth, the areas with high agricultural potential is decreasing, and this affects food production. This problem is particularly serious in rural regions of Kenya that depend on rainwater to irrigate agriculture, with the limited implementation of new technologies, low agricultural productivity in arid and semi-arid areas of the republic. Climate change is deteriorating Kenya's aridity situation due to increased weather variability that is unsuitable for sustainable food production (Chege & Wang, 2020).

According to Jagoda *et al*. (2010), there are several factors impeding the acceptance of new technologies, particularly in agribusiness enterprises due to the highly complex and turbulent environs. Worldwide changes and progress are associated with new technologies that help the business to generate new products, processes, and markets. Firms depend on technology transfer to acquire new knowledge and technique to enhance production capacity and to sustain competitive advantages. Thus agribusiness technology transfer is necessary for boosting food security in Kenya.

The purpose of this study is to examine the impact of agribusiness technology transfer and innovation in Kenya. The study addresses the following questions:

1. How can agribusiness technology transfer boost rural development in developing countries?
2. How can agribusiness in rural regions benefit from the rapid advances in agricultural technology being achieved in the developed world?

3. How extensive has the acceptance of new agribusiness technology been used in Kenya?

This paper is arranged as follows. Section 2 conducts a literature review. Section 3 presents a research methodology. Section 4 introduces the analysis of the results. Section 5 draws conclusions, while section 6 summarizes the study findings and provides perspectives for further research.

LITERATURE REVIEW

Agribusiness is an agricultural production enterprise. It refers to the range of activities and disciplines covered by modern agricultural innovation, enhancing the business of agriculture. The agribusiness system includes all the entities in the food and fiber value chain and the institutions that influence them. These activities include animal keeping, farm machinery manufacturing, and sales among others. Technology Transfer (TT) is a process by which science and technology are diffused through human activity (Jasinski, 2009). Scholars view TT as a systematic process where knowledge and skills developed by one entity is utilized by another entity for the advancement of knowledge. Autio and Laamanen (1995) refer to TT as a deliberate process, an objective-oriented interface, and a vigorous process between two or more entities (Ramanathan, 2011). The TT process is said to be effective if the receiving entity can efficiently utilize the transferred technology and ultimately adopt it.

Innovation has improved the agro-industry value chain and introduced new products, processes, market solutions, and procedures (Shaw *et al.*, 2005). Schumpeter (1942) (1942) viewed entrepreneurial innovation as an important part of the business life cycle. Disruptive innovation occurs when a company optimizes its profitability by developing new products or services that disrupt the current market and cause changes in the use of resources. Innovation, in Schumpeter's view, comprises the aspects of inventiveness; the introduction of new processes, products, or services; investment in research and development (R&D); and improvement in technologies.

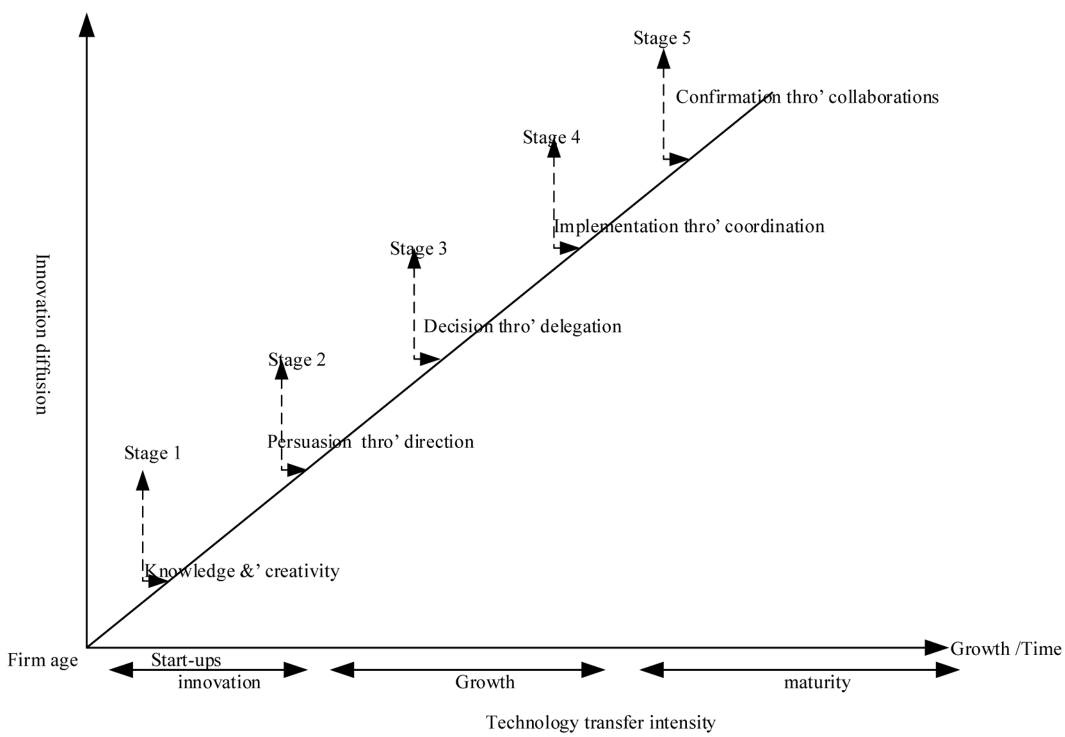
Technology Transfer and Firm Performance

Most of the agribusiness activities in developing countries are food production, which is the backbone of most African countries and occupies a pivotal role in developing the continent. Most of the farming activities such as planting and harvesting are time-delineated, and therefore, the availability and predictability of the seasons and markets are important for effective operations. Support policies targeting agribusiness sectors are based on the premise that improving SMEs should be based on technology improvements and diffusion. Government policies focus on promoting stakeholder cooperation in research and diffusion of technology, and the empowerment of small-scale farmers to access the market for the sales of their produce. However, most research institutions have challenges involving TT needed by agribusiness enterprise systems due to inadequate funding. Major challenges facing industry and governments in the developing countries are inadequate technological infrastructures and lack of financing for agricultural-related activities (Ong'ayo, 2017). Successful approaches may include capacity building of the recipients' organization human capital to enhance the TT process. R&D on university–agribusiness sector collaboration can advance useful, practical knowledge for optimal firm performance (Appiah-Adu *et al*., 2016).

Theoretical Model

This study was based on the diffusion of innovation model postulated by Rogers (2003) and as shown in **Figure 1**. Innovation is the process that individuals or other adopters see as new ideas, practices, or objects, while communication is the process in which members generate and share relevant information with each other to achieve mutual understanding (Rogers, 2003). The model is suitable for this study because of its flexibility in absorbing dynamism in technology. Diffusion and adoption of new technology after being communicated to farmers are adopted and hence farm productions improved and hence food security status improved. Various agricultural technologies are geared at empowering farmers to contribute positively to food security.

Figure 1. diffusion of innovation model (researcher's own elaboration)



Impact of Agribusiness Technology in Developing Countries

The comparative sluggishness of agricultural productivity in recent years, especially in South Asia and Africa, where the many rural poor live, highlights the need for new ideas to advance rural livelihoods. Making new investments to increase new technology and ensure its application can help harness the potential gains in productivity and farm incomes. Agriculture in Africa and South Asia faces a paradox of innovation. Economic returns to and growth effects of R&D and knowledge diffusion are documented to be very high, technology uptake in developing countries is decreasing (WorldBank Group, 2019).

The implementation of novel technology in agriculture has been critical in determining the rate at which farmers are able to raise productivity for the benefit of growth and the pace of poverty reduction. Farmers will innovate to increase subsistence production, but as innovation generally implies some type of investment, the chances of farmers investing and innovating are greatly enhanced by the existence of sustainable markets (WorldBank Group, 2019).

Developing nations need to increase agricultural technology and the use of innovation by farmers, to eliminate poverty, meet the rising demand for food, and cope with the hostile effects of climate change. New technologies enhance access to information with reduced costs. This, in turn, increases agricultural productivity. The main motivation for increasing agricultural productivity and increasing income is the implementation of innovative technological practices by farmers. This will allow farmers to increase yields, manage inputs efficiently, embrace new technology in crop production methods, improve product quality, protect natural resources and adapt to challenges of climatic conditions (Chege & Wang, 2020).

Table 1. Chain of technology transfer effects

Chain	*Technology Transfer providers*	*Technology Recipient*
Inputs *(resources)*	· Personnel · Technology know-how	· Staff · Financial Investments
Outputs *(immediate results)*	· Justification of technologies · technology improvement	· Establishment of a demonstration model · Development of transfer roadmap · Implementation of prototype
Outcomes *(short term)*	· The beginning of follow-up plans · Incentive for research · services diversification · strategic corporations · staff capacity building · Interaction forum in the region	· Capacity building for personnel · use of new methods and technical tools · Creation of patents · Development of instruction models
Impacts *(long-term benefits)*	· Increased prominence · Improve research profile · collaboration and partnership	· Increase in profits · Provides competitive advantage · Enhanced technological prowess

Source:

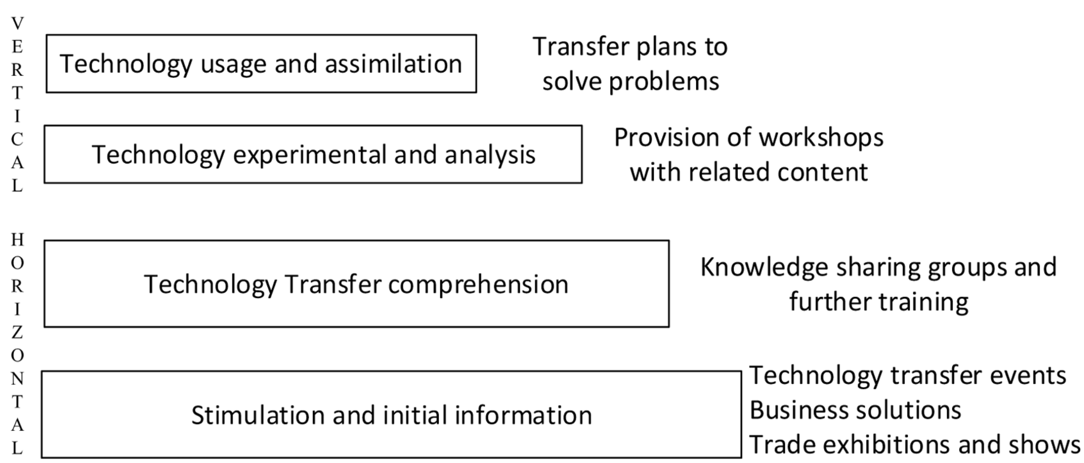
Rapid Advances in Agribusiness Technology

It is inevitable that technological advances will lead to an adopting area becoming relatively better off compared with a non-adopting area. This simply underlines the importance of balancing investment in technology generation between marginal and favored environments. Additionally, it's difficult to separate the impact of technological change from concomitant changes in population, policies, or land tenure. Most of the evidence about the poverty-reducing effect of agricultural technology comes from Asia. In Africa, there are far fewer examples of where agricultural technology has benefited poor people (Dfid, 2015).

Freebairn (1995) analyzed over 300 other studies related to the Green Revolution revealed a general increase in inequality between regions as a result of technology uptake. However, evidence from Zimbabwe revealed a post-independence Green Revolution amongst smallholders which had a very significant impact on poverty, which was realized by the introduction of hybrid maize, expanded access to credit, guaranteed prices, and marketing subsidies.

Globally competitive markets and firms need to take advantage of new TT opportunities to enhance their target market share and respond to customers' needs (Muthoni & Kithinji, 2013). The most useful assessments of technology's impact on poverty are those that follow farming communities' experiences over a longer-term period. These assessments should show how the rural poor have benefited from new technologies, principally through increased employment opportunities and higher wage rates. **Figure 2** shows the process of technology diffusion and assimilation in developing countries.

Figure 2. Phases of the transfer process



Use of Agribusiness Technology in Kenya

In Africa, technological resources are often not well developed, and SMEs are usually characterized by very low levels of technological know-how. Hence, examining the mechanisms that enable the adoption, mastering, and improvement of technologies can be an important focus of innovation system research in Africa (Chege & Wang, 2020). It thus becomes crucial to investigate how what mechanisms, and what type of resources that can be built as a result of TT interactions.

Modern agribusiness calls for the employment of a lot of technology. Agribusiness and technology are inseparable, where increased yield is paramount. Technology is a critical component in agricultural sustainability in developing countries. In Kenya, agricultural technology encourages water conservation through the use of drip irrigation renewable energy solutions, such as solar pumps, drip kits, seedling trays, and water tanks ensures that the cost of production is reduced, therefore increasing profits (Chege & Wang, 2020). Additionally, solar pumps emit no greenhouse gases thus, promotes conservation of the environment.

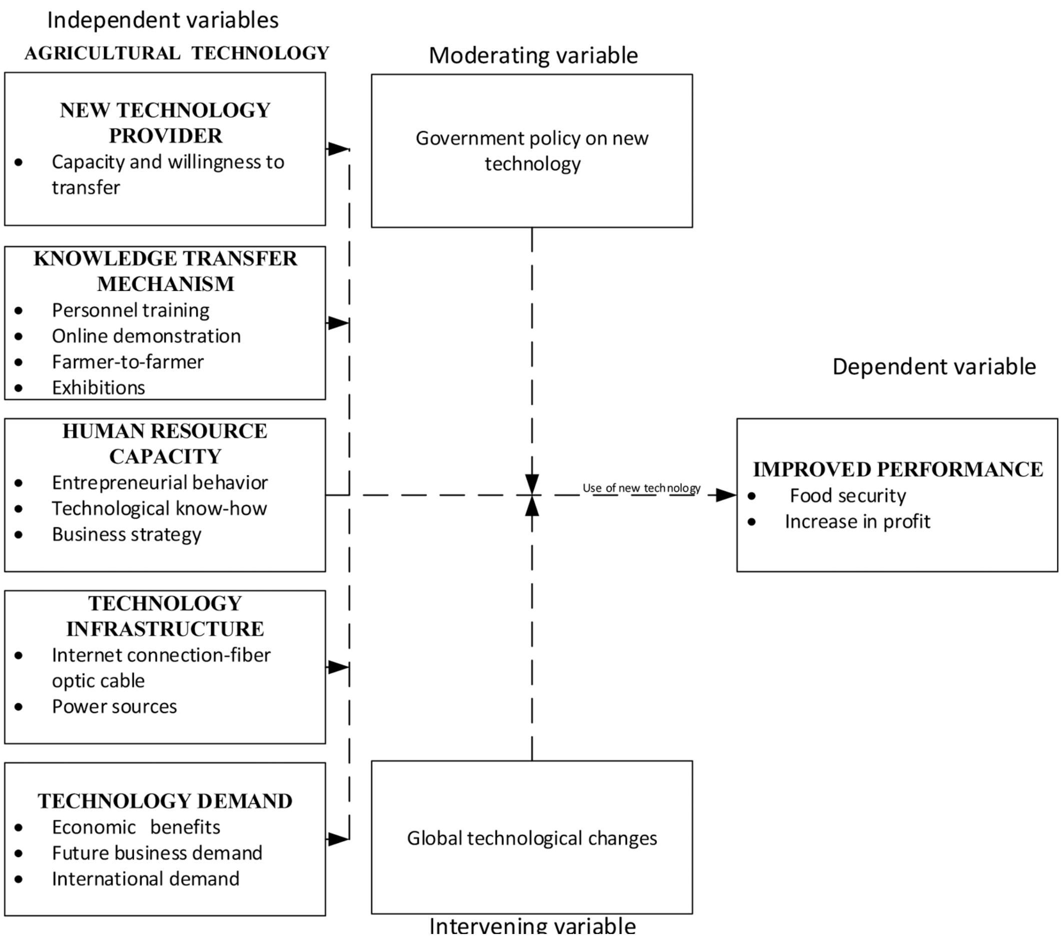
Digital marketing, for example, is one of the major tools used by agribusiness in Kenya to boost their businesses. Online presence through a website, Facebook page, tweeter page, and a YouTube channel enhances global marketing access. According to Lee (Lee & Win, 2004), the main reason for the fruitful transferred technology is the absorption capacity of the recipient. This ability to assimilate new technology is connected to the firm's human resources, infrastructure, and recipient's operational efficiency. Organizations face challenges of using scarce resources such as human capital, technology information, intangible asset, and market position while carrying out innovation activities and technology transfer (Park & Lee, 2011). Successful technology innovation management requires a well-defined management strategy to align innovation projects with resources and objectives that promote essential innovation capabilities (Newbert, 2008). Absorptive capacity is explained as the ability to use new technological knowledge acquired from external sources (Buratti & Penco, 2001). If the recipient's absorptive capacity is high, there is a high probability of using technology to generate new products and services for business growth (Tsai and Wang, 2008). Some scholars have used firm size and firm R&D intensity as substitutions for absorptive capacity (Battistella *et al.*, 2016; Perkmann *et al*., 2013).

The Study Conceptual Framework and Study Hypothesis

Figure 3 shows the conceptual framework of the study variables interactions with various factors that influence food security in Kenya. The study independent variables include new agribusiness technologies, technology transfer mechanisms, human resource capacity, technology infrastructure, and agricultural technology demand. Additionally, the model captures moderating and intervening variables that influence the flow of technology transfer directly or indirectly that result in either positive or negative effects on food security. The study made the following propositions:

#H1: New TT providers will have a positive impact on the agribusiness performance
#H2: Knowledge transfer mechanisms will have a positive impact on agribusiness performance
#H3: Human resource capacity will positively influence TT and agribusiness performance
#H4: Technology infrastructure will positively influence the effectiveness of TT
#H5: Technology demand will positively influence the effectiveness of TT

Figure 3. Study conceptual framework



METHODOLOGY

The study used a quantitative research approach. The main source of information was from the agribusiness managers in Tharaka-Nithi County, Kenya. The study area was selected due to the following; first, the county's major economic activity is agriculture, with 98.2% of the county's households involved in agri-business (ROK, 2017). The county's 80% of the landmass is arable. The county has underutilized arable land due to the low implementation of contemporary agronomic practices. Secondly, the county lies in a semi-arid area with great potential due to plenty of rivers emanating from Mt. Kenya that can provide water for irrigation.

To get measures of generalizability, the study used random sampling to select the desired sample (Binu *et al.*, 2014; Guo *et al.*, 2013). Sample-size requirements may differ based on the statistical analysis, and a variety of opinions observed in the literature, even when the same tools are applied. The sample that ranges between 10% to 30% is recommended when the components in the study sample are found to be more than 30 elements (Mugenda & Mugenda, 1999). From the list of agribusiness enterprises provided by the county government, there were about 950 agribusiness enterprises from which a random sample of 300 enterprises was obtained.

Questionnaire Design and Data Collection

Based on the relevant literature, a questionnaire was developed to identify the agribusiness technology transfer and to analyze the impact on transferred agribusiness technology in Kenya. The level of technological capabilities acquired was assessed by the use of a questionnaire designed in reference to relevant earlier papers as displayed in **Table 2**. 300 respondents met the requirement to use a structural equation modeling (SEM), as the ratio of a sample size to estimated parameters should be at least 10:1 (Kline, 2005). According to (Hair *et al.*, 2010), the desired lowest number of construct indicators should be three; but, 5-7 indicators are usually applied to signify a construct. In order to address the research questions of the study, the SEM approach as the covariance-based SEM was used to test the implication of the indirect and direct effects. The SEM analysis was taken using a measurement model analysis and structural model analysis (Etezadi-Amoli & Farhoomand, 1996). In this study, the statistical software package utilized for SEM was AMOS (Blunch, 2013). Descriptive statistical analyses were also employed in order to analyze the profile information provided by respondents

To improve the response rate for the study, an integrated method of questionnaire distribution was used; two trained research assistants used respondent's email, face-to-face, and a mobile short message informing the respondents to check their emails and to confirm their availability. The research assistants assisted the respondents in filling the questionnaire. The researcher distributed the questionnaire to 300 respondents, collected 295 out of which 290 were suitable for the present study, as shown in **Table 3.**

RESULTS

Respondents' Bio-data

Table 3 shows that 60% of the respondents were female, which reveals that female entrepreneurs have higher chances of doing business in the countryside. About 40% of SMEs sampled had between one and five employees, while enterprises with six to 10 employees were 35%. Most of the enterprises were in the manufacturing and agriculture sectors (65%). Rural SMEs contribute to informal employment that is significant to Kenya's economic growth (ILO, 2015).

Presented in Table 4 is the type of technology and transfer provider in Agribusiness in Kenya. These results support previous work by Okello and Ireri (2017). They found that agribusiness enterprises use technology to disseminate information and to gather agribusiness information. In addition, the participants used technology as a platform for training and learning. Smallholder farmers used their mobile phones to get information from various sources when expert feedback is required.

Table 2. Variable Constructs Measurement Indicators

No	Variable constructs and indicators (Measure)	References
	A. New Technology (NT)provider	
1	Capacity and willingness to transfer technology	(Battistella *et al*., 2016; Kande *et al*., 2017)
2	Technology transfer resources	
3	Scientific and technology know-how	
	B. Knowledge transfer mechanism (KTM)	(Bozeman, 2000; Bozeman *et al*., 2015; Han & Lee, 2013; Jafari *et al*., 2014)
1	Personnel training and coaching	
2	Online demonstration	
3	Farmer-to-farmer transfer	
	4 Institutional exhibitions and agricultural shows	
	C. Human resource capacity (HRC)	(Buratti & Penco, 2001; Jabar & Soosay, 2010; Perkmann *et al*., 2013)
1	Entrepreneurial behavior	
2	New technology know-how	
3	Regular training on new technology	
4	Technology-enabled strategy and innovativeness	
	D. Technology demand (TD)	(Jasinski, 2009; Omato & Kithinji, 2013; Ramanathan, 2011)
1	Economic benefits of technology transfer	
2	Future business demand	
3	International demand for new technology	
	E. Technology infrastructure (TI)	(Newbert, 2008; Wernerfelt, 1984)
1	Internet connection via fiber optic cable	
2	Government support for agricultural technology infrastructure	
3	Collaboration with a relevant research institution to boost technology transfer	
	F. Agribusiness performance (APF)	(Fazli *et al*., 2013; Nickolas, 2018)
1	Increased profitability through global market access	
2	Food security	
3	Increased income for rural livelihood	

Table 3. Socio-economic Characteristics of Agribusiness owners in Kenya

Item	Classification	Frequency	Percentage %
Gender	Male	116	40
	Female	174	60
Age (years)	18-25 years	58	20
	26-30 years	72	25
	31-35 years	116	40
	Above 35 years	44	15
Business experience (years)	Less than 1 year	15	5
	1-2 years	29	10
	3-4 years	116	40
	5-6 years	130	45
Education level	Masters	3	1
	Bachelors	29	10
	Diploma	73	25
	Secondary certificate	142	49
	Primary certificate	43	15
	Crop production	168	58
Industry category/sector	Livestock/dairy farming	55	19
	Fishing	41	14
	Beekeeping	26	9

Table 4. Type of technology transfer in agribusiness enterprises in Kenya

Nature of agribusiness	Type of technology	Transfer provider
Crop production	Contract/ commercial farming	Media stations-Television vision programs, East African Breweries
	Use of hybrid seeds-safe farming	NGO, the private sector, Kenya seed company
	Mobile money transfer (M-PESA)	Safaricom.
	Greenhouses farming	Private sector/NGOs, University
	Irrigation systems	Private sector/NGOs and university
Livestock	Milk cooling equipment	Brookside Kenya
	Artificial Insemination	University, Ministry of Agriculture
Fish farming	Sandtrap, environments management system	Ministry of Agriculture, NGOs, CBOs
Beekeeping	Langstroth hives and honey extraction machine	County government, The ministry of agriculture, Community Based organizations

Structural Equations Modeling

This study utilized an SEM approach as the main statistical method using IBM **S**tatistical Package for the **S**ocial **S**ciences (SPSS) Analysis of a Moment Structures (AMOS) software for data manipulation and statistical analysis (Carver & Nash, 2011; Meyers *et al.*, 2013). The main benefit of SEM is that it stipulates the scholar with a chance to implement a more holistic approach to model structure (Hair *et al*., 2010). In addition, SEM has shared features that adapt the bias in the estimates because of the measurement error associated with inadequate measures of data by several indicators for all latent variables. Also, SEM evaluates indirect effects amongst latent constructs that lead to the estimation of the total effects, unlike multiple regressions where the indirect effect is not considered. Thus, SEM is suitable for scrutinizing the effects of TT on the performance of agribusiness enterprises. The SEM procedure involves two functions: the structural model and the measurement model. In this study, an assessment of normality by maximum likelihood estimation was used in data screening while the maximum likelihood estimation method was applied to estimate models normality. The assessment of normality for this study showed that the skewness oscillated from 20.203 and .068 while kurtosis oscillated from 20.56 and .89. Thus, the data were normally distributed and had acceptable values of skewness and kurtosis (Byrne, 2010).

Based on the results of data screening of the indicators and constructs, the measurement model was examined via Confirmatory Factor Analysis (CFA). The CFA recognized the latent constructs characterized in the construct items, and the study applied maximum-likelihood-method with Promax Kaiser-Normalization-method because it offers a constant method to the estimation complications that occur in larger estimation circumstances. Furthermore, CFA was used to test model fit, Construct Reliability (CR), and convergent validity. In addition, standardized positive factor loadings of $> .05$ and ≤ 1 were utilized in the model (Hayes, 2009).

These results confirmed the validity of a 37-item, 6-factor model that included Technology Providers (TP), Transfer Mechanism (TM), Recipient's Capacity (RC), Demand Environment (DE), Resource Allocation (RA) and performance (PEF) which are indicated in **Table 5**. The concepts that did not fit the recommended lowest level of .30 were excluded from the model (Hair *et al*., 2010). Finally, 25 items remained in the model after these steps. These models generated eigenvalues greater than one that explains 70.7% of the entire variance of the variables constructs. Furthermore, a group of descriptive goodness-of-fit indices was consulted to assess the model fit in the confirmatory models. The fit statistics in Table 5 displays a reasonably good fit for the model with $x^2/df = 1.954$, GFI =.972, CFI =998, NFI = .959, root mean square error of approximation (RMSEA) = .079.

Table 5. Structural model fit Indices

INDEX	VALUE ATTAINED	CUT-OFF VALUE
CHI^2/DF	1.954	<3
CFI	0.998	>0.9
NFI	0.959	>0.9
GFI	0.972	>0.9
RMSEA	0.079	<0.08

The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy (KMO=0.961), approximate Chi-Square (633.468), and the Bartlett test of sphericity ($p<0.001$) established that the analysis was suitable.

The results of the CFA in relation to the measurement models for the constructs of the six-factor model were evaluated for convergent validity. The convergent validity was evaluated through the average variance extracted (AVE and CR). In the first analysis, construct composite reliability is estimated centered on the criteria that the indicator's assessed pattern coefficient is significant on its fundamental factor by all constructs' composite reliability (Hayes, 2009). In the second analysis, the AVE for each construct to specify the quantity of variance in the item clarified through the construct and based on the criteria, measurement error should be greater than .05 (Fornell

and Larcker, 1981) indicate high convergent validity. Results of convergent validity testing showed that the model CR ranged between 0. 937 (TM) and 0.817 (RAC), and the AVE values ranged between 0.507 (RA) and 0.657 (TM). The results of CR and AVE established that all constructs indicators for the study had acceptable reliability. According to Alam (2011), the threshold of an alpha value of 0.6 is acceptable to indicate appropriate reliability. The convergent validity of all 25 study's constructs items loadings and composite reliabilities (CR) were higher than 0.7 (Su *et al*., (2013), Fornell & Larcker, (1981). Moreover, the AVE for each variable construct exceeded 0.50 showing satisfactory reliability (Table 6). In addition, results showed that all study dimensions produced good internal consistency where the Cronbach's alpha values are higher than 0.70.

The second step in data preparation in SEM is to test for discriminant validity. Discriminant validity signifies the degree to which indicators of different variable constructs differ from each other (Hayes, 2009). **Table 6** displays the result of the discriminant analyses; it is evident that the six constructs are different from each other. The findings suggest that fit indices meet the requirements for SEM analysis, even though the values for GFI and GFI do not exceed 0.9 (the threshold value).

Table 6. Discriminant validity

Construct	TP	TM	RAC	DE	RA	APF
AVE	0.558	0.657	0.582	0.653	0.507	0.623
NT	**1.000**					
KTM	0.321	**1.000**				
HRC	0.128	0.042	**1.000**			
TD	0.193	0.084	0.239	**1.000**		
TI	0.161	0.075	0.448	0.569	**1.000**	
APF	0.085	0.057	0.136	0.204	0.122	**1.000**
NT-New technology. **KTM**-knowledge Transfer Mechanism. **TD**-Technology Demand. **TI**- Technology Infrastructure. **APF**-Agribusiness Performance. **RAC**- Recipient Acquisition Capacity. **RA**-Resource Allocation. TM-Technology Management. DE-Demand environment						

Test of Hypothesis

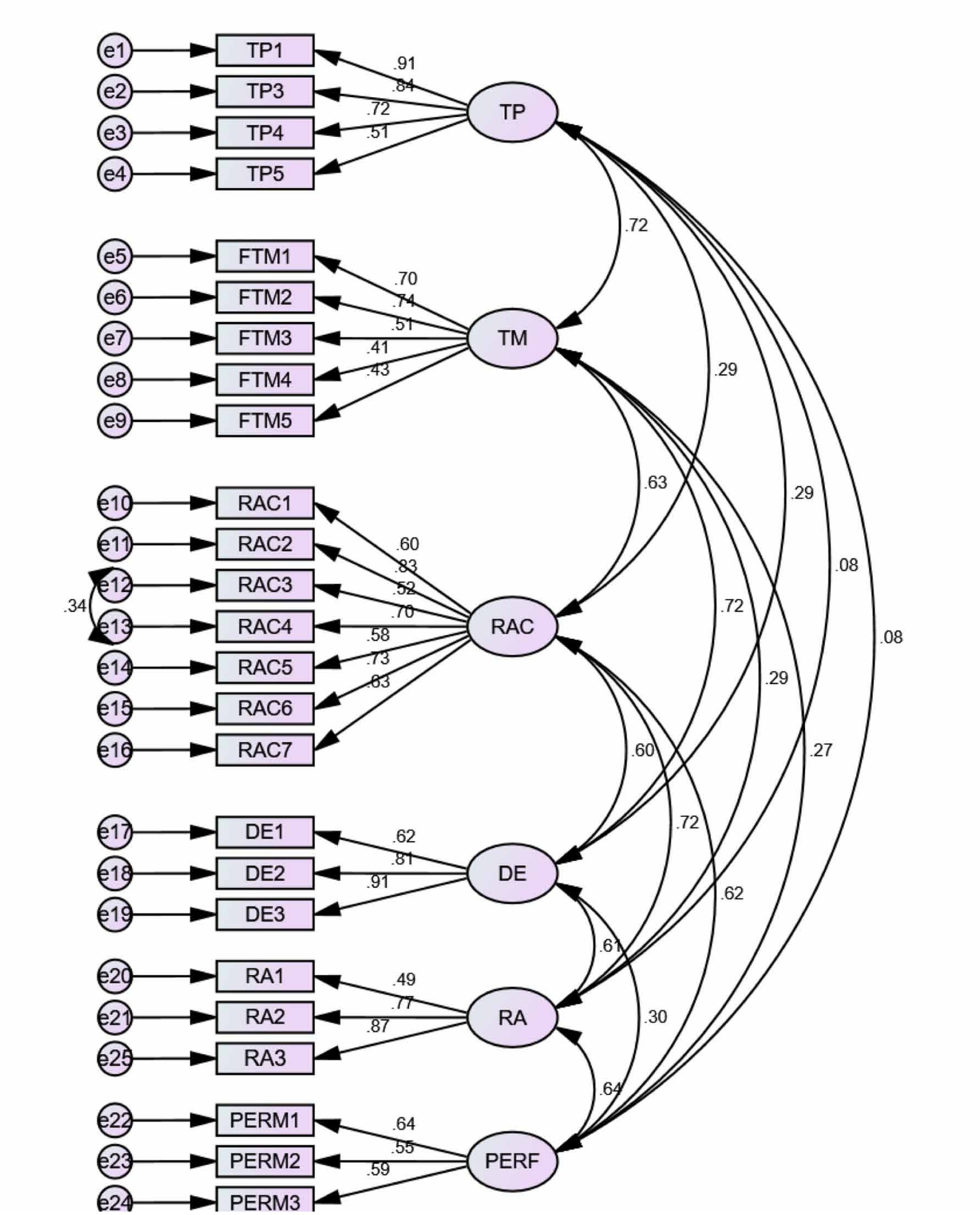
Since the overall fit indices of the SEM indicate a good fit, the structural relations and their path coefficients were analyzed. Path coefficients and standard estimates enabled hypothesis testing, as shown in Figure 4.

The hypothesis testing showed that technology providers had a positive effect on the effectiveness of TT and firm performance ($\beta = 0.586$, CR=7.707, $p = 0.00$). Thus, the first hypothesis (H_1) was accepted. Regarding the second hypothesis, it was found that technology transfer mechanisms ($\beta = 0.180$, CR=2.972, $p < 0.05$) had a positive influence on TT effectiveness. Thus, hypothesis two (H_2) was accepted, showing that technology providers and transfer mechanisms have a significant influence on the technology transfer effectiveness that has an impact on agribusiness performance. The capacity of the technology provider and proper transfer mechanism of technical information and training (on-site demonstration, workshop, and exhibitions) play a significant role in the implementation of the transferred technology.

The findings showed that the recipient's absorptive capacity (β=.363, CR=5.551, p=0.00) has a significant impact on the effectiveness of transfer technology, which supports the third hypothesis. In order for technology transfer to actually be effective and successful, the capabilities of the recipient organization, and the infrastructure of the wider local context are important. They both impact the degree to which technology can be transferred, further developed, and adapted to specific local needs and use. These outcomes indicated that the capacity of entrepreneurs influences the implementation of transferred technology and its impact on a firm's productivity.

Similarly, the findings showed that the technology demand environment (β=.174, CR=3.419, p=0.00) has a positive impact on technology transfer, thus, supporting the fourth hypothesis. These findings suggest that the learning abilities are influenced by the organization's environment, and the absorptive capacity is associated with the decision of resource distribution for the TT process. Furthermore, the results showed that resource availability in agribusiness enterprises (β=.502, $P<0.05$) plays a significant role in the TT process; thus, supporting hypothesis 5. This infers that agribusiness enterprises need to develop and acquire sufficient technical resources for the transferred technology. These resources refer to their technical capabilities, R&D skills, and advanced machinery. In order to capitalize on technology transfer, this study asserts that firms will need to possess appropriate resources in place first before acquiring new technological resources (Newbert, 2008).

Figure 4. structural equation model results



DISCUSSION

Technology transfer has been acknowledged as a technique to create a new invention and a driving force for economic development. In order to make technology transfer effective, the efforts of both provider and recipient's capacities are required. This paper assessed the impact of technology transfer and innovation on agribusiness performance in a developing country. The study employed an integrated effectiveness model of technology transfer that depicts the interaction of transfer dimensions such as transfer providers, recipient's capacity, demand environment, and resource availability.

Based on the first and second hypotheses, the results showed that TT has a significant impact on agribusiness performance. The transfer providers and effective transfer mechanisms indicated significant results that support H_1 and H_2. The results were similar to the empirical study conducted by (Günsel, 2015) on the effectiveness of TT on SMEs performance. The results showed a significant relationship between the TT mechanism and firm performance. This finding implies that managers of both the provider and recipients' organizations involved in technology transfer should collaborate to make sure that all relevant information on transferred technology is appropriate and available to the smallholder farmers. The results indicated that the main purpose of TT between providers and farmers is focused on improving yields and solving problems, the farmers need to comprehend the practicality of the transferred technology based on economic capability, alternative solutions available, and their previous experience. Scholars have recognized economic income disparities between agribusiness sectors as a measure of the digital divide when developing technology interventions in developing nations (Ahmed *et al*., 2015; Jagoda *et al.*, 2010; Lybbert & Sumner, 2010). From the analysis, a number of accompanying elements need to be in place in order to make the technology transfer project a success. These additional elements are not only provided through training from the industry to the recipients but additionally from entirely different actors. Thus, TT to agribusiness enterprises is distinct and more intricate in terms of the external institutions involved in the transfer process. Such planning allows for transfer methods different from what can be identified in this study (Szogs, 2010).

Regarding the third hypothesis, the results showed that the recipient's absorptive capacity (β=.502, $P<0.05$) has a positive influence on the effectiveness of TT that impacts on firm performance. If the recipient's absorptive capacity is high, there is a high probability of using technology to generate new products and services for business growth (Tsai and Wang, 2008). For effective TT implementation, recipients' capability development should be considered. Thus, the mere provision of equipment or operation instructions, designs, or patents will not guarantee the effective use of the technology without adequate capabilities available at the recipient's organization. Additionally, there are social aspects like inequitable distribution of resources, access to farming information, lack of cohesion in marketing approaches that affect smooth TT. Most of the developed countries such as Brazil, China, and India, have strong domestic research capacity in agribusiness, compared to developing countries, particularly in Africa, that have the weak technical capacity and limited resources. Thus, the rate of agribusiness growth and the flow of technology innovations in developing countries has diminished (Lybbert and Sumner, 2010). Consequently, the need for agricultural technology transfer has transformed agribusiness development through interventions that reduce these constraints.

Regarding the fourth and fifth hypothesis, the study findings indicated empirical support for a direct relationship between demand environment, resource availability, TT, and agribusiness performance; thus, supporting H_4 and H_5. Inadequate resource availability and environmental dynamics limit the implementation of the transferred technology. Extending policy application to technologies that influence enhanced food production is a significant government intervention for agribusiness growth and expansion (FAO, 2019). Resources requirements such as honey extraction machines, modern hives, fish pond management practices, and water for irrigation is a challenge for agribusiness enterprises. The challenges of inadequate resources can be addressed through concerted efforts of agricultural stakeholders to support effective TT solutions. Furthermore, places with inadequate irrigation water supplies need intervention strategies such as water conservation and harvesting techniques to enhance production. Farmers' resource availability to access related technologies limits their production capacity and, subsequently, food security. The provision of water resources for irrigation is vital to agribusinesses enterprises due to unpredictable climate change.

Technology transfer challenges that emanate from environmental conditions require continued attention due to globalization and the nature of competition. New technologies demand for sustained economic growth requires novel thinking and further innovation for sustainable food security.

SOLUTION AND RECOMMENDATIONS

The study's theoretical implication advances the literature in TT research centered on the perspectives of agricultural businesses in developing countries. In practical terms, this study found that although TT brings many benefits to agribusiness through various applications, its implementation in the countryside is a challenge that limits business growth. Thus, government policy and support programs should facilitate TT in terms of infrastructure and resources to boost economic development and food security, by the use of emerging technologies on the dietary supplements (such as biofortification) to integrate most nutrients into a single food package to increase affordability, and monitoring seasonal climate changes to improve yield through crop varieties and labor-intensive technology.

Furthermore, government policy should endeavor to facilitate different forms of technical skills and financial incentives for SMEs. This could be linked to issues of training and facilitating the process of TT as a prerequisite for access to funding and further capabilities. In addition, the linkage between the research institutions and SMEs should be strengthened. Thus, the need for continuous interactions that entail interactive, mutual learning processes, with feedbacks that also flow back from the end-user to the provider, needs to be further advanced. Policymakers should incorporate technology diffusion strategies that deal with climate change among agribusiness enterprises (Lybbert & Sumner, 2010).

FUTURE RESEARCH DIRECTIONS

This paper had limitations that create an avenue for future study. The study used semi-structured questionnaires as a data collection instrument, which has a limitation on the construct validity (Avolio *et al.*, 1991). The questionnaire gathered information from the manager and staff who work for the firm; nonetheless, technology and agribusiness performance changes over time. Additionally, the paper did not cover other interactive factors that relate to employees' and entrepreneur's characteristics and attitudes that influence TT. Future research can benefit from applying a longitudinal survey to capture the impact and relationships between TT, recipient's capacity, and firm performance. Using this research design would produce validated results. Similarly, undertaking a comparative study with agribusinesses in urban areas would give more insight into the comparison between SMEs operating in a different location but with some common features in Kenya.

CONCLUSION

This study analyzed the impact of TT and innovation on agribusiness performance in developing countries. The goal of technology transfer in agribusiness enterprises is to develop the technological capabilities of entrepreneurs and to meet the country's food security objectives. The study findings revealed a positive relationship between TT and performance agribusiness enterprises. Furthermore, the transfer providers and recipient's absorptive capacity influenced the effectiveness of TT that has an impact on agribusiness performance. However, the resource availability and demand environment limit the TT to rural agribusiness enterprises. Thus, government policy on technology transfer should focus on creating an enabling environment that promotes TT and economic strategies that narrow the technology gap. The results of the present study are significant for agribusiness enterprises, education practitioners, and policymakers in identifying appropriate TT mechanisms that promote agribusiness capacity and sustainable agricultural sector.

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Chapter 12
Design of a Digital Kissan Hub Prototype for Farmer Produce Organizations to Empower Agribusiness

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ABSTRACT

The agriculture sector in India has witnessed significant improvements in the adoption of modern technologies and mechanization to enhance crop yield levels in recent decades. The farmers require timely marketing of their produce to improve their liquidity for meeting their expenses. The lack of digitization and dominance of middlemen, poor market support, lack of knowledge, and inability to store their produce for better prices are core issues to be addressed for the economic prosperity of farmers. Today only 27% consumer price value reaches farmers making agriculture a non-viable activity; hence, farmers are becoming poor, bankrupt, and committing suicide. The real fact is that Indian farmers are poor, but agribusiness is very prosperous. Implementing modern agricultural practices, legal farmer produce organizations (FPO), digital kissan hub (DKH) would promote agriculture and agribusiness. This chapter reviewed the digitization in agribusiness and designed a prototype of a digital hub to empower FPO and to enhance farmers income and ensure food security of the nation.

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INTRODUCTION

The agribusiness sector covers the need for agriculture inputs and a diverse range of activities such as crop management, harvesting, food processing, grading, packing, transportation, marketing, and final delivery to consumers. This sector is the most interdisciplinary field covering modern agriculture practices, government subsidies, financial grants, latest technologies, and tools. Agribusiness encompasses half of the global labor force, real estate property, and 40% of consumption. A group of businesses such as food processing, financial planning, lending, insurance, commodity trading, and natural resource management is directly linked to agribusiness.

The growth of agribusiness in India depends on current national policies, socioeconomic status, food security policies, commerce, nourishment, protection of the environment, and intellectual property laws. Inefficient commercialization, ineffective sales force, lack of networking facilities are the root causes for lower and unsteady selling prices of agricultural produce. The farmers in India are highly dependent on intermediate agents for selling perishable goods such as flowers, fruits, and vegetables. Both the farmers and consumers are losing money, whereas the intermediate agents are earning a lot of money and controlling the sales without adding any value to the produce. The farmers are becoming poorer day by day. More than three lakh farmers have committed suicide since 1995 and farmers are suffering in many parts of the country. The adoption of digital and modern technologies is expected to bring many benefits to farmers. Some of the benefits are increased crop yield, enhanced profitability, reduced environmental footprint and access to new markets without heavy investments. Application of digital technology facilitates quick responsive chains, dynamic product pricing, innovative credit management services and better environmental compliance. The above-anticipated advantages call for the urgent need for promoting digitization in agriculture and agribusiness. Researchers have proposed an action plan to establish Digital Kissan Hub to promote digitization in agriculture and agribusiness sectors.

BACKGROUND

The Current State of Agricultural Land and Crop Productivity in India

India has 140 million hectors of agricultural land area and stands in second place, whereas the US is in the first place. The crop yield in India is significantly lower at 1.3 yields/ha only, while the US is producing 40 yields/ha. India's total agriculture produce feeds only 17 percent of the global population. Today Indian farmers are much dependent on human labor, using less machinery and the majority are owning less than five acres of land. The wastelands account for 13 million hectors in India. The states such as Madhya Pradesh, Rajasthan and Gujarat have about 50% wastelands. If these wastelands are cultivated, then food productivity increases significantly, giving more job opportunities and also enhances agricultural exports. India is loosing 500 billion rupees worth agricultural produce year after year, for not having an efficient post-harvest supply chain and warehouse infrastructure.

Opportunities and Threats for Indian Agribusiness

India has the largest arable land; if cultivated efficiently, it can assure food security for the entire world. The Indian food industry has immense potential to promote food production, value addition to contributing to the world food business. Milk, tea, fruits, and vegetable production in India is the highest in the world. India is in the second position for sugar production. India is in the sixth position for world grocery market share and retail grocery sales are at 70 percent of total business value. Thirty-two (32) percent of the food market in India is captured by the food processing sector. The Indian agriculture sector development is at least 28 years behind its times as per NITI Aayog reports. The real challenge today is bridging this gap in the agriculture and agribusiness sectors.

REVIEW OF RECENT LITERATURE

The authors have conducted a survey of literature on the agribusiness industry across the world and curated papers from high impact factor research journals from IEEE, Elsevier, and Springer publications. This survey has revealed the difficulties faced by the agribusiness sector. The authors have presented some of the facts from these papers by way of illustration.

Tun et al. (2018) found that successful implementation of any innovative technology depends on the customer's attitude, value addition, and ease of operations. Authors have surveyed the emerging technologies in agribusiness and their impact on a farmer's life in the Taiwan region. This survey discovered that farmers in northern Taiwan are taking advantage of mobile apps in agribusiness than the Southern Taiwan region. The agribusiness portal was developed for selling organic fertilizers. This portal facilitates registration of farmer's data and stores all purchase details. This portal enables the farmers to place an online order and tracks all the fertilizer purchases, and also the profit earned. Farmers can save time and cost by using this portal (Bukhori et al., 2017). A study on the use of Enterprise Resource Planning (ERP) for food production in Brazil was carried out (Sara et al., 2019). This study revealed the enhanced production capacity of farmers. This ERP implementation increased efficiency and reduced costs of production, transportation, and sales. The online data analysis of agribusiness operations enhanced the production and profit levels of farmers.

Supply chain management plays an important role in agribusiness. The criteria to select the right supplier is based on weighted parameters such as professionalism, performance history, competent price, meeting delivery schedules, service quality, proximity, response time, warranty, and supplier guarantee policies. This survival and dynamic strategy parameters adopted are selecting multiple suppliers for each commodity, storage, and backup facilities to make up for the delivery delays or fluctuations in prices, strategies to mitigate the competition, market conditions. This strategy has additional cost overload for the business, but it helps to maintain the business growth, the market share, customer satisfaction and profits even in unfavorable conditions (Lu et al., 2018). Chen et al. (2018) have studied the farmer's performance in safe pig farming. This study covered 540 pig farmers registered with 27 pig farming cooperatives in China. The authors analyzed the effect of cooperative services on farmer's safe pig farming practices. The results revealed that the quality of services rendered, production scale, and education level of the farmers have a more positive impact on the pig's safe farming. The farmers are borrowing loans from banks. The farmer generally does not have good financial management knowledge.

Bankers will influence the farmer's financial management plans. The bankers always try for the safe recovery of their loans, so the banker's advice to the farmer on financial management plans would be biased. The farmers should approach an expert financial management consultant to carry out their successful agribusiness. Farmers update themselves with information regarding product demand-supply, market conditions, and prices. This knowledge would help them to select the best crop or farm activity and invest wisely (Aniek et al., 2018).

Haberli et al. (2019) have surveyed innovative techniques and support systems adopted by Chilean fruit farmers. This survey has discovered that some progressive farmers are regularly exploring and applying the latest technologies, researched techniques, availing government facilities, adapting to changing social, market, demands, environmental, and commercial conditions. A case study to understand the Italian shopper's behavior for promoting agribusiness named Customer Company Territory Interaction Satisfaction (CCTIS) was carried out. The objective of this study was to identify methods for increasing the revenues for farmers and suppliers and to enhancing the level of the shopper's satisfaction (Fabio et al., 2012). Gabriela et al. (2019) discussed agribusiness project Agropuzzle II under LLP Leonardo da Vinci Program. This project aims at developing, updating the skills and competency levels of farmers involved in sustainable agriculture. This project imparted the knowledge to all the partners in the agriculture domain to empower them. Henry et al. (2015) conducted a case study to promote the tea farmer's products by tea farmers cooperative using Analytical Network Process (ANP). The objective of this study was to analyze the factors influencing the operations of tea farmers cooperative for promoting tea business. The results revealed that collaborations with affiliated institutions and markets have a profound impact on the tea business. This study has suggested that the policies of tea cooperatives should be designed to empower the small tea farmers to access, compete in domestic and international markets.

Jim et al. (2019) have foreseen the problems that might be faced by the farmers soon. The authors also suggested innovative and efficient solutions to overcome these problems. There is a need for increased public funding for agricultural research. This paper also identified the technology-based solutions to increase the revenues for farmers and agribusiness. The world's largest agribusinesses companies such as Corteva Agriscience and the legacy companies of DuPont, Dow Agrisciences, and Pioneer HiBred have been merged and their impact on rural populations needs to be assessed. These company mergers would bring about innovation and expected to play a significant role in solving the problems of the agriculture industry and promote small farmer contributions.

Bibhu et al. (2014) discussed the implementation of the Indian government scheme "Strengthening/ Promoting Agricultural Information Systems during the Tenth Plan". This scheme has a budget of 100 crore rupees which was dedicated to strengthening the information technology infrastructure in agriculture. The funds are to be utilized for developing Agricultural Resources Information Systems (AgRIS) and Kissan Call Centres in states and union territories, head, and regional offices. The funds are used for the development of four portals and 40 websites describing the activities of both head-office and all other sub-offices governed by this scheme. Bibhu et al. (2015) have highlighted the significance of ICT in promoting the retail business of agricultural produce in the Indian markets. The authors have presented some successful agricultural business case studies driven by ICT.

The farmers can visit relevant web portals to acquire knowledge on agricultural input resources, advanced crop planning, monitoring, and harvesting techniques. Agribusiness web portals also present information about demand predictions, marketing resources, financial management, and investors' requirements for promoting FPO and agribusiness products. Governments have established ICT based channels such as mobile apps, radio stations, call centers to provide instant expert advice to farmer's specific questions. The data on-farm management practices were collected from the prefecture of the Rodopi region of Thrace/Northeastern Greece from September to December in the year 2011. This data covered 120 livestock farmers from various age groups through a well-designed questionnaire. This collected data was analyzed for identifying the common behavioral and thinking patterns among the farmers. Farmers with similar behavioral patterns are grouped into clusters. This clustered formation revealed that 54% of the farmers are showing interest in consulting and adopting ICT for their day to day farming activities (Zacharia et al., 2014)

Deepthi et al. (2017) have carried out a study on applications of expert system software for diagnosing agricultural crop diseases. Some of the expert systems studied by the authors are Citex: expert system applied for production of Orange fruits crop. Amrapalika is an expert system for discovering diseases, insects and disorders in Indian mango fruits. POMME is an expert system for monitoring diseases in apple plants. Tomatex is an expert system useful for tomato growers. AgPest for pest analysis and management of insect diseases. Agricultural Expert System (AES) is an expert system providing various services such as price updates, demand fluctuations, crop yield trends, measures to prevent the attacks of insects and weather forecasting.

A study on the agribusiness companies' attempts to promote their business online was conducted. The correlations between the online world attempt to promote business and the attributes of management were considered. This study has collected the data from forty-five wine producers was analyzed considering three assorted attributes of the company's online activities. The outcome of this study revealed that companies with a smaller size, limited turnover in business and led by highly educated young managers are more engaged impressively in the online world. The bigger company's presence in the online world is a moderate level. This outcome of the study has both hypothetical and applied value in business and management domains (Antonino et al., 2017). Yun et al. (2016) reviewed seven successful agricultural information systems in China. Authors discovered that ICT played a significant role in the transformation of traditional agriculture into advanced digital technology-based agriculture with enhanced social and economic advantages.

These ICT based systems have imparted digital skills to farmers for accessing every useful information from the internet. Authors suggested the implementation of IoT, precision agriculture, hygienic food, big data, cloud technologies as the need of the hour for promoting agriculture and agribusiness. The authors highlighted the role of ICT in precision agriculture for effective crop planning and monitoring to enhance the crop yield by reducing the operational costs. IoT technology implementation in agribusiness would seamlessly connect farmers with markets and consumers. Agricultural information systems should be interconnected with all the stakeholders for the benefit of the food security chain (Bilali et al., 2018). Sreekantha et al. (2017) studied the applications of IoT for online monitoring of crops by the farmers using smart-phones.

This paper has discussed the various protocols and technologies applied associated with IoT to facilitate effective crop monitoring. Hofackera et al. (2018) discovered that customers are using social networks to interact with suppliers to express their opinion, log complaints and to share the experience about products, services. The extensive usage of social networks by consumers also promotes a business opportunity. Marketing managers should analyze online consumer behavior to understand consumer's problems and promote online business. This paper presented eight tips for social network marketing professionals to focus upon. The authors also presented the problems and opportunities arising from ever-changing customer behavior and business models. Szczecin et al. (2016) discussed the new ICT policy for promoting precision agriculture launched by the government. This ICT policy enhances the exchange of data and information on-line in the digital world. The government is focusing on establishing standard protocols for the data exchange. Intellectual property rights and patent filings are also promoted by the collaboration of researchers, producers, and industry. The need for the development of a digital technology hub was also discussed. Agro-medical food production is an upcoming trend for value addition to the food chain and lifestyle.

A survey on the applications of Unmanned Arial Vehicle (UAV), also known as drones in agriculture, was carried out. Drones are applied in precision forming for real-time crop monitoring and gathering important data about soil fertility, crop conditions, pests activity and disease status. Drones are ideal for the activities that are too cloudy, dirty or hazardous for human operations. The data collected from these drones can be used for many applications such as water, crop monitoring, wild animal detection, pests management and seepage detection in the irrigation systems (Sreekantha et al., 2018). Sundar et al. (2016) represented agribusiness as a group of an integrated and interconnected chain of business processes executed from the agriculture field to consumers. Agribusiness is a major source of jobs and income across the globe. The authors discussed the scope of agribusiness opportunities and threats in India. This paper presented about fifty business ventures, constraints, and challenges for doing agribusiness in India. Authors suggested tips for attracting foreign investments in the agribusiness, cultivating waste and barren lands, adoption of mechanization, and advanced technologies in agriculture. The exploration of new markets, buyback guarantees for crop produce, cooperative farming, large scale production and quality are the points covered in this paper. A survey on the growth of automation and mechanization in agriculture was carried out. Authors discovered that America and Europe are ahead in the mechanization of agriculture, followed by Japan. In India, Haryana and Punjab states are using the highest agriculture machinery, while there is very little use of machinery in north-eastern states. The size of the agriculture equipment market is about US$ 6.5 billion and has recently witnessed significant growth. The crop yield can be enhanced by 30 percent, and the cost of input operations can be reduced by 20 percent by adopting automation in agriculture (Sreekantha et al., 2016).

Abdul et al. (2011) presented the scope for agribusiness in India. About 69% of Indians depend on the rural economy for their living. The majority of the rural people are earning only US$ 175 per-capita when compared to national per-capita income is US$ 480. India's agriculture production is second in the world but the crop yield/ha is very less. The volume of wastage of fruits and vegetables is more than the consumption in the UK. The total agricultural produce waste is about $6.7 billion.

The prospects for agribusiness are high in India but at present, agribusiness is not effectively exploited because of the lack of factors such as efficient food processing industry, backward and forward linkages, poor marketing network, cold storage facilities, supply chain, and cost-effective transportation systems.

An expert system prototype for diagnosis of paddy crop diseases was designed. Authors have interacted with agricultural experts, scientists to gather knowledge and also analyzed the real data from their field study. This expert system prototype was implemented using Matlab Fuzzy logic toolbox. The results obtained from this expert system prototype were satisfactory (Deepthi et al., 2017; Sreekantha, 2019). Raja et al. (2013) reviewed successful promotion strategies for agribusiness products from rural farmers, planters, and low-income groups of producers. Authors described innovative policies, practices and procedures for a sustainable governance model for global agribusiness institutions.

The Greek agriculture sector is family driven. These families are an integral part of agriculture holdings and form the foundation for all social and economic development. These families are the suppliers for agro-based food manufacturing units and contributing to the growth of the food manufacturing industry. The Greek food industry is having surplus local suppliers but only a few national and international big brand companies. All these family-based holdings are supplying to the local market only, so there is excess supply. Naturally, the prices would drop and farmers would make a profit. These family holdings are also not grading, not doing good packing or adding value for their products to increase the shelf life of the product to reach remote markets. Farmers are not making good profits. Authors discovered that unfair local competition in the local Greek market is the main cause of the loss of farmer's income (Apostolos et al., 2015).

Robert et al. (2019) presented FinTech, an ICT based solution for financial services to small and medium scale businesses in Saharan Africa region. FinTech was integrated with many agriculture-based digital services such as digital crop insurance, digital marketplaces, etc. These digital services are accessible to farmers and Sustainable Development Groups (SDG) through smart-phones. The authors presented a case study on Digital Green Loop services offered to Indian farmers by linking them to regional business houses and transport companies to sell their produce to the right companies. This service would enable farmers to sell for the best prices and also helps to reduce the costs and time to reach consumers. Hello, Tractor is yet another app that facilitates farmers to avail of smart tractor rental services or even purchase of new tractors online. The emerging technologies such as AI, IoT, big data analytics, data science, mobile apps are applied in the design of the digital ecosystem to empower farmers. Digital ecosystems leverage innovation in agribusiness. In today's constantly changing business environment, the markets, costs, benefits, scalability challenges are required to be redefined. In developing economies, the agribusiness should have inclusive growth of technologies, innovations, and emerging challenges for sustainable development. The private sector should also play a significant role in the rapid growth of agribusiness. AI, Machine learning, and IoT based mobile app services provide personalized expert agronomic advice to farmers in real-time.

Divya et al. (2015) discussed mKRISHI company's collaboration with fish farmers, government authorities and other stakeholders in the agribusiness domain to develop a digital solution called mKRISHI® -AQUA service for fish farming.

This tool helps the farmers to continuously monitor the conditions of the fish farm by collecting the data about the dissolved oxygen levels, feed consumption trends, chemical use, habitat, effluent management, and diseases. This data is used to predict fish farm growth, potential risks and estimated fish yield. This software presents a visual representation of all parameters of a fish farm. These visual output patterns enable farmers for faster decision making. At the outset, this tool helps the farmer for better planning and management of a fish farm.

This paper discusses establishing a single HUB between Lazio (Guidonia-CAR) and Abruzzo (Pescara-Agribusiness) in A24-A25 great communication route motorway in Italy. The driving factors for the successful implementation of the macroeconomic model are partnerships among the public and private entities, territorial marketing activities. About forty-three companies joined together by the fifth year of the Polo agribusiness. The local economy is driving the value of investments and turnover (GDP) every year. The implementation of Polo agribusiness of Borgorose is creating employment year after year in Italy (Maurizio et al., 2016). Dariusz et al. (2015) reviewed the development of electronic commerce in agribusiness in Poland's agricultural market. Authors discovered that the adoption of electronic commerce in Polish agribusiness is increasing. This paper also discussed some Polish agribusiness e-commerce applications. Poland witnessed more B2B e-commerce development in agribusiness. Traditional agri-food chain companies leveraged to e-commerce solutions to enhance their market position. The cyber mediators are trying to take the benefit of divided the Polish agricultural market.

An analysis of the share of agribusiness and its aggregates in the Chinese national economic growth during the years from 2000 to 2014 was carried out. Authors have taken National Input-Output Tables (NIOT) data and found that the contribution of agribusiness share in Gross Domestic Product (GDP), global output and employment market is reducing due to a reduced share of agriculture sector itself. The food industry needs the greatest attention to the growth of global agribusiness. This study has identified that the GDP of the agribusiness had the highest share in global output. During this study period, China has experienced the highest economic growth that led to considerable changes in the agribusiness. Authors have observed that agricultural labor was quickly migrating to other industries (Aldona et al., 2019).

Bruna et al. (2018) discovered that many laws are simply "unenforceable" in Brazil. This paper explored how incentives contribute to the enforcement of formal rules. The land use and conservation law and agro-chemicals law are curated for this study. These laws are dealing with the storage and return of containers. Five propositions were developed for this study related to the incentives for the enforcement of formal rules, namely: the alignment of the formal rule with the social norms, the influence of private interest; the influence of the state's interest; monitoring costs; and adoption costs to formal norms. The authors applied the multiple case study method, consider the analyses of descriptive statistics. It is worth noting that a cut-out was made about the crops and regions selected. These results supported four of the five propositions of this study. The exception was due to the effect of cost to adopt the rule. It was concluded that rules addressing assets of common ownership are characterized by a more complex enforcement mechanism since it does not involve only pure economic issues.

The authors attempted to identify the core agricultural information needs of farmers in the central Punjab region of Pakistan. A simple image-based, touch application with minimal text was developed. This application delivers information about weather, pesticides and fertilizer information to farmers. This experiment indicated that mobile apps are viable options to deliver agro-information. The authors also presented a KIOSK application that delivers real-time and credible information to the farmers of central Punjab. These apps should be managed by a trustworthy group or an organization, then only farmers adopt and perceive its value in the long term. (Syed et al., 2016). Andreas et al. (2017) expressed that knowledge-based bio-economy and digitalization are two promising approaches for the prosperity of agribusiness. This prosperity demands an active contribution from all stakeholders. Authors stressed the need for innovation, robotics, and artificial intelligence applications. The knowledge-based digital bio-economy is likely to generate the emergence of new sectors with new employment opportunities.

E-NAM: Electronic National Agriculture Market - An ICT Innovation

E-NAM is an innovative ICT platform for agricultural produce marketing. Govt. of India launched the E-NAM portal in April 2016. About 45.4 lakh farmers and 451 Mandies have registered in this portal. The vision of E-NAM was to integrate and interconnect the farmers, buyers, and sellers to all national markets.

The information about marketing, demand, and transportation of agriculture products are made available online to all stakeholders through national ICT infrastructure. The state of Karnataka has also implemented innovative online marketing practices to enhance the competition in agricultural marketing. The National Institute for Agricultural Marketing (NIAM) has designed a plan for capacity building for different stakeholders of E-NAM such as farmers, traders, Agricultural Products Marketing Committee (APMC) secretaries, and directors. The efficient functioning of agriculture marketing enables fair price discovery, dynamic supply chain, and scaling up in the business value chain.

International Status of Digital Marketing in Agriculture

The ever-growing population, dynamic appetite patterns, and increasing demand for food security are driving factors for agriculture development. The agriculture sector is providing jobs and livelihoods for 65% of poor people working in agriculture. The food and agribusiness is a five trillion US$ industry representing ten percent of world consumer expenses. SME's are providing the biggest employment opportunities across the world. Countries such as China and Africa have adopted ICT in its nationwide vegetable market transforming them into e-market centers. These e-marketplaces enable users to easily access online information through mobile phones. The ICT based projects launched in rural agriculture in Brazil have leveraged about 1,30,000 farmers to access national as well as global markets during the years 2010 to 2016. The credit facilities extended to farmers, exporters, and food processing industries helped them to promote their products to global markets in Cambodia, Uzbekistan, and Vietnam between 2008 and 2014. Only less than 1.5% of students are opting for agriculture as a career in Australia and the USA. Agribusiness is the second-largest wealth-creating industry in the Australian economy, as stated by the Agribusiness Council of Australia. The agribusiness sector is one of the biggest and highly interdisciplinary domains in the US.

Research Gaps Identified and Findings From the Literature Survey

Authors have reviewed about 35 papers from high impact journals and presented the literature review. Researchers have also refereed much literature on websites related to agribusiness across the world to update the status of agribusiness and tools for carrying out agribusiness. Authors discovered that there are many IT-based tools and apps for agriculture and agribusiness, but all these apps and software tools are from independent vendors serving different purposes, not interoperable and integrated. These tools are to be used by individual farmers alone, not as Farmer Producer Organization. The E-Nam platform launched by Govt. India is also good, but it is designed to be used by the Agriculture Produce Market Committee. The implementation of this E-NAM is not very successful because of the various problems implementation. So the authors proposed to develop a fully integrated end to end Digital Kissan Hub Platform solution to serve all the requirements of both farmers and FPO. This Digital Kissan Hub Platform would be established in the Private and Public Partnership model. All the farmers and all the stakeholders of agribusiness will be shareholders of this model. These stakeholders cooperate and promote agribusiness successfully.

DESIGN DIGITAL KISSAN HUB PROTOTYPE

What is Digital Kissan Hub (DKH)

DKH is a digital platform for connecting consumers, farmers, and food processing industries to local, national, and world food markets for leveraging agribusiness. The DKH enables seamless sharing of knowledge, information, and carry out business transactions across the world to leverage the delivery of agriculture produce from surplus to deficit regions of the world. The above facts call for the development of an efficient, cost-effective DKH to enable the farmers to earn the best prices for their produce.

Digital Kissan Hub - Key Objectives

The objective of the proposed DKH is to provide a platform for buyers, sellers, input providers, insurers, lenders, data providers, and professionals of agribusiness for closer interaction and carry out business transactions using digital technologies. DKH intends to support the *DiReCT* model, which stands for *Di*scover, *Re*ach, *C*onnect, and *T*rade to achieve the following objectives during the first phase of implementation and beyond.

1. Auto-discovery of supply and demand for agricultural commodities such as cereals, fruits, vegetables, oil and seeds, spices, dry fruits, forest products and flowers, etc.
2. Registration and on-boarding of FPOs and their produce on the algorithm-driven platform
3. Connecting large institutional buyers to FPOs
4. Connecting small and medium, local and remote retailers to FPOs
5. The ability for fertilizer manufactures and retailers to reach FPOs and offer competitive prices for their inputs
6. Connecting farmers, FPOs to lenders, banks and financial institutions
7. Local language support for all dashboard functions
8. Direct connect to GST and provide business insights for better financial health
9. Directly connect to accounting software for seamless integration and updates to books of accounts

Digital Kissan Hub - Need of the Hour

Many projects and agencies have tried to support or create an ecosystem to overcome some of the hindrances for the development of FPOs and the implementation of digital technologies for sustainable agribusiness. However, the adoption of technologies have not been very effective across all FPOs/ Farmers due to following reasons:

1. The adoption of technology needs awareness, scale, expert mentoring, and reach. Establishing a DKH proposed would help with spreading awareness and reach as many FPOs.
2. The technology chosen should ensure that its usage is simple and experiential. Many technologies have seen limited adoption due to its complexity and the number of steps needed for a farmer or FPOs to connect or to reach potential buyers or to know where the demand exists and chose the corresponding buyers
3. Making the process simple and providing the needed contextual information is essential to ensure FPOs are not overwhelmed with data and complexity
4. Local language support is necessary to ensure adoption among the local FPOs.

Based on the above facts, researchers propose to set up an independent DKH for empowering FPOs jointly with Nitte (Deemed to be University) and the National Institute of Agricultural Marketing (NIAM). a govt. of India undertaking. This center will empower Farmer Produce Organizations, Agribusinesses, Government and Non-Government agencies working together with a large number of smallholder farmers as members to make better-informed decisions and improve overall operational efficiency by implementing digital technologies. The key differentiator of this center would be to choose the right technology, built with simplicity in mind and addresses the key challenges outlined above. Also, the center would start by initiating and ensuring technology adoption to solve critical use-cases, as suggested by the FPOs.

Scope and Benefits of Digital Kissan Hub

Today attracting youth to words agriculture, promoting agriculture as a viable activity, and enhancing farmer's income, efficient use of wastelands are very crucial. The above facts can be realized by establishing strong and systematic marketing channels to empower farmers to earn the best possible prices for their commodities. The stakeholders of agribusiness are agricultural producers, wholesalers and food manufacturers, subsidiary services, fertilizers, and chemical companies, agricultural equipment companies, and the research community. This DKH enables all these stakeholders of agribusiness to buy, sell, and transact online. The farmers would get information on agricultural inputs, market, demand, price updates, messaging services, information on seeds, pesticides, and fertilizers through mobile apps.

Farmers would visit agriculture-based portals to get complete information updates for products and services such as fertilizers, transportation, cold storage, loans, subsidies, warehouse, price updates, food processing, grading, packaging, etc. Social media networks have also penetrated rural India, where farmers are using digital services through their smart-phones.

Today agribusiness visibility on social networks media is also vital since farmers and agriculture allied business stakeholders spend their quality time online. Understanding agricultural products, consumer's smart-phone usage patterns, and their willingness to utilize smart-phone to browse dynamic content is very important. The creativity and quality of the content will determine to what extent consumers are engaged and interested. Nowadays, the content shared with consumers is very important for the success of digital marketing for agribusiness. Reaching and engaging the consumers by penetrating customer's space through effective content delivery is vital for agribusiness. The farmers shall register with FPO and avail DKH services to enhance crop yield, profit and decrease the use of artificial fertilizers and chemicals to enter into new market places and adopt more mechanization.

Insights Into Digital Kissan Hub Features

The DKH manages all the big data about FPO operations and performs automated, semi-automated functions and delivers actionable information to leverage timely decision making. The user-friendly dashboard features facilitate data analytics for small farmers to empower them with the right knowledge inputs. The DKH promotes farming as an exciting option for young people to perceive agriculture as agribusiness, a paradigm shift in approach. Modern agriculture is empowered with integrated technologies such as AI, IoT, cloud, and big data management, etc., to the delivery latest information to the right person, at the right time to make the right decisions leading to enhanced profits for the farming community. The implementation of digital tools today is cost-effective and hence affordable. The dynamic crop view information from satellite maps, online customized weather forecasting, drone surveying, IoT, and WSN services are driving real-time and remote crop yield management. Embedded devices interlinked with cloud platforms provide web-based services to monitor crop growth and alert deviations from normal growth in real-time. Many start-up companies are providing services on precision farming.

FARMER PRODUCER ORGANIZATION (FPO)

The Proposed Framework for Farmers Allied Activates

The farmers should be involved in multiple allied activates apart from primary farming to have enhanced and sustained income levels and also to compensate for losses incurred in one or other activities. The information about a complete list of possible farming and allied activities required to be registered with FPO are shown in Figure 1. from top left to right are

1. Profile of farmers personal and family details
2. Fertilizers and pesticides being used and required
3. The information about the memberships in farmer groups and associations
4. Information about membership in cooperatives and corporations
5. The land and other assets details
6. Farming equipment and transport vehicles owned by the farmers, and their utilization information
7. Poultry, egg, ducks, fish and any other birds farming activities being carried out
8. Details about dairy farming activities
9. Details about the goat and pig farming
10. Honey, tissue, vermin and sericulture and bio-fertilizers activities
11. Banking accounts details
12. The soil profile of the farmer's lands
13. Crop growing patterns and profile
14. About vegetables, fruits and cereals information
15. Information about the address, contact nos, social networks, and groups

Figure 1. Farming and allied activity details

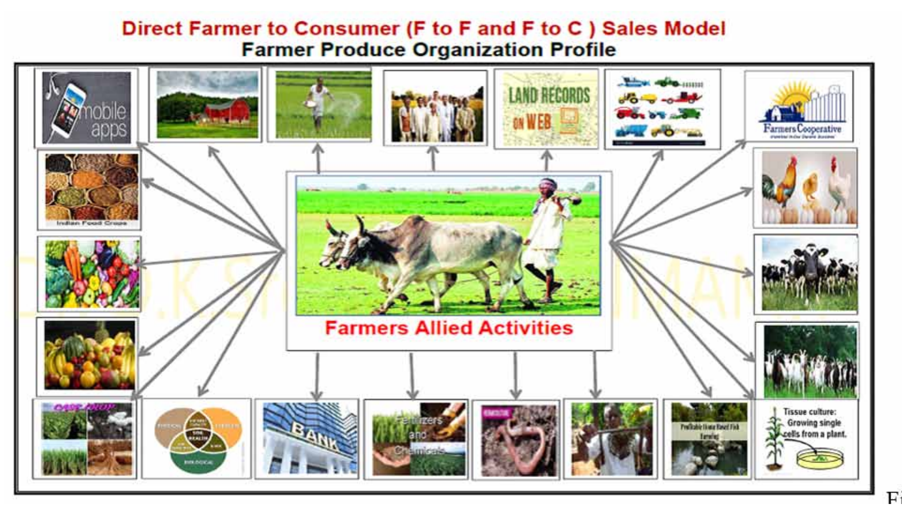
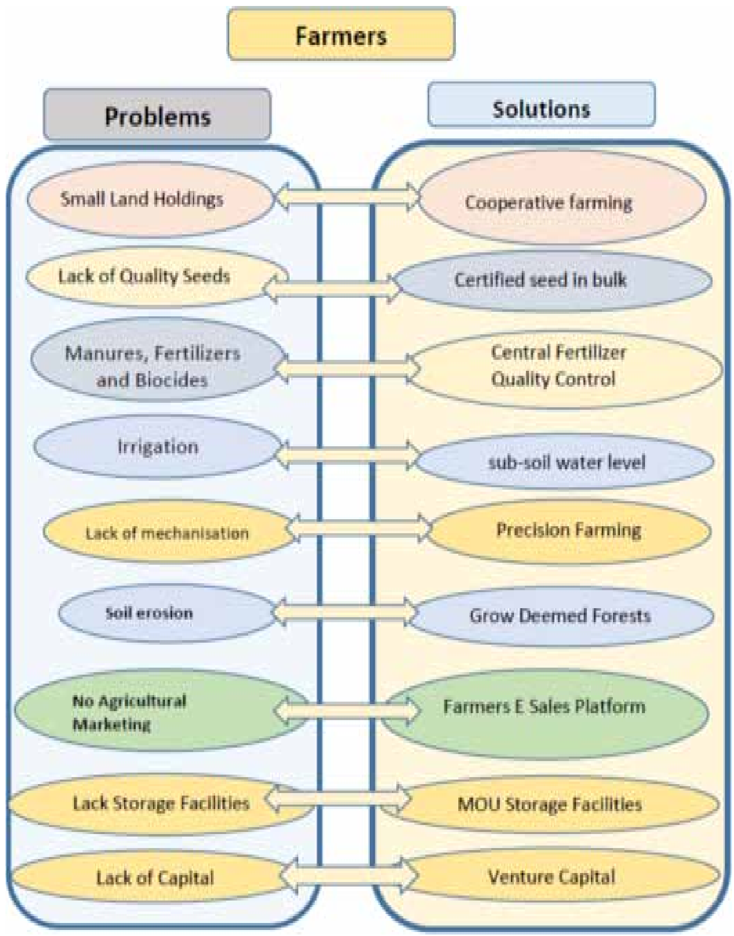


Figure 2. Farmers Problems and solutions



The farmers should register with an (FPO) by giving all the above information in details and procure his membership id. The majority of farmers in India have less than 5 acres of land and they cannot afford to have big machines and invest in precision farming. They depend on human labor and they do not access to know the latest technologies and facilities. The problems faced by small farmers and possible solutions are shown in Figure 2. Small farmers can form a group and carry out cooperative farming to meet the solutions suggested.

The Present State of Farmer Producer Organization (FPO)

FPOs are promoted through various Central Government schemes operated in the states. The filed visits confirm that farmers are reaping the benefits of FPOs. The state of Karnataka has about 230 registered FPOs. All the FPO stakeholders need to be trained on team building, communication skills, managing the workers, handling digital transactions, financial and accounting management. Imparting these skills to farmer members of FPO through training from experts is essential. This training would enable the farmers to optimize all their resources to sustain competition and reinvent themselves in the digital world. Only a handful of FPO are successful, and many others face challenges for their sustainability.

Important Challenges Faced by FPO's are as Follows

1. Limited or no access to market information and retail markets
2. No access to modern technology for processing of agri-products for value addition
3. Lack of awareness to leverage technology where ever available
4. Limited access to finance and investors
5. The lack of administrative capacity resulting in poor management of books of accounts leading to issues with accountability and transparency
6. Inadequate post-harvest infrastructure leading to wastage

FPOs can overcome the above challenges by the application of digital, IoT, Precision farming, and AI technologies to enable them for efficient and cost-effective operations.

Proposed Framework for FPO Stack-holders Interactions

The information about the complete list of possible activities of registered FPO are shown in Figure 3. from top left to right are

1. Complete Profile of FPO, and it's a governing body, bylaws, etc.
2. Collaborations with investors and venture capitalists
3. The information about the farmer members, farmer groups, and associations
4. Collaborations with fertilizer, pesticides, and chemical companies required by farmers
5. Collaborations with farming equipment and transport vehicle companies and that are owned by the farmers
6. Collaborations for Govt. Schemes, subsidies, rebates, and rules
7. Collaborations and financial management of FPO
8. Collaborations for personal, operational management of FPO
9. Collaborations of FPO with start-up companies for innovations
10. MoUs with research institutes, transport, cold storage companies, cooperatives, and bankers
11. Information about the implementation of Precision farming, IoT and AI applications in FPO operations
12. Collaborations with suppliers, whole-sellers, and retailers
13. Collaborations for marketing research and demand prediction
14. Online portals and apps of FPO to link all stakeholders
15. Collaborations with technical support for the implementation of digital solutions

Intrastate and Interstate Collaboration Between FPOs

The collaboration between FPOs in different districts, regions within a state should be established for their mutual benefit. The farmers in different districts are growing different crops based on weather conditions and resource availability. Every FPO should conduct a market and demand survey to identify

Figure 3. The framework of the FPO activities profile

Figure 4. Intrastate and interstate collaboration between FPOs for agribusiness

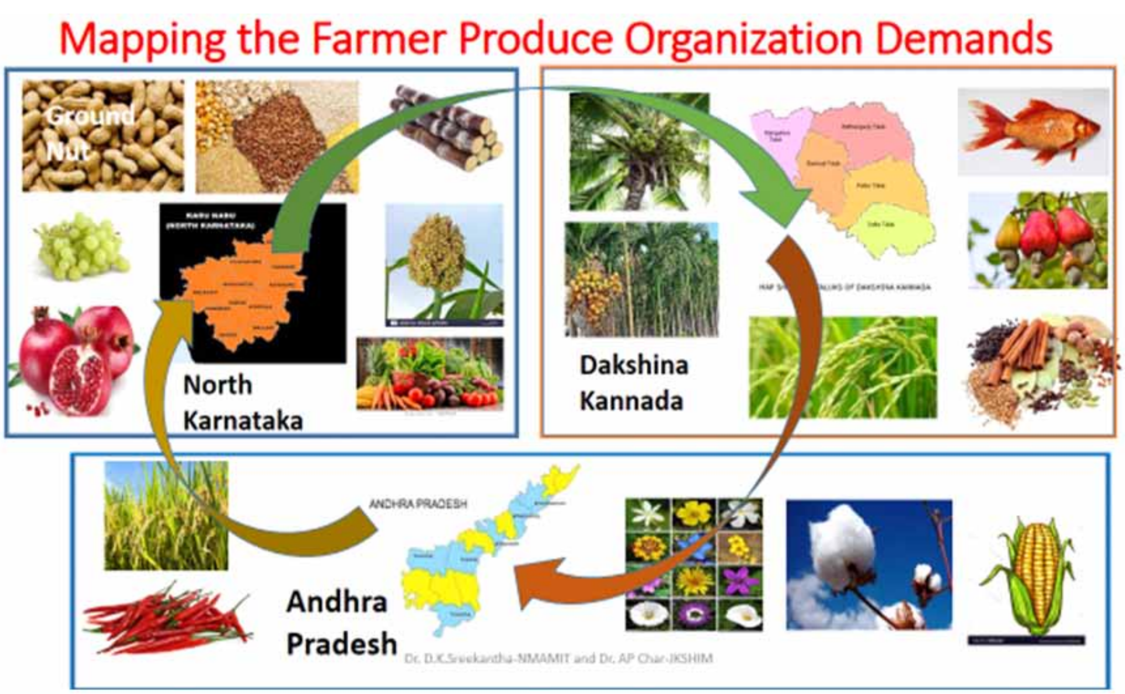


Table 1. Stakeholders of FPO and their role in agribusiness

Sl. No	Stakeholders	The objective of collaboration with FPO
1	Bankers	Financial support for FPO and farmers
2	Transport companies	To transport farmer's produce and other goods from farm to market places and consumers
3	Insurance companies	Providing insurance to all farmers and FPO related activities
4	Fertilizers and chemical companies	Wholesale business with FPO's for bulk purchase of fertilizers, chemicals, and pesticides
5	Agriculture equipment companies	Wholesale business with FPO's for bulk purchase/renting/services of tractors, harvesters, agricultural implements, etc.
6	Investors & Venture capitalists	Promote agribusiness and to invest in start-up companies for implementing innovation in agriculture and agribusiness
7	Cold/storage services	● Farmer's perishable produce such as flowers, vegetables, fish, etc., needs cold storage service to ensure good quality until it reaches consumers. ● Non-perishable farmer produce needs to be stored in safe warehouses to ensure good quality until farmers get the best market prices to sell
8	Agriculture research center	● Farmers and FPO should collaborate with agriculture research experts to update their knowledge and implement advanced technologies in agriculture and agribusiness to enhance crop yield, improve crop quality and to reduce the cost of operations.
9	Government bodies	● Govt. of India and each state government have many schemes, subsidies for promoting agriculture and FPO should encash these schemes to enhance farmer's income.
10	Market Research	● For exploring new markets and predict the demands well in advance for farmers to produce

Figure 5. Stakeholders of FPO for agribusiness

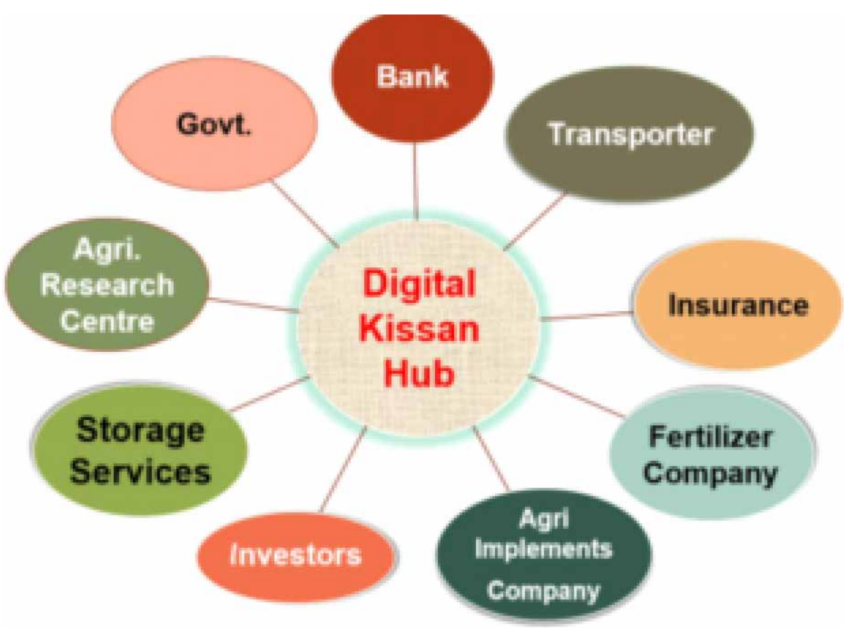


Figure 6. Services of Digital Kissan Hub

the supply of farmer produce that can be exchanged with other FPO promoting agribusiness within the state. Similarly, the FPO in each state can explore the opportunities to agribusiness across the states covering the entire nation.

Researchers have demonstrated this concept in Figure 4 by quoting the example of Karnataka state. The farmer's in the Dakshina Kannada region covering Mangalore and Udupi are growing coconut, areca nut, cashew nut, spices, and jasmine flowers apart from fish abundantly available in the coastal region. The North Karnataka region covering Bagalkot, Bijapur, Raichur and Gulbarga regions are growing sugarcane, groundnut, jawar, cereals and fruits such as grapes, pomegranate, chikku and vegetables in excess. The FPO in these regions can collaborate and exchange their farmer produce promoting sustained agribusiness and enhance farmer's income. Similarly, the FPO from Karnataka can collaborate with FPO in Andhra Pradesh state for agribusiness for crops such as red chili, cotton, maize, paddy, and cereals.

The Stakeholders of FPO Connected Through DKH

Each FPO can establish a DKH to interconnect all its stakeholders for promoting agribusiness. The primary stakeholders of FPO's agribusiness are shown in Figure 5, and Table 1 describes the role of each stakeholder in promoting agribusiness.

Digital Technology Solutions for DKH

The digital technology solutions provided by DKH to FPO for promoting agribusiness are described in Table 2.

The DKH is an integrated technological hub, as shown in Figure 7 and Figure 8.

Table 2. Technology solutions for DKH

Sl No	Technology	Applications of technology in Agribusiness
1	Bigdata	✓ The data of all business activities of FPO are managed as big data in the cloud to support online operations by all stakeholders of DKH
2	Internet of Things (IoT)	✓ IoT enables farmers to monitor and control the water pumps, farm equipment, farm conditions remotely ✓ IoT leverages precision farming practices ✓ IoT enables FPO to monitor and control the transport of farmer produce and quality checking ✓ RFID tags enable tagging the produce and digital recording of all data
3	Mobile apps	✓ FPO has linked all its stakeholders through their portal hosted in hybrid cloud, and all the services are deployed using mobile apps
4	Fog Computing	✓ Fog computing is used at the edge devices deployed in the farm or field to carry out preliminary processing with limited resources. The cloud platform would share the major processing requirements
5	Wireless Sensor Networks	✓ Wireless sensor networks are deployed in the farms since the soil health, corp conditions, and weather conditions in the field are monitored in real-time ✓ The animal stock of farmers can be traced using biometric collars
6	Robotics	✓ The farmers can use robots in their fields for carrying out operations for substituting human labor ✓ The robotic operations are very efficient and cost-effective ✓ Robots used for spraying pesticides to save pesticide quantity requirements by almost 80%, reducing the wastage and saving money. ✓ The price of robots are decreasing year after year, expected to drop down by 60-70% over the next decades empowering farmers
7	Drones	✓ The applications of the drone in agriculture can help crop monitoring and spraying of fertilizers and pesticides. ✓ Protecting crops from wild animals
8	Autonomous Tractors	It can be programmed to plow a specific field, pumping water, etc. without human supervision in just a few hours thus savings driver cost and time, working round the clock.
9	Vertical farms	Vertical farms are used to save space and work in controlled environments even in indoor and rooftops in cities making efficient use of space and other resources
10	Contract farming companies.	A group of farmers can form an FPO for a cooperative farming activity where they can use heavy mechanization and advanced techniques in agriculture to make wholesales purchases of input and to make wholesale sales

Figure 7. Technology Solutions

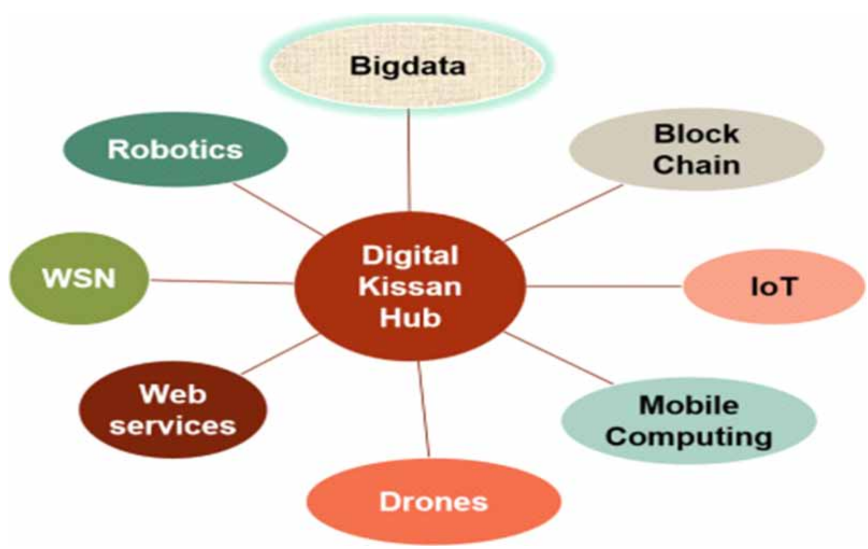


Figure 8. Digital Kissan Hub Technology

Mobile app Services From DKH to Help Farmers

DKH provides information on pre-harvest mobile services to farmers as shown in Figure 9. Farmers can log on to the DKH portal and access information about their soil health data. DKH is connected to the soil which extracts soil health data from the farm through the soil sensors deployed through the IoT network. Farmers can also access any time regional weather data such as rainfall and plan their farm activities. DKH is collaborating with the agricultural research centers to provide personalized consultancy to the farmers based on their specific requirements. FPO also provides crop planning services to farmers based on market prices, demand, weather conditions, and other input resources.

The information about market conditions, government schemes, subsidies are updated to farmers from time to time through messaging services. Farmers can organize themselves into various groups based on their farm interests and interact by sharing their experience and thus promoting peer learning.

DKH Services for Crop Yield Monitoring

FPO also supports farmers by providing services on crop yield management, as shown in Figure 9. The services are crop cost and yield management. WSN, IoT, and Drone solutions are integrated to provide automated crop monitoring services. The stakeholders of FPO such as investors and bankers, provide information on loans for crops, purchase of agricultural implements, and subsidies. The agricultural implements companies like Mahindra, JohnDeer, etc. would provide information about their products and services. The fertilizer companies would collaborate with FPO for bulk sales and govt. subsidies on fertilizers, pesticides, and chemicals.

All this information is available to farmers at fingertips through DKH app crop management services, as shown in Figure 10.

Figure 9. Pre-harvestings Mobile Services

Figure 10. Crop Management solutions

Table 3. Digital Kissan Hub major activities

Sl. No	Activity	Deliverables
1	Organizing a diagnostic study to identify the FPOs in the states and carrying out the baseline survey of the prospective areas to collaborate through social mapping using PRA techniques and tools	Mobilizing the farmers and promotion for the formation of producers group/producers association.
2	Mentoring FPO in governance, analysis and controlling operations to meet the objectives of FPO	Overall project coordination, implementation, supervision, management, procurement, accounting, auditing, and report preparation of work plans
3	Facilitate FPOs to implement e-governance for organization development	Preparation and submission of a feasible business plan to banks/ appropriate financial institutions and developing a paperless office
4	Facilitate and support FPOs in establishing e-marketplace for providing marketing services with retail chains, exporters, and processors, etc.	Marketing tie-ups with input and output suppliers/ manufacturers
5	Helps FPO to establish and enhance the relationships with business partners of FPO	Sharing all the latest credit facilities, information from banks, other commercial lending institutions, insurance companies, transport companies, chemical, fertilizers and pesticides, and equipment manufacturing companies
6	GST connect and business insights, revenue and expenses monthly/quarterly/yearly	Top customers, top vendors, and active/inactive customers management Get business network and expand the network
7	Web-based apps that can be accessed through mobiles will provide the interface for all FPOs	Visibility in the market, promotion of products and services

The Digital Kissan Hub's major activities and the outcome from these activities are described in Table 3.

PROPOSED IMPLEMENTATION STRATEGY

Researchers have studied the readily available digital platforms in the market, such as E-NAM a govt of India Initiative, and NAPANTA a start-up venture. The team of researchers from agricultural technical, management, educational and research institutes and start-ups are working together for the successful implementation of this DKH prototype.

Team of DKH Prototype Implementation Partners

The authors proposed to establish a team of institutions and organizations with mutual collaborations for the successful implementation of the DKH platform. A project proposal has been submitted to Govt. of India for funding. Authors propose to establish a DKH as an incubation center utilizing the funds from the government at NMAM Institute of Technology, Nitte. Figure 11. shows the list of implementation partners for establishing DKH

Roles of Implementation Partners

The role of implementation partners for establishing DKH is shown in Table <<tbc4>>4 below

Figure 11. DKH Implementation partners pie chart

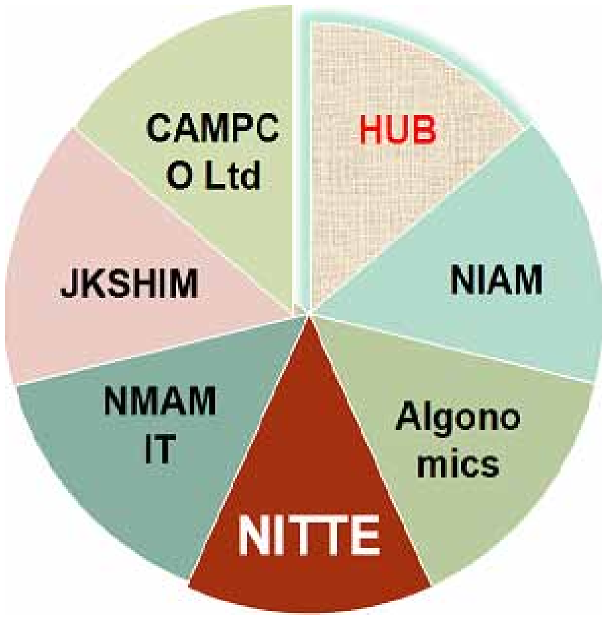


Figure 12. DKH Implementation partners List

NITTE –Nitte Deemed to be University, Mangalore

NIAM- National Institute of Agricultural Marketing, Jaipur

HUB – Horticulture University, Bagalkot

NMAMIT-NMAM Institute of Technology, Nitte

JKSHIM Justice KS Hegde Institute of Management, Nitte

CAMPCO– Farmer Producer

Organization

Algonomics, Ltd Bangalore

Table 4. Roles of implementation partners

Sl. No	Organization	Role	Existing Associations	TimeLine in Years
1	Nitte Deemed to be University, Mangalore	Project Implementation Coordinator	To establish MOU with all Partners and Manage project	3 Years
2	NMAM Institute of Technology, Nitte	✓ Establishing and Management of DKH ✓ Farmers Technical Training	Has MOU Nitte Deemed to be University, Mangalore	1- Establishing DKH 2- Management of DKH
3	National Institute for Agricultural Marketing	Supporting in fieldwork, FPO management	Has MOU Nitte Deemed to be University, Mangalore	1- Fieldwork and training 2- Project Implementation 3- Management of DKH and supporting FPO business
4	University of Agriculture and Horticulture Science	Educating Farmers and supporting Farmers' registration to FPO.	Has MOU Nitte Deemed to be University, Mangalore	1- Farmers registration 2- Training Farmers 3- Expert Agricultural advise in project implementation
5	JKSHIM, Nitte	✓ FPO Training on Business and Management skills ✓ Market Research ✓ Farmers Business Training	Has MOU Nitte Deemed to be University, Mangalore	1. Farmer Registration, FPO Skill Training and Market Support 2. Business Development and Market Research
6	FPO	✓ Enable few FPO for registration to DKH ✓ Training FPO on DKH operations ✓ Training FPO on Business skills	To establish MOU with few active FPO who are ready to collaborate	1. FPO registration Training 2. Training and Skill Development 3. Market Research and Business Development
7	Algorithmics	✓ Technical Partner for DKH development and operations	To establish MOU	1. Establish DKH and start pilot operations 2. Expand to neighboring state 3. Innovate, Update and maintain DKH

Digital Kissan Hub - Implementation Stages

The project is implemented in multiple phases

- Pilot project implementation with few FPOs
- Implementing in Karnataka
- Implementing in neighboring states / related clusters
- Establishing sustainable governance in FPO for three years

SOLUTIONS AND RECOMMENDATIONS

This paper has presented the Digital Kissan Hub (DKH) prototype for Farmer Produce Organizations (FPO) to empower them to prosper in agribusiness. The authors have discussed the need for establishing the DKH, its objectives, and its role in promoting agribusiness.

The concept of FPO and its benefits to the farmers was explained. The stakeholders of FPO and their role in leveraging agribusiness are described using tables and appropriate diagrams. A survey of literature, national and international state of agribusiness, FPO was also illustrated. The review on the adoption of digital technology solutions in agriculture, agribusiness across the nation, and countries was also described. The integrated framework for DKH and FPO interactions, support services, and deliverable was also covered. The authors also showed the action plan for the implementation of FPO and DKH and the role of project partners with a case study in their region. At the outset, the researchers conclude that establishing DKH for FPO would promote agribusiness and helps to enhance the farmer's income and benefit all stakeholders of FPO.

CONCLUSION

The researchers' objective was to develop a Digital Kissan Hub prototype for empowering Farmer Produce Organizations. Authors believed that implementation of digitalization and automation in agriculture and agribusiness would enhance overall productivity, efficiency and profitability and reduce the cost of operations. Authors have conducted an extensive survey of literature and discussed many existing digital solutions such as web portals and mobile app which are independent and meet different purposes individually from different vendors. These solutions are not interoperable and cannot be easily integrated due to a lack of standards. Researchers also studied a few digital platforms, but they all suffer from implementation issues due to lack of infrastructure, skilled human resources and stakeholders' participation as one single operating entity.

Authors proposed DKH and FPO tightly integrated with farmers as primary stakeholders. The project partners team would mentor a group of like-minded farmers to come together to form a legal entity called FPO and conduct the business of their product using DKH digital platform. No third party intermediates are involved in FPO set-up. FPO is primarily **By the Farmers, For the farmers to the Farmers a Win-Win** context for the benefit of farmers and consumers, avoiding all intermediate agents. This paper discussed all the functional aspects of the DKH prototype with a feasibility study, design and action plan for successful implementation. Researchers are working on the successful implementation of this prototype soon.

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Chapter 13
Design of an Agribusiness Innovative and Autonomous Robot System for Chemical Weed Control for Staple Food Crops Production in Sub-Saharan Africa

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ABSTRACT

Agriculture and agribusinesses suffer from many challenges, despite their significance to global economic growth. One of the challenges is the lack of appropriate technology to drive the industry to the next level of development. This technological gap contributes to reduced yield and profit without a reduction in manual labour, cost, and stress. Robotics have been explored to boost agricultural production and improve agribusiness productivity. Several weed control robots have been developed for research and field uses, but these systems are not suitable for weed control in large commercial farms or lack control schemes for navigation and weed control. This study presents the design of an autonomous robot system for chemical weed control. The system uses control theory, artificial intelligence, and image processing to navigate a farm environment, identify weeds, and apply herbicide where necessary. Upon implementation and adoption, this system would increase agricultural productivity with minimal human input, thereby leading to an increase in revenue and profit for agribusinesses.

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INTRODUCTION

The concept of Agribusiness is the sum of all operations involved in the production and distribution of farm produce, farm production operations, storage, processing, and distribution of farm commodities (Ikenwa, Sulaimon, & Kuye, 2017). It is a generic term for different businesses involved in the production and along the value chain of an agricultural commodity which includes but not limited to subsistence and mechanized farming, the supply of seeds, fertilizers, manure, chemicals, machinery, marketing, and financing of the agricultural industry (Munonye & Esiobu, 2017).

In recent times, there has been increased pressure on the agricultural industry and agribusinesses to operate and deliver more efficiently and effectively due to an increase in the world's population (Munonye & Esiobu, 2017). Agribusiness has the capacity and potential to provide increased employment, poverty reduction, higher income, and food security (Tersoo, 2013). Nevertheless, given the sector's ability to revolutionize the sub-Saharan African region's agricultural commodity production, agribusiness suffers from numerous constraints. The challenges associated with agribusinesses in Sub-Saharan Africa include poor policy articulation, inadequate working capital, lack of suitable technology, and inadequate agricultural infrastructure (Munonye & Esiobu, 2017). These challenges limit the revenue and profits generated from the industry.

Productivity in agriculture and agribusinesses can be increased by appropriate, accurate, and usable information and knowledge. Agricultural information interacts with agricultural productivity in a variety of ways, influencing it. It helps inform land, labor, livestock, capital, and management decisions. Consequently, the processing of agricultural information (through extension facilities, research, and education programs) is most mostly handled by agricultural organizations that build information systems to disseminate knowledge to farmers (Demiryurek, 2008). This knowledge enables the farmers to make informed decisions to take advantage of market incentives and handle constant improvements in their production processes. Information obtained from farms can be collected using systems that employ the concepts of Precision Agriculture, Artificial Intelligence, and Robotics. These devices rely on the use of sensors to obtain environmental data which can then be analyzed using a variety of software tools.

Globally, there has been an increase in the application of robotic systems to automate agriculture-based problems (Roldán et al., 2018). According to the United Kingdom Robotics and Autonomous Systems (UK-RAS) Network, robotics and autonomous systems will transform numerous global industries including the agricultural sector through the development of technologies aimed at maximizing profit and increasing yield (UK RAS Network, 2018). In addition, advancements in precision agriculture have resulted in the utilization of intelligent machines to minimize human involvement while increasing agricultural output. The development of robots and their application in agriculture has increased leading to the exploration of possibilities to adapt rational mobile robot solutions based on behavioral approaches (Pedersen, Fountas, & Blackmore, 2008).

A major problem faced by farmers is the prevalence of weeds. A weed is any unwanted crop that grows in an unwanted area. Weeds reduce not only yield but also the confidence of farmers by creating a poor return on investment. Weeds also result in higher production costs and lead to seedling contamination. Manual weed control with hand-held hoes and manual application of herbicides with knapsack sprayer is labor-intensive and exhausting. This fatigue-inducing weed control approach discourages a lot of people from moving into crop farming (Olaniyi, Daniya, Kolo, Bala, & Olanrewaju, 2020). In a quest to improve agricultural productivity, attempts have been made to introduce robotic systems for weed management. However, these systems have drawbacks such as inadequacy for vast outdoor fields, lack of control schemes, lack of intelligent technology, and requirement of human involvement. The need for a device capable of detecting and managing weeds in farmland exists because of these shortcomings. This system requires minimal human intervention, large farmlands, incorporates control and smart operation schemes.

In this study, the design process of an autonomous robotic system for chemical weed control is presented. This system utilizes precision agricultural and robotic concepts to carry out effective weed management. This system is expected to increase agricultural output, for high investment returns and increased profits. The implementation of this design and subsequent adoption of this system by farmers in sub-Saharan Africa has the potential to improve the development of a crop commodity along the agricultural value chain and agribusiness sectors.

PROBLEMS OF AGRICULTURE IN NIGERIA

Nigeria is the largest economy in West Africa and the second-largest in sub-Saharan Africa. Nigeria is large and vast with 68 million hectares of it being arable land, 12.6 million hectares of freshwater resources, and an ecological diversity that provides the necessary resources for the production and cultivation of a wide variety of crops (Ewetan, Adebisi, & Emmanuel, 2017). The Nigerian economy has been described as an "Agrarian Economy", where agriculture plays a vital role in the country's social and economic development (Anigbogu, Agbasi, & Okoli, 2015). Agriculture contributes about a quarter of the total nominal Gross Domestic Product (GDP) of Nigeria. This number is, however, lower than the sector's previous contribution because agricultural production has declined over the years. This decline has led to many major food products being imported into Nigeria that can be grown locally.

The decline of agricultural production in Nigeria has been attributed to the over-dependence of the country's economy on crude oil and the increase in population without a corresponding increase in agricultural products (Anigbogu et al., 2015; Nwankpa, 2017). Despite efforts by the government to improve agricultural production by introducing schemes and programs such as Operation Feed the Nation (OFN), Green Revolution, and National Food Acceleration Production Programme (NAFPP), agricultural output has not improved significantly. The reasons are due to policy inconsistencies, corruption, and mismanagement (Nwankpa, 2017).

Additional factors that affect the development of agriculture in the region are the absence of good agricultural infrastructure, market problems, unstable prices, and poverty, especially in rural areas (Ufiobor, 2017). In addition, the system's lack of innovativeness arising from unstimulated drivers of agricultural development is another aspect that adversely affects agricultural production. These factors lead to low returns on investment, mismanagement, wastage of produce, and inability to obtain suitable agricultural inputs such as fertilizers, herbicides, insecticides among others.

The implementation of smart and intelligent technologies in agriculture can optimize operations involving crop care, harvesting, seeding, and yield improvement. However, the application of these concepts in the Nigerian agricultural sector is hindered by factors such as lack of capital and inadequate facilities. For instance, a lack of capital involved in the deployment of smart technologies hampers the adoption of automation in farms. Even if the equipment is acquired, the lack of electricity access for the majority of the country's population impedes the use of mechanized and smart farming equipment. In addition, the lack of adequate knowledge of precision farming technologies is prevalent to the majority of the farmers in Nigeria are in rural areas. These farmers, due to their illiteracy, are also unskilled in the abilities required to deploy the technology (Elijah, Babale, & Orakwue, 2017).

Weeds: The Farmers' Battle

In crop production, the prevalence of weeds has been and continues to be a challenge to farmers in the sector. The effects are not only conspicuous in the growth of the crops being cultivated but also in the production yield and capability of the farmers. In sub-Saharan Africa, weeds result in a rice loss of about 2.2 million tons, the losses which are estimated at about $1.45 billion (Olaniyi, Daniya, Abdullahi, Bala, & Olanrewaju, 2019).In Imoloame & Omolaiye (2017), a yield loss of about 51 to 100% was reported to have been sustained due to weed competition in maize farms in Nigeria. In the long run, more efforts are being exerted to reduce the negative effects of weeds on the farm which increases the production cost. This process often dampens the morale of the farmers due to the reduced profit realized at the end (Olaniyi et al., 2019).

In practice, there exist different approaches in controlling weeds on the farm. One such method is manual weed control. In this approach, the use of hoes and other tools are being employed to manually and physically remove the weeds from the farm. The applications of various herbicides through spraying and direct application (where spraying may be difficult) are also adopted. The characteristic features of this practice are the extent of manpower, fatigue and cost involved.

Hence, in order to solve these identified challenges and make farming of crops more lucrative, there is a need to develop a more comprehensive and all-encompassing system for the identification and control of weeds in farmlands. This is with the view of making the practice more lucrative in terms of the return of investment, yield of production and reduction in the amount of stress involved.

Precision Agriculture for Weed Control

Precision Agriculture (PA) is a theory which is based on the observation, measurement, and response to variability in crop fields or aspects of livestock management.(Beluhova-Uzunova & Dunchev, 2019). This process involves the application of inputs only when and where it is required. The PA has become the third stage of the agricultural revolution, second to mechanization and the green revolution. The concept aims at increasing and maintaining the sustainability of crop production and animal rearing by the applications of Artificial Intelligence, Internet of Things, Big Data, and Robotics (Saiz-Rubio & Rovira-Más, 2020).

The PA underscores the fact that increased agricultural output can be obtained by understanding variability within a crop field. The objective is not to obtain the same outputs or yield all around the farm but to analyze the environment and distribute various inputs based on site-specificity. This process has the potential to result in a high return on investment and maximize benefits from farming such as increasing productivity, improving profitability, and reducing wastage (Banu, 2015). The size of arable farmlands in Nigeria has grown over time due to increasing demand and population (Abdullahi & Sheriff, 2017). It has become almost impossible for farmers to maintain knowledge of field conditions due to the variability associated with the environment. The PA gives farmers the opportunity to simplify and automate data acquisition and analysis, thereby resulting in quick, intelligent, and in some cases, automated decision making.

In the past, the predominant small-scale farms allowed farmers to observe the spatial variability of their farmlands and apply inputs accordingly. However, the advent of mechanized agriculture led to an increase in the size of farms with a uniform application of inputs across the land. The PA bridges the gap between the two practices by obtaining information about the farmland and applying inputs based on data analysis with the aid of sensors and actuators. Farm operations such as herbicide application, fertilizer application, and irrigation can be carried out intelligently, thereby allowing the farmers to obtain high yields, minimize inputs, reduce wastage, and optimize profits (Beluhova-Uzunova & Dunchev, 2019).

In the aspect of chemical weed control, PA plays an important role by precisely managing production factors such as herbicides to increase yield and efficiency (Hakkim, Joseph, Gokul, & Mufeedha, 2016). In Rodenburg et al., (2019), it was reported that a frequently observed complaint by farmers regarding the use of herbicides is the high cost involved. In addition, it was observed that the majority of farmers in Sub-Saharan Africa use herbicides complementarily to hand-weeding (Rodenburg et al., 2019). The PA can successfully be implemented to minimize wastage of herbicides resulting from a uniform application across the farm (even in areas that do not require herbicide). Furthermore, PA reduces the need for frequent herbicide usage, which may have negative effects on the environment, human health, and crops.

Review of Literature

Autonomous robots have been implemented for a wide range of farm operations. In Belgium, an autonomous tractor has been used in uneven and inconsistent terrain for farm operations. Depending on the type of terrain, the user calibrates the robot to prevent the robot from falling off its desired path. Additionally, Vitirover is a robot designed for use in New Zealand that can detect and cut weeds in a grape field. Hortibot, in addition, is an autonomous robot developed and used in Denmark. This device is used for spraying or laser removal of weeds. However, the system and the technique it employs are very costly and can hinder farmers' adoption (Sujaritha, Lakshminarasimhan, Fernandez, & Chandran, 2016).

In the aspect of automatic weed detection and control, several works exist in literature. Mohan et al., (2016) developed an automatic weed detection system and smart herbicide sprayer robot for maize production in India. In this system, the image processing technique is used to detect weeds and spray herbicides accordingly. However, there is no technique to control the amount of herbicide sprayed. Similarly, automatic detection and smart herbicide sprayer robot were developed by Aravind, Daman, & Kariyappa, (2015). The system detects weed using image processing and sprays herbicide accordingly. However, due to the size of the system, it is not suitable for large and commercial farm operations.

A weed control system for precision agriculture based on computer vision was proposed by Arakeri, Vijaya Kumar, Barsaiya, & Sairam, (2017). The system captured real-time images from a farm and uploaded them to a remote server to be analyzed by a machine-learning algorithm. Based on the output of the algorithm, the herbicide is then sprayed accordingly. Although the system exhibited an accuracy of weed detection of 96.83%, the system could not autonomously navigate the farm. In addition, no control scheme was incorporated to limit the amount of herbicide sprayed.

In Nielsen, Andersen, Pedersen, Bak, & Nielsen, (2002), the control of an autonomous vehicle for weed and crop registration in precision agriculture was presented. The system was capable of following a reference path autonomously due to the control scheme implemented. However, the system lacked any feature for weed identification, and the navigation of the robot was based on a predefined path, which may not be suitable for dynamic environments. Similarly, Hameed, Cour-Harbo, and Hansen, (2014) presented a task and motion planning technique using a team of autonomous vehicles for selective weed control. The system obtained satellite images using unmanned helicopters and transmitted them to the ground vehicles. This enabled the ground vehicle to visit infested areas for weed treatment. Despite showing satisfactory performance in path tracking, the system lacked an image-processing algorithm for autonomous weed detection or a control scheme for weed control.

Kulkarni & Deshmukh (2013) developed an advanced robotic weed control system. The system employed the use of a color sensor and an infrared sensor to identify weeds. The system, however, provided no technique for weed control, and color alone is not a suitable criterion for identifying weeds. In Bak & Jakobsen, (2004), an agricultural robotic platform with four-wheel steering for weed detection was developed. The work focused on the navigation of the robotic device within a field. Although the vehicle was capable of following a predefined path within a field, no information was provided on its weed detection capabilities.

Kounalakis, Malinowski, Chelini, Triantafyllidis, & Nalpantidis, (2018) developed a robotic system which employed deep learning for visual recognition and detection of weeds in grasslands. The system used convolutional neural networks to identify weeds while keeping a low false-positive rate under harsh operating conditions. However, the system provided no weed control mechanism. Similarly, (Sujaritha, Annadurai, Satheeshkumar, Kowshik Sharan, & Mahesh, 2017) developed a weed detection robot that used a fuzzy real-time classifier. This system was capable of detecting weeds in sugarcane fields and navigating within the field. The system, however, provided no weed control mechanism.

A gesture-controlled wireless agricultural weeding robot was presented in Gokul, Dhiksith, Sundaresh, & Gopinath, (2019). The robot consisted of an arm that could be remotely controlled using a wearable glove for weed removal. Although made cost-effective by the elimination of optical sensors, the system did not eliminate the need for human intervention and did not incorporate automatic weed identification. In addition, a maize crop and weed species detection system using an unmanned aerial vehicle (UAV) and visible and near-infrared (VNIR) were presented in Pignatti et al., (2019). The system captured images using the UAV and identified weeds using hyperspectral data. However, the system had no weed control mechanism.

Hussmann, Knoll, Czymmek, Meissner, and Holtorf (2019) presented the development of a low-cost delta robot system for weed control applications in organic farming. The system classifies weed via an image acquisition unit and sends coordinates of the weed to the controller. The robot then proceeds to remove the weeds using a weeding tool. Although this system proved effective for weed removal, the setup is not suitable for large outdoor farms. In Sujaritha, Lakshminarasimhan, Fernandez, & Chandran, (2016), a solar autonomous robot was developed for weed control. This robot is powered by solar energy and uproots weeds in a grape field. However, for high accuracy, the weeds need to be isolated, or else the crop could be accidentally uprooted.

Furthermore, in Sabanci and Aydin (2017), a smart robotic weed control system for sugar beet was developed. The system was capable of detecting weeds and spraying herbicide if the need arises. A major limitation of this system is the structure since it cannot be used in the field without significant modifications. Also, in Olaniyi, Daniya, Kolo, Bala, & Olanrewaju, (2020), a weed detection and control system was developed for low land rice precision farming. This system used neural networks and fuzzy logic to detect and control weeds respectively. However, the system still required human intervention as the farmer needed to carry the system around the farm. This increased the stress and fatigue experienced by the farmer.

Based on the aforementioned review, it is evident that there is a need for an improved system to address the research gaps identified. These gaps include:

a. The suitability for use in large farmlands.
b. The elimination of human intervention.
c. The inclusion of control mechanisms for autonomous operation.
d. The incorporation of weed control schemes for weed removal.

The need for an increase in agricultural production in sub-Saharan Africa emerges due to declining oil prices and the need to diversify the region's economy. The vast land and fertile soil available in the region provides the potential for food-producing nations in that area to become giants. This, in turn, will, in the course of time, lead to continental and global food security. Autonomous systems and precision farming play a vital role in boosting farm production.

Therefore, in this paper, a conceptual design of an autonomous robotic system for the identification and chemical control of weeds in a conventional farm setting is proposed. The proposition adopts the use of control theory, computer vision, and artificial intelligence techniques in its navigation and herbicide applications. It is envisaged that upon implementation of this design, the need for manual removal of weeds and associated challenges would be eliminated. In addition, the adoption of this system will result in a decrease in human intervention, stress, and fatigue in crop production. This, in turn, will lead to an increase in revenue and an improvement in the value chain of agribusiness.

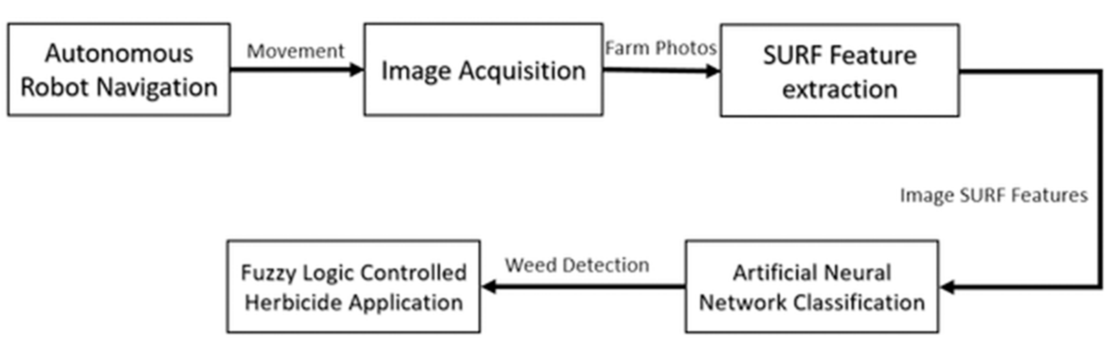
RESEARCH IMPLEMENTATION STRATEGY

This section presents the implementation techniques, specifications, and considerations for the autonomous robot system for chemical weed control. The section covers the theory behind basic concepts used in the development of the system and the description of the various modules that make up the system.

System Overview and Description

The autonomous robot system for chemical weed control consists of various modules that interact to carry out weed detection and control. These subsystems execute robot navigation, weed identification, and herbicide application. The various modules and their interaction are shown in Figure 1.

Figure 1. Dataflow diagram for various system modules



The block diagram for the system architecture is presented in Figure 2. The hub of the system is the Atmega 2560 microcontroller. The choice of this microcontroller is influenced by its powerful abilities, especially in the area of control and automation. Images acquired from the camera are analyzed using the image-processing algorithm and artificial neural network resident on the microcontroller. After the images are processed and weeds are identified, the microcontroller will send control signals to the DC pump for herbicide application. The amount of herbicide to be applied is determined by a Fuzzy control algorithm on the microcontroller. The DC motor and servo motor are used for movement within the farm environment. The direction of the movement is determined by the inputs from ultrasonic sensors. These sensors are used to identify the presence of ridges in the farm and in turn, are used to estimate the location of the robot with respect to the ridges. The circuit diagram of the system is shown in Figure 3.

Figure 2. Block Diagram of System Architecture

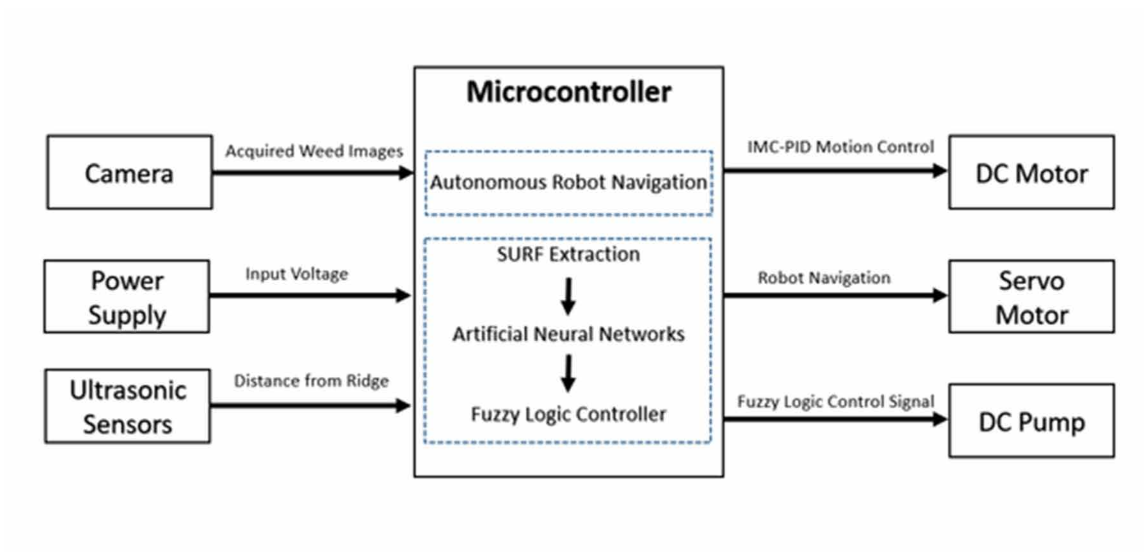
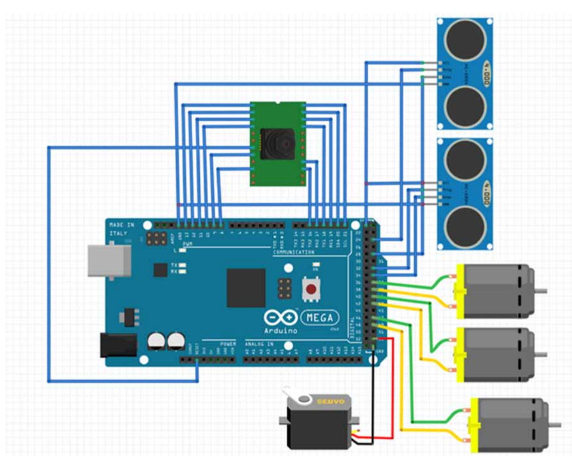


Figure 3. Circuit Diagram of Mobile Robot



Autonomous Robot Navigation within the Farm Environment

The mobile robotic system consists of three wheels (two rear and one front). The rear wheels are driven by a 775 12V DC motor while the front wheel is controlled by a servo motor. Their main function is a movement within the environment. There are two ultrasonic sensors that are used to identify the presence of ridges on the farm. This ensures that the robot moves in between the ridges to ensure proper capturing of the images.

The speed of the system is determined by the DC motor. The system moves at a predefined speed, which is controlled using the relationship shown in equation 1.

$$N = K\frac{V - IaRa}{\varnothing}\,\text{r.p.m} \tag{1}$$

Where:

N = Speed of DC Motor
V = Applied Voltage
Ia = Armature Current
Ra = Armature Resistance
Φ = flux / pole (Theraja & Theraja, 2005).

Equation 1 shows that the speed of the motor is directly proportional to the applied voltage and inversely proportional to the magnetic flux. Hence, the speed can be controlled by varying the applied voltage (voltage control), varying the magnetic flux per pole (flux control) or varying the armature resistance (Rheostatic control).

In the aspect of the robotic navigation, the robot will move between the ridges, and when it reaches the end of the ridge, it will make a left or right turn depending on the previous turn direction. The algorithm for the movement between the ridges is presented as follows:

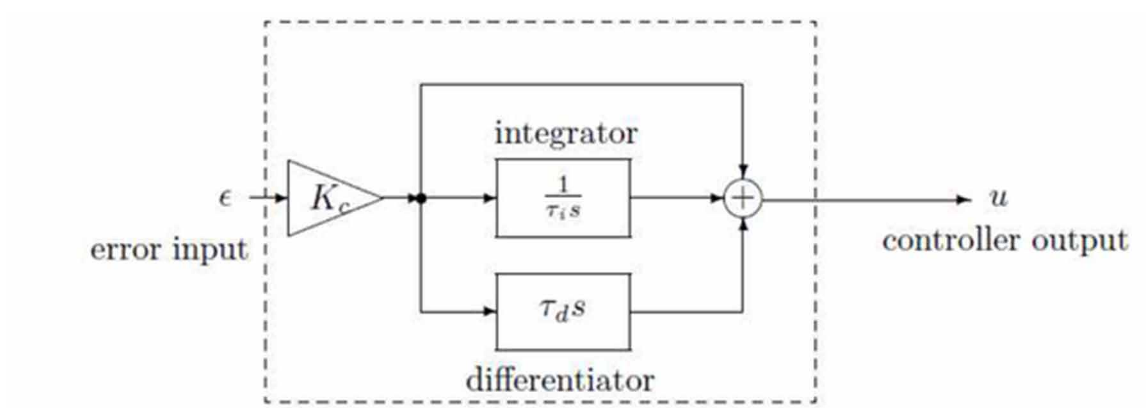
```
function robotNavigation (leftSensorDistance, rightSensorDistance)
define thresholdValue, error as double;
define direction as int;
while(1) {
error = leftSensorDistance - rightSensorDistance;
If (error<=thresholdValue)
direction = 0;
Else
direction = 1;
 End If
 direction = - direction; }
 end function
```

The algorithm shows the technique of movement between ridges on the farm. The robot consists of two ultrasonic sensors, each on the left and right sides of the robot. Evaluating the error (line 5) is carried out to determine if the robot is between ridges or has reached the end of the ridge. This process is achieved by comparing the error with a pre-determined threshold value (line 6). If the error is less than the threshold, the robot continues moving straight between the ridges, a process that is represented by a direction value of 0 (line 7). However, if the robot reaches the end of the ridge, which implies the error is above the threshold, the robot turns either right (direction value of 1) or right (direction value of -1) depending on the previous direction value. This turning motion will make the robot move into the next ridge space.

Motion Control Scheme

To ensure proper robotic movement, system stability, and satisfactory system response, a Proportional-Integral-Derivative (PID) control scheme is used. The PID control scheme is a feedback control technique that is widely used in the control and automation industry. Its high demand is because of its control features and capabilities for a wide range of industrial applications such as DC motors. About 95% of control loops are implemented with a PID controller due to the device's structural simplicity and robust performance in a wide range of applications (Mohindru, Sharma, & Pooja, 2015). In order to achieve a PID scheme with high performance and robustness, the appropriate proportional, integral, and derivative gains of the controller need to be selected. The process of this selection is known as PID tuning. However, the tuning of control parameters to achieve optimum performance is a tedious task. This difficulty is due to the number of parameters involved (three) and finding the appropriate combination has proven to be quite challenging. However, in this case, the PID tuner application provided by MATLAB is used to tune the PID parameters. The application analyses the output from the system model and uses a computational optimization approach to obtain the PID gains. The PID control process is shown in Figure 4.

Figure 4. A PID Control Process (Kambiz & Mpanda, 2012)



Due to the advantages exhibited by the PID controller, in this study, a PID tuning approach is adopted to ensure optimum system response, stability, and accuracy of the robot navigation. In order to implement the PID control scheme, a mathematical representation of the system must be acquired. In the case of this system, the major components are the DC motor, servo motor, and DC pump. These components can be modeled using the transfer function of an electromechanical system given in equation 2.

$$G(s) = \frac{\Omega(s)}{V_a(s)} = \frac{k_t}{(R + LS)(Js + B) + k_t k_b} \quad (2)$$

Where:

Ω = Angular Displacement
V_a = Applied Voltage
R = Armature resistance
L = Armature inductance
J = Rotor inertia
B = Viscous friction co-efficient
K_t = Torque Constant
K_b = Back EMF constant

The values of the parameters are obtained from the DC motor used in the system design obtained in Bala, (2015). These values are as follows:

K_t = 3.475 NM/Amp
K_b = 3.475 V/rad/sec
B = 0.03475 MN/rad sec
J = 0.068 Kg/m^2
L = 0.055H
R_a = 7.56 Ω

Substituting these values in equation 2, we obtain equation 3.

$$G(s) = \frac{3.475}{0.00374S^2 + 0.51599S + 12.33831} \quad (3)$$

After the system has been modeled, the PID transfer function needs to be obtained. The PID transfer function is given in equation 4.

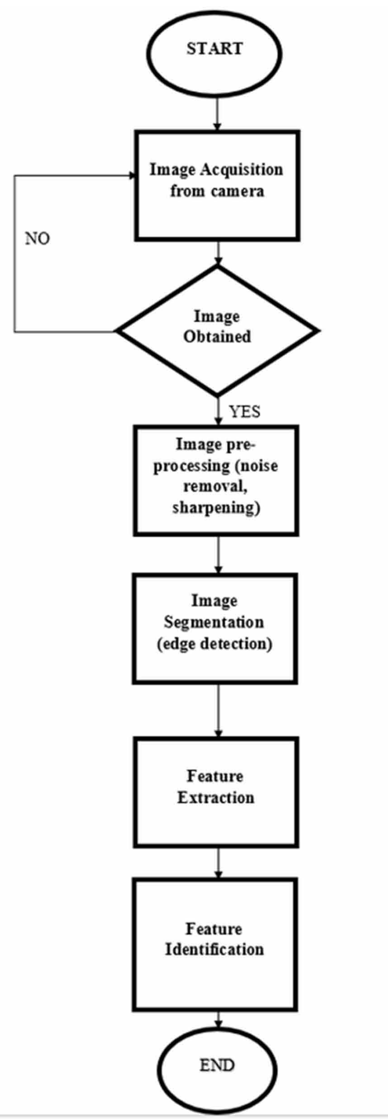
$$G_{PID}(s) = K_p + \frac{K_i}{s} + K_d s \quad (4)$$

Here, K_p, K_i, and K_d respectively represent the proportional, integral, and derivative gains of the controller.

Weed Identification using SURF and ANN

The weed detection module is responsible for identifying weeds on the farm. The module takes an input image from a camera and runs it through an artificial neural network (ANN). The neural network determines if the image input contains weeds or not. If a weed is detected, the herbicide will be sprayed accordingly. The images go through the stages of image processing which are highlighted in Figure 5. After the image is processed and the required features are extracted, the data is passed into the neural network for further processing.

Figure 5. Image Processing Stages



In image processing, feature extraction and feature recognition are essential aspects. These actions are widely used in pattern recognition, object identification, visual navigation, and tracking (Wang, Zou, & Shi, 2018). Popular image feature matching algorithms include the Scale Invariant Feature Transform (SIFT), the Speeded Up Robust Features (SURF), and the Histogram of Oriented Gradients (HOG). The features that are extracted from the images in this study are the Speeded Up Robust Features (SURF). The rationale for the use of SURF lies in its powerful object recognition capabilities and robustness. In addition, the speed of the SURF algorithm makes it suitable for real-time applications (Wang et al., 2018).

SURF is one of the most robust and popular feature extraction techniques in image processing (Rahmani & Narouei, 2020). The algorithm consists of feature point detection, feature descriptor evaluation, and feature point direction identification (Feng, Wang, Yang, & Li, 2019). The detection of the interest points involves the use of a Hessian matrix. The determinant of this matrix reaches the extreme at points of maximum change in the brightness gradient. The Hessian matrix for a two-dimensional function is given in equation 11 (Mukhina & Barkalova, 2018).

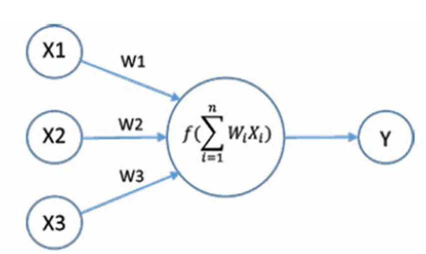
$$H\left(f\left(x,y\right)\right)=\begin{bmatrix}\frac{\partial^2 f}{\partial x^2} & \frac{\partial^2 f}{\partial x\partial y}\\ \frac{\partial^2 f}{\partial x\partial y} & \frac{\partial^2 f}{\partial y^2}\end{bmatrix} \tag{11}$$

The SURF algorithm is an improved version of the SIFT algorithm and is characterized by its matching speed and robustness (Wang et al., 2018). After the SURF features are extracted, the data is passed through an Artificial Neural Network for feature identification.

Artificial Neural Networks are powerful mathematical models that attempt to simulate and mimic the operation of biological neural networks. The basic building block of neural networks is the neuron. The output of the neuron sums up all weighted inputs and bias (Krenker, Bester, & Kos, 2011). Neural Networks can perform a wide number of tasks like classification, data processing, decision-making, and robotics.

The neural network is trained using data obtained from images through the process of supervised learning. The neural network is trained using weed images, which are obtained from the Kaggle dataset repository (Kaggle, 2020). The SURF features of these images are extracted and these features form the dataset which is used in the training, testing, and verification of the ANN. 70% of the data is used for training, 15% used for testing and 10% for verification. The neural network is designed based on the structure of a neuron shown in Figure 6.

Figure 6. Artificial Neuron (Oken, 2017)



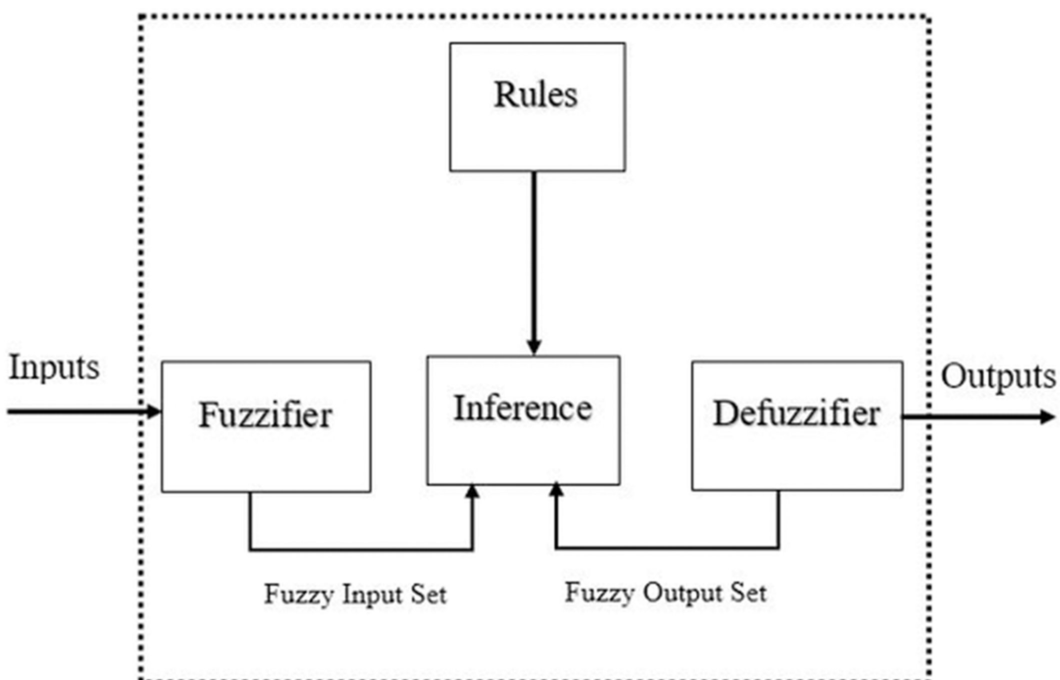
From Figure 6, the variables X1, X2, and X3 represent the inputs, while Y is the output of the neural network. In the case of this study, the inputs to the ANN are the SURF features obtained from the images. The output of the neural network is the classification result obtained from the ANN.

After the data is passed through the neural network, the output determines if a weed is detected or not and, thus, if the herbicide is required or not. The herbicide is applied based on the control signal sent from the fuzzy controller which determines the amount of herbicide to be used.

Herbicide Control Application With Fuzzy Logic

Fuzzy Logic was first introduced by Dr. Lofti Zadeh in 1965 as a technique to model uncertainty and vagueness in natural language (Singh & Mishra, 2015). It is a technique that mimics the human method of reasoning and attempts to make decisions in imprecise situations (Olaniyi, Salami, Adewumi, & Ajibola, 2014). Fuzzy Logic has been an attractive technique in linear and nonlinear control applications, pattern recognition, and even financial systems (Singh & Mishra, 2015). A fuzzy logic system consists of four main parts which are the fuzzifier, rules, inference engine and the defuzzifier (Singhala, Shah, & Patel, 2014). Figure 7 shows a fuzzy logic system.

Figure 7. Fuzzy Logic System



Fuzzification is the process of converting a crisp input into a fuzzy input (Olaniyi et al., 2014). This is usually achieved using membership functions. A membership function is a graphical representation of how a crisp input is mapped to a degree of membership from 0 to 1 (Waris & Ahmad, 2011). There are different types of membership functions used in fuzzy logic, which include triangular, trapezoidal, Gaussian and singleton membership functions (Goni, Gumpy, & Zira, 2018).

After fuzzification is achieved, the fuzzy inference engine evaluates the output based on a set of pre-defined fuzzy rules. Fuzzy rules are conditional statements that evaluate fuzzy outputs from a set of fuzzy inputs (Waris & Ahmad, 2011). Fuzzy rules are usually of the form:

If x is A, then y is B

A and B are linguistic values defined by fuzzy sets. A linguistic value is an input or output value that is not numeric but rather a natural language term (Goni et al., 2018). The first part of the rule is called the antecedent, while the second part is referred to as the consequent (Waris & Ahmad, 2011).

After the inference engine evaluates the rules based on the inputs, a control decision needs to be made. This process is called defuzzification and involves finding a crisp output that summarizes the fuzzy outputs. Some methods of defuzzification include centroid, bisection, weight average, and the largest of the maximum (Olaniyi et al., 2014).

In this study, the Fuzzy Inference System (FIS) was designed using the Fuzzy Logic Toolbox in MATLAB (version R2019a). The Mamdani FIS was used in this study due to its intuitiveness, widespread acceptance, and suitability for human inputs. The inputs to the Fuzzy Controller is the output from the neural network. Based on the developed membership functions, the output of the fuzzy controller will be the amount of herbicide to be sprayed, if required.

RESULTS AND DISCUSSION

This section presents the results from the design of the autonomous robot system for chemical weed control. The section comprises of results from the image processing algorithm, the motion control scheme, and the fuzzy controller for herbicide application.

PID Controller for Movement

From the algorithm of navigation within the farm environment, it can be seen that the robot is required to go left, right or straight depending on the sensor inputs. In order to realize accurate, stable, and effective system performance, a PID control scheme was implemented. The model of the control system is shown in Figure 8.

The PID controller was implemented using Simulink (version r2019). The controller was placed in series with the model of the electromechanical system presented earlier. A step input with an amplitude of 1 was used as the input to the system. The PID controller was tuned using the PID tuner application provided by MATLAB. The application evaluated three appropriate PID gains based on the system response of the transfer function. The system response graph is presented in Figure 9.

Figure 9 has three graphs, namely: the step input, the response of the plant without a control scheme, and the response of the plant with the PID controller. The step input provides a reference signal for all other outputs to follow. This implies that outputs from the plant need to be the same as or close to the reference input.

Figure 8. PID Control Scheme for Robot System

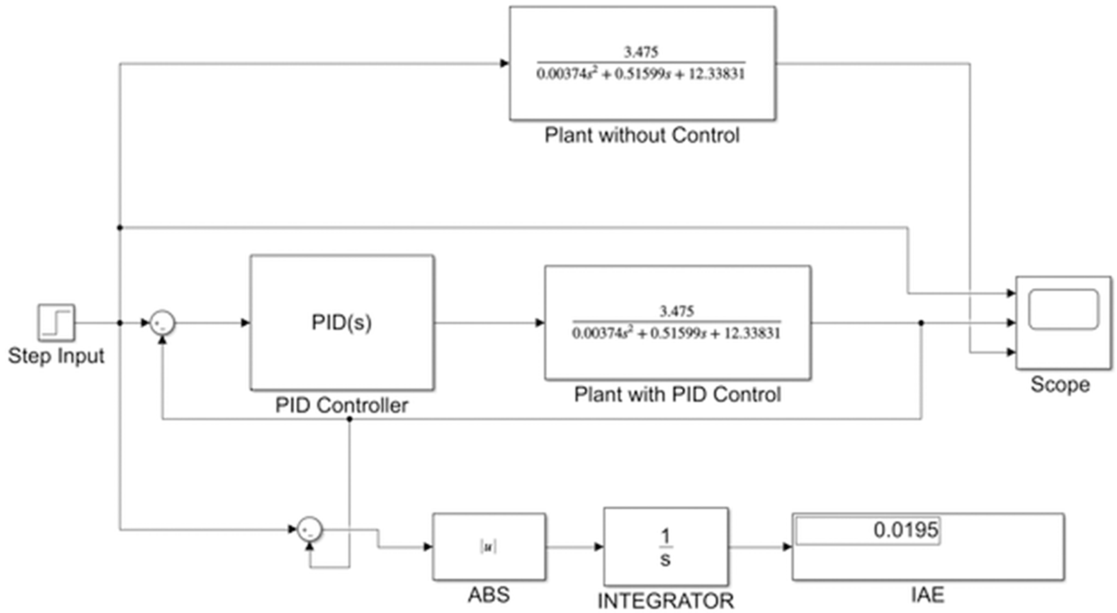
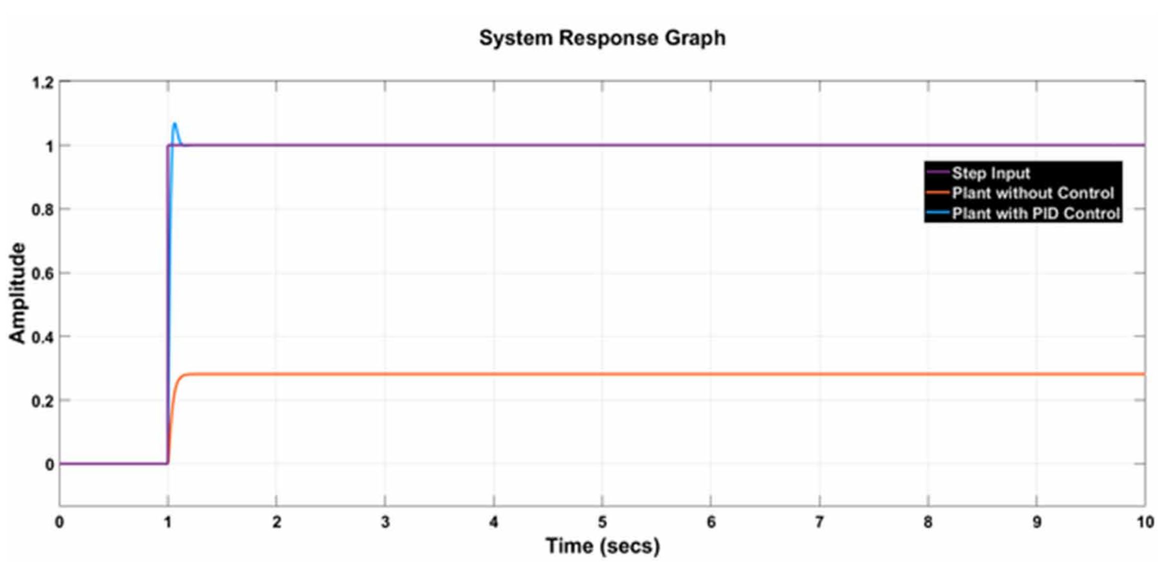


Figure 9. System response graph



On the one hand, the plant without a control scheme has a final value of 0.2 which is much lower than the reference input of 1. This indicates that without a control scheme, the movement of the robot will not be as accurate as required due to a drop in the amplitude. On the other hand, the output of the plant with the PID control scheme closely follows the reference input. This implies that with the PID controller, the robot movement will be accurate and precise.

In terms of the system response performance, Table 1 presents the values of the various metrics used in performance evaluation.

Table 1. System Response Performance

Parameter	Value
Proportional Gain	7.0678
Integral Gain	271.2664
Derivative Gain	0.033725
Rise Time	0.0279 secs
Settling Time	0.102 secs
Overshoot	6.97%
Integrated Absolute Error (IAE)	0.0195

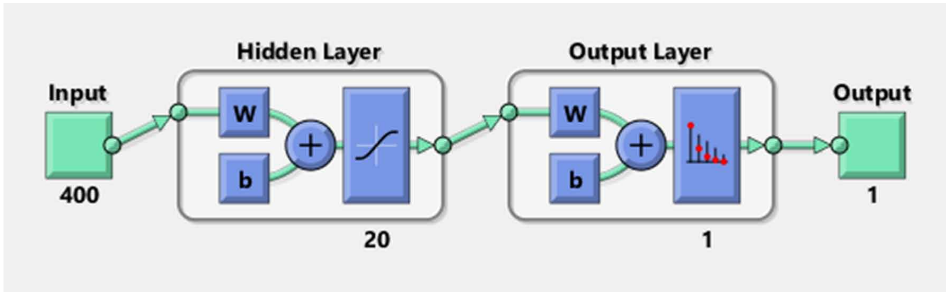
The rise time of the system is 0.034 seconds. This is the time it will take for the system to go from 10% to 90% of the output. This performance shows a fast response by the system. In addition, the system has a settling time of 0.1 seconds. This indicates the time it takes for the system to settle to its final steady-state value. The system has an overshoot of 6.97% which indicates that the output moves past its desired value before settling down at the steady-state value. In terms of the IAE, the system had an error value of 0.0195 for a simulation time of 10 seconds. This value is low and thus, desirable in control performance.

SURF and ANN for Weed Identification

In the area of image processing, 1300 images were obtained from the Kaggle dataset repository. These images consisted of images containing weeds and images without weeds. Each of these images was annotated with either 1 or 0 signifying the presence or absence of weeds, respectively. The class annotations resulted in a dataset of 1300 entities with class values of either 1 or 0. In each of the images, the SURF features were extracted and the strongest 200 SURF features were stored in a database. The resulting database had 1300 entities of 400 SURF coordinates (x and y values) each. This means that each image consisted of 400 parameters. These parameters consist of x and y coordinates of 200 SURF features.

The creation of this dataset was done in order to train, test, and validate the ANN using the process of supervised learning. A neural network was designed with a structure consisting of 400 inputs and 1 output. 20 hidden layers were implemented for the network in order to increase the accuracy of classification. The ANN was designed using the neural network toolbox provided by MATLAB, and the structure of the network is shown in Figure 10.

Figure 10. Structure of ANN



The inputs to the ANN are the SURF features, while the output is the classification result. The neural network was designed using a 70-15-15 rule. This means that 70% of the data was used for training, 15% for testing, and 15% for validation. The network was evaluated using the Receiver Operating Characteristic (ROC) which is a metric for evaluation of classification performance. Figure 11 shows the ROC curve for the ANN.

The ROC curve shows that the curve leans more towards the left, which is desirable in classification. The neural network gave a performance accuracy of 90.7%. This implies that the network will be able to accurately identify weeds in a farm environment.

Fuzzy Logic Controller for Herbicide Application

The Fuzzy Inference System (FIS) was designed in MATLAB (r2019 version). The FIS comprised of one input (weedDetect) and one output (sprayStatus). The input consisted of two triangular membership functions named noWeed and yesWeed, which respectively indicated the absence of weeds and the presence of weeds. Similarly, the output had two membership functions named noSpray and yesSpray, signifying whether or not herbicide is required. Figures 12 and 13 respectively show the membership functions for the input and output.

Figure 11. ROC curve for the ANN

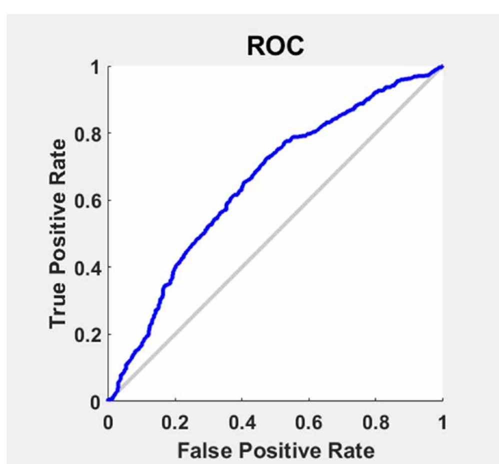


Figure 12. Membership Function for Input

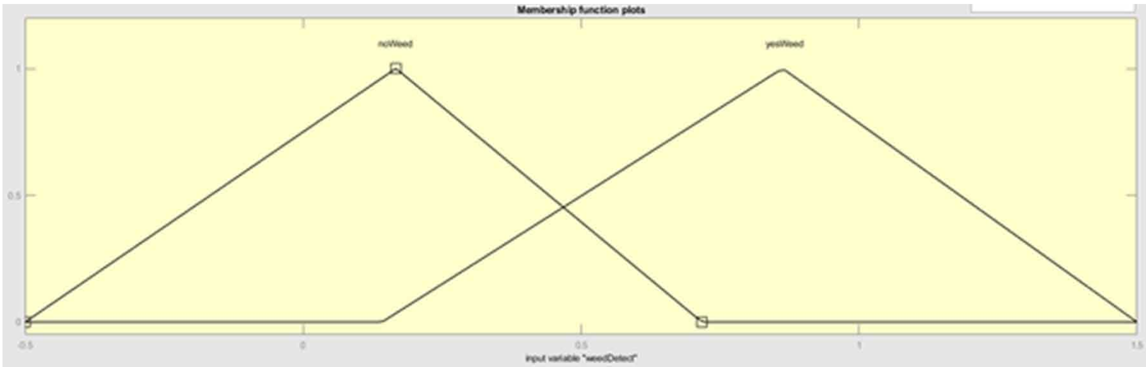
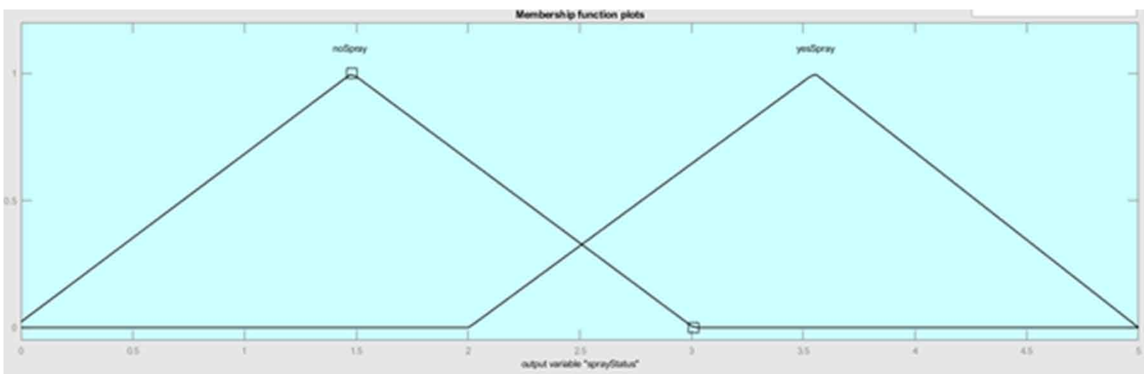


Figure 13. Membership Function for Output



The input to the FIS is the presence or absence of weed. This parameter is obtained from the output of the neural network. The input consists of two membership functions. These functions are noWeed and yesWeed with ranges of -0.5 to 0.72 and 0.14 to 1.5, respectively. The output of the FIS is the application of the herbicide. The output consists of two membership functions which are noSpray and yesSpray with ranges of -0.03 to 3.0 and 2.0 to 5.0 respectively.

The rule base for the FIS consisted of rules developed based on the presence or absence of weeds. If a weed is detected, the herbicide will be applied, and if a weed is not detected, no herbicide is required. The surface view for the rule base is shown in Figure 14, while the rules of the FIS are presented in Table 2.

Figure 14. Surface View for the Rule Base

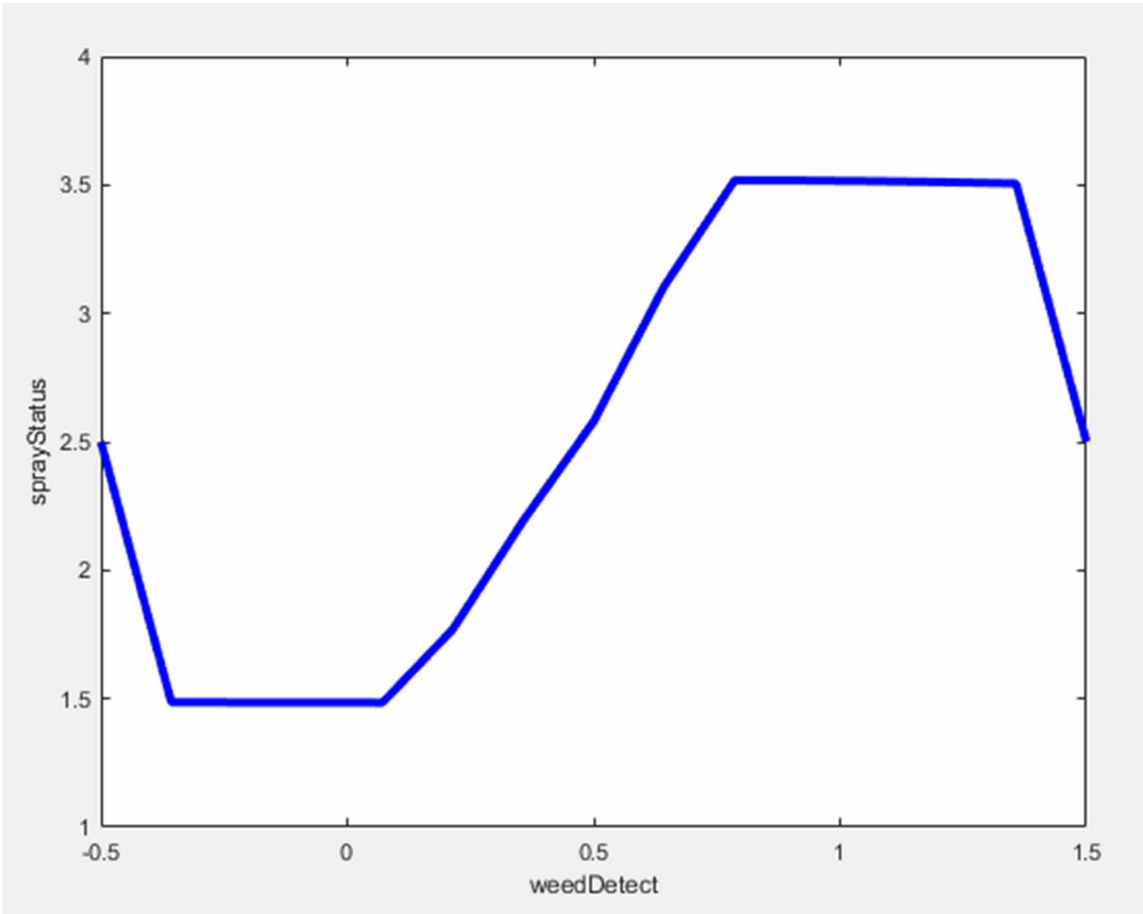


Table 2. Fuzzy Rules

weedDetect	sprayStatus
noWeed	noSpray
yesWeed	yesSpray

CONCLUSION AND FUTURE DIRECTIONS

Conclusion

Agri-business has the ability and opportunity to provide expanded jobs, elimination of hunger, higher income, and boost the production of nutritious food crops. Given the ability of the sector to revolutionize the agricultural commodity production of the Sub-Saharan African region, agribusiness suffers from numerous constraints which include weak policy articulation, insufficient working capital, lack of sufficient technologies and insufficient agricultural infrastructure. These obstacles restrict the industry's sales and earnings. Advances in precision agriculture in terms of the use of smart machines to minimize human involvement have increased agricultural output. The production of robots and their use in agriculture has increased and the possibility of incorporating logical mobile robot solutions based on behavioral approaches has been explored. In this study, the conceptual design of an autonomous robotic system for chemical weed control was presented in a quest to boost crop-based agribusiness productivity.

The autonomous robot system for chemical weed control was designed based on navigation, control, image processing, neural networks, and fuzzy logic techniques. The navigation algorithm presented in the research methodology is used by the robot for movement within the farm environment. To ensure accuracy, stability, and robust performance, a PID controller was implemented. The controller gave a rise time, settling time, overshoot, and IAE of 0.0279 secs, 0.102 secs, 6.97%, and 0.0195 respectively. This indicated a satisfactory system performance. The ANN was developed using SURF features obtained from an image dataset and gave a classification accuracy of 90.7%. The output of the ANN classification is fed into the fuzzy controller, which in turn determines if herbicide application is required. Based on the output of the FIS, the herbicide is applied (or not). The system utilizes visual and ultrasonic sensory inputs to obtain information about the environment. The data obtained from the sensors is analyzed using artificial intelligence algorithms for intelligent farm operations.

The system will enable farmers to cover large areas of arable land with minimal human involvement as regards the minimization of human labor. That implies that farmers could use the system to cover a large area of land instead of hiring a large workforce for manual weeding. Farmers who manage farm operations alone can also introduce this device to simplify their tasks, allowing them the flexibility to concentrate on other operations. It would reduce herbicide application labor costs in crop production substantially. The system will minimize herbicide wastage in the aspect of the application of herbicides. With the autonomous robotic system, the herbicide will only be applied by the device when a weed is detected. This would eliminate the excessive use of herbicide where weeds are not present, thereby reducing the expense of buying herbicides and hiring labor.

This system, upon implementation and adoption, is expected to increase crop yield and profit for agroprenuers with minimal human intervention. In addition, crop production of staple foods in sub-Saharan Africa will be positively influenced due to the potential of the system to encourage crop production on a large scale. This will also improve national and regional food crop production and generate more revenue in the value chain of a crop commodity.

Future Research Focus

The following areas are suggested for future research works.

1. Prototype Development and Hardware Implementation: This will involve the implementation of the algorithms on microcontroller firmware and evaluating the performance of the system in the field.
2. An assessment of robot navigation, weed detection, and herbicide application accuracy on its metric performance in farmers' fields.
3. Field Experimental Assessment: Conduct the comparative efficiency of the Autonomous Robot System with the conventional methods of chemical weed control in a named crop commodity in farmers' fields.

RECOMMENDATIONS

The following recommendations are made for researchers and stakeholders in the agricultural sector:

a. Provision of funding for research and development in smart farm systems to boost agricultural productivity.
b. Sensitization and workshops for farmers on the importance of precision agriculture to agricultural development.
c. Promotion of intelligent and automated farm systems, especially in rural areas, to improve the adoption of state-of-the-art technologies by farmers and to boost crop production of staple foods in sub-Saharan Africa.

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KEY TERMS AND DEFINITIONS

Artificial Neural Networks: Artificial neural networks are mathematical models that attempt to simulate and mimic the operation of the human brain.

Control System: A control system is a system that comprise of processes and subsystems which are integrated for the main purpose of achieving a desired output or performance when given a specified input.

Fuzzy Logic: Fuzzy logic is a method that deals with inaccuracy and indecision. Fuzzy logic imitates the way the human brain works to solve problems, thereby aiding a system to make the right decision in imprecise situations.

Herbicide: This is any chemical or agent used to inhibit plant growth.

Image Processing: This is a technique or process that makes a software identify, analyze, and understand the content of video and images.

Robot: A robot is an electromechanical system capable of performing a pre-programmed mission. Such tasks can be difficult for humans to perform, or repeated tasks requiring accuracy.

Weed: Weed is any plant that grows in an unwanted place.

Appendix 1 (SURF Algorithm)

```
clc;
clear;
myDirectory = dir('data');
surfData = [];
surfClasses = [];
for i = 3:2602
if(rem(i, 2) == 1)
img = imread(strcat('data\', myDirectory(i).name));
gray_img = rgb2gray(img);
new_img = imresize(gray_img, [200 200]);
surfpoints = detectSURFFeatures(gray_img);
strongpoints = surfpoints.selectStrongest(200);
strongpointsLocation = strongpoints.Location;
strongpointsMatrix(1:200) = [strongpointsLocation(:, 1)];
strongpointsMatrix(201:400) = [strongpointsLocation(:, 2)];
surfData = [surfData; strongpointsMatrix];
else
if(rem(i, 2) == 0)
textFileName = strcat('data\', myDirectory(i).name);
textValues = importdata(textFileName);
surfClasses = [surfClasses;textValues(1)];
end
end
end
save('dataset.mat', 'surfData');
save('dataClasses.mat', 'surfClasses');
```

Appendix 2 (ANN Design)

```
% Solve a Pattern Recognition Problem with a Neural Network
% Script generated by Neural Pattern Recognition app
% Created 14-May-2020 15:05:02
%
% This script assumes these variables are defined:
%
% surfData - input data.
% surfClasses - target data.
```

```
x = surfData';
t = surfClasses';
% Choose a Training Function
% For a list of all training functions type: help nntrain
% 'trainlm' is usually fastest.
% 'trainbr' takes longer but may be better for challenging problems.
% 'trainscg' uses less memory. Suitable in low memory situations.
trainFcn = 'trainscg'; % Scaled conjugate gradient backpropagation.
% Create a Pattern Recognition Network
hiddenLayerSize = 10;
net = patternnet(hiddenLayerSize, trainFcn);
% Choose Input and Output Pre/Post-Processing Functions
% For a list of all processing functions type: help nnprocess
net.input.processFcns = {'removeconstantrows','mapminmax'};
% Setup Division of Data for Training, Validation, Testing
% For a list of all data division functions type: help nndivision
net.divideFcn = 'dividerand'; % Divide data randomly
net.divideMode = 'sample'; % Divide up every sample
net.divideParam.trainRatio = 70/100;
net.divideParam.valRatio = 15/100;
net.divideParam.testRatio = 15/100;
% Choose a Performance Function
% For a list of all performance functions type: help nnperformance
net.performFcn = 'crossentropy'; % Cross-Entropy
% Choose Plot Functions
% For a list of all plot functions type: help nnplot
net.plotFcns = {'plotperform','plottrainstate','ploterrhist', ...
'plotconfusion', 'plotroc'};
% Train the Network
[net,tr] = train(net,x,t);
% Test the Network
y = net(x);
e = gsubtract(t,y);
performance = perform(net,t,y)
tind = vec2ind(t);
yind = vec2ind(y);
percentErrors = sum(tind ~= yind)/numel(tind);
% Recalculate Training, Validation and Test Performance
trainTargets = t .* tr.trainMask{1};
valTargets = t .* tr.valMask{1};
testTargets = t .* tr.testMask{1};
trainPerformance = perform(net,trainTargets,y)
valPerformance = perform(net,valTargets,y)
```

```
testPerformance = perform(net,testTargets,y)
% View the Network
view(net)
% Plots
% Uncomment these lines to enable various plots.
%figure, plotperform(tr)
%figure, plottrainstate(tr)
%figure, ploterrhist(e)
%figure, plotconfusion(t,y)
%figure, plotroc(t,y)
% Deployment
% Change the (false) values to (true) to enable the following code blocks.
% See the help for each generation function for more information.
if (false)
% Generate MATLAB function for neural network for application
% deployment in MATLAB scripts or with MATLAB Compiler and Builder
% tools, or simply to examine the calculations your trained neural
% network performs.
genFunction(net,'myNeuralNetworkFunction');
y = myNeuralNetworkFunction(x);
end
if (false)
% Generate a matrix-only MATLAB function for neural network code
% generation with MATLAB Coder tools.
genFunction(net,'myNeuralNetworkFunction','MatrixOnly','yes');
y = myNeuralNetworkFunction(x);
end
if (false)
% Generate a Simulink diagram for simulation or deployment with.
% Simulink Coder tools.
gensim(net);
end
```

Chapter 14

Internet of Things–Enabled Agribusiness Opportunities in Developing Countries:
Agribusiness Engagement Opportunities in Nigeria

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ABSTRACT

In Africa, about 300 million people are undernourished, and there is mounting evidence linking food insecurity to rapid population growth. Profitable production of crops and animals in large quantity is hinged on improved practices using modern tools: internet of things (IoT). The internet of things has the purpose of providing ICT infrastructure facilitating the exchange of 'things' in a secure and reliable manner. Its function is to overcome the gap between objects in the physical world and their representation in information systems. Agribusiness empowered by IoT has opportunities in crop and animal health assessment and monitoring. They include agricultural drone services, crop and livestock production and management, digital information platforms, online sales and purchase of agricultural products (e-commerce), export and marketing of farm produce or processed products. In conclusion, young people will be gainfully engaged if they can be provided the Internet of Things enabled agribusiness.

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INTRODUCTION

Agriculture is mostly undertaken as part of life rather than been seen as a business in Nigeria. However, numerous opportunities are available for all and sundry to turn agriculture to agribusiness.

Agriculture is a profit-driven oriented business; hence, factors that influence the profitability of a farm are of great paramount and interest to the farmer. IoT can be made relevant if it can address the general needs of a locality, be made available and affordable, easy to use, and packaged in the local/indigenous languages. With the intensification of crop/ livestock production systems and increased market demand for animal-based products, the importance of information is growing in many developing countries (Morton and Matthewman, 1996). Hence, there is a need for the continual exchange of information and data, decoding, and interpretation as well as actions taken to achieve desired success.

BACKGROUND

In recent times, the use of technology to drive innovation is important to its sustainability and relevance. Internet of Things (IoT) is a topical technology deployed for improvement and enhanced productivity of life. Internet of Things is a novel technological tool that is gaining recognition in various facets of life – medicine, security, transportation, engineering, and lots more. It is the networking of objects through software, sensors, network connectivity to collect and exchange data (GSI, 2015) with little or no human interference. However, enabling the agribusiness with IoT entails networking of objects embedded with software, sensors, and network connectivity in agricultural product processing, transportation and logistics, storage of produce, agro-consults, agro-allied and input, product export, marketing, production of crops and farm animals. In Nigeria, opportunities abound in these agribusiness outlets for the profitable use of IoT.

Agriculture contributes 40% to the Gross Domestic Product (GDP) and employs about 70% of the working population in Nigeria (CIA, 2013). Agriculture is also the largest economic activity in rural areas, where almost 50% of the population lives (Odetola and Etumnu, 2013). The agriculture sector has been the mainstay of the economy since independence, and it remains a resilient sustainer of the populace. In the 1960s, Nigeria was the world's largest exporter of groundnut, the second-largest exporter of cocoa and palm produce, and an important exporter of rubber and cotton (Sekunmade, 2009). The country also enjoys diversity in climatic conditions in different zones at the same time. The humid and sub-humid zones favor the production of crops and forests, while the savanna region is conducive for ruminant production. It is estimated that about 84 million hectares of Nigeria's total land area has potential for agriculture; however, only about 40% of this is under cultivation (Photius Coutsoukis, 2004). Agriculture provides income, employment, raw materials for industries, food security for the populace, and foreign exchange for the country. In fact, a continuous increase in the human population is an indication that there is a ready-made market for agricultural produce.

In spite of these opportunities, the state of agriculture in Nigeria remains poor and largely underdeveloped. The sector continues to rely on primitive methods to sustain a growing population without efforts to add value. This has reflected negatively on the productivity of the sector, its contributions to economic growth as well as its ability to perform its traditional role of food production among others (Odetola and Etumnu, 2013). This state of the sector has been blamed on oil glut and its consequences on several occasions (Falola and Heaton, 2008). Insufficient production and disease outbreaks on crops and animals can lead to food insecurity, economic downturn, and death due to hunger reduced quality and halting access to important export markets. The importation of crops and animal products to subsidize indigenous production is on the increase, and this is not sustainable; it is cost-ineffective. Also, the recent outbreak of Covid-19 in the world is already having an impact on food security. Unfortunately, Nigerian agriculture is largely primitive, subsistent, and in the hands of traditional farmers. However, these challenges can be combated through the production of crops and animals in commercial quantity (Bamigboye and Ademola, 2019) enabled with IoT. Hence, the need for enabling Nigeria Agribusiness with Internet of Things is addressed by the present study by answering the following questions:

- Is agriculture the same as agribusiness?
- What are the opportunities that can be derived from agribusiness in Nigeria?
- Are there challenges in engaging in agribusiness in Nigeria?

LITERATURE REVIEW

Agriculture and Agribusiness in Nigeria

Agribusiness is the sum total of all operations involved in the manufacture and distribution of farm supplies, production operations on the farm, and the storage, processing, and distribution of farm commodities and items made from them (Davis and Goldberg, 1957). It includes crop production, seed supply, agrochemicals, farm machinery, distribution, processing, marketing, and retailing of agricultural produce to ultimate consumers. Agribusiness has evolved from agriculture and has become a vast and complex system that reaches far beyond the farm to include all those who are involved in bringing food and fiber to consumers (Bairwa *et al*., 2014). It emphasizes the notion that for agriculture to be sustainable, it needs to be viewed as a business (Nwuneli, 2010). Agriculture entails the production of animals and crops for human consumption, while agribusiness is transforming agriculture into a profitable business. Production of agricultural produce involves a host of levels coming into play for a complete cycle to be achieved (food on consumers' tables). These levels are business-worthy!

It is well recognized that the human population is on the increase both in Nigeria and the world at large. Among the ten largest populous countries of the world, one is in Africa (Nigeria), five are in Asia (Bangladesh, China, India, Indonesia, and Pakistan), two are in Latin America (Brazil and Mexico), one is in Northern America (United States of America), and one is in Europe (Russian Federation). Amongst these, Nigeria's population, currently the seventh-largest in the world, is growing the most rapidly. Consequently, the population of Nigeria is projected to surpass that of the United States shortly before 2050, at which point it would become the third-largest country in the world, exceeding 300 million (UN, 2017). The rapid increase in population is a pointer to threatened human existence if there is no commensurate food production. Hence, there is a severe need for food production in commercial quantity in Nigeria. Unfortunately, based on Nigeria's official definition of smallholders, more than 80 percent of farmers in Nigeria are considered smallholders because they own less than 5 hectares of land. Smallholders produce 99 percent of Nigeria's agricultural outputs (Mgbenka and Mbah, 2016). Another outstanding issue impeding the efficient performance of key players in agriculture is age. The report has it that the average age today of a farmer in Nigeria is between 55 and 60 years, and by the year 2030 will rise to between 75 and 80 years. Interestingly, these old farmers have all the experience, knowledge, and information (techniques) of Agriculture but not Agribusiness. Generally, Nigerian youths are not into agriculture and are not even going into it. A large number of graduates estimated to be between 10 to 12 million young people per year (AGRA, 2015) in Nigeria alone with little or no hope of employment. Both animal and crop production in Nigeria is largely dominated by traditional/smallholder farmers (Bamigboye et al., 2015; Sabo et al., 2017). Smallholder farmers are characterized by marginalization in terms of accessibility, resources, information, technology, capital, and assets, but there is great variation in the degree to which each of these applies (Odoemenem and Obinne, 2010).

Agriculture presents a unique opportunity for African youth, not only because it is the largest contributor to GDP in most of the African countries, but also because it continues to experience significant growth. However, Nigerian youths remain uninterested in agriculture. This trend is further highlighted by the aging farming population in Africa. Available data from Nigeria reveals that the current average age of a farmer is between 55 and 60 years (Sahel, 2018).

The potential of the agriculture sector in Nigeria is huge. Nigeria is blessed with 98 million hectares of arable land and 2.5million hectares of irrigable land, out of which 83 million hectares are suitable for cultivation, but only 30 to 34 million hectares are presently under cultivation. The nation has one of the best agroecology to grow a variety of crops (Ashaye, 1983, Oriola, 2009). Its natural assets include land, climate and rainfall, its coastal areas, and its history as an agrarian economy. In addition, the country's population represents a large domestic market that can support and sustain local production and processing. Today, Nigeria is one of the world's largest producers of cassava, cashews, tubers (sweet potato, yams), fruits (mango, papaya), and grains (millet, sorghum, and sesame) (Nwuneli, 2010). However, the country has not been able to take the best advantage of her climatic conditions, the large expanse of land, and ever-increasing teeming population to make her sufficient in food production. Despite the fact that a variety of crops thrive well with maximum yield in different Ecozones of the country, Nigeria remains one of the food-deficit countries in sub-Sahara Africa (Arthur, 2009).

The economic downturn, unemployment, and poverty can be altered through the agricultural sector that is transformed into an agribusiness system. Turning agriculture to agribusiness will encourage youth participation at all levels; hence, food security and sustainable development will be attained in the country.

Transforming Nigerian Agribusiness with Technology

The advent of the oil boom may be said to have spelled doom to Nigeria. It was supposed to be a blessing and double honor combined with agriculture. However, it led to the diversion of the country's focus on agribusiness instead of diversification. This was bought to bare when Nigeria that had been experiencing food security was compelled to import processed agricultural products. The position of being the highest producer and exporter of some crops was lost to other countries. The citizens became insecure food-wise, laziness sets in, and youth will rather take to other easier ways of income-generating means than agribusiness. This brought to the limelight deployment of relevant agro-technological innovations to increase efficiency, effectiveness, and ease of work on the farm to improve productivity.

Initially, it started with the advent of tractors and other implements attached to it. However, the use of these farm machinery was not welcomed by the older farmers due to their attachment to the crude way of farming and the inability to adapt to changes. Furthermore, the expanse of land under cultivation in a particular place owned by an individual is quite small and does not encourage mechanization. Nevertheless, over time, both old and young are embracing the use of tractors and other implements on their farms. Also, they took to the use of irrigation on their farms during dry periods to ensure all-round food production. In recent times, precision agriculture, which is associated with accurate or exact farming, without the wastage of agricultural inputs, has become commonplace.

Precision agriculture is one of the most famous applications of IoT in the agricultural sector, and numerous organizations are leveraging this technique around the world. In this approach of farm management, a key component is the use of IT and various items like sensors, control systems, robotics, autonomous vehicles, automated hardware, variable rate technology, and so on (Ravindra, 2018).

Interestingly, though agriculture goes with the new technology of the modern world, Nigerian elders can no longer match or comply with the requirements of current trends and latest modern technological advances in agriculture (mechanization, use of high-yielding varieties, application of inputs and weather forecast compliance). Hence, there is placement and void to be filled by Nigerian youths.

Internet of Things in Agriculture as practiced in Nigeria

In Nigeria, agriculture serves as one of the main resources for income generation for individuals, private and public organizations. However, agriculture in Nigeria as an enterprise and food security outlets for her populace is still backward in the use of IoT. Internet of Things has the potential to improve, enhance, and absolutely change the face of Nigerian agriculture to a world-class standard. Internet of Things is just becoming popular in all facets of life in Nigeria. However, its usage in agriculture is still backward. Mostly, IoT usage in agriculture is believed to be only profitable for large-scale farmers. But very few farmers in Nigeria practiced large-scale farming. Hence, most farmers have not seen the need for their usage on their farms (Bamigboye and Ademola, 2019).

Mobile Feed and Water Dispensing System

Feeding of poultry is a major task that is time-consuming and labor-demanding. Its efficiency also can determine the profitability of a poultry farm. In Nigeria, feed dispensing methods working based on IoT was developed by researchers. Arulogun *et al*. (2010) developed a mobile intelligent poultry feed dispensing system. The system was able to move, detect and avoid obstructions and dispense solid feed to poultry. However, Olaniyi *et al*. (2014) designed a mobile intelligent poultry feed and water dispensing system; using a fuzzy logic control technique.

This unit was responsible for dispensing solid feed to the poultry birds. It comprises a solid feed trough, a 12 V DC motor connected to a conveyor, and a feeder. The solid feed trough is expected to be filled with the appropriate solid feed to be administered to the birds. A feed sensing unit that comprises a light-dependent resistor check the feed level and, in turn, determines if there is a need to dispense the feed or not. The microcontroller will then send a signal through the PID controller to the DC motor, which will enable it to rotate. The rotation of the DC motor will in turn, rotate the conveyor, which will result in the dispensing of the solid feed to the feeder. The poultry feed from the feeder after the feed is dispensed to the feeder for the pre-defined time determined by the microcontroller. A relay circuit is connected between the microcontroller and the DC motor so as to enable the proper functioning of the system (Olaniyi *et al*., 2016).

Virtual Fences

The use of virtual fences to monitor the perimeters of large farmlands and plantations is of tremendous advantage. The most obvious is in terms of cost savings when compared to building high brick fences and employing security personnel to patrol the entire perimeter. With virtual fences, relatively cheap modules can be installed, and the entire perimeter monitored remotely (Ajayi and Olaifa 2016).

Staff Monitoring Tech

The Nigerian Satellite Company Limited has successfully designed, implemented, tested, and deployed an RFID-based Staff Attendance and Access Control System (RFID-SAACS). RFID-SAACS is a vital tool for staff management, administration, and monitoring that impacts staffs' attitude to work, as time theft by staff is completely eliminated. The logged data can also serve as a means of staff monthly appraisal, while an additional utilization of the RFID-SAACS system includes integration into the payroll system to facilitate precise salary computation and payment based upon vetting of employees' overall performance (NCSL, 2015). This is used in some automated farms in Nigeria.

E-payment, Purchases, and Sales of Inputs and Produces

Also, the use of point-of-sale (PoS) terminals for the purchase of farm produce to achieve cashless transactions is now common in Nigeria. A PoS terminal is an electronic device that is used for verifying and processing credit/debit card transactions, which transmits data over a standard telephone line or an Internet connection. The Nigeria Interbank Settlement Services (NIBSS) had observed in its recent report that PoS is the most popular non-cash payment channel, preferred among the non-cash payment options by 93.6% of merchants and 35.8% of consumer usage. It described the usage of cards and PoS as fair, with an average of three to four out of every 10 customers requesting to pay for transactions by card/PoS (Adeoye, 2015). Electronic payment through PoS terminals has risen by 191% to N241 billion in 2014 (Komolafe, 2014).

E-Wallets

Furthermore, as part of an ambitious strategy to transform agriculture, the Growth Enhancement Support (GES) initiative, introduced in 2012, farmers' cellphones as electronic wallets – distributing vouchers amounting to a 50% subsidy for purchase of fertilizer. Ministry officials opine that the phones could eventually be used for multiple purposes, from communicating weather and climate information to accessing market data. Experiences in other African countries showed that such uses could deliver higher prices to farmers. Records also show that 1.2 million farmers received their subsidized fertilizer and seeds through cellphone vouchers in 2013, resulting in the addition of 8.1 million metric tons to Nigeria's domestic food supply. As a result, Nigeria reduced its food imports by over 40% by 2013, moving the country closer to self-sufficiency in agriculture (Hultman, 2015).

Livestock Monitoring and Management

The SMART Livestock Tracker application was created to check to a level the issue of stolen and missing livestock. The SMART {Self-Monitoring Analysis and Reporting Technology} Livestock Tracker works with GPS collar, which is secured with a lash on the animal's neck. The capacity of the GPS collar is to refresh the area of the creature by means of GPS. To find the area of their livestock, agriculturist needs to ask for the area of their livestock through the android gadget. Once asked for, ask for information from the gadget that will provoke the GPS collar to give its present area. At long last, the GPS collar will send its present area back to the android gadget. This procedure will just take not as much as a moment relying upon organized speed and scope. This application gives better other options to agriculturists to track their livestock, whether it is missing or stolen (Artmann, 1999; Anyasi *et al*., 2018).

Agriculture is a profit-driven oriented business; hence, factors that influence the profitability of a farm are of great paramount and interest to the farmer. IoT can be made relevant if it can address the general needs of a locality, be made available and affordable, easy to use, and packaged in the local/ indigenous languages (Bamigboye and Ademola, 2019).

Opportunities in Internet of Things Enabled Agribusiness in Nigeria

Several opportunities abound that can be explored by the streaming youths in developing countries like Nigeria. They can make a living through technological tools at their disposal through the application of Internet of Things in agribusiness. These opportunities are but not limited to:

1. Use of agricultural drones

In recent times, drones are used to cover occasions and events in Nigeria. However, drones can be used for pests and disease surveillance and early detection for both crops and farm animals, monitoring of the farm whether the farmer is present or absent, spraying of pesticides, herbicides, and other chemicals on infected crops and animals. It can also be used for security purposes both for locating missing animals and forestalling crops and livestock herders' clashes.

Drones are being used in agriculture in order to enhance various agricultural practices. The ways ground-based and aerial-based drones being used in agriculture are crop health assessment, irrigation, crop monitoring, crop spraying, planting, and soil and field analysis. The major benefits of using drones include crop health imaging, integrated GIS mapping, ease of use, saves time, and the potential to increase yields. With strategy and planning based on real-time data collection and processing, drone technology will give a high-tech makeover to the agriculture industry (Ravindra, 2018).

Nigerian youths can team-up to set-up drone service outlets for interested farmers. Disease surveillance and routine check at affordable rates can be made available to farmers. Also, the use, maintenance, and repairs of drones can be another lucrative agribusiness to venture into by Nigerian youths. Furthermore, training, workshops, and write-up on agricultural drones can be ventured into for money-making too. These are attractive outlets yet to be fully explored for agricultural drones.

2. Digital Information platforms for Farmers

Trending innovative information related to crop and farm animal production is essential for farmers to stay relevant and productive in the present age. As the world is evolving, so are the agricultural practices. Hence, the farmers must be abreast of this vital information. Information on acquisition of agricultural loans, where to purchase best seeds and seedlings to be planted, best breeder stock for livestock production, and market information are all important to farmers in order to expand and improve productivity.

This is another agribusiness that can be very interesting to young citizens in Nigeria and Africa at large. They can set-up credible platforms that address all the information needs of farmers. They can link farmers to investors and loan facilities as well as other relevant opportunities sought by farmers.

iGrow connects people who want to become providers of capital financing with farmers who are recipients of capital financing to jointly increase the scale of planting / cultivation and the welfare of the agricultural world.

Until now, only with the Indonesian market, iGrow has succeeded in employing more than 7500 farmers in more than 2,500 hectares of land and obtaining good, high-quality crops. Not only that, but iGrow has also become a source of income for farmers, landowners, and capital providers.

In Indonesia, there are millions of hectares of land that are not optimally exploited, and there are also millions of farmers who still live below the poverty line because of insufficient employment. But there are the needs and demands of the community for food from agricultural products to continue to grow by the day.

iGrow identifies plants that have high demand in the market, good price stability, and characteristics. It connects farmers and land that can be used and opens opportunities for financing the planting to the urbanites. iGrow is not only a product with a commercial vision, but it also has a great mission to be able to preserve life on earth and to make food security fairly attainable for all humans, utilizing the available resources on earth.

Farmcrowdy is Nigeria's First Digital Agribusiness Platform that empowers rural farmers by providing them with improved seeds, farm inputs, training on modern farming techniques, and provides a market for the sale of their farm produce. This gives the farmers the capacity to farm more acres and, by extension, leads to increased food production and security in Africa.

Since launching in 2016, Farmcrowdy has empowered over 25,000 small-scale farmers across Nigeria. They have developed a clear process to control their capacity to provide a realistic market offer. Today, Farmcrowdy has a pre-incubation time of 2-3 months to identify and launch a project. Areas of interest of Farmcrowdy are:

a. Crop and Land Selection

They identify crops to be cultivated based on season, demand, and location. They also do their due diligence on potential yield per area, land availability, and potential partners in terms of input providers and mechanization.

b. Farmers

To keep things organized, they do not work with individual farmers. Instead, once they identify a state or location, they reach out to the farmers' association or community leaders to help identify experienced and committed farmers to be worked with.

c. Inputs

They then provide input in the form of improved seed varieties, training on modern farming techniques, and mechanized tools to the farmers. They also assign technical field specialists to each farm/location.

d. Off-takers

Ready buyers of farm produce are sourced for in order to make the farmers` work easier. This will enable farmers to concentrate on farming and not have to worry about selling the products after harvest. This will help prevent them from being exploited or underpriced such that they don't sell their produce at unprofitable margins.

3. Smart Greenhouse farming and services

Greenhouse farming is a methodology that helps in enhancing the yield of vegetables, fruits, crops, etc. Greenhouses control the environmental parameters through manual intervention or a proportional control mechanism. As manual intervention results in production loss, energy loss, and labor costs, these methods are less effective. A smart greenhouse can be designed with the help of IoT; this design intelligently monitors as well as controls the climate, eliminating the need for manual intervention.

For controlling the environment in a smart greenhouse, different sensors that measure the environmental parameters according to the plant requirement are used. A cloud server for remotely accessing the system can be created when it is connected using IoT.

This eliminates the need for constant manual monitoring. Inside the greenhouse, the cloud server also enables data processing and applies a control action. This design provides cost-effective and optimal solutions for farmers with minimal manual intervention (Ravindra, 2018). The present-day youths in Nigeria can establish agribusiness outlets through the use of smart greenhouses for the production of fruits, vegetables and crops. Also, they can offer services by setting up, managing, or repairing the facility for interested farmers. An example of this is as cited:

https://illuminumgreenhouses.com

Illuminum Greenhouses is a drip installation and Agri-Tech greenhouse organization that uses new modern technologies for providing services. It builds modern and affordable greenhouses by using solar-powered IoT sensors. With these sensors, the greenhouse state and water consumption can be monitored via SMS alerts to the farmer with an online portal. Automatic irrigation is carried out in these greenhouses.

The IoT sensors in the greenhouse provide information on the light levels, pressure, humidity, and temperature. These sensors can control the actuators automatically to open a window, turn on lights, control a heater, turn on a mister or turn on a fan, all controlled through a *WiFi* signal.

4. Telemedicine for Animals

Most of the animal farms like piggery and poultry farms are located far from high-density population areas (also known as cities) because of the odor generated from their operation and the space required by their operations. As a result of this, farms are located in remote areas and villages where access to quality veterinary medicine and doctors is limited. Telemedicine (also referred to as "telehealth" or "e-health") allows health care professionals to evaluate, diagnose and treat patients in remote locations using telecommunications technology. Telemedicine allows patients in remote locations to access medical expertise quickly, efficiently, and without travel. This concept can also be applied to animals also. A telemedicine app or platform which helps bridge the gap and connects farmers to experienced veterinary doctors from all over the world is a very good agribusiness idea (Agricdemy, 2018).

5. Robotics/Automation in production and processing of agricultural produce

The use of robots to work instead of humans is becoming more popular in recent times, especially in industries. However, they can also be deployed to work on livestock and crop farms to attain maximum efficiency and productivity. Robots can be programmed to feed animals with respect to a level of feed reduction in their feeder. They can be used for egg collection in poultry houses, spraying of chemicals on crops, and so on (Agricdemy, 2018).

6. **Wearable for Animals**

Fitness enthusiasts are very familiar with wearables that keep track of their pulse, the number of steps walked, sleeping patterns, etc. Just as these metrics are important for human health, there are equally important metrics crucial for animal health, which farmers should stay abreast of. There are wearable devices which can track the health metrics of farm animal and relay them to farmers. The wearable can also let farmers know when their animals are due to receive medicine and vaccine (Agricdemy, 2018). It can also monitor reproductive performance and other management practices. This is a good agribusiness idea to be considered.

7. E-commerce and on-line purchase of agricultural produce

In today's world, with the wide acceptance of e-commerce and online shopping, an online grocery shopping e-commerce website is a good agribusiness idea to implement. Farmers and consumers can be directly linked together by creating a webpage as a meeting place. A website can be set up in such a way that farmers can post and list their farm produce directly for sale while the developer receives a commission on any sale they make. People would then be able to buy fresh fruits and vegetables from the comfort of their homes and offices (Agricdemy, 2018).

8. Transportation and logistics

In Nigeria, most of the farm produce is not always available in industrial quantity in a place at a given time. Hence, buyers or middlemen go around seeing farmers who are ready to sell the produce at a given time, and they buy from them in bits. Transporting these goods is also a big challenge in Nigeria, due to the fact that they are purchased in bits, the produce sometimes may not fill up a lorry. However, with the advent of IoT, the transporter can be guided to others within the vicinity in need of this service (Bamigboye and Ademola, 2016). It is a lucrative agribusiness that youths can also explore.

9. Agro-consult services

There is a rising demand for agricultural consulting services. People having knowledge and experience in the field can start providing consulting services to new farmers and institutions seeking to invest in agriculture (Agricdemy, 2018). Linkage platforms where farmers can engage experts on issues can be created, and farmers have their problems resolved without seeing the consultants, yet payment is made for a consultation.

10. Value addition in the form of processing of crops, livestock and livestock products

Opportunities for income and wealth creation are abundant in the processing of crops and livestock. Due to the short shelf-life, value addition elongates the shelf-life of these products. Collection/purchase from farmers, distribution, and marketing of the products can be IoT empowered.

Agri Marketplace's vision is to become the largest agricultural fair-trade platform, connecting farmers to industrial all around the world.

Agri Marketplace's mission is to become the global reference for digital agricultural food crop transactions through a complete platform solution.

Agri Marketplace provides a full-solution that operates throughout the entire agro-industry supply chain:

- Unlimited access to a global market from anywhere, at any time.
- Transparent and reliable market information, deal creation, and negotiation.
- Integrated and secure platform payment processes.
- Tailored product quality verification and logistic services.
- A market with only verified buyers and sellers.

11. Storage

Agricultural products are mostly perishable after harvesting; this necessitates storage of produce. IoT enabled storage facilities to fortify farmers with information on stored produce, shelf-life, optimum temperature, and humidity, as well as allowing the farmers to regulate the condition in real-time from anywhere on their devices. An example of this is IoT enabled silo.

Youths can provide services for grain farmers during the glut season to store dry grains till the value appreciate enough to be sold.

12. Exportation of farm produce and legal implication

International markets are available for much agricultural produce. However, standards and specifications must be met. Hence, young enterprising individuals can acquire IoT based machines and create platforms for interested farmers. Knowledge and information about producers and prospective buyers can be connected through this means (platform). Also, legal services can be provided to farmers who export their produce. Most of these farmers don't have the legal know-how to draft contracts, prepare agreements, etc. This is one of the very good agribusiness ideas that can be exploited by legal personnel. An example is the Agri Marketplace.

CONCLUSION

Agriculture is an enterprise that should be undertaken as a business. It offers opportunities in agricultural drone services, digital information outlets, logistics and transportation services, the exportation of produces, agro-consult services, telemedicine for animals, E-commerce and on-line purchase of agricultural produce and lots more. Young people in Nigeria prefer white-collar jobs; hence, the high rate of unemployment. Unemployed youths in Nigeria can earn a livelihood through these streaming opportunities. Technology in terms of mechanization, is being employed to drive agriculture. However, enabling agribusiness with IoT can encourage youth involvement in agriculture in Nigeria. Therefore, agriculture in Nigeria should be practiced as a worthwhile business. The government should encourage youths to go into agribusiness to ensure food security of the nation and collaborate with communications network providers to enhance internet availability for farmers to aid the use of IoT in agribusiness.

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