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Debesh Mishra, Suchismita Satapathy, Prasenjit Chatterjee

SOFT COMPUTING AND OPTIMIZATION TECHNIQUES FOR SUSTAINABLE AGRICULTURE

SMART COMPUTING APPLICATIONS

Debesh Mishra, Suchismita Satapathy, Dr. Prasenjit Chatterjee

Soft Computing and Optimization Techniques for Sustainable Agriculture

De Gruyter Series on Smart Computing Applications

Edited by Prasenjit Chatterjee, Dilbagh Panchal, Dragan Pamucar, Sarfaraz Hashemkhani Zolfani

Volume 4

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ISBN 978-3-11-074495-8
e-ISBN (PDF) 978-3-11-074536-8
e-ISBN (EPUB) 978-3-11-074537-5
ISSN 2700-6239

Library of Congress Control Number: 2021952316

Bibliographic information published by the Deutsche Nationalbibliothek
The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available on the Internet at http://dnb.dnb.de.

Cover image: monsitj / iStock / Getty Images Plus
Printing and binding: CPI books GmbH, Leck

www.degruyter.com

Acknowledgements

I would like to take this opportunity to acknowledge a great many people who have contributed directly or indirectly to compile this book. I am very thankful and grateful to those people who have made this book possible. Further, my sincere gratitude and appreciation to my family members for their wholehearted support and encouragement, without which, I would not have been able to complete this professionally enriching and personally satisfying journey.

Debesh Mishra, PhD

I would like to deeply thank my publisher for giving me an opportunity to publish my content. Our publishers have also helped me a lot by taking precious time to help me carry out my experiments and encouraged me to complete my work accurately within the time I was given to do so. They have been a guiding force with encouragement to perform my work. I would like to thank my husband, Pravudatta Mishra, for encouraging me to complete my book project. My daughter, Meghana, also helped me a lot by giving me relaxation from some of her valuable family time. I would like to express my thanks to my father, Dr. R. B. Satapathy, and my mother, B. P. Mishra, my in-laws, Dr. S. N. Mishra and late Dr. B. M. Mishra, who has inspired me to work on this book. KIIT authority Prof. (Dr.) A. Samant is always an inspiration for me in achieving my goal. My colleagues, friends of KIIT, as well as my students all have equally encouraged me. At last, I would like to thank and owe my contribution before almighty God for invisible help.

Suchismita Satapathy, PhD

I express my sincere gratitude to the publisher and co-authors who have devoted their time and effort to make this highly comprehensive book possible.

Prasenjit Chatterjee, PhD

https://doi.org/10.1515/9783110745368-202

Preface

Agriculture plays an important role in developing countries and has become the backbone of their economic level. However, the findings of agricultural data have proven to be more useful for multiple purposes, and the farmers also need accurate suggestion for forecasting of the yield and farm-related productivity. For agricultural management, the emerging expert systems have been useful tools in providing integrated, area-specific, and interpreted prediction or forecasting and guidance in every aspect in agriculture. However, in order to achieve a sustainable agriculture, there is a need for an effective and useful application of these expert systems at optimum levels. Moreover, the use of soft-computing methods has been shown to have the ability to solve non-linear problems without mathematical models and the introduction of human knowledge, including cognition; confession; better understanding; and computer training that can create intelligent system. The use of soft-computing technology enables to model and analyze very complex-problems, while traditional methods cannot provide complete and inexpensive analytical solutions for such problems. Therefore, this intended book aims at covering all emerging global aspects in agriculture including the risks and opportunities available, the existing ergonomic risks, and effective management of agricultural activities through the applications of different computational and optimization techniques in order to achieve a sustainable agriculture.

This book is comprised of seven chapters. Chapter-1 elaborates the importance and applications of soft-computing techniques in agriculture. Chapter-2 explains the concept of organic-farming with the possible opportunities for an effective farming culture through organic-farming, and is mainly focussed on the agri-sectors of Ethiopia and Kenya, respectively. Chapter-3 deals with the agri-based improvements through proper agricultural waste-management system. This chapter has discussed the use of Fuzzy-EDAS method for the prioritization of the functions associated with agriculture-based waste-management, which is further followed by the development of fuzzy-based model for an effective agri-waste management. In Chapter-4, adaptive neural-fuzzy inference system (ANFIS) method is used for the prediction of productions of both “apple and dry-onions” in the province of Algeria based on the “Food and Agriculture Organization (FAO)” data by considering their harvested areas, yields, and production from the period of 1961 to the period 2019. Agriculture-based risks may result in adverse consequences on the farmers and their community. All the associated risks in the worldwide agricultural sectors reflect individual-country's risk to economic-stability. Therefore it becomes essential to evaluate risk-levels in agriculture to appropriately intervene strategies which can be under-taken at different levels to enhance stability as well as performance in global agricultural sectors. Chapter-5 deals with the evaluations of the agriculture-based risk-management in view of different risk-factors involved throughout the agricultural

https://doi.org/10.1515/9783110745368-203

sectors of the world with the use of metaheuristic approaches like Particle-Swarm Optimization (PSO) and Genetic Algorithm (GA). The Chapter-6 is focussed on the sustainable developments in agriculture. In this chapter, initially the strength, weaknesses, opportunities and threat (SWOT) analysis was used for evaluation of existing agricultural systems without the aid of IoT followed by IoT-based agricultural systems. Step-wise Weight Assessment Ratio Analysis (SWARA) method was then used for ranking of deficiencies in the existing agricultural systems without the aid of IoT. Further agricultural sustainability evaluation was made by the use of fuzzy-logic. Finally, Chapter-7 concludes the book while focusing on the benefits of soft-computing techniques. The utilization of soft-computing techniques in agriculture-based analysis in addition to latest machineries with the aid of Artificial Intelligence (AI) and/or Internet of Things (IoT) is recommended to be more beneficial to worldwide agricultural-systems.

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Abbreviations

AA: Agent-Architectures
AHP: Analytic Hierarchical-Process
AI: Artificial Intelligence
ANFIS: Adaptive Neural-Fuzzy Inference System
ANN: Artificial Neural-Network
ANP: Analytic Network-Process
ARIMA: Auto-Regressive Integrated Moving-Average
BSO: Brain-Storm Optimization
BT: Boosted-regression Tree
CFD: Computational Fluid Dynamics
DE: Differential-Evolution
EC: Evolutionary-Computing
ECI2: Economical-Impacts
EDAS: Evaluation based-on Distance from Average-Solution
ELM: Extreme Learning-Machine
ENVI3: Environmental-Impacts
EP: Evolutionary-Programming
FA: Firefly-Algorithm
FAO: Food and Agriculture Organization
FFS: Farmer Field Schools
FIS: Fuzzy-Inference System
FL: Fuzzy Logic
FMEA: Failure Mode and Effect Analysis
GA: Genetic Algorithm
GARCH: Generalized Auto-Regressive Conditional Hetroskedastic
GDP: Gross Domestic-Product
GEP: Gene-Expression Programming
GIS: Geographical Information-System
HPSO-GA: Hybrid Particle-Swarm Optimization and Genetic-Algorithms
HypoMgT: Hypomagnesaemic tetany
ICT: Information and Communication Technologies
IoT: Internet of Things
ISSA: International Social Security Association
MARS: Multivariate Adaptive-Regression Spline
MCDA: Multi-Criteria Decision-Analysis
MCDM: Multi-Criteria Decision-Making
MIMO: Multi Input and Output

https://doi.org/10.1515/9783110745368-205

MSDs: Musculoskeletal Disorders
MT/Year: Million-Tonnes/Year
MT: Model-Tree
NALEP: National Agricultural Livestock targeting Extension Programme
NDA: Negative-Distance from Average
NDVI: Normalized Difference Vegetation Index
NFGP: Neuro-Fuzzy with Grid-Partitioning
NFS: Neuro Fuzzy-Systems
NFSC: Neuro-Fuzzy with Sub-Clustering
NNDE: Neural-Network Differential-Evolution
NNPSO: Neural-Network Particle Swarm-Optimization
OHS: Occupational Health and Safety
OWAS: Ovako Working-Posture Analysing-System
PADETES: Participatory Demonstration and Training Extension System
PDA: Positive-Distance from Average
PES: Participatory Extension System
PPD: Plant Protection Department
PSO: Particle Swarm Optimization
PSO-SVM: Particle-Swarm Optimization–Support Vector-Machine
QEC: Quick Exposure Check
REBA: Rapid Entire Body Assessment
RF: Random-Forest
RPAS: Remotely Piloted Aircraft Systems
RULA: Rapid Upper Limb Assessment
SA: Simulated-Annealing
SI1: Social-Impacts
SVM: Support Vector-Machine
SVM: Support Vector-Machine
SVMFA: SVM Firefly-Algorithm
SWARA: Step-wise Weight Assessment Ratio Analysis
SWOT: Strengths, Weaknesses, Opportunities and Threats
TFNs: Trapezoidal Fuzzy-Numbers
TOPSIS: Technique for Order-Preference by Similarity
UAV: Unmanned Aerial Vehicles
USDA: United States Department of Agriculture
WDO: Wind-Driven Optimization
WMA: Waste-Management Alternatives
WRMSDs: Work-Related Musculoskeletal Disorders
WSNs: Wireless Sensor Networks

1 Soft-computing in agriculture: An Introduction

Abstract: Agriculture has been playing a tremendous role in developing-countries by becoming the foundation of their economy-levels and contributing more GDP in comparison to other sectors. However, the knowledge acquired from agriculture-based data has been more useful for different purposes, and also the farmers need adequate as well as accurate advices with regard to prediction of the yield, and productivity in addition to crop-prices. Moreover, the applications of soft-computing techniques have proved leading to two main advantages, such as in solving non-linear problems with non-availability of mathematical models, and in introducing human-knowledge including cognition; recognition; better-understanding; and learning in the computing fields that enabled in constructing of intelligent-systems. Four technical disciplines have been included in soft-computing. The first two, such as probabilistic-reasoning and fuzzy-logic reasoning systems are knowledge-driven approaches. While, the remaining two included neuro-computing and evolutionary-computing that are data-driven searching and optimizing approaches. The applications of soft-computing techniques enable in modeling and analyzing very complex-problems for which the conventional methods cannot produce analytical, cost-effective, or complete solutions. The soft-computing integrates both biological-structures and computing-techniques, and can be more effectively used in the agricultural sectors throughout the world.

Keywords: Soft-computing, Agriculture, Techniques, Application, Worldwide, Production, Statistics

1.0 Introduction

With the continuous growth in the world population, there has been augmented need for the production of more and better quality foods. However, owing to the climate-change, urban-growth and unsustainable agricultural-practices, there has been a greater loss of available arable-land hindering for the sustainability of agriculture and causing serious problems in the balance of production-consumption process. In this context, the requirement of agricultural modernization finds a crucial step in view of facing forthcoming hitches in the agricultural sectors throughout the world. The causes of reduced performances by agricultural-systems were mainly because of lower technological advancement that could be resolved with appropriate development as well as improvement. However, due to the complexities in innovation process, there has been lack of instant adoption of newer technologies in agriculture, and it is because of complex decision-making problems faced by the farm operators. The farmers are required to consider several conditions as well as inputs, such as nutrients, water, fertilizers, climate or weather, etc. that can influ-

https://doi.org/10.1515/9783110745368-001

ence the complete agricultural-systems for better optimization of agricultural operations. In this context, the adoption of newer innovative technologies can be regarded to contribute largely to innovativeness as well as farm-sustainability. Although there has been a higher requirement for a smart, more technological-advanced agriculture, however the application of advanced optimization and computation techniques for better interpretation and analysis of farm-data for a smart-agriculture is limited to only to developed countries.

Complex computations for dynamical-systems have motivated researchers in adapting either existing methods or in developing new computational tools for facilitating of these computations, such as soft-computing [106], machine-learning [131, 146, 171], probabilistic and stochastic techniques [23, 71, 144], and topological as well as geometrical techniques [20, 157], respectively.

In the last three-decades, the soft-computing has been studied extensively in scientific-researches in addition to engineering-computing. Although, the application of soft-computing techniques was found to be useful to solve complex-problems, but still new approaches have been advancing to develop the methodology for more reliable, robust and efficient solutions. Advancement in soft-computing has been evolved as the method-fusion in soft-computing combining or cascading different soft-computing techniques for considerable improvement of system-performance over any individual-technique like "neuro-fuzzy systems" [72, 80, 110, 120, 154, 163]. There have been some earlier researches and applications of soft-computing in agricultural as well as biological engineering [48, 176, 187]. The interest of soft-computing applications in agricultural sectors has also grown substantially in the last-decade, such as in crop management [27, 63, 136, 181, 182], soil-analysis [8, 124], precision-agriculture [47, 75, 108], and so on.

1.1 The global agriculture-based research-systems

The agriculture-based research-systems that are globally existing help in supporting and funding the necessary researches to develop the agriculture in addition to their related aspects for the purpose of reducing "hunger and poverty" in the world. In this context, the "Consultative-Group on International Agricultural-Research (CGIAR)" plays a vital role in the agriculture-based research-systems, which was established in 1971 that has been an association of both private and public members for supporting and funding a number of "International Agricultural-Research Centres (IARCs)" as illustrated in Table 1.1, to carry-out researches for reduction of "hunger and poverty" in the world. The funding-bodies of CGIAR include "developing and industrialized" country-governments, foundations in addition to different regional and international organizations.

Tab. 1.1 International Agricultural-Research Centres (IARCs)

IARCs: Head-quarter	Website	Concerned roles and activities
INTERNATIONAL CENTER FOR TROPICAL AGRICULTURE (CIAT): Colombia	www.ciat.cgiar.org	Focusing on scientific-solutions to hunger in the tropics.
CENTER FOR INTERNATIONAL FORESTRY RESEARCH (CIFOR): Indonesia	www.cifor.cgiar.org	Conducting of researches to enable in more informed as well as equitable decision-making about the forests' utilization and management in lesser developed-countries. Helping the policy-makers and practitioners in shaping of effective policies. Improving the management of tropical-forests. Addressing the requirements and perspectives of people depending on forests for livelihoods.
INTERNATIONAL MAIZE AND WHEAT IMPROVEMENT CENTER (CIMMYT): Mexico	http://www.cimmyt.org/	For sustainably increasing the productivity of maize-and-wheat systems to ensure the worldwide food-security and to reduce-poverty. Working and bringing together the public-research and extension-organizations, private-companies, research-institutes, NGOs, and farmers' associations in worldwide countries, to fight against "hunger and poverty".
INTERNATIONAL POTATO-CENTER (CIP): Peru	http://www.cipotato.org/	Seeking in the reduction of poverty and achievement of food-security on a sustained-basis in developing-countries. Improving in the management of natural-resources in the "Andes as well as other mountain-areas".
INTERNATIONAL CENTER-FOR-AGRICULTURAL-RESEARCH IN THE DRY-AREAS (ICARDA): Syria	http://www.icarda.cgiar.org/Facelift.htm	Improving in the livelihoods of the resource poorer in the dry-areas. Contributing in the enhancement of livelihoods of the resource poorer in dry-areas by improving food-security and alleviating-poverty through researches and partnerships for achieving sus-

IARCs: Head-quarter	Website	Concerned roles and activities
		tainable increments in agricultural-productivity and incomes. Ensuring efficient and more equitable-use and conservation of natural-resources.
INTERNATIONAL CROPS-RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS (ICRISAT): India	http://www.icrisat.org/	Improving the well-being of the poorer people of the dry-areas. Seeking in the reduction in poverty, increasing the agricultural-productivity, enhancing food-and-nutritional security and protecting the environment of the dry-tropics.
INTERNATIONAL FOOD-POLICY RESEARCH INSTITUTE (IFPRI): USA	http://www.ifpri.org/	Providing of policy-solutions to reduce the poverty, and elimination of hunger and malnutrition. Achieving sustainable food-security and poverty-reduction in developing-countries through scientific-researches and other research-related activities in the fields of livestock, agriculture, fisheries, forestry, policy, and natural-resources management.
INTERNATIONAL INSTITUTE OF TROPICAL AGRICULTURE (IITA): Nigeria	http://www.iita.org/	Seeking solutions to hunger, malnutrition, and poverty. Engaged in the developmental needs of sub-Saharan Africa. Enhancing crop-quality and productivity, reducing the associated risks to producers and consumers, and generating wealth from agricultures.
INTERNATIONAL LIVESTOCK-RESEARCH INSTITUTE (ILRI): Kenya	http://www.ilri.org/	Bringing in higher-quality science and capacity-building to-bear on poverty-reduction, and sustainable development.
BIOVERSITY INTERNATIONAL: Italy	http://www.bioversityinternational.org/	Improving peoples' lives through: good nutrition, particularly in developing-countries; enhancing sustainable farming-practices to secure the future food-supplies; and conservation as well as use for ensuring of everyone to grow with the food-they-need.
INTERNATIONAL RICE RE-	http://irri.org/	Finding of sustainable-ways for

IARCs: Head-quarter	Website	Concerned roles and activities
SEARCH INSTITUTE (IRRI): Philippines		the improvement of the well-being of present as well as future generations of poorer rice-farmers and consumers. Protecting the natural-environment.
INTERNATIONAL WATER MANAGEMENT INSTITUTE (IWMI): Sri Lanka	http://www.iwmi.cgiar.org/	Improving the management of lands and water-resources for foods, livelihoods, and the environment. Developing goals for the reduction of poverty and hunger. Maintaining of sustainable-environment.
WORLD AGROFORESTRY-CENTRE: Kenya	http://www.worldagroforestrycentre.org/	Generating and application of the best available-knowledge to stimulate agricultural-growth, increasing the farmers' income, and protecting the environment.
WORLD FISH-CENTER: Malaysia	http://www.worldfishcenter.org/wfcms/HQ/Default.aspx	Reducing the poverty and hunger by improvements in "fisheries and aquaculture".
AFRICA RICE-CENTER: Benin	http://www.warda.cgiar.org/	Contributing in poverty-alleviation and food-security through research, developments and partnership-activities in Africa. Increasing the productivity as well as profitability of the rice-sectors to ensure the sustainability of the farm-environment.
INTERNATIONAL CENTER FOR LIVING AQUATIC RESOURCES MANAGEMENT (ICLARM): Malaysia	www.iclarm.org	Improving the production as well as management of aquatic-resources. Providing sustainable-benefits to present as well as future generations of lower-income producers along with consumers in developing-countries.
ASIAN VEGETABLE RESEARCH AND DEVELOPMENT CENTRE (AVRDC): Taiwan	www.netra.avrdc.org.tw/docs/intro.html	Enhancing the nutritional well-being and increasing the incomes of poorer-people in the urban as well as rural areas of developing-countries through superior methods of vegetable-production, marketing and distributions, and preserving the environment-

IARCs: Head-quarter	Website	Concerned roles and activities
		quality.
CENTRO AGRONOMICO TROPICAL DE INVESTIGACION Y ENSENANZA (CATIE): Costa-Rica	www.catie.ac.cr	Promoting and stimulating of researches and technical-cooperation in plants, animals, and forest-related production. Providing alternatives to satisfy the requirements of the "American-tropics".
INTERNATIONAL-BOARD FOR SOIL-RESEARCH AND MANAGEMENT (IBSRAM): Thailand	www.ibsram.org	Assisting and speeding up of the applications of soil-science for the enhancement of food-production sustainability in developing-countries.
INTERNATIONAL CENTRE OF INSECT-PHYSIOLOGY AND ECOLOGY (ICIPE): Kenya	www.icipe.org	Seeking researches in integrated control-methodologies for crops and livestock insect-pests and for insect-vectors of tropical-diseases. Strengthening the technological-capacities of the developing-countries in insect-science, and its' application through training in addition to collaborative-works.
INTERNATIONAL FERTILIZER-DEVELOPMENT-CENTRE (IFDC): USA	www.ifdc.org	Solving the food-related deficit-problems of the developing-countries by focusing on the developments of fertilizers and fertilizer-practices in order to meet the special-needs of tropical as well as sub-tropical soils and climates.
CARIBBEAN AGRICULTURAL RESEARCHES AND DEVELOPMENT INSTITUTE (CARDI): West Indies	www.cardi.org	Accelerating the sustainable agricultural-development through strategic-management of appropriate-technology that can help in the progress of the economic and social well-being of "Caribbean-based peoples".
TROPICAL SOIL-BIOLOGY AND FERTILITY PROGRAM (TSBFP): Kenya	–	Contributing in human-welfare in addition to the environmental-conservation in the tropics by the development of improved-practices for sustaining of tropical soil-fertility through the management of biological-processes and organic-resources, and with

IARCs: Head-quarter	Website	Concerned roles and activities
		judicious utilizations of inorganic-inputs.
INTERNATIONAL CENTRE FOR INTEGRATED MOUNTAIN DEVELOPMENT (ICIMD): Nepal	www.icimod.org	Helping in the promotable development of an environmentally and economic sound mountain-ecosystem. Improving the living-standards of mountain-populations. Research and development for facilitating the generation of new mountain-specific knowledge-of-relevance for the development.
CAB INTERNATIONAL (CABI): UK	www.cabi.org	Collecting, analyzing and disseminating information on agricultures, forestry, management of natural-resources and related-sciences including human health and nutrition.
AUSTRALIAN CENTRE FOR INTERNATIONAL AGRICULTURAL RESEARCH (ACIAR): Australia	www.aciar.gov.au	Directing in the mobilization of Australia's research-capacity in order to help in solving agricultural-research problems of developing-countries. Promoting in bilateral-development related research-collaboration between "Australia and individual developing-countries.
THE COOPERATIVE RESEARCH CENTRE FOR LEGUMES IN MEDITERRANEAN AGRICULTURE (CLIMA): Western Australia	www.general.uwa.edu.au/u/climaweb/	Providing focus on sustainable-agriculture legumes in the "Mediterranean-climate of Southern-Australia". Covering of research as well as training on variety of disciplines, genetic-engineering of bacteria and legumes to assess the farmers' attitudes on risks and new-species.
INTERNATIONAL INSTITUTE FOR LAND-RECLAMATION AND IMPROVEMENT (ILRI): Netherlands	www.ilri.nl	Undertaking of applied-researches on sustainable-development of irrigated-agriculture. Holding of annual post-graduate training-courses related to drainage, irrigation and other allied subjects.

IARCs: Head-quarter	Website	Concerned roles and activities
		Providing of technical-support and specialists' advisory-services to drainage as well as irrigation projects.
THE WORLD BANK: Washington DC	www.worldbank.org	Fighting against poverty with professionalism-based lasting-results and passion. Helping peoples to help themselves and the associated environment by sharing-knowledge, providing-resources, building-capacity and forging-partnership in both private as well as public sectors.
JAPAN INTERNATIONAL RESEARCH CENTRE FOR AGRICULTURAL SCIENCES (JIRCAS): Japan	www.jircas.affrc.go.jp	Promoting in the advancements of worldwide agricultures, forestry, and fisheries in developing-regions through integrated collaborative-research programme. Developing new research strategies for the enhancement of production as well as utilization systems for sustainable agricultures, forestry and fisheries. Conducting researches on different topics in order to maintain, rehabilitate, and improve the natural-resources' utilization with adequate emphasis on tropical-forests and coastal-based eco-systems.
CANADIAN INTERNATIONAL DEVELOPMENT AGENCY (CIDA): Canada	www.cida.gc.ca	Supporting in the sustainable-development activities for reducing poverty. Contributing in more equitable, prosperous, and secured world.
CENTRE ON INTEGRATED RURAL DEVELOPMENT FOR ASIA AND THE PACIFIC (CIRDAP): Bangladesh	www.cirdap.org.sg	Assisting in national-action for the promotion of regional-cooperation, acting as a servicing-institution for its member-countries for promoting integrated rural-development through researches, action-researches, pilot-projects, and training as well as information dissemination. Providing focus on four-areas of

IARCs: Head-quarter	Website	Concerned roles and activities
		concern, such as: agrarian-development, infrastructure/institutional development, resource-development including human-resources and employments.
THE OVERSEAS-DEVELOPMENT INSTITUTE (ODI): UK	odi@odi.org.uk	Inspiring and informing on policies as well as practices leading to the poverty-reduction, suffering-alleviations and sustainable-livelihood achievements in developing-countries. Working with partners in the private as well as public sectors in both developed and countries for carrying out high-quality applied-researches, practical policy-advices, and policy-based dissemination.
INTERNATIONAL INSTITUTE FOR ENVIRONMENT AND DEVELOPMENT (IIED): UK	www.iied.org	Providing expertise and leaderships in re-searching as well as to achieve sustainable-development at local, regional, national and international levels. Seeking to help in shaping of a future to end the global-poverty and maintaining of sustainable, equitable as well as efficient management natural-resources throughout the world.
INTERNATIONAL DEVELOPMENT RESEARCH CENTRE (IDRC): Canada	www.idrc.org	Helping the communities in the developing-world to find solutions to economic, social, and environmental related problems through different advanced researches.
FOOD AND AGRICULTURE ORGANIZATION (FAO): Italy	www.fao.org	Increasing the nutrition-levels, food-security and standard-of-living of rural-population through improvement in agricultural-productivity and betterment in the existing conditions.

1.2 Soft-computing applications

The soft-computing applications have proved leading to two main advantages, such as to solve non-linear problems with non-availability of mathematical models, and by introducing human-knowledge including cognition; recognition; better-understanding; and learning in the computing fields that enabled in constructing of intelligent-systems. Four technical disciplines have been included in soft-computing. The first two, such as probabilistic-reasoning and fuzzy-logic reasoning systems are knowledge-driven approaches. While, the remaining two included neuro-computing and evolutionary-computing, which are data-driven searching and optimizing approaches [37].

Based on the past studies, various applications of soft-computing techniques for different purposes were summarized in Table 1.2.

Tab. 1.2: Applications of soft-computing techniques for different purposes

References	Soft-computing techniques	Areas of application
[115,148]	Neural-network, Fuzzy logic, Evolutionary-computations	Aircraft and air-traffic
[25,41,57,59]	Fuzzy logic, Neural-network, Evolutionary-computations	Communication-networks
[31,46,85,98,149,174]	Evolutionary-computations, Fuzzy logic, Neural-network	Control and monitoring
[12,89,121, 151,172,189]	Fuzzy logic, Neural-network, Evolutionary-computations	Cooling as well as heating
[34,81]	Fuzzy logic, Neural-network	Data-communications
[104]	Artificial neural-network, Fuzzy logic	Data-security
[13,66]	Fuzzy logic, Neural-network	Induction motor-drives
[132,190]	Fuzzy logic, Neural-network	Inverters and converters
[88,183]	Fuzzy logic, Neural-network	Manufacturing-technologies
[9]	Fuzzy logic, Neural-network	Mobile-robots
[76]	Evolutionary-computations, Fuzzy logic	Multi-agent robots
[167]	Genetic-algorithm	Network-optimization
[158]	Evolutionary-computations	Power-control
[161]	Artificial neural-network	Radio-planning
[102]	Artificial neural-network	Resource-allocations
[82]	Artificial neural-network, Fuzzy logic, Evolutionary-algorithm	Satellite-imaging
[150]	Artificial neural-network	Scheduling

References	Soft-computing techniques	Areas of application
[105,175]	Neural-network, Fuzzy logic	Space-craft
[17]	Fuzzy logic, Neural-network	Steel process-industry
[30]	Fuzzy logic	Switched reluctance-motor-drives
[162]	Data mining	Rainfall-prediction
[143]	Neural-network, Fuzzy logic	Greenhouse tomatoes' yield prediction
[35,86]	Artificial neural-network	Crop-yield prediction
[28,141]	Fuzzy based neural-network, Fuzzy logic	Irrigation control and planning
[153]	Fuzzy based neural-network	Identifying types of trashes in ginned-cotton
[97]	Artificial neural-network	Extrusion-control
[90]	Artificial neural-network	Bread baking-process
[122]	Artificial neural-network, Genetic-Algorithm	Path-planning of an agricultural mobile-robot
[99]	Artificial neural-network, Genetic-Algorithm	Setting target-corn yields
[111,112]	Fuzzy logic, Genetic-Algorithm	Optimization of design and functional parameters of threshing-units
[113]	Artificial neural-network, Genetic-Algorithm	Dynamic-optimization for tomato cool-storage to minimize water-loss
[119]	Artificial neural-fuzzy interface-system	Image-segmentation for weed-detection
[124]	Fuzzy neural-network	Soils-classification
[107]	Artificial neural-fuzzy interface-system	Classification of uniform plant, soil, and residue color-images
[77,78]	Artificial neural-network, Genetic-Algorithm	Rainfall-runoff modelling
[68]	Artificial neural-network, Genetic-Algorithm	Greenhouse cropping-control
[53]	Artificial neural-network, Genetic-Algorithm	Greenhouse cultivation-control
[129]	Artificial neural-network, Genetic-Algorithm	Classification of corn kernels for detection of fungi-infection
[179]	Artificial neural-network, Artificial neural-fuzzy interface-system	Outdoor automatic-camera parameter-control controller

Smart-farming gives more emphasizes on the use of 'information and communication technology' in the farm-management cycle. The latest technologies such as the

'Internet of Things' and 'Cloud-Computing' can be used to influence such development by introducing more 'robots' and 'artificial intelligence' in farming that includes Big-Data, capturing of large volumes as well as variety of data, analysis and utilization in decision-making [178].

In context to the Indian agricultural sectors, the largest important crops' producing states during the period 2017-2018 was illustrated in Table 1.3, which was further followed by Table 1.4 representing the statistics of food-grains' production in Indian agriculture from 1966 to 2018; Table 1.5 representing the statistics of season-wise food-grains' production in Indian agriculture from 1966 to 2018; Table 1.6 representing the statistics of food-grains such as rice, wheat and maize productions in Indian agriculture from 1966 to 2018; Table 1.7 representing the statistics of oil-seeds such as soybeans, groundnuts, mustard and rapeseeds, and sunflowers productions in Indian agriculture from 1966 to 2018; and Table 1.8 representing the statistics of other cash-crops such as "cottons, sugarcane, and jutes and mesta" productions in Indian agriculture from 1966 to 2018; respectively.

Tab. 1.3: Largest important crops' producing states in India during 2017-2018 [1]

Crops' Group	Crops	Producing States	Production in Million-Tonnes
Food-grains	Maize	Karnataka, Maharashtra and Madhya-Pradesh	3.5
		All India	28.7
	Rice	West-Bengal	14.9
		Punjab	13.3
		Uttar-Pradesh	13.2
		All India	112.9
	Wheat	Uttar-Pradesh	31.8
		Punjab	17.8
		Madhya-Pradesh	15.9
		All India	99.7
Oil-seeds	Soybeans	Madhya-Pradesh	5.3
		Maharashtra	3.8
		Rajasthan	1.0
		All India	10.9
	Groundnuts	Gujarat	3.9
		Rajasthan	1.2

Crops' Group	Crops	Producing States	Production in Million-Tonnes
		Andhra-Pradesh	1.0
		All India	9.1
	Mustard and Rape-seeds	Rajasthan	3.4
		Haryana	1.1
		Madhya-Pradesh	0.9
		All India	8.3
	Sunflowers	Karnataka	0.1
		Bihar and Odisha	0.02
		All India	0.2
Other Cash-Crops	Cottons	Gujarat	12.6
		Maharashtra	6.5
		Telangana	4.7
		All India	34.8
	Sugarcane	Uttar-Pradesh	177.0
		Maharashtra	83.1
		Karnataka	28.2
		All India	376.9
	Jutes and Mesta	West-Bengal	7.6
		Bihar	1.4
		Assam	0.8
		All India	10.1

Tab. 1.4: Statistics of food-grains' production in Indian agriculture from 1966 to 2018 [1]

Year	Area in Million-hectares	Production in Million-tonnes
1966 to 1967	115.3	74.2
1967 to 1968	121.4	95.0
1968 to 1969	120.4	94.0
1969 to 1970	123.5	99.5
1970 to 1971	124.3	108.4
1971 to 1972	122.6	105.1
1972 to 1973	119.2	97.0
1973 to 1974	126.5	104.6
1974 to 1975	121.0	99.8
1975 to 1976	128.1	121.0
1976 to 1977	124.3	111.1
1977 to 1978	127.5	126.4
1978 to 1979	129.01	131.9
1979 to 1980	125.2	109.7
1980 to 1981	126.6	129.5
1981 to 1982	129.1	133.3
1982 to 1983	125.1	129.5
1983 to 1984	131.1	152.3
1984 to 1985	126.6	145.5
1985 to 1986	128.0	150.4
1986 to 1987	127.2	143.4
1987 to 1988	119.6	140.3
1988 to 1989	127.6	169.9
1989 to 1990	126.7	171.0
1990 to 1991	127.8	176.3
1991 to 1992	121.87	168.3
1992 to 1993	123.1	179.4
1993 to 1994	122.7	184.2
1994 to 1995	123.8	191.5
1995 to 1996	121.0	180.4
1996 to 1997	123.5	199.3
1997 to 1998	124.0	192.2
1998 to 1999	125.1	203.6
1999 to 2000	123.1	209.8
2000 to 2001	121.0	196.8
2001 to 2002	122.7	212.8

Year	Area in Million-hectares	Production in Million-tonnes
2002 to 2003	113.8	174.7
2003 to 2004	123.4	213.1
2004 to 2005	120.0	198.3
2005 to 2006	121.6	208.6
2006 to 2007	123.7	217.2
2007 to 2008	124.0	230.7
2008 to 2009	122.8	234.4
2009 to 2010	121.3	218.1
2010 to 2011	126.6	244.4
2011 to 2012	124.7	259.2
2012 to 2013	120.7	257.1
2013 to 2014	125.0	265.0
2014 to 2015	124.3	252.0
2015 to 2016	123.2	251.5
2016 to 2017	129.2	275.1
2017 to 2018	127.5	284.8

Tab. 1.5: Statistics of season-wise food-grains' production in Indian agriculture from 1966 to 2018 [1]

Year	Rabi		Kharif		Total	
	Area in Million-hectares	Production in Million-Tonnes	Area in Million-hectares	Production in Million-Tonnes	Area in Million-hectares	Production in Million-Tonnes
1966 to 1967	37.0	25.3	78.2	48.8	115.3	74.2
1967 to 1968	39.9	34.2	81.4	60.7	121.4	95.0
1968 to 1969	40.0	34.4	80.4	59.5	120.4	94.0
1969 to 1970	41.2	37.1	82.3	62.3	123.5	99.5
1970 to 1971	41.9	39.5	82.3	68.9	124.3	108.4
1971 to 1972	43.4	42.1	79.2	62.9	122.6	105.1
1972 to 1973	40.9	38.3	78.3	58.6	119.2	97.0
1973 to 1974	42.4	36.8	84.1	67.8	126.5	104.6
1974 to 1975	41.3	40.7	79.7	59.1	121.0	99.8
1975 to 1976	45.0	47.1	83.1	73.8	128.1	121.0
1976 to 1977	43.1	44.6	81.1	66.5	124.3	111.1
1977 to 1978	44.6	48.6	82.8	77.7	127.5	126.4
1978 to 1979	46.1	53.8	82.8	78.0	129.0	131.9

Year	Rabi		Kharif		Total	
	Area in Million-hectares	Production in Million-Tonnes	Area in Million-hectares	Production in Million-Tonnes	Area in Million-hectares	Production in Million-Tonnes
1979 to 1980	44.4	46.4	80.7	63.2	125.2	109.7
1980 to 1981	43.4	51.9	83.2	77.6	126.6	129.5
1981 to 1982	45.2	53.9	83.9	79.3	129.1	133.3
1982 to 1983	46.0	59.6	79.0	69.9	125.1	129.5
1983 to 1984	47.0	63.1	84.1	89.2	131.1	152.3
1984 to 1985	45.4	61.0	81.1	84.5	126.6	145.5
1985 to 1986	46.2	65.1	81.8	85.2	128.0	150.4
1986 to 1987	45.7	63.2	81.4	80.2	127.2	143.4
1987 to 1988	44.8	65.7	74.8	74.5	119.6	140.3
1988 to 1989	45.6	74.2	82.0	95.6	127.6	169.9
1989 to 1990	45.3	70.0	81.4	100.9	126.7	171.0
1990 to 1991	47.0	76.9	80.7	99.4	127.8	176.3
1991 to 1992	43.8	76.7	78.0	91.5	121.8	168.3
1992 to 1993	45.2	78.0	77.9	101.4	123.1	179.4
1993 to 1994	46.9	83.8	75.8	100.4	122.7	184.2
1994 to 1995	48.6	90.4	75.1	101.0	123.8	191.5
1995 to 1996	47.4	85.3	73.6	95.1	121.0	180.4
1996 to 1997	48.2	95.5	75.3	103.8	123.5	199.3
1997 to 1998	49.7	90.6	74.3	101.5	124.0	192.2
1998 to 1999	51.1	100.6	73.9	102.9	125.1	203.6
1999 to 2000	49.8	104.2	73.2	105.5	123.1	209.8
2000 to 2001	45.8	94.7	75.2	102.0	121.0	196.8
2001 to 2002	48.5	100.7	74.2	112.0	122.7	212.8
2002 to 2003	45.3	87.5	68.5	87.2	113.8	174.7
2003 to 2004	48.0	96.1	75.4	117.0	123.4	213.1
2004 to 2005	47.8	95.0	72.2	103.3	120.0	198.3
2005 to 2006	48.8	98.7	72.7	109.8	121.6	208.6
2006 to 2007	51.0	106.7	72.6	110.5	123.7	217.2
2007 to 2008	50.4	109.7	73.5	121.0	124.0	230.7
2008 to 2009	51.3	116.2	71.4	118.1	122.8	234.4
2009 to 2010	51.8	114.1	69.5	104.0	121.3	218.1
2010 to 2011	54.2	123.6	72.4	120.9	126.6	244.5
2011 to 2012	52.6	128.0	72.0	131.2	124.7	259.2
2012 to 2013	53.0	129.0	67.6	128.0	120.7	257.1
2013 to 2014	55.9	136.3	69.0	128.6	125.0	265.0

Year	Rabi		Kharif		Total	
	Area in Million-hectares	Production in Million-Tonnes	Area in Million-hectares	Production in Million-Tonnes	Area in Million-hectares	Production in Million-Tonnes
2014 to 2015	55.5	123.9	68.7	128.0	124.3	252.0
2015 to 2016	54.0	126.4	69.2	125.0	123.2	251.5
2016 to 2017	56.0	136.7	73.2	138.3	129.2	275.1
2017 to 2018	55.5	144.1	72.0	140.7	127.5	284.8

Tab. 1.6: Statistics of food-grains such as rice, wheat and maize productions in Indian agriculture from 1966 to 2018 [1]

Year	Food-grains					
	Rice		Wheat		Maize	
	Area in Million-hectares	Production in Million-Tonnes	Area in Million-hectares	Production in Million-Tonnes	Area in Million-hectares	Production in Million-Tonnes
1966 to 1967	35.2	30.4	12.8	11.3	5.0	4.8
1967 to 1968	36.4	37.6	14.9	16.5	5.5	6.2
1968 to 1969	36.9	39.7	15.9	18.6	5.7	5.7
1969 to 1970	37.6	40.4	16.6	20.0	5.8	5.6
1970 to 1971	37.5	42.2	18.2	23.8	5.8	7.4
1971 to 1972	37.7	43.0	19.1	26.4	5.6	5.1
1972 to 1973	36.6	39.2	19.4	24.7	5.8	6.3
1973 to 1974	38.2	44.0	18.5	21.7	6.0	5.8
1974 to 1975	37.8	39.5	18.1	24.1	5.8	5.5
1975 to 1976	39.4	48.7	20.4	28.8	6.0	7.2
1976 to 1977	38.5	41.9	20.9	29.0	6.0	6.3
1977 to 1978	40.2	52.6	21.4	31.7	5.6	5.9
1978 to 1979	40.4	53.7	22.6	35.5	5.7	6.2
1979 to 1980	39.4	42.3	22.1	31.8	5.7	5.6
1980 to 1981	40.1	53.6	22.1	36.3	6.0	6.9
1981 to 1982	40.7	53.2	22.1	37.4	5.9	6.9
1982 to 1983	38.2	47.1	23.5	42.7	5.7	6.5
1983 to 1984	41.2	60.1	24.6	45.4	5.8	7.9
1984 to 1985	41.1	58.3	23.5	44.0	5.8	8.4
1985 to 1986	41.1	63.8	23.0	47.0	5.8	6.6
1986 to 1987	41.1	60.5	23.1	44.3	5.9	7.5

Year	Food-grains					
	Rice		Wheat		Maize	
	Area in Million-hectares	Production in Million-Tonnes	Area in Million-hectares	Production in Million-Tonnes	Area in Million-hectares	Production in Million-Tonnes
1987 to 1988	38.8	56.8	23.0	46.1	5.5	5.7
1988 to 1989	41.7	70.4	24.1	54.1	5.9	8.2
1989 to 1990	42.1	73.5	23.5	49.8	5.9	9.6
1990 to 1991	42.6	74.2	24.1	55.1	5.9	8.9
1991 to 1992	42.6	74.6	23.2	55.6	5.8	8.0
1992 to 1993	41.7	72.8	24.5	57.2	5.9	9.9
1993 to 1994	42.5	80.3	25.1	59.8	6.0	9.6
1994 to 1995	42.8	81.8	25.7	65.7	6.1	8.8
1995 to 1996	42.8	76.9	25.0	62.1	5.9	9.5
1996 to 1997	43.4	81.7	25.8	69.3	6.2	10.7
1997 to 1998	43.4	82.5	26.7	66.3	6.3	10.8
1998 to 1999	44.8	86.0	27.5	71.2	6.2	11.1
1999 to 2000	45.1	89.6	27.4	76.3	6.4	11.5
2000 to 2001	44.7	84.9	25.7	69.6	6.6	12.0
2001 to 2002	44.9	93.3	26.3	72.7	6.5	13.1
2002 to 2003	41.1	71.8	25.2	65.7	6.6	11.1
2003 to 2004	42.5	88.5	26.5	72.1	7.3	14.9
2004 to 2005	41.9	83.1	26.3	68.6	7.4	14.1
2005 to 2006	43.6	91.7	26.4	69.3	7.5	14.7
2006 to 2007	43.8	93.3	27.9	75.8	7.8	15.1
2007 to 2008	43.9	96.6	28.0	78.5	8.1	18.9
2008 to 2009	45.5	99.1	27.7	80.6	8.1	19.7
2009 to 2010	41.9	89.0	28.4	80.8	8.2	16.7
2010 to 2011	42.8	95.9	29.0	86.8	8.5	21.7
2011 to 2012	44.0	105.3	29.8	94.8	8.7	21.7
2012 to 2013	42.7	105.2	30.0	93.5	8.6	22.2
2013 to 2014	44.1	106.6	30.4	95.8	9.0	24.2
2014 to 2015	44.1	105.4	31.4	86.5	9.1	24.1
2015 to 2016	43.5	104.4	30.4	92.2	8.8	22.5
2016 to 2017	43.9	109.7	30.7	98.5	9.6	25.9
2017 to 2018	43.7	112.9	29.5	99.7	9.4	28.7

Tab. 1.7: Statistics of oil-seeds such as soybeans, groundnuts, mustard and rapeseeds, and sunflowers productions in Indian agriculture from 1966 to 2018 [1]

Year	Oil-seeds							
	Soybeans		Groundnuts		Mustard and Rapeseeds		Sunflowers	
	Area in Million-hectares	Production in Million-Tonnes	Area in Million-hectares	Production in Million-Tonnes	Area in Million-hectares	Production in Million-Tonnes	Area in Million-hectares	Production in Million-Tonnes
1966 to 1967	–	–	7.3	4.4	3.0	1.2	–	–
1967 to 1968	–	–	7.5	5.7	3.2	1.5	–	–
1968 to 1969	–	–	7.0	4.6	2.8	1.3	–	–
1969 to 1970	–	–	7.1	5.1	3.1	1.5	–	–
1970 to 1971	0.03	0.01	7.3	6.1	3.3	1.9	0.1	0.08
1971 to 1972	0.03	0.01	7.5	6.1	3.6	1.4	0.1	0.08
1972 to 1973	0.03	0.03	6.9	4.0	3.3	1.8	0.1	0.08
1973 to 1974	0.05	0.04	7.0	5.9	3.4	1.7	0.2	0.1
1974 to 1975	0.07	0.05	7.0	5.1	3.6	2.2	0.3	0.2
1975 to 1976	0.09	0.09	7.2	6.7	3.3	1.9	0.3	0.2
1976 to 1977	0.1	0.1	7.0	5.2	3.1	1.5	0.2	0.1
1977 to 1978	0.2	0.1	7.0	6.0	3.5	1.6	0.2	0.1
1978 to 1979	0.3	0.3	7.4	6.2	3.5	1.8	0.1	0.1
1979 to 1980	0.5	0.2	7.1	5.7	3.4	1.4	0.06	0.03
1980 to 1981	0.6	0.4	6.8	5.0	4.1	2.3	0.1	0.07
1981 to 1982	0.4	0.3	7.4	7.2	4.4	2.3	0.2	0.1
1982 to 1983	0.7	0.4	7.2	5.2	3.8	2.2	0.4	0.2
1983 to 1984	0.8	0.6	7.5	7.0	3.8	2.6	0.7	0.3
1984 to 1985	1.2	0.9	7.1	6.4	3.9	3.0	0.8	0.4
1985 to 1986	1.3	1.0	7.1	5.1	3.9	2.6	0.7	0.2
1986 to 1987	1.53	0.89	6.98	5.88	3.72	2.60	1.02	0.42
1987 to 1988	1.5	0.9	6.8	5.8	4.6	3.4	1.6	0.6
1988 to 1989	1.7	1.5	8.5	9.6	4.8	4.3	1.1	0.3
1989 to 1990	2.2	1.8	8.7	8.1	4.9	4.1	1.1	0.6
1990 to 1991	2.5	2.6	8.3	7.5	5.7	5.2	1.6	0.8
1991 to 1992	3.1	2.4	8.6	7.0	6.5	5.8	2.1	1.1
1992 to 1993	3.7	3.3	8.1	8.5	6.1	4.8	2.0	1.1
1993 to 1994	4.3	4.7	8.3	7.8	6.2	5.3	2.6	1.3
1994 to 1995	4.3	3.9	7.8	8.0	6.0	5.7	2.0	1.2

Year	Oil-seeds							
	Soybeans		Groundnuts		Mustard and Rapeseeds		Sunflowers	
	Area in Million-hectares	Produc-tion in Million-Tonnes	Area in Million-hectares	Produc-tion in Million-Tonnes	Area in Million-hectares	Produc-tion in Million-Tonnes	Area in Million-hectares	Produc-tion in Million-Tonnes
1995 to 1996	5.0	5.1	7.5	7.5	6.5	6.0	2.1	1.2
1996 to 1997	5.4	5.3	7.6	8.6	6.5	6.6	1.9	1.2
1997 to 1998	5.9	6.4	7.0	7.3	7.0	4.7	1.7	0.8
1998 to 1999	6.4	7.1	7.4	8.9	6.5	5.6	1.8	0.9
1999 to 2000	6.2	7.0	6.8	5.2	6.0	5.7	1.2	0.6
2000 to 2001	6.4	5.2	6.5	6.4	4.4	4.1	1.0	0.6
2001 to 2002	6.3	5.9	6.2	7.0	5.0	5.0	1.1	0.6
2002 to 2003	6.1	4.6	5.9	4.1	4.5	3.8	1.6	0.8
2003 to 2004	6.5	7.8	5.9	8.1	5.4	6.2	2.0	0.9
2004 to 2005	7.5	6.8	6.6	6.7	7.3	7.5	2.1	1.1
2005 to 2006	7.7	8.2	6.7	7.9	7.2	8.1	2.3	1.4
2006 to 2007	8.3	8.8	5.6	4.8	6.7	7.4	2.1	1.2
2007 to 2008	8.8	10.9	6.2	9.1	5.8	5.8	1.9	1.4
2008 to 2009	9.5	9.9	6.1	7.1	6.3	7.2	1.8	1.1
2009 to 2010	9.7	9.9	5.4	5.4	5.5	6.6	1.4	0.8
2010 to 2011	9.6	12.7	5.8	8.2	6.9	8.1	0.9	0.6
2011 to 2012	10.1	12.2	5.2	6.9	5.8	6.6	0.7	0.5
2012 to 2013	10.8	14.6	4.7	4.7	6.3	8.0	0.8	0.5
2013 to 2014	11.7	11.8	5.5	9.7	6.6	7.8	0.6	0.5
2014 to 2015	10.9	10.3	4.7	7.4	5.8	6.2	0.5	0.4
2015 to 2016	11.6	8.5	4.6	6.7	5.7	6.8	0.4	0.3
2016 to 2017	11.1	13.1	5.3	7.4	6.0	7.9	0.3	0.2
2017 to 2018	10.4	10.9	4.9	9.1	5.9	8.3	0.2	0.2

Tab. 1.8: Statistics of other cash-crops such as "cottons, sugarcane, and jutes and mesta" productions in Indian agriculture from 1966 to 2018 [1]

Year	Other Cash-Crops					
	Cottons		Sugarcane		Jutes and Mesta	
	Area in Million-hectares	Production in Million-Tonnes	Area in Million-hectares	Production in Million-Tonnes	Area in Million-hectares	Production in Million-Tonnes
1966 to 1967	7.8	5.2	2.3	92.8	1.1	6.5
1967 to 1968	8.0	5.7	2.0	95.5	1.2	7.5
1968 to 1969	7.6	5.4	2.5	124.6	0.8	3.8
1969 to 1970	7.7	5.5	2.7	135.0	1.0	6.7
1970 to 1971	7.6	4.7	2.6	126.3	1.0	6.1
1971 to 1972	7.8	6.9	2.3	113.5	1.1	6.8
1972 to 1973	7.6	5.7	2.4	124.8	0.9	6.0
1973 to 1974	7.5	6.3	2.7	140.8	1.1	7.6
1974 to 1975	7.5	7.1	2.8	144.2	0.9	5.8
1975 to 1976	7.3	5.9	2.7	140.6	0.9	5.9
1976 to 1977	6.8	5.8	2.8	153.0	1.0	7.1
1977 to 1978	7.8	7.2	3.1	176.9	1.1	7.1
1978 to 1979	8.1	7.9	3.0	151.6	1.2	8.3
1979 to 1980	8.1	7.6	2.6	128.8	1.2	7.9
1980 to 1981	7.8	7.0	2.6	154.2	1.3	8.1
1981 to 1982	8.0	7.8	3.1	186.3	1.1	8.3
1982 to 1983	7.8	7.5	3.3	189.5	1.0	7.1
1983 to 1984	7.7	6.3	3.1	174.0	1.0	7.7
1984 to 1985	7.3	8.5	2.9	170.3	1.1	7.7
1985 to 1986	7.5	8.7	2.8	170.6	1.5	12.6
1986 to 1987	6.9	6.9	3.0	186.0	1.0	8.6
1987 to 1988	6.4	6.3	3.2	196.7	0.9	6.7
1988 to 1989	7.3	8.7	3.3	203.0	0.9	7.8
1989 to 1990	7.6	11.4	3.4	225.5	0.9	8.2
1990 to 1991	7.4	9.8	3.6	241.0	1.0	9.2
1991 to 1992	7.6	9.7	3.8	254.0	1.1	10.2
1992 to 1993	7.5	11.4	3.5	228.0	0.9	8.5
1993 to 1994	7.3	10.7	3.4	229.6	0.8	8.4
1994 to 1995	7.8	11.8	3.8	275.5	0.9	9.0
1995 to 1996	9.0	12.8	4.1	281.1	0.9	8.8
1996 to 1997	9.1	14.2	4.1	277.5	1.1	11.1

Year	Other Cash-Crops					
	Cottons		Sugarcane		Jutes and Mesta	
	Area in Million-hectares	Production in Million-Tonnes	Area in Million-hectares	Production in Million-Tonnes	Area in Million-hectares	Production in Million-Tonnes
1997 to 1998	8.8	10.8	3.9	279.5	1.1	11.0
1998 to 1999	9.3	12.2	4.0	288.7	1.0	9.8
1999 to 2000	8.7	11.5	4.2	299.3	1.0	10.5
2000 to 2001	8.5	9.5	4.3	295.9	1.0	10.5
2001 to 2002	9.1	10.0	4.4	297.2	1.0	11.6
2002 to 2003	7.6	8.6	4.5	287.3	1.0	11.2
2003 to 2004	7.6	13.7	3.9	233.8	1.0	11.1
2004 to 2005	8.7	16.4	3.6	237.0	0.9	10.2
2005 to 2006	8.6	18.5	4.2	281.1	0.9	10.8
2006 to 2007	9.1	22.6	5.1	355.5	0.9	11.2
2007 to 2008	9.4	25.8	5.0	348.1	0.9	11.2
2008 to 2009	9.4	22.2	4.4	285.0	0.9	10.3
2009 to 2010	10.1	24.0	4.1	292.3	0.9	11.8
2010 to 2011	11.2	33.0	4.8	342.3	0.8	10.6
2011 to 2012	12.1	35.2	5.0	361.0	0.9	11.4
2012 to 2013	11.9	34.2	5.0	341.2	0.8	10.9
2013 to 2014	11.9	35.9	4.9	352.1	0.8	11.6
2014 to 2015	12.8	34.8	5.0	362.3	0.8	11.1
2015 to 2016	12.2	30.0	4.9	348.4	0.7	10.5
2016 to 2017	10.8	32.5	4.4	306.0	0.7	10.9
2017 to 2018	12.4	34.8	4.7	376.9	0.7	10.1

At present, one of the computational tool such as the "computational fluid dynamics (CFD)" modeling has gained more attraction in agri-food industries, which can provide a cost-effective way of designing and optimizing equipment and processes by reducing the risks in equipment-modification and process scaling-up [10]. About 2.4% of the geographical area in the world accounts for India, with 4% of water-resources in addition to a requirement in supporting of about 17% of human-population and 15% of livestock. The world population has been expected for increasing to 9.1 billion from the present 2.3 billon by 2050, which may have a further requirement of enhancement in overall food-production by 70%. Therefore, the agriculture sector has been getting vast priority for more research, and so far different innovative techniques have been applied by various researchers' worldwide to solve agriculture related problems. The sustainability issues related to the productivity of crops is a major concern in India and there is a higher requirement for adequate investigation on the issues related to the agricultural productivity for individual grown crops in Indian agricultural sectors [93]. Almeida Et al. have elaborated about rapid automated-method for determining sulfadiazine on-site in farming of fishes by the utilization of a stainless-steel veterinary syringe that was coated with a selective-membrane of PVC as a potentiometric-detector in flow-injection analysis purposes [3]. Ozilgen Et al. have discussed about producing methods of red-pepper spices in Turkey, their contaminations with aflatoxin in addition to the uncertainties about the assessed data in order to achieve possible improvements through the application of "Failure Mode and Effect Analysis (FMEA)" and "exponentially weighted average" charts [127]. Chen Et al. have studied about the fast-segmentation of higher-resolution images i.e. "quickbird images" of satellite by the use of watershed transform in combination with an efficient region-merging [29].

Papageorgiou Et al. have investigated the yield and yield-variability prediction in cotton-crops with the aim of providing a decision-support system for precision-agriculture in Central Greece by the use of soft-computing technique of fuzzy cognitive-maps for connecting the associated parameters defining yield in cotton-crops [128]. Michaels Et al. have proposed a robotic based mechanical weed control for organic farming of carrots cultivation. They used an autonomous agriculture-robot such as "BoniRob" allowing an "App-concept" with arrangements of variable sensors and actuators for coping with a diverse range of cases [109]. Huang has discussed the developments of ANNs and deep-learning algorithms with regard to their biological-connections in agri-food sectors. If proper care is not taken pertaining to plant's disease detection and control, then it causes serious effects on plants by adverse impacts on quality, quantity as well as productivity. Leaf diseases have been found to be hazardous in pine-trees in United States [74]. Singh and Misra have used genetic-algorithm as an image-segmentation technique to automatically detect and classify the diseases of plant leaf [156]. The use of machine-vision provides image-based automatic process-control, inspection, and robot-guidance [5, 42]. For plant disease detection, automatic techniques are preferred due to lesser efforts, time and getting more accurate results. Image-processing has been used to measure the affected areas of diseases and for determining the colour differences of the affected areas [11, 42]. Different methods have been developed for the segmentation of images on the basis of various features obtained in the image such as colour-information, segment or boundaries of an image [15, 16]. Linear-programming models has been considered to be effective tools for supporting of initial as well as periodic planning for the agricultural sectors requiring technical-coefficients measurable with the use of computer-simulation models [21].

Environmental and individual heterogeneity has been recognized by agricultural-economists as the principal-components of dynamic human natural systems [123]. Filip et al. have considered the field-operations and the evolution of processes in agriculture from non-organized hand-made activities into more organized as well as specialized processes by the use of a set of algorithms based approaches for spatial-configuration division, route-planning or path-planning in addition to approaches with the use of cost-parameters such as fuel, energy, and time-consumption [54]. Considering the present scenario in the development of automation-systems, the human-sensory as well as mental-inputs can be replaced by the use of 'communication and information technologies' providing a number of emerging benefits, such as improved repeatability associated with work performance as well as capacity enhancements. In addition, the labour-costs and material-inputs (e.g., fertilizers and agrochemicals) can be decreased to a larger extent. Moreover, an increased products' quality can be achieved through automation systems by providing better-control of processes [18]. A combination of heuristic methods represents a metaheuristics aiming for effective promotion of the exploration of the search-space. Thus, it is possible to develop a general heuristic method for guiding a specific heuristic and it can be classified based on the employed neighbourhood-structure or the strategy to obtain the solution [64]. The metaheuristic methods have been classified in different ways by different researchers and authors ([7,50], such as evolutionary-computing, swarm human as well as society inspired and physics based [36, 43, 87]; single and population based [38, 49]; and so on.

Soft-computing techniques enable in modeling and analyzing very complex-problems for which the conventional methods cannot produce analytical, cost-effective, or complete solution [73]. The soft-computing integrates both biological-structures and computing-techniques. Among different soft-computing techniques, fuzzy logic (FL) has been established that appears as the fundamental ideas of soft-computing [184,185]. John Holland developed "Genetic Algorithms (GAs)" in 1975 that became more popular by one of his student [65]. In an imprecise-environment, the FL develops non-numeric and multi-valued linguistic-variables for modelling human-reasoning. Similarly, "Artificial Neural-Networks (ANNs)" comprises of inter-connected artificial-neurons that mimic the biological neurons' properties. GAs is used to solve problems by selecting, recombining and mutation. The soft-computing techniques are used in achieving robustness, tractability, and providing a low-cost solution having a tolerance of uncertainty, imprecision, partial-truth, and approximation, which enables soft-computing to solve problems in an analytical, cost-effective, or complete-manner than that of conventional methods. Advancement in soft-computing involves "combination or cascading or fusion" of different soft-computing techniques to improve system-performance over any conventional technique like the neuro-fuzzy systems [75, 77, 79, 80, 154, 163]. This fusion provides cost-effective, high-performance, and reliable computing-schemes with more innovative-solutions [126]. Based on some early researches, the soft-computing has been applied in agricultural as well as biological engineering applications [48,176], and its interest has also increased steadily in the last-decade.

1.3 Computations in agriculture

Agriculture has been playing a crucial-role in developing-nations by becoming their economy-foundation and contributing in more GDP in comparison to other sectors. However, the knowledge acquired from agriculture based data is more useful for different purposes, and the farmers also need adequate and accurate advices with regard to prediction of the yield, productivity in addition to crop prices. Gandhi and Armstrong have focused on the application of association rule-mining technique for the assessment of rice-crop yields based on seasonal-rainfalls in Rajasthan (India) [56]. While, Singh and Singh have assessed the wheat-crop yield by the use of decision-tree algorithms [155], and Rajeswari and Arunesh have analyzed soil-data by the use of data-mining classification-techniques [138]. Computation to determine the best compromise among different required criteria becomes a challenge because of not-compatibility of all such criteria. Thomopoulos and Bakalis have demonstrated the interest of information-systems as well as computational-methods for decision-support in agriculture and food policies [166]. Agriculture has been associated with the improvement in the economic-rate of the country. An emerging concept in agriculture has been reported as the prediction of crop-yield [103,135,142]. Vadivu Et al. have studied on the prediction of rice variety in addition to quality that helped in computing sufficient resources for cultivating crops [169]. Bodake Et al. have revealed that over the past-decades, the machine-learning algorithms have been used widely for the prediction of crop-yields, including genetic-algorithm, support vector-machine (SVM), linear-regression, ANN, Naïve-Bayes (NB), and so on [19]. Dynamic variations of inputs are considered in machine-learning algorithms, such as dynamic variations in temperature values (for higher values), availability of water, and utilization of fertilizers for the current time-period [83].

For the current and future food-security, sustainable crop-production has become a most significant factor throughout the world. Through innovative technologies, the design strategies for higher crop-yields on less land with few resources can be achieved. Advanced scientific-visualization coupled with computational modeling enables the researchers in exploring and interacting with complex agricultures, nutrition, and climate-data for the prediction of crops' response to diverse environments that can help in the design and development of strategies in order to meet the future yields as well as nutritional demands [32]. For sustainable food-systems one of the major components is crop production, but it is more sensitive to climate-change. Based on the present prediction of climate models, an increased level in temperatures as well as carbon-dioxide in atmosphere, changing-patterns in regional and global precipitations, and rise of the frequency and intensity of extreme-weather events will affect both quality as well as quantity of crops significantly over the next hundred-years [114]. For adequate water and fertilization, even the elevated carbon-dioxide atmosphere has been revealed to enhance the biomass and crop yield by using both C3 as well as C4 photo-synthetic path-ways [100]. However, it has been shown by different studies that a decreased nutritional grain-quality and legumes resulted by growing crops under higher concentrations of carbon-dioxide [44,114,165]. It was expected that wheat, maize, and rice will show decreased yields owing to the climate-change in tropical as well as temperate regions with limited and poor resources water and soil-nutrition [26], which will adversely impact the developing countries having a higher urban-demand for nutritional food, and requiring for an increased production of crops and utilization of resources [22,40,60].

Srinivasan and Kumar have suggested for the use of three dimensional in addition to immersive data-visualization for the improvement of better understanding of researchers about complex-data [160]. Quinn has studied the spread of viral crop-diseases in "Uganda", and has described the application of computer-vision, spatial-modelling, active-learning in addition to optimization for the viral-diseases affecting cassava as well as banana crops [137]. For those with no or little knowledge of farming, the extension-service plays a key role for larger population of smallholders in terms of innovation, management, advice in addition to monitoring of agricultural activities [168]. The classical as well as modern approaches to artificial-intelligence (AI) are used to solve problems related to the technologies of precision-agriculture. The typical classical approaches to AI include expert systems that can be applied to solve problems. However, some of the modern approaches to AI include artificial neural-networks, genetic-algorithms, evolutionary-computing, and agent-architectures [55]. Arabameri Et al. have investigated the predictive-performance of seven multi-criteria decision-making, statistical in addition to machine-learning based models with their groups for gully-erosion susceptibility-mapping by considering the 'Dasjard-River' watershed in Iran [4]. Shiri Et al. have made a comprehensive-comparison of twelve soft-computing models for the estimation of daily 'evapotranspiration' values in humid-regions, such as gene-expression programming (GEP); neuro-fuzzy with sub-clustering (NFSC); neuro-fuzzy with grid-partitioning (NFGP); multivariate adaptive-regression spline (MARS); random-forest (RF); boosted-regression tree (BT); model-tree (MT); support vector-machine (SVM); SVM firefly-algorithm (SVMFA); extreme learning-machine (ELM); neural-network particle swarm-optimization (NNPSO); and neural-network differential-evolution (NNDE), respectively [152]. Alioui and Acar have evaluated the performance of a constrained-version of the "Non-dominated Sorting Genetic-Algorithm 2 (NSGA 2)", a multi-objective evolutionary optimization-algorithm in MATLAB and found it to be an effective technique as compared to the other optimizing techniques [2].

A number of constrained evolutionary-algorithms have been utilized over the last decades, such as adaptive trade-off-model [173]; infeasibility-driven evolutionary-algorithm [139'; self-adaptive penalty [177]; MOEA/D-I Epsilon [51]; and non-dominated sorting genetic-algorithm [39]. For the producers in modern agriculture for 'smart farming', the agricultural data with their effective management have become the key-elements for critical decision-making. Saiz-Rubio and Rovira-Más have reviewed the existing status of advanced farm-management systems from data-acquisition in crop fields to variable-rate applications in order to help the growers to make optimized decisions for saving money through adequate protection to the environment and producing food with appropriate transformations to match sustainably the forthcoming growth in population [145]. A fuzzy-based decision-support system was designed for potato, corn, and kiwi with soil-moisture as input variables and subsequent rain-forecast [62]. Further, Navarro-Hellín Et al. have developed a decision-support system for the estimation of irrigation on weekly basis for citrus-orchards by considering climatic as well as soil variables [117]. However, the decision-support systems may be more reliable and robust with the consideration of different variables, but based on the decision makers' priority setting, some procedures remain-controversial leading to different-solutions at different-times [92]. The software-solutions provided for farm management help in automatic acquisition of data as well as processing, planning, monitoring, decision-making, documentation, and management of the farm-related activities [91], and also include the basic functions for record-keeping such as crop-production rates like harvests and yields; profits and losses; scheduling of farm-tasks; weather-prediction; tracking of soil-nutrients; and field-mapping. Further, a critical-feature of these applications include in early warning of hazards related to weather for preventing in exposure to risks by the farmers, policy-makers, and other aid-agencies [6].

As the agriculture sectors are in the process of transformation through the introduction and use of latest-technologies, these sectors seem to move to the next-level of improved productivity as well as farm-related profits [70]. Throughout the world, precision-agriculture has become one of the modern revolutions in agriculture [188]. The "United States Department of Agriculture (USDA)" already reported of precision-agriculture technologies to increase the net-returns in addition to operating-profits, in October 2016 [147]. Based on market-analysis, the factors facilitating the sustainable farming technologies adoption included better-education and farmers' training, information-sharing, sufficient availability of financial-resources, and increased consumer-demands for organic-food [67]. With the application of the new technologies, valuable advantages are obtained at farm-levels, such as saving of work as well as money, increased production, cost-reduction with minimal efforts, and producing quality-food with environment-friendly practices [45]. Zhai Et al. have made a survey on thirteen different decision-support systems including their applications for mission-planning in agriculture, water-resources management, climate-change adaptations, and food-waste control. They have further suggested that with the adoption of advanced information-systems and internet technologies in "Agriculture 4.0", huge farm-data can be gathered, analyzed as well as processed, such as meteorological-information, soil-conditions, marketing-demands, and land-uses, to assist the farmers in making appropriate decisions and getting higher-profits [186].

In the future, there will be growing demand by the human-beings for agricultural products with a further requirement in the expansion of farm-lands and growth in yields of agriculture products. However, due to global-warming, the extreme weather-conditions often damage the crops [116]. Moreover, the future world will be acquired with more 2 billion populations of people rendering the residential spaces and prohibiting in further expansion of farm-lands [130]. Gebbersand and Adamchuk have pointed out that owing to the ongoing crisis of foods; most of the countries around the globe are involved in developing 'intelligent agriculture' [58]. For instance, many farms have started in relying on natural resources such as utilization of hydro-power, geothermal-energy or solar-power for the reduction of cultivating costs [164]. Navarro-Hellín Et al. have argued of the inadequate labour-force to be a serious-issue in the next few-decades [118]. Agricultural ecosystems need to be established to combat the crisis of food by continuous monitoring farm-data for improving production-related issues [84]. The maintenance of privacy as well as security has been a major concern with regard to the governance of big-data [95,125,159]. There has been a fear of mishandling of data by getting into the wrong-hands [61]. Therefore, while developing the applications with the use of big-data, it should be ensured of restricted and confidential handling of big-data with good trust building with the farmers. Further, new organizational-linkages in addition to cooperative approaches need to be established within the agri-food chains [159]. In some instances, there may also be a major challenge in anonymization of data for ensuring that these data cannot be tracked-back into individual-firms [125]. Other challenges in association to farm-data includes their underutilization [14]; poor quality and availability of the data [95, 125]; and lack of appropriate integration [180]; respectively.

The interest in the agricultural sustainability and food-systems was started with regard to environmental-concerns during 1950s to 1960s. But, the sustainability ideas began with the past studies from Rome, Greece and China [33, 69, 96, 133]. These days, major sustainability concerns for the development in agricultural technology and practices focus on avoidance of adverse-effects on the environment, more accessibility to farmers, and improvement in food productivity. Sustainability in agricultural-systems has been found to address the economic, environmental as well as social outcomes in agriculture [134]. Loures Et al. have used the data obtained from three farms in border of Portuguese-Spanish, and considered three parameters such as seeding-failures, differentiated irrigation and fertilization for determining the ecological benefits along with the economic as well as productivity aspects of an efficient integrated arrangement of "remotely piloted aircraft systems (RPAS)/unmanned aerial vehicles (UAV)" and "normalized difference vegetation index (NDVI)" techniques in smaller Mediterranean-farms. The obtained results on the basis of these methods highlighted the fact of economic-savings in productivity-factors, thus promoting for a sustainable-agriculture both in ecological as well as economic aspects [101].

With the involvement of crop management practices including chemical, biological, and physical processes such as water, soil as well as climatic scenario, the sustainable agricultural processes and production systems have become more complex. Moreover, the interactive computer-based expert-systems help the decision-makers in utilization of data as well as models for solving un-structured problems [140]. A framework is usually offered by the decision-support systems within which the complex-systems can be characterized in a structured way in an understandable manner for drawing-out any additional information [24]. For the applicability of successful decision-support for assisting in the sustainability of agriculture resources, the important agriculture related parameters that need to be considered for effective agriculture-management include type of soils, seeds, irrigations, fertilizers, and climatic-data associated with different farming activities (Figure 1.1).

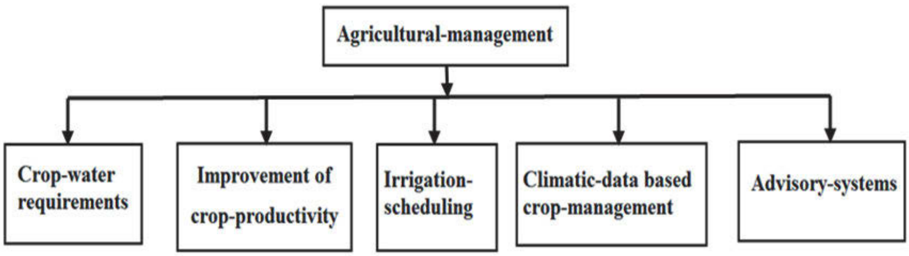

Fig. 1.1: Activities for effective agriculture-management

Lampridi Et al. have revealed that the interest of scientific-community in agricultural sustainability has been increasing in the last three-years, which included the most used methods as indicators-based tools, indexes, and frameworks, followed by multi-criteria approaches [94]. Three basic pillars of sustainable-development need to be addressed and appraised simultaneously for agricultural sustainability, such as economic, environmental, and social issues, in association with different agricultural-practices [170]. Based on the data obtained from Agricultural Statistics at a Glance [1], the area and production of major-crops in various countries in 2016 was illustrated in Table 1.9.

Tab. 1.9: The area and production of major-crops in various countries in 2016 [1]

Crops	Country	Area in Hectares	Production in Metric-tonnes
Paddy	Bangladesh	1100×10^4	5045×10^4
	Brazil	194×10^4	1062×10^4
	China	30746×10^4	21109×10^4

Crops	Country	Area in Hectares	Production in Metric-tonnes
	India	4319×10^4	16370×10^4
	Indonesia	1515×10^4	7935×10^4
	Myanmar	672×10^4	2567×10^4
	Nigeria	560×10^4	1134×10^4
	Philippines	455×10^4	1762×10^4
	Thailand	934×10^4	2665×10^4
	Viet Nam	773×10^4	4311×10^4
	Total in the world	16521×10^4	75615×10^4
Wheat	Australia	1128×10^4	2227×10^4
	Canada	926×10^4	3214×10^4
	China	2469×10^4	13327×10^4
	France	556×10^4	2950×10^4
	Germany	320×10^4	2446×10^4
	India	3042×10^4	9229×10^4
	Pakistan	922×10^4	2563×10^4
	Russian Federation	2731×10^4	7329×10^4
	Ukraine	620×10^4	2609×10^4
	United States of America	1774×10^4	6283×10^4
	Total in the world	22025×10^4	74901×10^4
Maize	Argentina	534×10^4	3979×10^4
	Brazil	1495×10^4	6414×10^4
	Canada	131×10^4	1388×10^4
	China	4417×10^4	26361×10^4
	India	990×10^4	2590×10^4
	Indonesia	444×10^4	2357×10^4
	Mexico	759×10^4	2825×10^4
	Russian Federation	277×10^4	1531×10^4
	Ukraine	425×10^4	2807×10^4
	United States of America	3510×10^4	38477×10^4
	Total in the world	19536×10^4	110022×10^4
Pulses	Australia	201×10^4	241×10^4
	Brazil	260×10^4	262×10^4
	Canada	404×10^4	813×10^4
	China, mainland	260×10^4	451×10^4
	Ethiopia	151×10^4	273×10^4

Crops	Country	Area in Hectares	Production in Metric-tonnes
	India	3084×10^4	1815×10^4
	Myanmar	436×10^4	657×10^4
	Nigeria	372×10^4	311×10^4
	Russian Federation	168×10^4	294×10^4
	United States of America	167×10^4	341×10^4
	Total in the world	8715×10^4	8345×10^4
Sugarcane	Australia	44×10^4	3440×10^4
	Brazil	1022×10^4	76856×10^4
	China	140×10^4	10321×10^4
	Colombia	40×10^4	3476×10^4
	Guatemala	26×10^4	3353×10^4
	India	495×10^4	34844×10^4
	Mexico	78×10^4	5644×10^4
	Pakistan	113×10^4	6545×10^4
	Thailand	140×10^4	9009×10^4
	United States of America	36×10^4	2925×10^4
	Total in the world	2653×10^4	186118×10^4
Groundnuts	Argentina	34×10^4	100×10^4
	Cameroon	45×10^4	74×10^4
	Chad	79×10^4	87×10^4
	China	444×10^4	1636×10^4
	India	580×10^4	746×10^4
	Myanmar	98×10^4	157×10^4
	Nigeria	268×10^4	358×10^4
	Senegal	88×10^4	71×10^4
	Sudan	231×10^4	182×10^4
	United States of America	62×10^4	253×10^4
	Total in the world	2795×10^4	4490×10^4

On the basis of the FAO data [52], Table 1.10 represented the statistics of “Grapes production in tonnes” for the countries like “Algeria and Egypt” during the period of 1961 to 2019, which was followed by Table 1.11 representing the statistics of “Groundnuts with shells production in tonnes” for the countries like “Egypt and Libya” during the period of 1961 to 2019, respectively.

Tab. 1.10: The statistics of "Grapes production in tonnes" for the countries like "Algeria and Egypt" during the period of 1961 to 2019 (Source: [52])

Year	Algeria	Egypt
1961	1845000	106000
1962	1668000	120172
1963	1696000	105412
1964	1416000	91042
1965	1902000	90047
1966	931300	118014
1967	889000	117000
1968	1399000	117000
1969	1237000	110000
1970	1275000	108000
1971	1295000	128000
1972	761000	164000
1973	794000	166000
1974	837000	227000
1975	587000	225000
1976	518000	307598
1977	370000	248000
1978	263000	274000
1979	386000	242311
1980	407000	299131
1981	400000	297977
1982	255000	305664
1983	315000	344000
1984	415000	357000
1985	469000	395000
1986	465000	452000
1987	282000	510000
1988	301000	557000
1989	270426	621000
1990	262794	584694
1991	251370	526716
1992	229073	658061
1993	212652	726082
1994	141294	707049
1995	196351	739478

Year	Algeria	Egypt
1996	195400	943702
1997	192190	867905
1998	146670	957734
1999	177905	1009560
2000	203617	1075100
2001	196159	1078910
2002	234397	1073815
2003	277968	1196852
2004	283900	1275288
2005	334021	1391750
2006	398018	1431970
2007	244999	1485010
2008	401992	1531418
2009	492525	1370241
2010	560562	1360251
2011	402592	1320801
2012	543169	1378815
2013	570840	1434666
2014	518035	1596169
2015	568069	1686706
2016	571351	1691194
2017	566579	1734424
2018	502978	1641075
2019	549833	1626259

Tab. 1.11: The statistics of "Groundnuts with shells production in tonnes" for the countries like "Egypt and Libya" during the period of 1961 to 2019 (Source: [52])

Year	Egypt	Libya
1961	25000	11000
1962	49446	9200
1963	45230	9230
1964	46169	10500
1965	49878	10889
1966	40000	11972
1967	33000	13261
1968	37000	12792

Year	Egypt	Libya
1969	45000	10104
1970	40000	10685
1971	34000	11075
1972	31000	13692
1973	28000	11000
1974	27000	12325
1975	28000	12503
1976	29983	12721
1977	33288	12945
1978	25993	12740
1979	27012	15000
1980	25540	13200
1981	25500	13000
1982	23783	13000
1983	20000	14000
1984	21000	14000
1985	23000	14000
1986	21000	14000
1987	23000	14000
1988	32000	14200
1989	28535	14300
1990	26255	14400
1991	27395	14500
1992	30350	14000
1993	106025	14300
1994	116946	14500
1995	130642	15000
1996	124981	15300
1997	125988	16000
1998	132351	18000
1999	180771	18979
2000	187169	20000
2001	205066	20768
2002	191037	22000
2003	195869	24000
2004	191846	23000
2005	199560	26000
2006	183970	23000

Year	Egypt	Libya
2007	217580	23000
2008	208835	23000
2009	198012	26000
2010	202906	22000
2011	206574	17000
2012	205419	17000
2013	204796	17000
2014	183438	17000
2015	197246	16778
2016	205946	15352
2017	243296	14478
2018	209843	13771
2019	231223	13065

1.4 Conclusion

The soft-computing has been studied extensively in the last three-decades for different scientific-researches in addition to engineering-computing. Although, the applications of soft-computing techniques were found to be useful in solving a variety of complex-problems, but still new-approaches has been advancing to develop the methodology for more achievement.

The benefits of robustness, tractability, and providing lower-cost solutions having a tolerance of uncertainty, imprecision, partial-truth, and approximation enable the soft-computing to solve problems in an analytical, cost-effective, or complete-manner than that of conventional methods.

More advancement in soft-computing involves combination or cascading or fusion of different soft-computing techniques for significant improvement of system-performances over any conventional techniques.

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2 Challenges and possible opportunities in the global agri-sectors

Abstract: In most of the cases, the concept of organic-farming has been found to fulfil the objectives of sustainable agriculture that help to manage and control the use of fertilizers, pesticides, and by regulating of other farm-related activities prohibiting in organic production-systems. Moreover, through effective use of organic-farming, the soil-fertility can be considerably enhanced by making the soils capable of supplying all the essential-nutrients to crops for proper-growth and development. In order to explore the present scenario in the agri-sectors and to identify the possible opportunities for an effective farming culture through organic-farming, the present study was focussed on the agri-sectors of Ethiopia and Kenya, respectively.

Keywords: Agriculture, Organic-farming, Agricultural extension-services, Livestock; Challenges, Ethiopia, Kenya, SWOT Factor-analysis

2.0 Introduction

The human being desires of getting more and more from natural-resources results in biodiversity-degradation in addition to adverse impacts on the environment. At the present scenario of the world, sustainability finds a significant concern to save the natural-resources. A successful supervision of resources can be achieved through sustainable agriculture for satisfying the changing human-needs with enhanced the environment-quality, and thus conservation of natural-resources. In most of the cases, the concept of organic-farming has been found to fulfil the objectives of sustainable agriculture that help to manage and control the use of fertilizers, pesticides, and by regulating of other farm-related activities prohibiting in organic production-systems.

Moreover, through effective use of organic-farming, the soil-fertility can be considerably enhanced by making the soils capable of supplying all the essential-nutrients to crops for proper-growth and development. In order to explore the present scenario in the agri-sectors and to identify the possible opportunities for an effective farming culture through organic-farming, the present study was focussed on the agri-sectors of Ethiopia and Kenya, respectively.

2.1 Literature review

The challenges associated with developing countries in adaption of food-safety standards included technical, financial and structural limits, inefficient organization-potential in addition to the controlling and supporting abilities [42]. The socio-

https://doi.org/10.1515/9783110745368-002

economic constraints by mango-exporters in Europe have been reported as hindering the good agricultural practices [22]. Based on a study in Thailand, the varying family-income may cause different capabilities for the purchase of expensive tools and equipment [41]. The major-barriers in adopting technologies included the difficulties associated with economics, education and information, dependability to changes, technology-application, social-challenges, and landlessness, infrastructural, and personal factors [36]. Because of the adverse environmental impacts of conventional agriculture systems, there has been a growing demand for the development of sustainable agricultural [33].

Good agriculture practices refer to a variety of approaches such as agriculture sustainability, safe and quality foods, enabling farmers to absorb new market-vantages by improved supply-chain controls, improved natural-resources utilization, workers' health and working-conditions, family-health of consumers as well as farmers, and creation of newer market-opportunities for farmers' in developing nations [6]. For about 200 million farmers of small-scale categories in Asia, Africa as well as Latin America, livestock has been reported in providing the main source of income [11]. Farm-animals play as the main source of finance for agricultural family-units [40]. The behaviour of workers has been regarded as a key determinant of dermal-exposure influenced by knowledge, attitude as well as risk-perceptions [13]. The findings by Kaustell Et al. suggested of user-centred approaches in facilitating in the development of more effective health and safety intervention strategies for the farmers [21]. In an intervention related study for the prevention of hearing losses, it was found that the negligence of wearing for hearing protection by the farmers were because of inconveniences, discomforts and creation of newer hazards by limiting effective communication with others [12, 25]. But, Kaustell Et al. have stated of a limited study with respect to the indication of lasting and durability of effectiveness for such interventions strategies [21]. Deshmukh Et al. have suggested of the key-strategies for agricultural development as "developing local-market opportunities and in-storage infrastructures; crops' planting with higher economic-values; developing governmental-supports; strategic-plans preparations for organic-farming; considering the crops' qualities and farm sustainability-indexes; utilizations of sustainable water-resources management; and developing extension-programs on the basis of farmers' need", respectively [9]. Baksh Et al. have suggested for the need of higher emphasis on occupational health and safety for the agricultural sectors in Trinidad that can be achieved through well-directed policies, programs and practices by the government in addition to related agencies [5]. The capability of feeding the population lies in agriculture, which serve as a revenue-source to the nation, providing employment opportunities as well as serving as raw-materials' source to agro-based businesses [29]. However, these functions could not be attained in the recent times with the rapidly growing population and significant exports' reduction [29].

A number of side-effects have been recorded from the use of synthetic-fertilizers and other agro-chemicals causing water pollution [39]. With the use of non-renewable resources i.e. fossil-fuel, most of the agriculture based inorganic chemicals and fertilizers are manufactured that contributes to pollution in addition to degradation of environment [3]. Parikhani Et al. have revealed of the barriers to application of good agriculture practices in Meshkinshahr through factor-analysis as barriers related to infrastructures, institutional-supports, informational-educational, personal, and economical in livestock units [31]. Zeeshan Et al. have suggested for education-related initiatives for the development of food-safety knowledge along with food-handling preparations among the students of "University of Agriculture", Peshawar [46]. Based on a study on the Amish-communities of Ohio, it was recommended that through active participation and integration of the affected groups' knowledge, the complex problems of farms as well as safety practices can be properly addressed [32]. With regard to a numerous outbreaks related to food-borne illness and the association with food-products from farmers' market, Scheinberg Et al. have suggested for customized food-safety training-programs for the selling of safer-foods in Pennsylvania. One of the physiological-disorder such as "Hypomagnesaemic tetany (HypoMgT)" in ruminants has been reported to be caused by inadequate-intake or impaired-absorption of magnesium in the gut, and if it is not detected as well as treated in time, then it can cause in the death of the affected animals [38]. Kumssa Et al. indicated of adequate awareness among the UK farmers regarding the HypoMgT-related risks [23]. In view of the critical-effects of pesticides on human-health, a study was conducted in Hamadan Province of Iran for evaluating the knowledge, attitudes, and practices of using pesticides among the farmers. It was proposed to develop and to make availability of educational-sets to farmers consisting of association and applications with poisons, their storages and carriages, methods in effective protection facilities, and reducing the exposures to poisons [37]. However, a number of studies have been made at different regions of the world regarding the uses as well as safety-concerns of pesticides in agriculture, such as in Çukurova province [30]; in Kuwait [19]; and in Jimma-Zone of South-west Ethiopia [14]; respectively. Past studies have reported of the negligence of using farm-related personal protective equipment [2, 28, 35]. For instance, Coca Et al. have revealed of introduction in additional physiological burdens besides discomfort-rates by the personal protective equipment to their users in terms of increased heat-stresses, heart-rates, and core-temperature [8]. Bahşi and Kendi in their study in Konya and Osmaniye provinces, Turkey found of 45.9% farmers without any idea about occupational health and safety, and only 24.3% with such education. They suggested for more awareness requirement on occupational health and safety in the agricultural sectors [4].

2.1.1 Strengths, weaknesses, opportunities and threats (SWOT) analysis

Strengths, weaknesses, opportunities and threats (SWOT) analysis provides a framework to enable the researchers in identifying as well as prioritizing the goals. It also helps in the identification of useful strategies to achieve the desired goals. Furthermore, a significant role is played by the agro-based industries in the growth of world-economy with considerable fostering of food-security in addition to basic-needs of human-being. However, many countries have been facing with the problems of inadequacy food and emerging food-crisis.

Moreover, the application of SWOT analysis in the farming sectors has been widely noticed in previous researches. For instance, Mahajan and Patil have used SWOT analysis of the Indian agro-based industries and found the strengths as huge natural-resources, suitability of geographical conditions with some problems as lack of infrastructural facilities, lower product-quality and others [24]. Based on experts' perception and use of the SWOT analysis, a study was conducted for investigating the prospects of organic-agriculture in Bhutan [43].

2.2 Research Methodology

This study was made by in-depth review of literature related to the farming issues throughout the world and subsequent discussion with experts for their useful suggestions. The present study was focussed on the agri-sectors of Ethiopia and Kenya. The selected experts were 15 in numbers and were considered from both Ethiopia and Kenya. The experts were from agricultural as well as academic backgrounds with more than 20 years of expertise in their domain-areas.

Further, a "strengths, weaknesses, opportunities, and threats (SWOT)" analysis was used for the evaluation of the activities involved to initiate an organic agriculture system throughout the world for the benefits of farmers as well as farming-communities [17]. The experts' defined different activities of SWOT based on the existing scenario of agricultural production as well as development policies in the selected regions such as Ethiopia and Kenya, respectively.

2.3 Results

2.3.1 Agricultural extension-services in Ethiopia

The SWOT analysis of the agricultural extension-services in Ethiopia was as shown in Table 2.1. It was found of constituting of six strengths related to the existing extension-services, such as "Providing a comprehensive extension strategy for agricultural activities spelling-out the vision the country through systematic interventions of bottle-necks; Convenient service provision for the farming-communities; Providing a well-structured as well as decentralized extension-system; Providing adequate support to the agricultural vocational-training institutes to produce skilled extension-personnel; Providing a robust workforce of extension-agents; and Providing better access to extension facilities at community-levels"; respectively. There were five weaknesses such as "Lack of clear policy on involvement of non-state performers in agricultural extension services; Weaker linkage in research, extension, farmer, and industry; The extension-delivery system is insensitive to gender; Public-dominated with wide focus on rain-fed agricultural systems and very small focus on modernization; and Weaker market-linkages in addition to marketing information-systems". Further, six opportunities were found as "The multi-stakeholders innovation platform get benefits of incentives; Establishment of higher potential for "Participatory Extension System (PES)" under the latest extension strategies; Providing adequate platform for the farmers in the development of groups and social-networks; Providing adequate platform for market-oriented extension systems, business-development, entrepreneurship skills, and value-chain developing approaches; Providing adequate platform for all type of agro-processing industries for value-chain addition and with embedded extension-services; and Providing growth of farmers' cooperative-networks and unions for complementary extension-services".

Similarly, five threats were found as "Smaller farm-sizes because of higher population reduces the viability of small-scale agricultural systems, and weakens the value of extension-advices; Climatic-changes and recurrent-droughts; Higher turnover of skilled-professionals in agricultural extension-services; Providing a commanded type extension-management and delivery-system; and Unsteady price-values for agricultural products in the international markets; respectively.

Tab. 2.1: SWOT analysis of agricultural extension-services in Ethiopia

Strengths	Weaknesses
Provide a comprehensive extension strategy for agricultural activities spelling-out the vision the country through systematic interventions of bottlenecks	Lack of clear policy on involvement of non-state performers in agricultural extension services
Convenient service provision for the farming-communities	Weaker linkage in research, extension, farmer, and industry
Provide a well-structured as well as decentralized extension-system	The extension-delivery system is insensitive to gender
Provide adequate support to the agricultural vocational-training institutes to produce skilled extension-personnel	Public-dominated with wide focus on rain-fed agricultural systems and very small focus on modernization
Provide a robust workforce of extension-agents	Weaker market-linkages in addition to marketing information-systems

Strengths	Weaknesses
Provide better access to extension facilities at community-levels	
Opportunities	Threats
The multi-stakeholder's innovation platform get benefits of incentives Establishment of higher potential for "Participatory Extension System (PES)" under the latest extension strategies Provide adequate platform for the farmers in the development of groups and social-networks Provide adequate platform for market-oriented extension systems, business-development, entrepreneurship skills, and value-chain developing approaches Provide adequate platform for all type of agro-processing industries for value-chain addition and with embedded extension-services Provide growth of farmers' cooperative-networks and unions for complementary extension-services	Smaller farm-sizes because of higher population reduces the viability of small-scale agricultural systems, and weakens the value of extension-advices Climatic-changes and recurrent-droughts Higher turnover of skilled-professionals in agricultural extension-services Provide a commanded type extension-management and delivery-system Unsteady price-values for agricultural products in the international markets

2.3.2 Agricultural extension-services in Kenya

The SWOT analysis of the agricultural extension-services in Kenya was as shown in Table 2.2. It was found of constituting of four strengths related to the existing extension-services, such as: Stronger training of staffs and higher professionalism at all service-levels; Constituted with well-resourced extension staffs; Wider coverage of all covered extension systems; and Revitalisation of the agricultural extension system by the "National Agricultural Livestock targeting Extension Programme (NALEP)". Further, the six weaknesses were revealed as "Weaker farmers' participation and excessive supply-driven approach; Limited public-resources for agricultural extension allocation; Limited capabilities of small-scale farmers for paying extension-services; Weaker monitoring as well as evaluation; Lower motivation among staffs; and Poorer gender-specific design-consideration and delivery of extension-services".

Moreover, five opportunities were found as "Enthusiasm of small-scale farmers for paying for private extension-services; Adoption of "Farmer Field Schools (FFS)" approach for participatory extension-delivery; Advocating of demand-focused extension-services by "National Agricultural Sector Extension Policy"; Higher penetration-level of ICT such as internet, mobile-phones, and computers; and More initiatives by a large number of NGOs to reform in making demand-focused extension system". However, six threats were found as "Poorer accountability of public extension systems; Inappropriate flexibilities in public extension systems; Poorer coordination, linkages, and conflicts among extension services providers; Inadequate operational-funds; Poorer physical-infrastructure; and Lower-levels of rural-incomes"; respectively.

Tab. 2.2: SWOT analysis of agricultural extension system in Kenya

Strengths	**Weaknesses**
Stronger training of staffs and higher professionalism at all service-levels Constituted with well-resourced extension staffs Wider coverage of all covered extension systems Revitalisation of the agricultural extension system by the "National Agricultural Livestock targeting Extension Programme (NALEP)"	Weaker farmers' participation and excessive supply-driven approach Limited public-resources for agricultural extension allocation Limited capabilities of small-scale farmers for paying extension-services Weaker monitoring as well as evaluation Lower motivation among staffs Poorer gender-specific design-consideration and delivery of extension-services
Opportunities	Threats
Enthusiasm of small-scale farmers for paying for private extension-services Adoption of "Farmer Field Schools (FFS)" approach for participatory extension-delivery Advocating of demand-focused extension-services by "National Agricultural Sector Extension Policy" Higher penetration-level of ICT such as internet, mobile-phones, and computers More initiatives by a large number of NGOs to reform in making demand-focused extension system	Poorer accountability of public extension systems Inappropriate flexibilities in public extension systems Poorer coordination, linkages, and conflicts among extension services providers Inadequate operational-funds Poorer physical-infrastructure Lower-levels of rural-incomes

2.3.3 Challenges with organic-farming in the livestock sectors of Ethiopia and Kenya

Based on in-depth review of literature, seventeen numbers of associated-challenges with organic-farming in the livestock sectors of Ethiopia and Kenya were identified as illustrated in Table 2.3. However, after obtaining the responses of concerned experts in this study on a three-point likert-scale [18], factor-analysis was done for the associated-challenges under the three dominant-factors such as "Infrastructure-related, Institutional-related, and Informational-related", respectively. The result of factor-analysis with the use of "Minitab17 version-software" resulted in thirteen significant challenges with factor-loading values of ≥ 0.5 as shown in Table 2.4 and Table 2.5, respectively.

The challenges representing the infrastructure-related factor included six challenges, such as "Inefficient utilization of decontamination in livestock-sites; Inadequate access to quality and affordable vaccines; Absent of access to safe as well as healthy foods; Bad-quality of old livestock-buildings; Inadequate availability of equipment and facilities; and Lack of veterinary-clinics and timely detection of illness". Further, the challenges representing the institutional-related factor included three challenges, such as "Excessive use of antibiotics as well as hormones in livestock; Delays in compensation-payments by insurances; and Inadequate support for organic-milk and dairy-related production".

Similarly, the challenges representing the institutional-related factor included three challenges, such as "Inadequate access to extension-services; Inadequate livestock-related information; Inadequate knowledge and techniques for organic as well as safer productions; and Un-familiarity with hygienic and healthy issues related to livestock management", respectively.

Tab. 2.3: Associated-challenges with organic-farming in the livestock sectors of Ethiopia and Kenya

Sl. No.	Challenges
1	Inadequate access to quality and affordable vaccines (C1)
2	Absent of access to safe as well as healthy foods (C2)
3	Inefficient utilization of decontamination in livestock-sites (C3)
4	Inadequate availability of equipment and facilities (C4)
5	Lack of veterinary-clinics and timely detection of illness (C5)
6	Excessive use of antibiotics as well as hormones in livestock (C6)
7	Bad-quality of old livestock-buildings (C7)
8	Inadequate support for organic-milk and dairy-related production (C8)
9	Inadequate access to extension-services (C9)
10	Over aged farm-workers (C10)
11	Inadequate livestock-related information (C11)
12	Lower literacy-levels (C12)
13	Inadequate knowledge and techniques for organic as well as safer productions (C13)
14	Un-familiarity with hygienic and healthy issues related to livestock management (C14)
15	Non-guaranteed costs of safe-products (C15)
16	Habit of livestock farm-workers in using chemical-drugs as well as methods owing to their fastest effects and lesser costs (C16)
17	Delays in compensation-payments by insurances (C17)

Tab. 2.4: Associated-challenges under the three dominant-factors

Associated-challenges	Dominant-factor 1	Dominant-factor 2	Dominant-factor 3	Communality
C1	0.566			0.405
C2	0.697			0.425
C3	0.538			0.453
C4	0.574			0.438
C5	0.766			0.462
C7	0.577			0.612
C6		0.577		0.551
C8		0.536		0.449
C17		0.622		0.512
C9			-0.622	0.378
C11			-0.545	0.411
C13			-0.724	0.308
C14			-0.631	0.333
Variance	3.774	2.908	2.686	9.367
% Variance	0.135	0.114	0.098	0.335

Tab. 2.5: Significant associated-challenges with organic-farming

Challenges	Factor (Source)
Inadequate access to quality and affordable vaccines (C1)	Infrastructure-related [16, 26, 34, 36]
Absent of access to safe as well as healthy foods (C2)	
Inefficient utilization of decontamination in live-stock-sites (C3)	
Inadequate availability of equipment and facilities (C4)	
Lack of veterinary-clinics and timely detection of illness (C5)	
Bad-quality of old livestock-buildings (C7)	
Excessive use of antibiotics as well as hormones in livestock (C6)	Institutional-related [16, 26, 27, 34, 36]
Inadequate support for organic-milk and dairy-related production (C8)	

Challenges	Factor (Source)
Delays in compensation-payments by insurances (C17)	
Inadequate access to extension-services (C9)	Informational-related [10,20,26,27,34,36,44]
Inadequate livestock-related information (C11)	
Inadequate knowledge and techniques for organic as well as safer productions (C13)	
Un-familiarity with hygienic and healthy issues related to livestock management (C14)	

Further, from the “Pearson Correlation-Coefficient Matrix” for the thirteen significant associated-challenges with organic-farming as shown in Table 2.6, it was found that higher correlation-coefficient as well as significant-correlation at $p \leq 0.01$ level (2-tailed) was obtained between the challenges “Inadequate availability of equipment and facilities (C4)” and “Absent of access to safe as well as healthy foods (C2)” with p-value of0.471, which was followed by “Bad-quality of old livestock-buildings (C7)” and “Lack of veterinary-clinics and timely detection of illness (C5)” with p-value of 0.416; and so on. Similarly, higher correlation-coefficient as well as significant-correlation was obtained between the challenges “Inadequate access to extension-services (C9)” and “Inadequate support for organic-milk and dairy-related production (C8)” at $p \leq 0.05$ level (2-tailed) with p-value of 0.315, which was followed by “Un-familiarity with hygienic and healthy issues related to livestock management (C14)” and “Excessive use of antibiotics as well as hormones in livestock (C6)” with p-value of 0.205; and so on.

Tab. 2.6: Correlation-coefficient matrix for the significant-challenges of SCM implementation

Significant-Challenges	C1	C2	C3	C4	C5	C7	C6	C8	C17	C9	C11	C13	C14
C1	--												
C2	0.362*	--											
C3	0.286	0.368	--										
C4	0.128	0.471*	0.268*	--									
C5	0.289*	0.412	0.318*	0.353	--								
C7	0.301	0.240	0.081	0.357*	0.416*	--							
C6	0.186	0.155	0.343*	0.268	0.309*	0.277*	--						
C8	0.144	0.168	0.088	0.125	0.172	0.117	-0.008	--					
C17	0.051	-0.021	0.080	-0.040	-0.022	0.033	0.082	0.372*	--				
C9	-0.014	-0.003	0.117	0.063	-0.003	0.063	0.117	0.315**		--			

Significant-Challenges	C1	C2	C3	C4	C5	C7	C6	C8	C17	C9	C11	C13	C14
C11	0.166	0.091	0.117	-0.026	0.091	0.133	0.108	0.146	0.133	0.255*	--		
C13	0.155	0.268*	0.197**	0.055	0.268*	0.188*	0.091	0.271*	0.188**	0.155	0.378*	--	
C14	0.168	0.056	0.334	0.033	-0.072	-0.017	0.205**	-0.104	-0.022	0.005	0.005	0.088	--

*Correlation was significant at p≤ 0.01 level (2-tailed).

**Correlation was significant at p≤ 0.05 level (2-tailed).

2.3.4 Possible opportunities for organic-farming in Ethiopia and Kenya

In order to identify the possible opportunities for organic-farming in Ethiopia and Kenya, with the opinion of experts and available literatures, a SWOT analysis was done to evaluate the 'strengths, weaknesses, opportunities, and threats' involved in organic-farming (Table 2.7).

The possible opportunities were revealed to be comprising of seven variables, such as "Possibilities of premium-prices to the farmers for certified organic-products; Enhanced soil-fertility through various organic-practices like green-manures, organic-manures, crop-rotations, and use of bio-fertilizers, etc.; Sustainable resources utilization leading in natural-resources conservation for the present as well as future generations; Larger food-security by enhanced production in addition to productivity; Improved global export-market by proper-certification and up-to-date maintenance of quality-parameters of organic-products; Generation of more employment opportunities through the establishment of various production-units of bio-pesticides and bio-fertilizers; and More-opportunities for enhanced social-contacts through project-meetings, and also by providing farmers' training about organic-farming", respectively.

Tab. 2.7: SWOT analysis for organic-farming

Strengths	Weaknesses
Organic-farming helps in achieving sustainable agriculture with regard to environment, health, wealth, and soil	More complex and costlier certification-process for small-scale farmers
The principles of organic-farming align well with the "Gross National Happiness" philosophy	Results in considerable reduction of yields in earlier periods of conversion resulting in economic-losses
Organic-farming finds similarity with conventional farming practices of farmers	Availability of limited technical-expertise to train the farmers about the organic-farming techniques
It avoids use of harmful-chemicals by resulting in safer-environment	Weaker governmental policy-supports for finance related help to farmers
Reduces costs as well as risks of farmers	Time-consuming in complete shifting to organic-

Strengths	**Weaknesses**
Reduces risks of harmful-pesticides' exposures Stronger political in addition to policy supports More-compatible with knowledge in local farming Stronger national-levels organic-programs with increased international supports	farming Lack of awareness about the potential benefits of organic-farming such as soil-health, biodiversity-conservation, pollution-free environment, and so on Inadequate coordination among different agencies for marketing and certification of organic-products
Opportunities	Threats
Possibilities of premium-prices to the farmers for certified organic-products Enhanced soil-fertility through various organic-practices like green-manures, organic-manures, crop-rotations, and use of bio-fertilizers, etc. Sustainable resources utilization leading in natural-resources conservation for the present as well as future generations Larger food-security by enhanced production in addition to productivity Improved global export-market by proper-certification and up-to-date maintenance of quality-parameters of organic-products Generation of more employment opportunities through the establishment of various production-units of bio-pesticides and bio-fertilizers More-opportunities for enhanced social-contacts through project-meetings, and also by providing farmers' training about organic-farming	Decreased trend of organic-sources owing to reducing livestock and forest-areas Lack of confidence on modernization hinders in the adoption of organic-farming Non-affordable cost of certification for small-scale farmers hinders in obtaining certification of organic-products Existence of global-competitiveness for exporting of organic-products There may be newer incidences of pest and diseases to organic-crops, which causes difficulties in managing through organic-practices Resulting in lower-yield levels

2.4 Discussion

With the implementation of a "Participatory Demonstration and Training Extension System (PADETES)" by the government of Ethiopia in 1995 for their agricultural extension-systems, the PADETES has been involved in the improvement of small-scale farmers for effective participation as well as utilisation of useful agriculture-based technologies to enhance the overall farm-productivity, net-incomes, and livelihoods [1]. Further, with the introduction of "Participatory Extension System (PES)" in 2010, which has been a modified version for subsequent success of the PADETES, the farming-communities were able to get the sources of knowledge, information, skills, and technologies [1].

Since 1982, the agricultural extension-systems of Kenya was introduced as well as supported by the World Bank [45]. Over the years, a number of efforts have been made in reforming the extension-systems in Kenya, which help to recognize extension-service delivery as key change-agents for transforming the subsistence agriculture and the farming-communities into modernized and commercial agriculture for effective attainment of food-security, income-improvements, and poverty-reductions to a greater extent [15]. Based on past studies, the country's agricultural extension-service delivery-systems have been characterized by multiple players with each of the providers' of extension-services having own peculiar-challenges [7]. Different major service-providers include public-services providers under the "Ministry of Agriculture", private-services providers under a variety of cash-crop programmes, and different NGOs in addition to farm-inputs supply enterprises. However, very poorer coordination was found among these actors driven by its own motives and interests.

With the use of SWOT analysis for the evaluation of organic-farming in Ethiopia and Kenya, the possible strengths were revealed to be comprising of nine variables, such as "Organic-farming helps in achieving sustainable agriculture with regard to environment, health, wealth, and soil; The principles of organic-farming align well with the "Gross National Happiness" philosophy; Organic-farming finds similarity with conventional farming practices of farmers; It avoids use of harmful-chemicals by resulting in safer-environment; Reduces costs as well as risks of farmers; Reduces risks of harmful-pesticides' exposures; Stronger political in addition to policy supports; More-compatible with knowledge in local farming; and Stronger national-levels organic-programs with increased international supports; respectively.

2.5 Conclusion

Based on the SWOT analysis of the agricultural extension-services in Ethiopia, six strengths were found to be related to the existing extension-services, such as "Providing a comprehensive extension strategy for agricultural activities spelling-out the vision the country through systematic interventions of bottle-necks; Convenient service provision for the farming-communities; Providing a well-structured as well as decentralized extension-system; Providing adequate support to the agricultural vocational-training institutes to produce skilled extension-personnel; Providing a robust workforce of extension-agents; and Providing better access to extension facilities at community-levels"; respectively. Further, six opportunities were found as "The multi-stakeholders innovation platform get benefits of incentives; Establishment of higher potential for "Participatory Extension System (PES)" under the latest extension strategies; Providing adequate platform for the farmers in the development of groups and social-networks; Providing adequate platform for market-oriented extension systems, business-development, entrepreneurship skills, and value-chain developing approaches; Providing adequate platform for all type of agro-processing industries for value-chain addition and with embedded extension-services; and Providing growth of farmers' cooperative-networks and unions for complementary extension-services". Similarly, based on the SWOT analysis of the agricultural extension-services in Kenya, four strengths were found to be related to the existing extension-services, such as: Stronger training of staffs and higher professionalism at all service-levels; Constituted with well-resourced extension staffs; Wider coverage of all covered extension systems; and Revitalisation of the agricultural extension system by the "National Agricultural Livestock targeting Extension Programme (NALEP)". Moreover, five opportunities were found as "Enthusiasm of small-scale farmers for paying for private extension-services; Adoption of "Farmer Field Schools (FFS)" approach for participatory extension-delivery; Advocating of demand-focused extension-services by "National Agricultural Sector Extension Policy"; Higher penetration-level of ICT such as internet, mobile-phones, and computers; and More initiatives by a large number of NGOs to reform in making demand-focused extension system".

However, the associated-challenges with organic-farming in the livestock sectors of both Ethiopia and Kenya were identified and grouped under the three dominant-factors such as "Infrastructure-related, Institutional-related, and Informational-related", respectively. The result of factor-analysis resulted in thirteen significant challenges with factor-loading values of ≥0.5. The challenges representing the infrastructure-related factor included six challenges, such as "Inefficient utilization of decontamination in livestock-sites; Inadequate access to quality and affordable vaccines; Absent of access to safe as well as healthy foods; Bad-quality of old livestock-buildings; Inadequate availability of equipment and facilities; and Lack of veterinary-clinics and timely detection of illness". Further, the challenges representing the institutional-related factor included three challenges, such as "Excessive use of antibiotics as well as hormones in livestock; Delays in compensation-payments by insurances; and Inadequate support for organic-milk and dairy-related production". Similarly, the challenges representing the institutional-related factor included three challenges, such as "Inadequate access to extension-services; Inadequate livestock-related information; Inadequate knowledge and techniques for organic as well as safer productions; and Un-familiarity with hygienic and healthy issues related to livestock management", respectively.

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3 Fuzzy-based framework for sustainable agriculture-based waste-management

Abstract: Agri-based improvements are normally accompanied by considerable dealing with the generated wastes from the unreasonable utilizations of farming-techniques and the ill-treatment of synthetic-substances in cultivation, which largely influence the rural in addition to the global environment. Both the agricultural systems and the associated activities, influence in the generation of unwanted wastes. However, these agriculture-based wastes have found with a number of applications now-a-days, through appropriate waste-management strategies. In this study, the agricultural waste management system was discussed with the help of Fuzzy-EDAS method for the prioritization of the functions associated with agriculture-based waste-management followed by the development of the fuzzy-based model for an effective agri-waste management.

Keywords: Agriculture-based, Waste-management, Sustainability, Worldwide, MCDM, Fuzzy-logic, EDAS, Ranking, Functions

3.0 Introduction

The wastes generated from agriculture typically include the residues from the raw agriculture-based products' processing as well as growth like vegetables, crops, fruits, dairy-products, poultry, and meat, etc. These wastes' composition depends on the system in addition to the activities involved in agriculture, which may be in the form of solids, liquids or slurries. Even though of occurrence of very rare-estimation on agriculture-based wastes, these wastes normally contribute for a significant proportion of the total waste-matters in the world. The management of agriculture-based wastes is becoming a complex-domain, with the interaction of several dimensions that have imposed the decision makers with continuous-challenges for the analysis as well as control of these wastes.

In this context, the application of fuzzy-based approaches has been found to provide more relevant outcomes that have become very significant and helpful supporting tools for effective waste-management in handling a variety of problems associated with several dimensions as well as conflicting-criteria. Moreover, because of the availability of several multi-criteria decision-making (MCDM) approaches, it becomes a harder-task in the selection of the proper MCDM method. Thus, in order to support the decision-makers and researchers, the objective of this study included the assessment of worldwide agricultural management through the use of fuzzy-based approaches in order to provide effective agri-based waste management strategies for more sustainable agriculture.

https://doi.org/10.1515/9783110745368-003

3.1 Literature review

As most of the pesticides after used by the farmers, and most of the packages along with bottles carrying these pesticides are usually thrown into ponds or/and fields, these wastes create un-predictable consequences on environment, like food-poisoning, perilous food-hygiene, and contaminated farm-land on account of their potential durability as well as toxic-chemicals' content. Chemical-contents of 1.8% in the packages have been reported by an estimation of "Plant Protection Department (PPD)" [23]. Impose of serious-damage on environment in addition to population is caused with these materials when instead of elimination; these are left on water-supplies, sewage-systems, collecting as well as storages parts of garbage. Therefore, both transportation as well as elimination of solid-wastes is much more essential after assembling them in proper technical and healthy conditions.

The classification the solid-waste management-system has been made as integrated as well as sustainable solid-waste management-systems [103]. For evaluating the solid-waste disposals' alternatives, Ohman Et al. used "Analytic Hierarchical-Process (AHP)" method in their study [80]. By the use of "Analytic Network-Process (ANP)", the prioritization was done for the urban solid-waste disposals means at the local-municipality in order to select the appropriate one [51]. The result of agriculture-based production expansion has increased the amounts of livestock-wastes, farm crop-residues, and agro-industrial by products. With the continuation in intensifications of farming-systems in developing countries, there is likeliness of significant augmentation of agriculture-based wastes throughout the world. About 998 million-tonnes of agricultural wastes was estimated to be created annually [1]. We are responsible in producing the solid-wastes in our day-to-day activities comprising of materials like bottles, packages, left-over, newspapers, equipment, batteries, dyes, devices, and so forth [25]. An investigation was made for assessing the sustainable urban solid-wastes disposals by focussing on bio-reactors storage-spaces [7]. Disordered storages as well as disposals of solid-wastes may cause in occurrences of several problems, such as quicker spreading of infectious-diseases, soil-contaminations, surface-water pollution, ground-water contaminations, annoying odour-emissions to the environment, pests and insects' difficulties, land-slides, detonations, air pollution, and so on [14]. Accomplishment of higher productivity can be done by utilizing inorganic as well as inexpensive fertilizers, but usually the farmers apply more fertilizers than that of actual crops' requirement [33]. Based on the digestion progressive phases, the percentages of "H_2S, NH_3 and CH_4" fluctuate, and also it depends on food-components, organic-materials, micro-organisms, and animals' health-status, respectively. The generation of greenhouse gases by these un-treated in addition to non-reusable waste-sources usually have negative-effects on soil-fertilities, besides resulting in water-pollutions. For livestock wastes, volume of water ranges in between 75% to 95% of total-volume, containing of organic-matters, inorganic-matters with several micro-organism's species, and parasite-eggs as residue [33].

With the intention of creating energy from wastes, the authors in a study have suggested for the use of thermal-disposal technology [104]. The sustainability-assessment in the growth of solid-wastes management-system was done in "Setúbal-Peninsula region (Portugal)", by Pires Et al. in their study with the use of four main-criteria, fourteen sub-criteria in addition to five-alternatives by ANP based-on "Technique for Order-Preference by Similarity (TOPSIS)" method [89]. Zurbrügg Et al. suggested for an integrated management-program emphasising on economic, environmental, political, social-cultural, and technical components that can lead to a sustainable solid-waste management-system [119]. For the selection of best-place for solid-wastes disposals in context with the economic, environmental as well as social-cultural aspects for "Marvdasht-region in Iran", Eskandari Et al. have used an integrated "multi-criteria decision-making (MCDM)" approach [27]. Likewise, Hanan Et al. have also used "multi-criteria decision-analysis (MCDA)" for the evaluation of waste-papers' management in "Isle (Wight-island in UK)", with seven recycling, revival as well as disposals alternatives in-terms of social and environment-related criteria [34]. A risk-based multi-criteria evaluating approach was used for project-alternatives' in waste-management [49]. Figure 3.1 illustrated the farm vegetable-wastes that were disposed-off without consideration of any precautionary measures.

Fig. 3.1: The disposed-off farm vegetable-wastes

At the present-time, with the rapid boost in population in addition to the changing life-standards of individuals make it difficult in the proper management as well as control of the wastes' composition, quantities and suitable disposals. With regard to the by-products of agriculture-activities, as these are not the primary-products, so usually referred to as "agricultural wastes", which take the form of crop-residues (straws, residual-stalks, roots, shells-etcetera, leaves, and husks), and animal-based wastes or manures. As these agriculture-related wastes are commonly available as well as renewable, so these can be considered as imperative-resources [96]. A greater need of farmers' as well as public awareness has been a prime-requirement for the beneficial utilizations of organic-wastes with their effective management in agriculture, in order to lessen the preconceived-notions, fears of nuisance-problems, environment-degradations in addition to the land-value's decrement [109]. Environmental impacts by the agriculture-based wastes not only depend on their creation quantities, but also on the disposal-techniques. However, the environmental pollution occurs because of inappropriate practices of disposals [97, 105]. The physical-characteristics of agriculture-based wastes as suggested by [64] were illustrated in Table 3.1, which revealed of higher percentage of vegetable-wastes (i.e. 15.6%) by wet-weight followed by banana-wastes (12.5%), sugarcanes-trashes (10.7%), grasses (10.2%), and others.

Tab. 3.1: The physical-characteristics of agriculture-based wastes

Agriculture-based wastes	Percentage by wet-weight
Vegetable-wastes	15.6
Banana-wastes	12.5
Sugarcanes' trashes	10.7
Grasses	10.2
Dry-leaves	9.8
Fruits' wastes	7.2
Weeds	5.9
Coconut-wastes	4.3
Flowers	3.6
Ashes	3
Eucalyptus	2.2
Parthenium	1.1
Others	13.8

Owing to the burning of agricultural wastes as general practices in the underdeveloped countries, the atmospheric-pollutions mainly happen. Ezcurra Et al. revealed of releasing of pollutants owing to the agricultural wastes' burning, which included carbon-monoxides, nitrous-oxides, and nitrogen-dioxides in addition to particles like smoke-carbon, etc. [28]. These pollutants cause formation of ozone as well as nitric-acids [37] resulting in acid-depositions, with serious pretences of ecological and human-health related threats [58]. The pollution that creates odour has been reported in contributing more social-tensions in Kampala of Uganda, among the urban livestock-based farm-workers [50]. Excessive applications of animal-wastes on land as "fertilizers and soil-conditioners" cause surfaces 'runoff and leaching' with contamination of surfaces or ground-waters. Consequently, nitrate-leaching on livestock happen to be one of the major 'nitrogen pollution concern' [66]. The greenhouse gases can be accumulated by "ammonia (NH_3), methane (CH_4) and nitrogen-oxides" formations in manure-decompositions. In ammonia-volatilization, the deposition of acid occurs resulting in precipitation of acids [65]. The contribution in 'Ozone-depletion' is mainly because of emissions of "nitrous-oxides (N_2O)" during the "nitrification de-nitrification cycle" [100].

Larger amounts of organic-matters are contained in the agriculture-based wastes, which can be further utilized to augment the food-security if used as 'bio-fertilizers and soil-amendments', animal-feeds, and for energy productions. In view of this, the waste-treatment technologies play a vital-role in enhancement of soil-fertilities as well as the crop-yields [5, 35]. Although the use of organic-fertilizers plays a crucial part in food-production activities, but smaller availabilities of nutrients have been a serious-constraint in most of the regions in Africa [12]. The compost-process also help to reduce the waste-volumes by solving serious issues related to environment including larger quantity of waste-disposals, killing of pathogens, weeds' germination decrement in agriculture fields, and odour-reductions [44]. Conversion of crop-residues into foods can be obtained through the ruminants that help in reduction of potential-pollutants. On the other hand, the rumens have the 'microbial enzyme-celluloses' as the only enzymes for the digestions of the most-abundant plant products and fibres [16]. Owing to the utilization of nutrients in by-products, the waste-disposals problem usually does not occur with ruminants [81]. Anaerobic-digestions help in the production of digestate-residues that are extensively used in land applications on account of their nutrients' soil-retention improving capabilities [111]. Furthermore, the utilizations of biomasses can be helpful in producing "heat and electricity" through different 'thermo-chemical technologies' like gasification or combustion processes [94]. A varying quantity of residues are formed at different stages in crops' development, such as "seeding, maintenance, harvesting, post-harvesting, and industrial-transformations, etc" that can be utilized as raw-materials for a broader-range of productions [3, 59, 75, 88]. The non-edible agricultural residues like 'rice-husks' are generated during the whole 'grain de-husking period', which was reported to be produced at the rate of 0.23 tonnes of rice-husks from processed rice per-tonne [56, 102]. The absence of 'enzymatic-capability' for digestions cause in some restrictions in feeding-use of the residues for ruminants, besides other-animals [45]. The existence for valorisations of rice-husks occurs in different proposals as "concrete, adsorbents, agglomerates, ceramics, energy and ethanol" [90].

With the application in average-amount of 8 kg/m^2, the 'rice-husk residues' can be used as fertilizing purposes [91]. For large-structures having additional dilute-contents, the naturally occurring organisms convert manure organic-matters into carbon-dioxides and methane, by transforming the organic-nutrients' into mineral forms available to plants [13]. For effluent-irrigation, a careful balancing is required for preventing ponds from the application fields, by maintaining proper-timing in addition to nutrient application-rates. Although, the odours reduction is the consequence of anaerobic-treatment, and the lagoon-effluents' odours are not so intense compared to slurry-manures, but the producers using the lagoon treatment-systems have been reported of suffering problems of odour-emissions as well as neighbour-complaints [62, 77]. Obi Et al. made a discussion regarding the effects of the agriculture-based toxic-wastes on the environment, and suggested for the effective management of these toxic-wastes [79]. In spite of having major opportunity in Indian context for energy generation potential from landfills, by means of thermal-treatment or methane-extraction, there exist obstacles of qualified-engineers' shortages in addition to experienced environment-professionals for the delivery of improved systems in waste-management [55]. By means of solid-state fermentations, the manufacturing of "bio-fuels, antibiotics, enzymes, vitamins, antioxidants, animal-feeds, and other-chemicals" is carried-out by agro-industrial wastes using multiple micro-organisms. It has been stated of developing country like India, to be very prone to higher and adverse environmental-impacts because of the crop-residues' volume with un-sustainable management practices [95]. Based on the review and discussion, Sadh Et al. highlighted about the solid-state fermentation along with their effects on the value-added products' formation [98]. The governments of developing countries can get advantages from the rising nexus thinking concept in order to manage the environmental-resources, which promotes a higher-level of involvement of stake-holders and higher-level integration going beyond the disciplinary-boundaries, and providing a supporting-platform to solve-issues like burning of crop-residues [10]. In order to minimize the nutrient-gap, the recycling of "surplus-crops, horticultural-residues, and animal-excreta" can be a viable-option. However, there occurs a scarcity of cumulative estimated-data on the availability of these. Bhattacharjya Et al. have estimated the recyclable bio-wastes in the states of central in addition to western India for the benefits of policy-makers [9]. With regard to the agriculture-based wastes, through different channels i.e. direct and indirect, these wastes have a toxicity-potential to plants, animals as well as human-beings.

3.1.1 Soft-computing in Agriculture

The use of soft-computing techniques aims at achieving robustness, tractability, and providing lower-cost solutions with tolerances comprising of imprecision, uncertainties, partial-truth, and approximations, which enables soft-computing to be capable of solving problems that have not yet been provided by conventional methods in a complete, cost-effective, and analytical manner. Among the soft-computing techniques, fuzzy-logic appears to be one that has been established initially as fundamental idea of soft-computing [114, 115, 116]. At present, the fuzzy-logic, artificial neural-networks and meta-heuristic approaches are considered as core-techniques of soft-computing. Although the applications of soft-computing techniques were found to be successful different complex environment to solve problems, but still there has been substantial advancements in the methodology in order to provide new approaches for more reliable, efficient and robust solutions.

Fuzzy-logic is a form of logic associated with multi-values and derived from fuzzy set-theory for dealing with approximate interpretation instead of precise. In-contrast to "yes or no" or "0 or 1" binary-logic (crisps), the fuzzy-logic helps in providing a set of membership-values inclusive of "0 and 1" to indicate the truth-degree (fuzzy). The successful application of fuzzy-logic was first reported in 1974, in laboratory scale process-control [67]. Similarly, this logic was applied to process-industry based systems [99], consumer-electronics [11,39], automation in train operations [112], traffic-based systems [38], evaluation of energy efficient motors by the "United-States Environmental Protection-Agency" [19], space docking automation by "National Aeronautics and Space Administration" [83], and in agricultural applications [40, 41, 42, 61], such as for the evaluation of precision-agriculture [4, 24, 43, 47, 63, 72, 84, 106, 110], for studied related to application of chemicals in agriculture [17, 18, 32, 53], for agricultural irrigation calculations [15, 26, 54, 57, 92, 108], and so on.

3.1.2 Multi-Criteria Decision-Making Applications in Agriculture

Day by day the pollutions due to a number of potential-risks associated with wastes are increasing; therefore, the waste-management has gained importance, and becoming more complex in the existing scenario of the world. As a result, it becomes necessary for an integrated system consisting of all-levels of waste-management factors in addition to their relationships [71]. Developments in the decision-support models have been occurred since late 1960s, in the field of waste-management [48]. However, the most widely used decision-support framework includes "life-cycle-assessment (LCA)", "cost-benefit-analysis", and "multi-criteria decision-making (MCDM)" techniques [48, 73, 76, 113]. The environmental-aspects are mainly focused in LCA, whereas the cost-benefit-analysis focuses on maximisation of economic-efficiency. But, MCDM techniques allow the consideration of social, economic along with environmental criteria as the three-pillars of sustainability. Moreover, the MCDM techniques have been considered to be most-effective decision-support framework for decision-making in solid-wastes-management [20, 21, 52, 101]. Further, based on the significant areas under consideration as energy, environment and sustainability, Mardani Et al. have revealed of the first application of MCDM techniques in these areas [69]. Bekar Et al. have used the "COmplex PRoportional ASsessment (COPRAS) of alternatives with Grey-relations (COPRAS-G) in addition to Fuzzy-COPRAS method" for evaluating the performance measures in "total productive-maintenance (TPM)" strategy [8]. Similarly, the Fuzzy-COPRAS approach has been demonstrated by Parezanović Et al., for formulating decisions on mobility-measures through the evaluation of twenty-six measures [85]. Based on the proposed MCDM methods by Alkaradaghi Et al., the decision regarding landfill-site selection in the north of Iraq assumed two-input groups of factors for the optimal-weight coefficient's value-satisfaction. These constant-groups were 'natural and artificial factors' including 13 selected-criterion [2].

The appropriateness of MCDM methods lie in obtaining of best possible-solution from a set of available-alternatives with regard to a set of evaluating criteria, and these methods have been successfully used for a wide-range of other diverse areas. For instance, in management-related applications [60, 68]; for selection of third-party reverse-logistics providers [117]; for areas related to productions [86, 93]; for sustainable-developments [82]; in construction-divisions [118]; and flood-controls [74]. However, the "Evaluation based-on Distance from Average-Solution (EDAS)" has been proposed as an efficient MCDM method [30, 31].

3.2 Methodology of Research

In this study the sustainability of agricultural sectors through proper agriculture-based wastes' management was focussed. The sustainability-parameters considered were constituted of three criteria that needed to be minimized, such as "social, economic and environmental impacts" of the agriculture-based wastes, and was based on the opinions of eight-experts with a thorough analysis of existing literature. Moreover, as distinguished by USDA [107], there existed six basic-functions in the agriculture-based waste-management (Figure 3.2), including "production, collection, transport, storage, treatment, and utilization", respectively. Where, the nature in addition to the quantities of agriculture-based wastes' generation denotes the production. For abundant quantities of produced wastes, proper management becomes highly essential in order to turn these wastes into a resource-concern. The complete production-analysis includes the "types or varieties, consistency, amounts, locations, and waste-production timings. Collection comprised of wastes' gathering from the origin-point or deposition to collecting-points. Transfer comprised of wastes' movement all over the systems. While, the temporary-containment of the wastes referred as storage. In order to facilitate more effective as well as efficient handling of wastes, the treatment of the wastes denoted the design to reduce the pollution-potentials and/or modifying the physical-characteristics. Whereas, utilization mainly referred to the reuse or recycling of wastes, such that these can be used as source of energy, organic-matters, or nutrients' to plants.

For subsequent analysis as evaluated by the experts, the worldwide common functions associated with the management of agriculture-based wastes were considered as six-alternatives, such as Production (WMA_1), Collection (WMA_2), Transfer (WMA_3), Storage (WMA_4), Treatment (WMA_5), and Utilization (WMA_6), respectively (Table 3.2).

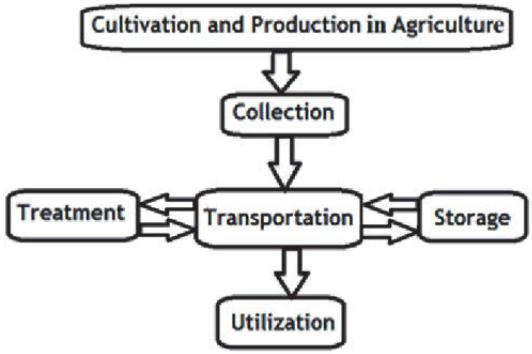

Fig. 3.2: Functions associated with the management of agriculture-based wastes

Tab. 3.2: Selection of waste-management alternatives (WMA) in agriculture

Waste-management alternatives (WMA)	**Description of activities**
Production (WMA_1)	The un-necessary wastes' production need to be minimized.
Collection (WMA_2)	The agriculture-based waste-management plan need to accompany with the collection-methods, collection-points' locations, collection-scheduling, labour-requirements, essential structural-facilities or equipment, installation as well as management costs associated with components, and impact of collections on wastes' consistency.
Transfer (WMA_3)	For effective transportations of wastes, it needs to be transferred in solids, liquids or slurry form. The agriculture-based waste-management plan need to accompany with the consistency-analysis of movable wastes, transportation-methods, the distances among transfer-points, equipment-requirements, and installation as well as management costs associated with costs of transfer-systems.
Storage (WMA_4)	The agriculture-based waste-management plan need to accompany with proper identification of the wastes' storage-

Waste-management alternatives (WMA)	Description of activities
	period, storage type and volume, locations, storage-facility installation-costs, management-cost of storage-processes, and the storage-impacts on wastes' consistency.
Treatment (WMA_5)	Waste-management should be followed up with the analysis of wastes' characteristics before treatment, which need to include the selection of type, sizes, locations, installation-cost of the treatment-facilities, and management-cost in the treatment-processes.
Utilization (WMA_6)	Recycling of the nutrients in the wastes need to be followed up with proper land application.

3.2.1 Selection of suitable MCDM technique for ranking of agriculture-based waste-management alternatives

Based on the suitability for the present-analysis, the "Evaluation based-on Distance from Average-Solution (EDAS)" method was chosen [31]. In this study, the EDAS method was used to rank the agriculture-based waste-management alternatives on the basis of sustainability parameters. The preferences of alternatives were made with regard to three significant-criteria, such as social-impacts (SI_1), economical-impacts (ECI_2), and environmental-impacts ($ENVI_3$), respectively. In the EDAS method, the alternatives' desirability was derived from the distances from an 'average-solution (AV)' that included the 'positive-distance from average (PDA)' and the 'negative-distance from average (NDA), respectively.

The measurement of PDA and NDA represented the difference between each-solution (alternative) in addition to the average-solution. The alternatives' evaluation was made on the basis of higher-PDA values as well as lower-NDA values. The solution i.e. alternative was found to be better than average-solution based on the higher-PDA values as well as lower-NDA values.

The EDAS method comprised of the following steps [30]:

Step-A: Selection of the available-alternatives and the significant criteria describing the alternatives for the construction of a decision-making matrix (DMM) as:

$$\begin{array}{cc} & \begin{array}{cccc} X_1 & X_2 & \dots & X_n \end{array} \\ DMM = \begin{array}{c} A_1 \\ A_2 \\ \vdots \\ A_m \end{array} & \begin{bmatrix} C_{11} & C_{12} & \cdots & C_{1n} \\ C_{21} & C_{22} & \vdots & C_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ C_{m1} & C_{m2} & \vdots & C_{mn} \end{bmatrix} \end{array}$$

Where, (A_1, A_2, A_3,...., A_m) represented the possible-alternatives among criteria of (X_1, X_2, X_3,...., X_n) with corresponding assigned weights as (W_1, W_2, W_3,..., Wn)

Step-B: Determination of the “average-solution (AV_j)” on the basis of all concerned criteria as:

$$AV_j = \frac{\sum_{i=1}^{n} x_{ij}}{n} \quad \text{(i)}$$

Step-C: Calculation of the “Positive-Distance from Average (PDA)” on the basis of beneficial in addition to non-beneficial criteria:

For j[th] beneficial criteria, $PDA_{ij} = AV_j \frac{max\left(0,(x_{ij}-AV_{ij})\right)}{AV_j}$ (ii)

For j[th] non-beneficial criteria, $PDA_{ij} = \frac{max\left(0,(AV_j-x_{ij})\right)}{AV_j}$ (iii)

Step-D: Calculation of the “Negative-Distance from Average (NDA)” on the basis of beneficial in addition to non-beneficial criteria:

For j[th] beneficial criteria, $NDA_{ij} = \frac{max\left(0,(AV_j-x_{ij})\right)}{AV_j}$ (iv)

For j[th] non-beneficial criteria, $NDA_{ij} = max\left(0,\left(x_{ij} - AV_{ij}\right)\right)\frac{1}{AV_j}$ (v)

Step-E: Calculation of the “weighted-sum of PDA (SP_i)” from the average-matrix as:

$$SP_i = \sum_{j=1}^{m} w_j PDA_{ij} \quad \text{(vi)}$$

Where, w_j denoted the weight of j[th] criteria

Step-F: Calculation of the “weighted-sum of NDA (SN_i)” from the average-matrix as:

$$SN_i = \sum_{j=1}^{m} w_j NDA_{ij} \quad \text{(vii)}$$

Step-G: Calculation of the “normalized-values of SP_i and SN_i” for all alternatives as:

Normalized weighted-sum of PDA, $NSP_i = \frac{SP_i}{max_i(SP_i)}$ (viii)

Normalized weighted-sum of NDA, $NSN_i = 1 - \frac{SN_i}{max_i(SN_i)}$ (ix)

Step-H: Calculation of the “appraisal-scores (AS_i)” for all alternatives as:

$$AS_i = \frac{1}{2}(NSP_i+NSN_i) \quad (x)$$

Where, $0 \leq AS_i \leq 1$

Step-I: Ranking of alternatives based on the decreasing values of appraisal-scores (AS_i), where the alternative having ‘higher-value of AS_i’ was chosen as the best-choice among all alternatives.

3.2.2 Use of fuzzy-logic

Further, the fuzzy-logic was used by the use of “MATLAB-2013 version software” in the simulink to develop the fuzzy-based model for the functions associated with the management of agriculture-based wastes. The inputs for the fuzzy-control were taken as the six-common functions associated with the management of agriculture-based wastes, such as “Production, Collection, Transfer, Storage, Treatment, and Utilization”, respectively. However, an agriculture-based waste was considered as output with the consideration for respective membership-functions and rules’ formation [22, 36].

3.3 Results and Discussion

Majority of generated crop-residues find their useful applications as fodders and fuel for other industrial or engineering as well as domestic purposes, still from surplus crop-residues of 140 MT, about 92 MT has been reported to be burnt annually [78]. Based on the reports by NPMCR [78] and Jeff Et al. [46] as shown in Table 3.3, it can be seen of the corresponding generated agriculture-based wastes in Bangladesh to be 72 MT/Year; while in India, it was accounted for 500 MT/Year, in Indonesia as 55 MT/Year, and in Myanmar as 19 MT/Year.

Tab. 3.3: Generated agriculture-based wastes in selected nations

Country-name	Generated agriculture-based wastes (Million-tonnes/Year)
Bangladesh	72
India	500
Indonesia	55
Myanmar	19

The generation of crop-residues by foremost crops (Table 3.4) can be suitably utilized as field-residues to act as a natural-resource contributing in soil-fertility improvements through composting, or through direct-ploughing into the soil. Achievement of irrigation-efficiency in addition to erosion-control can be made through good field-residues' management. It has been mentioned of a common-practice in most of the developing Asian countries to burn the surplus crop-residues [29, 70]. If the field-residues can be ploughed into huge-grounds of millions of hectares in shorter duration of time, then adequate waste-management may take place, in spite of the environmental-issues created by burning of residues. Suitable utilization of the generated wastes from the agri-based industry can be made through a variety of industrial-processing in addition to agro-based applications. In-contrast, gathering, processing in addition to transporting costs can be much more than the revenues, if such wastes can be used advantageously. Owing to the organic-composition of agriculture-based wastes, the societal-benefits can be obtained through these crop-residues.

Tab. 3.4: Crop-residues by foremost crops [6,87]

Crop-sources	Composition
Maize	Stover, Skins, and Husks
Millet	Stover
Rice	Husks and Bran
Sugarcane	Sugarcane tops, Bagasse, and Molasses
Wheat	Bran and Straws

3.3.1 Ranking by EDAS method

The preferences of the agriculture-based waste-management alternatives (WMA) were made with regard to three significant-criteria, such as social-impacts (SI_1), economical-impacts (ECI_2), and environmental-impacts ($ENVI_3$), and then, through the experts' opinion, the criteria-weights were assigned accordingly (Table 3.5).

Tab. 3.5: Criteria with assigned weight-values with respect to the alternatives

Criteria	Criteria-type	Assigned weight-values	
Social-impacts (SI_1)	Minimization	W_{SI1}	0.96
			0.86

Criteria	Criteria-type	Assigned weight-values	
			0.92
			0.77
Economical-impacts (ECI_2)	Minimization	W_{ECI2}	0.20
			0.60
			0.34
			0.44
Environmental-impacts ($ENVI_3$)	Minimization	W_{ENVI3}	0.48
			0.58
			0.56
			0.70

The linguistic-terms with corresponding "Trapezoidal Fuzzy-Numbers (TFNs)" used for the EDAS method was as shown in Table 3.6.

Tab. 3.6: Linguistic-terms with corresponding TFNs

Linguistic-terms	TFNs for the alternatives' rating
Very-less [VL]	{0, 0, 1, 2}
Less [L]	{1, 2, 2, 3}
Medium-less [ML]	{2, 3, 4, 5}
Medium [M]	{4, 5, 5, 6}
Medium-high [MH]	{5, 6, 7, 8}
High [H]	{7, 8, 8, 9}
Very-high [VH]	{8, 9, 10, 10}

The evaluation of alternatives with respect to criteria by experts was illustrated in Table 3.7.

Tab. 3.7: Experts' evaluation of alternatives with respect to criteria

WMA	SI_1						
	VL	L	ML	M	MH	H	VH
WMA_1	0	4	2	2	4	4	2
WMA_2	2	4	5	3	1	0	0
WMA_3	0	5	2	2	1	2	3

WMA	SI_1						
	VL	L	ML	M	MH	H	VH
WMA_4	4	5	4	2	1	0	0
WMA_5	0	0	4	1	4	6	0
WMA_6	3	6	4	2	0	0	4
ECI_2							
WMA_1	3	4	6	2	0	0	0
WMA_2	0	1	3	4	5	2	0
WMA_3	0	1	6	4	4	4	0
WMA_4	0	0	0	2	4	6	3
WMA_5	0	3	4	5	3	0	0
WMA_6	4	5	3	3	0	4	0
$ENVI_3$							
WMA_1	4	6	3	2	1	0	0
WMA_2	0	0	4	2	4	5	2
WMA_3	0	2	5	4	3	1	0
WMA_4	0	4	1	2	5	5	2
WMA_5	3	6	4	3	1	0	0
WMA_6	0	0	2	5	5	3	0

The average decision-matrix showing "average-solutions with respect to each criterion (AV)" was obtained as shown in Table 3.8.

Tab. 3.8: Average decision-matrix

WMA	W_{SI1}				W_{ECI2}				W_{ENVI3}			
	0.96	0.86	0.92	0.77	0.20	0.60	0.34	0.44	0.48	0.58	0.56	0.70
	SI_1				ECI_2				$ENVI_3$			
WMA_1	16.0	19.6	21.2	24.4	4.80	7.20	9.00	12.0	5.00	7.40	9.00	12.2
WMA_2	6.20	8.80	10.4	13.4	12.4	15.4	17.0	20.0	17.4	20.8	22.8	25.8
WMA_3	12.0	15.0	16.2	18.6	15.4	19.2	21.2	25.0	10.0	13.0	14.6	17.6
WMA_4	5.20	7.60	9.40	12.6	18.8	21.8	23.2	25.6	18.0	21.8	23.4	26.8
WMA_5	14.8	17.8	19.4	22.4	9.20	12.2	13.6	16.6	6.20	9.00	10.6	14.0
WMA_6	10.8	14.0	16.2	19.2	10.2	13.2	14.6	18.4	14.0	17.0	18.4	21.4
AV	10.8	13.8	15.4	18.4	11.8	14.8	16.4	19.6	11.7	14.8	16.4	19.6

The PDA-matrix along with the "SP_i and NSP_i values" for all alternatives was summarized in Table 3.9 and Table 3.10. Similarly, the NDA-matrix along with the "SN_i and NSN_i values" for all alternatives was summarized in Table 3.11 and Table 3.12, respectively.

Tab. 3.9: The PDA-matrix

WMA	Criteria											
	SI_1				ECI_2				$ENVI_3$			
WMA_1	-0.16	0.28	0.50	0.92	0	0	0	0	0	0	0	0
WMA_2	0	0	0	0	-0.45	-0.06	0.13	0.52	-0.14	0.27	0.50	0.89
WMA_3	-0.43	-0.03	0.16	0.53	-0.26	0.17	0.40	0.84	0	0	0	0
WMA_4	0	0	0	0	-0.05	0.34	0.53	0.88	-0.10	0.34	0.54	0.95
WMA_5	-0.24	0.15	0.38	0.79	0	0	0	0	0	0	0	0
WMA_6	-0.52	-0.10	0.16	0.57	0	0	0	0	-0.35	0.03	0.22	0.61

Tab. 3.10: The SP_i and NSP_i values of all WMA

WMA	SP_i				Average SP_i	Max. Average SP_i	NSP_i			
WMA_1	-0.15	0.24	0.46	0.71	0.30	0.47	-0.33	0.50	0.96	1.48
WMA_2	-0.16	0.12	0.33	0.85	0.30		-0.33	0.25	0.69	1.78
WMA_3	-0.47	0.07	0.28	0.77	0.16		-0.99	0.16	0.60	1.62
WMA_4	-0.06	0.40	0.48	1.05	0.47		-0.12	0.83	1.01	2.20
WMA_5	-0.23	0.13	0.35	0.60	0.20		-0.49	0.28	0.73	1.26
WMA_6	-0.67	-0.06	0.27	0.87	0.10		-1.40	-0.13	0.57	1.81

Tab. 3.11: The NDA-matrix

WMA	Criteria											
	SI_1				ECI_2				$ENVI_3$			
WMA_1	0	0	0	0	-0.01	0.37	0.58	0.94	-0.02	0.37	0.57	0.93
WMA_2	-0.17	0.23	0.45	0.83	0	0	0	0	0	0	0	0
WMA_3	0	0	0	0	0	0	0	0	-0.37	0.01	0.22	0.61

WMA	Criteria											
	SI_1				ECI_2				$ENVI_3$			
WMA_4	-0.12	0.30	0.53	0.90	0	0	0	0	0	0	0	0
WMA_5	0	0	0	0	-0.30	0.07	0.27	0.66	-0.14	0.27	0.47	0.85
WMA_6	0	0	0	0	-0.42	0.01	0.20	0.59	0	0	0	0

Tab. 3.12: The SN_i and NSN_i values all WMA

WMA	SN_i				Average SN_i	Max. Average SN_i	NSN_i			
WMA_1	-0.01	0.43	0.52	1.06	0.51	0.51	-1.09	-0.02	0.13	1.03
WMA_2	-0.16	0.19	0.41	0.64	0.26		-0.26	0.17	0.60	1.32
WMA_3	-0.17	0.01	0.12	0.43	0.10		0.15	0.75	0.98	1.34
WMA_4	-0.11	0.25	0.49	0.69	0.32		-0.36	0.03	0.49	1.22
WMA_5	-0.12	0.20	0.35	0.89	0.34		-0.74	0.29	0.60	1.25
WMA_6	-0.08	0.01	0.07	0.26	0.07		0.48	0.86	0.98	1.16

The final-ranking of all the alternatives based on the values of appraisal-score (AS_i) was illustrated in Table 3.13, which indicated the alternative such as: Storage (WMA_4) to be ranked at first-level, which was followed by the descending ranking of activities concerned with "Transfer (WMA_3); Collection (WMA_2); Utilization (WMA_6); Treatment (WMA_5); and Production (WMA_1)" of agriculture-based wastes; respectively (Figure 3.3).

Tab. 3.13: Final-ranking of all WMA

WMA	AS_i				Average AS_i	Ranking
WMA_1	-0.71	0.24	0.55	1.25	0.32	6
WMA_2	-0.29	0.21	0.65	1.55	0.55	3
WMA_3	-0.41	0.46	0.79	1.48	0.57	2
WMA_4	-0.24	0.43	0.75	1.71	0.68	1
WMA_5	-0.62	0.29	0.66	1.26	0.38	5
WMA_6	-0.46	0.36	0.78	1.48	0.53	4

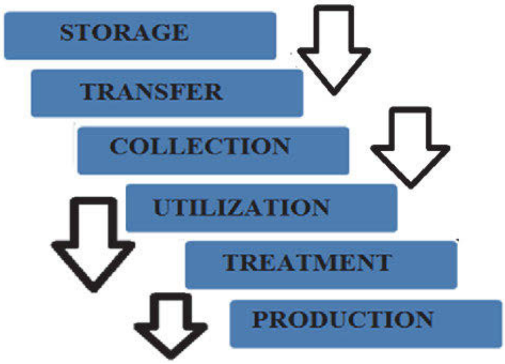

Fig. 3.3: Prioritized functions associated with agriculture-based waste-management

3.3.2 Fuzzy-logic modelling for the associated functions with agriculture-based waste-management

The obtained “multi input and output (MIMO)” mamdani-type fuzzy models as shown in Figure 3.4 consisted of six-inputs and a single-output for the wastes management strategies in the worldwide agriculture. The inputs related to the functions associated with agriculture-based waste-management with their ranges included: Cultivation and production (0-3) representing “Nil, Low, Medium, High”; Collection (0-3) representing “Nil, Low, Medium, High”; Treatment (0-3) representing “Nil, Low, Medium, High”; Transportation (0-3) representing “Nil, Low, Medium, High”; Storage (0-3) representing “Nil, Low, Medium, High”; Utilization (0-3) representing “Nil, Low, Medium, High”; respectively. Similarly, the output included “Agriculture-based wastes (0-3) representing “Nil, Low, Medium, High”.

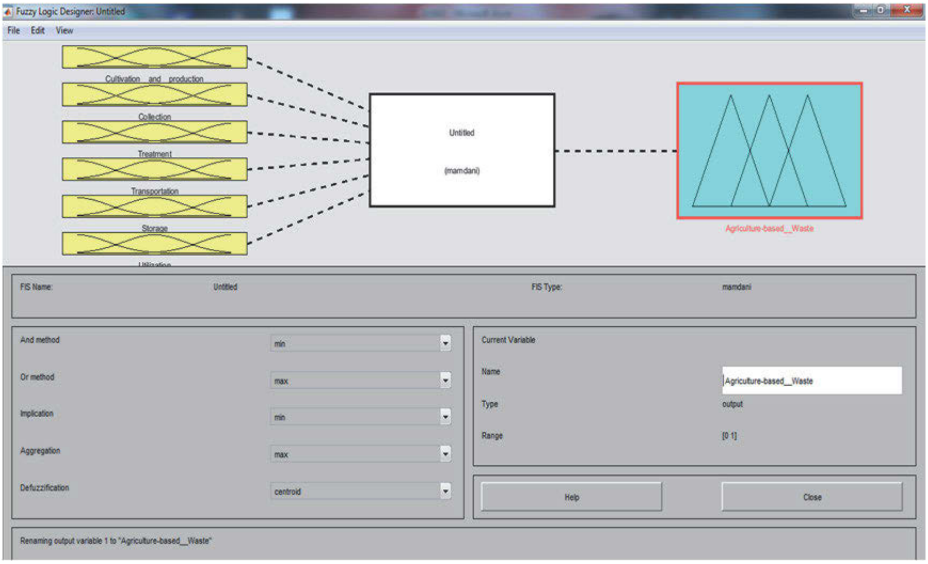

Fig. 3.4: Fuzzy-model with six-inputs and single-output

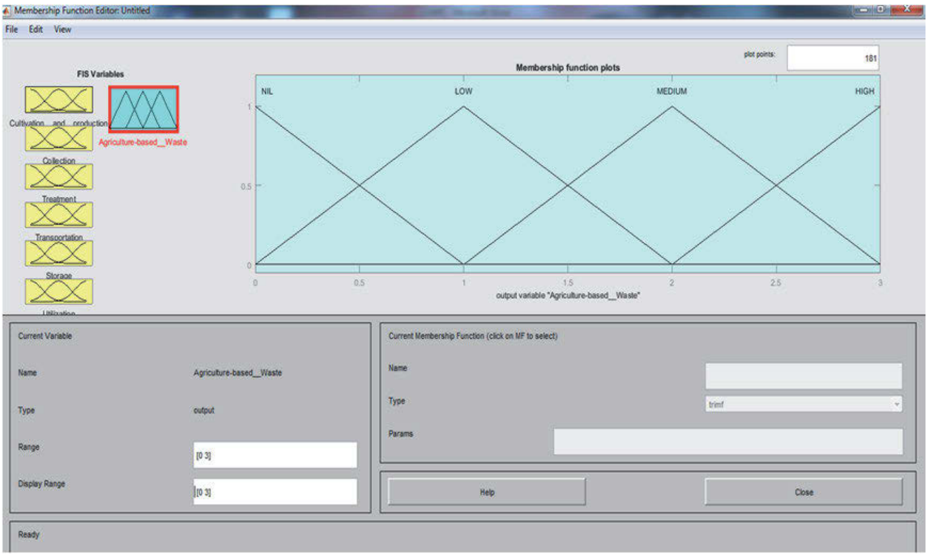

Fig. 3.5: Membership-functions for the fuzzy-model with six-inputs and single-output

The input-data's fuzzification was accomplished with the assignment of linguistic-variables and each of the membership function's range-values for all the six-inputs constituting of the functions associated with agriculture-based waste-management and the output as agriculture-based wastes were assigned accordingly (Figure 3.5). Based on the content in literature and suggestion of experts, triangular-type membership-functions ranging between “nil, low, medium and high” were chosen for optimal-performance for all the six-inputs and the single-output, respectively. Further, the rule-bases of the model were developed (Figure 3.6), and the rule-viewer was obtained as well as checked for any inconsistencies (Figure 3.7). The MATLAB-based final generated surface of the model constituting the functions associated with agriculture-based waste-management was shown in Figure 3.8.

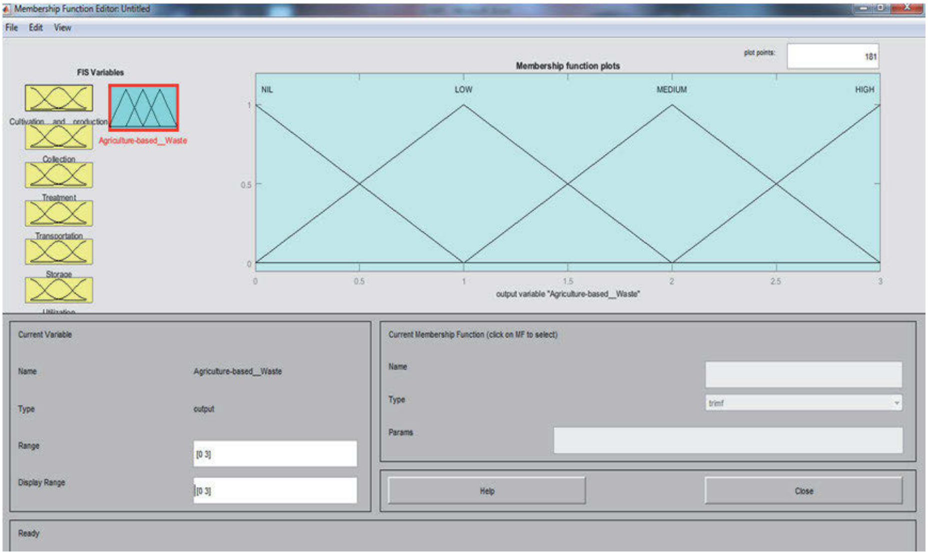

Fig. 3.6: Membership-functions for the fuzzy-model with six-inputs and single-output

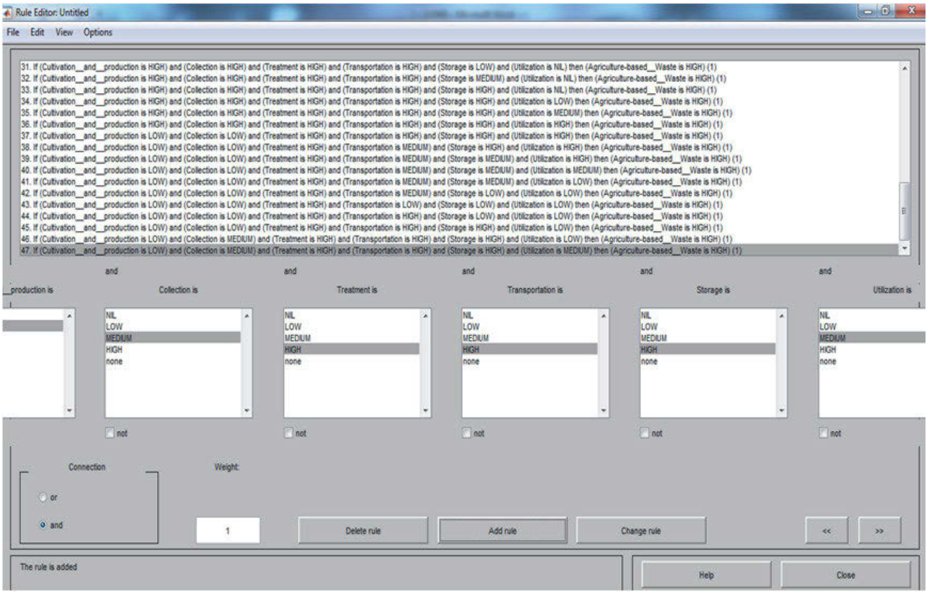

Fig. 3.7: Developed rules for the fuzzy-model

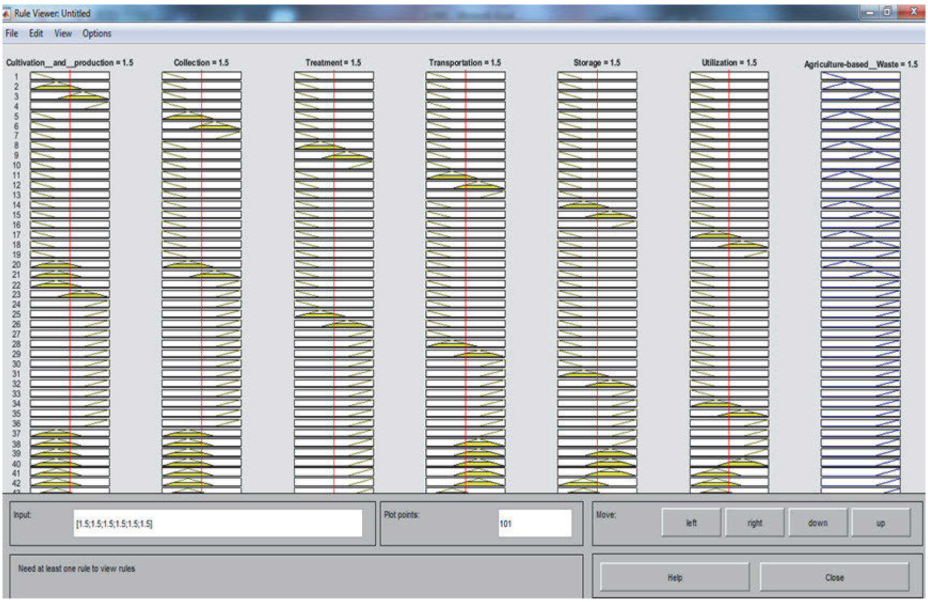

Fig. 3.8: Rule-viewer for the developed rules

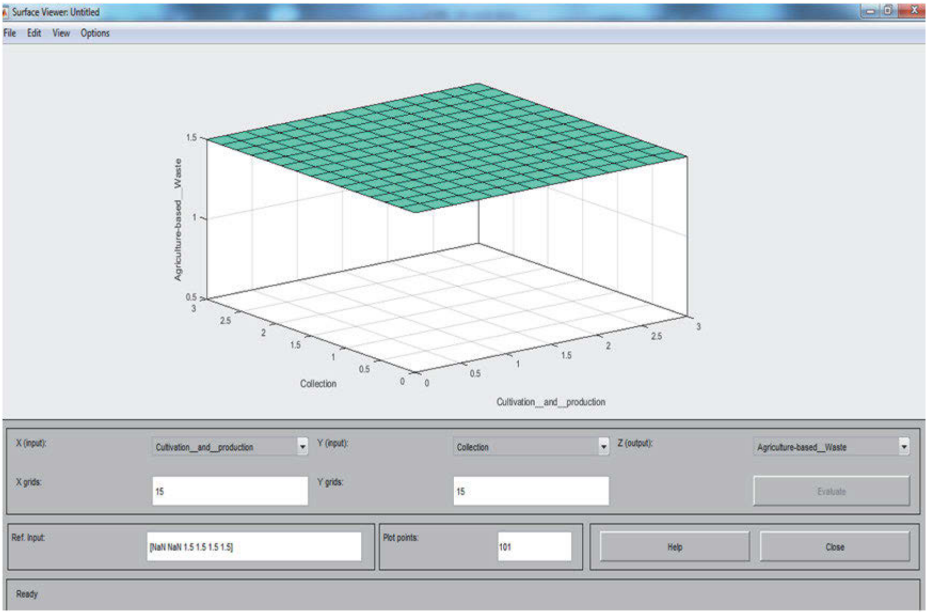

Fig. 3.9: Final generated surface of the fuzzy-model of agriculture-based wastes' management

3.4 Conclusion

Although the farming divisions have major contributions around the world, but due to the under-development of the food-sectors, the potential has not been tapped in these emerging sectors. The agri-business industries throughout the world need to be managed in different agri-related issues with the available opportunities, for their well-establishments. The agriculture-based products have been confronting with extreme challenges in the universal-market with regards to quality, pesticide-deposit, assortments with more timeframe of realistic-usability, packaging and many more, which in-turn infer these products to be progressively focused on confronting the global-challenges with the request to upkeep the value-benchmarks all through the value-chain including great rural-practices.

However, it has been discovered that, major amount of "fruits, vegetables and crops" are being wasted owing to the un-awareness as well as ineffective agriculture-based waste-management plans. Thus, the findings of this study will enable the decision-makers in taking appropriate-steps in this regard for more and further developments in the strategies of agriculture-based waste-management in order to accomplish a sustainable agriculture throughout the world.

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4 An adaptive neural-fuzzy inference system for effective crop management

Abstract: The adaptive neural-fuzzy inference system (ANFIS) is a multi-layer feed-forward network using neural-network learning-algorithms in addition to fuzzy-reasoning for mapping the inputs into output. Moreover, advancement in soft-computing techniques has provided new opportunities to researchers to explore their applications consisting of several intelligent computing-paradigms, and among the different soft-computing techniques, ANFIS has been an effective-system with efficient-combination of artificial neural-network (ANN) and fuzzy-logic for modeling of highly complex, non-linear, and dynamic-systems. Thus, the present study utilized the ANFIS method for the prediction of productions of both "apple and dry-onions" in the province of Algeria based on the "Food and Agriculture Organization (FAO)" data by considering their harvested areas, yields, and production from the period of 1961 to the period 2019.

Keywords: Adaptive neural-fuzzy inference system, ANFIS, Apple, Dry-onions, Production, Algeria

4.0 Introduction

In-fact, adaptive neural-fuzzy inference system (ANFIS) is a "fuzzy-inference system (FIS)" employed in the adaptive neural-networks framework [29, 42, 46]. For-simplicity, a typical ANFIS-architecture was expressed with only two-inputs that leaded to four-rules with single-output for the first-order "Sugeno fuzzy-model" [63,69]. Abyaneh Et al. made an attempt for the determination of water-requirement, single and dual crop-coefficient of garlic by the use of a drainage-lysimeter, and with the simulation of reference 'evapotranspiration' by artificial neural-network (ANN) method during the 'garlic-growth season' [2]. In order to emulate the biological-neurons to solve complex-problems, the "Artificial neural-networks (ANNs)" has been an effective way in providing similar interpretations as that of human-brain. In view of the different soft-computing techniques, ANFIS has been an effective-system with efficient-combination of artificial neural-network (ANN) and fuzzy-logic for modeling of highly complex, non-linear, and dynamic-systems. Thus, the present study aimed at utilizing the ANFIS method for the prediction of productions of both "apple and dry-onions" in the province of Algeria based on the "Food and Agriculture Organization (FAO)" data by considering their harvested areas, yields, and production from the period of 1961 to the period 2019.

Moreover, through effective use of organic-farming, the soil-fertility can be considerably enhanced by making the soils capable of supplying all the essential-

https://doi.org/10.1515/9783110745368-004

nutrients to crops for proper-growth and development. In order to explore the present scenario in the agri-sectors and to identify the possible opportunities for an effective farming culture through organic-farming, the present study was focussed on the agri-sectors of Ethiopia and Kenya, respectively.

4.1 Related Literature

Pydipati Et al. utilized the "colour co-occurrence method" for textural-analysis to determine the possibilities of 'classification-algorithms' for the identification of normal in addition to diseased citrus-leaves for crop pest-management [53]. Yang Et al. have reported of developing an image-capture as well as processing-system for the detection of weeds, followed by a fuzzy-logic based decision-making system for determining the herbicide requirements in agriculture [71,73]. Meyer Et al. used a digital-camera in a crop field-study in order to classify uniform-images of grasses, bare-soils, corn-stalks residues, and wheat-straw residues by the use of a "barium-sulphate reference panel" based on colour [45]. With the aim of developing a multi-spectral optical-system for crops' nitrogen-content remote sensing, Chen Et al. found significant-wavelengths in image-data for the estimation of cabbage seedling-leaves' nitrogen-content by step-wise multi-linear regression-analysis, which was further followed with the development of a feed-forward ANN-model with cross learning scheme to enhance the prediction-accuracy [14]. Al-Faraj Et al. proposed fuzzy-logic for developing a rule-based "fuzzy-logic crop-water stress-index" by the use of growth-chamber data, and then tested this method on tall-fescue canopies-grown in a greenhouse [6].

In order to overcome the difficulties of image-interpretation in a quick and effective manner, Yang Et al. have developed ANNs for distinguishing younger corn-plants from weeds [72]. Koller and Upadhyaya have developed an ANN-model by utilizing the leaf-area index values that were derived from aerial-images, and for the prediction of changes in leaf-area index on a daily-basis [37]. Further, the prediction was made on ANN-model for the processing tomato-yield based-on soils, crops, and environmental-parameters [38]. In view of precision-agriculture decision-support system, Van Alphen and Stoorvogel have developed a functional-approach for the characterization of soils involved in water-stress, nitrate-leaching, nitrate-stress, and content of residual-nitrogen, with the use of "fuzzy c-means classifier" for grouping of soil-profiles into functional-classes [67]. Elgaali Et al. have developed a "single-hidden-layer feed-forward ANN-model" for investigating the possible-effects of climatic-changes at regional levels on irrigation-water supply as well as demand in the region of "Colorado's Arkansas-River basin" [17]. With the use of ANNs, Anagu Et al. developed sorption-models with regard to basic soil-properties for estimating heavy-metal sorption in German-soils, and found the ANN-models to perform better-than on multiple linear-regressions [8]. The determination of "crop-coefficients (species-factor) and evapotranspiration" was considered to be important in order to estimate the irrigation-water requirements for better irrigation-scheduling as well as water-management [49]. Srinivasan and Malliga have proposed ANFIS approach for efficient prediction of crop-yield in the supply-chain of Jatropa [61]. Qaddom and Hines used adaptive neuro-fuzzy modeling for predicting tomato-yield by considering different environment-related variables [54]. Buono and Mushthofa have implemented fuzzy-inference system with regard to resilience of rice-yield, and also observed a correlation-value of 0.68 between the beginning rainy-season and its predicted-value [11]. Soto and Melin analyzed of the optimization of "Type-1 and Type-2 fuzzy-integrators" by using Genetic-Algorithms, with the aim of developing an integrated-approach for ANFIS-models to make minimal prediction-errors [60]. Chaudhari and Khot have proposed ANFIS-based model to maximize the profits associated with rice, by the use of "multi-objective linear-programming problem" by optimization-method. In their study, the input-variables included labour-wages, machinery-costs, fertilizer manure-costs and seed-costs; while the output was the associated profits through yields [13].

Thakare and Baradkar proposed a fuzzy-system by considering 22 crops and 15 soil-parameters for predicting maximum crop-yields, along with the crop-name and the suitable type of soil as well as climatic-condition [65]. Joshi Et al. have proposed a decision-support system for the prediction of crop-suitability, by summarizing of fuzzy-aspects for easier incorporation in an online-assisting of farmers [30]. Fuzzy-inference systems (FIS), ANNs, and ANFIS have been most popularity used alternate statistical-tools in the modeling of various environment-related problems involving complexities [41,74]. Several researchers have been trying in the management of modeling a variety of soil-parameters through different AI techniques [9]; in predicting saturated hydraulic-conductivity in soil and soil water-retention [44]; in estimating soil-erosions as well as nutrient-concentrations in runoffs [35]; in determining clay-dispersibilities [76]; in predicting clay-based soils' swell-potential [74]; in predicting 'cation-exchange' capacities in soils [64]; and in predicting soil-fractions with clay, sand, and silt in surface-layers [7]. A stable agriculture-system has been revealed as a mean to achieve correct irrigation-management, necessary moisture-contents of the soils in dry-areas, and satisfactory crop-yields in addition to soil-conservation [24,34,50]. Through effective energy-consumption in agriculture, sustainable agricultural-production can be accomplished owing to the reduction in associated costs, conservation of natural-resources, and reduction in the amount of air-pollution as well as green-house gases' emission [66]. The soils with appropriate and adequate 'crop-residues' or 'bio-diesel co-product' were found to augment the soil-based carbon and nitrogen contents, with considerable reductions in nitrogen-loss from soils, preventing nitrate-pollution of ground-water, and in enhancing the microbial-biomass in soils [57]. An enhanced production in agricultural sectors depends on effective farm-management and efficient use of energy [25]. With the use of intelligent neural-network, fuzzy-inference systems, and ANFIS, Nurani Et al.

have made an attempt in predicting ‘daily as well as monthly’ runoff in “the catchment-area of Lighvanchai (East-Azerbaijan province)”, and found the fuzzy-modeling to be more-accurate than other models with lowest-errors [52]. Vizhakat has used expert fuzzy-model for the prediction of avalanche, by developing better as well as simpler technique with the use of fuzzy-logic based algorithm [68].

Moreover, Mohaddes and Fahimifard have compared both ANFIS and ‘auto-regressive integrated moving-average (ARIMA)’ in forecasting three-perspectives (for 1, 2 and 4 years) ahead of the agriculture-based products’ export in Iran and found the non-linear ANFIS model to be better than the linear ARIMA model for all three-perspectives [47]. However, the ARIMA-model has been widely and successfully applied not only in forecasting of economic time-series, but also for modeling the empirical-dependencies between successive-times and successive-failures [27]. But, the ARIMA-model has been found to be un-capable in capturing non-linear patterns as well as approximation of linear-models to the emerging complexities involved in real-world problems. Whereas, the non-parametric as well as non-linear models that have been estimated by different methods, such as “Artificial Intelligence (AI)” can fit a data-base much better than linear-models with poor forecasting ability [55]. The AI-based systems are more established technology, which offers alternative ways in tackling complex-problems [31], and are able in dealing with non-linear problems with a higher speed ‘prediction as well as generalization’ tendency, once trained [33]. Moreover, the AI-systems comprise of diverse-areas like expert-systems, artificial neural-network (ANN), genetic-algorithms, fuzzy-logic, and other hybrid-systems [33]. For forecasting the US/Taiwan dollar exchange-rate through a comparative-study between neural-networks and ARIMA-models, the neural-networks was found in producing better results than the ARIMA-models [26, 70, 75]. Similarly, Gencay has found the generated forecasts by neural-network to be superior to the random-walk and “Generalized Auto-Regressive Conditional Hetroskedastic (GARCH)” models in forecasting daily-spot exchange-rates for the “Swiss-Franc, Deutsche-Mark, British-Pound, French-Franc, and the Japanese-Yen”, respectively [23]. In a comparative forecasting-study between non-linear and linear models for Iran’s rice, meat, eggs, and poultry retail-prices, such as the “Adaptive Neuro-Fuzzy Inference-System (ANFIS)” and ANN as the non-linear models; and the “ARIMA and GARCH” as the linear models, the non-linear models found to be better than the linear models [19]. Further, Fahimifard Et al. applied both ANFIS and ARIMA for forecasting of poultry retail-prices in Iran, and found ANFIS to perform better in all the three-cases of forecasting in 1, 2 and 4 weeks-ahead than the ARIMA-model [20]. The common crops in Iran include barley, wheat, suger-beet, potatoes, alfalfa, and corns, which require more quantities of virtual-water than other crops, and the determination of the virtual-water for these crops can help in better assistance for water-resources management. In this regard, Ahmadaali Et al. have revealed of ANFIS to be an effective and promising model for crops’ virtual-water estimation purposes [4]. In view of the estimation of ‘evapotranspiration’ for water-resources management, environmental-assessment, and farm irrigation-scheduling in Iran, Abyaneh Et al. used two AI-techniques such as ANN and ANFIS for computing garlic crop-water requirements, and found them to be the most suitable techniques [1].

Navarro Hellin Et al. have proposed an automated "Smart-Irrigation Decision-Support System" by considering two machine-learning techniques, such as PLSR and ANFIS, for managing agricultural irrigation that estimated the weekly irrigation-needs of a plantation based on both climatic-variables and soil-measurements [51]. Menaka and Yuvaraj used both "Particle Swarm Optimization (PSO)" and ANFIS based models for the prediction of the crops' yield by considering all the important input-parameters necessary for the growth in addition to crop-yield [43]. Shanoor Et al. have used the "k-means algorithm" for image-segmentations, and "Color Layout Descriptors" for the extraction-features to train the ANFIS, for tracing-out the cotton-plant leaf-spots from the leaves in order to assist in the diagnosis of cotton-leaf spot related diseases like "Bacterial-Blight, Alternaria, and Myrothecium" more accurately [59]. Citakoglu Et al. applied both the ANFIS and ANN for modeling the "monthly mean-reference evapotranspiration" estimation because of their better estimate capability than the classical-methods, and further the ANFIS was found more-successful than ANN [15]. Elhami Et al. used ANFIS as well as linear-regression model for modeling of chickpea and lentil production in Esfahan-province of Iran, and found the ANFIS-model to be predicting better than linear-regression [18]. ANFIS has been reported to be a good-tool for prediction of sustainability-indices acquired from "geographical information-system (GIS)" [28]. Mokarram Et al. used ANFIS for the prediction of soil-fertility with the use of soil-parameters, such as "copper (Cu), phosphorus (P), manganese (Mn), zinc (Zn), iron (Fe), soil-potassium (K) and organic-matter (OC)" in Fars-province of south-west Iran [48]. Dahmardeh Et al. have suggested for the successful application of AI in the estimation of soil "carbon and nitrogen" with ANFIS to be more-accurate as compared to ANNs. Further, through sensitivity-analysis based on ANFIS estimations, it was found that greater percentages of 'green-gram' in intercropping will be helpful in reducing the "carbon and nitrogen" percentages [16]. Rahmon Et al. built a neuro-fuzzy system by the use of "MATLAB version-8" with 100-rules on five-input parameters as linguistic-variables for the determination of the disease-type either as bacteria or fungi or virus in "soya-bean", and also to determine the intensity-rate as the crisp-output [56]. Kalpana Et al. used ANFIS-models for the judgment of disease-severities in rice [32]. Al-Dosary Et al. have suggested about the suitability of ANFIS-model application for the "energy and draft requisites of the disk-plow estimation" with satisfactory-accuracy to match with tractor-powers [5]. Farhadi Et al. suggested of the optimization-process that they developed in a case-study by the use of ANFIS-models with "genetic-algorithm (GA)" as a promising-tool for the selection of optimal-conditions for maximum paclitaxel-biosynthesis [22].

4.2 Methodology

Several architectures have been built in the field of crop yield prediction. Owing to the well-known fact of suitability of neuro-fuzzy modelling as an alternative to use fuzzy-set, the present study utilized the ANFIS method for the prediction of crop productions by considering two major production achievements in the province of Algeria based on the FAO data [21]. For this purpose, both “apple and dry-onions” were considered by taking their harvested areas, yields, and production from the period of 1961 to the period 2019.

Moreover, ANFIS has been an established system accepting numerical-inputs and producing single-output values that proved in the present-case to be an advantage. For this study, by the use of ANFIS in the fuzzy-logic toolbox of “MATLAB 2013 version”, the fuzzy inference-system (FIS) was created for subsequent analysis.

4.3 Results and Discussion

On the basis of the data obtained from FAO [21], the last ten years’ statistics of Apple cultivation in Algeria from 2010 to 2019 was illustrated in the Figure 4.1, which represented the area harvested in ha, yield in hg/ha, and the production in tonnes.

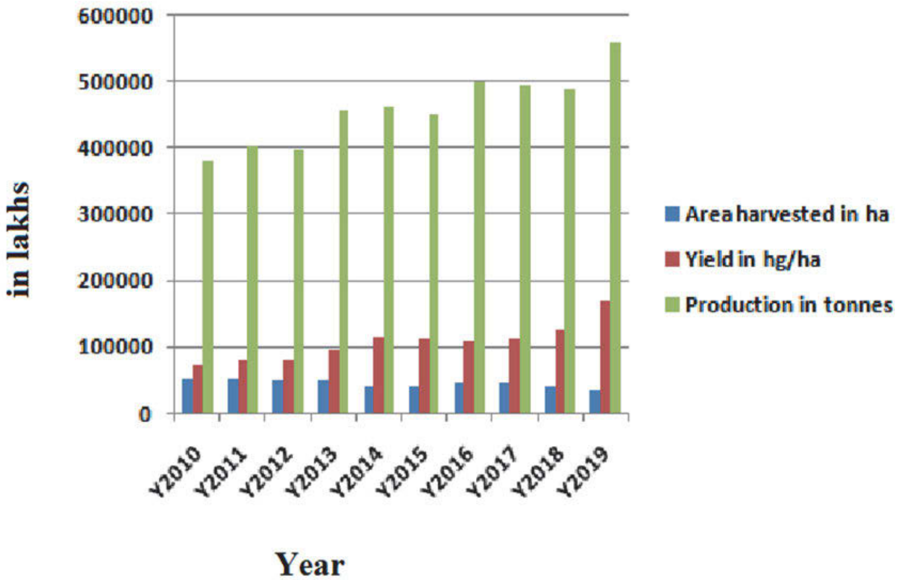

Fig. 4.1: Ten years’ statistics of Apple cultivation in Algeria from 2010 to 2019

The data from the year 1961 to 2019 for Apple cultivation in Algeria was considered for subsequent prediction by ANFIS method. Two inputs included area harvested in ha as input-1, and yield in hg/ha as input-2, while the production in tonnes was considered as the output for the ANFIS model-1 (Figure 4.2). Further, with significant adjustments in the ANFIS network-structure, the most effective and the best-adjustment was obtained with minimal-errors in the ANFIS model-1, which included the number in addition to the different types of membership-functions like "triangular; Gaussian; bell-shaped; sigmoid; and trapezoidal", the output membership-function types like "linear or constant", the optimization-methods like "hybrid or back-propagation type", and the epoch-numbers, respectively. For the ANFIS model-1 for the Apple production, bell-shaped membership function was considered to be more suitable.

Figure 4.3 illustrated the training-error for the ANFIS model-1 at five epochs for Apple production in Algeria, which was further followed by the training-data and the FIS-output for the ANFIS model-1 shown in Figure 4.4. Similarly, Figure 4.5 illustrated the ANFIS model-structure for the model-1. It was found of the ANFIS in well predicting the apple productions in Algeria with minimal occurrences of errors.

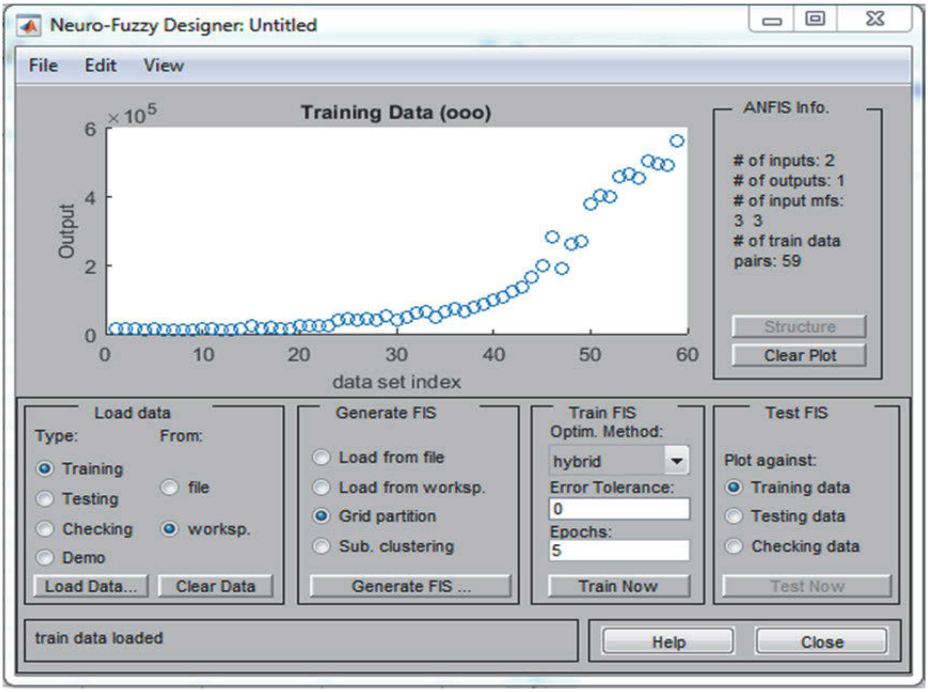

Fig. 4.2: Training-data for the ANFIS model-1 for Apple production in Algeria

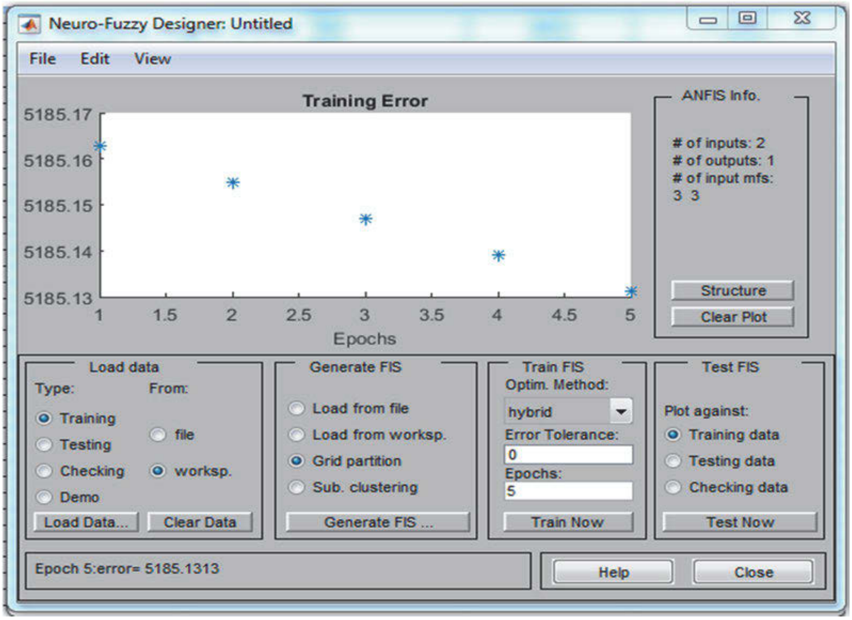

Fig. 4.3: Training-error for the ANFIS model-1 for Apple production in Algeria

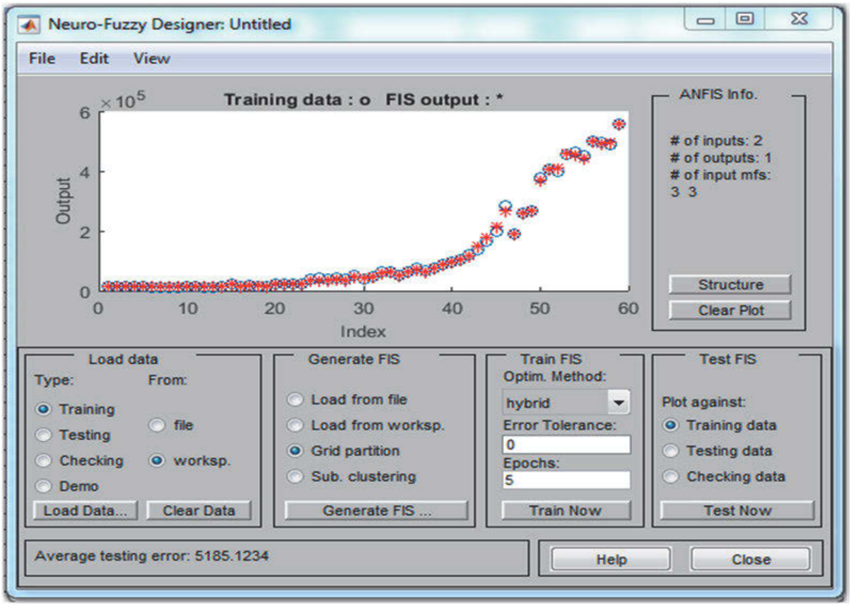

Fig. 4.4: Training-data and the FIS-output for the ANFIS model-1 for Apple production in Algeria

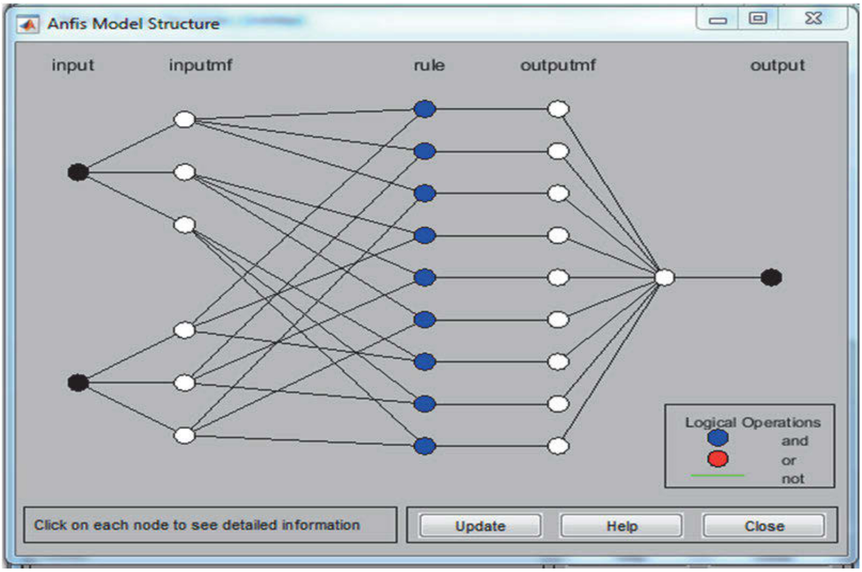

Fig. 4.5: The ANFIS model-structure for Apple production in Algeria

The fuzzy-based rule-viewer of the ANFIS model-1 was shown in Figure 4.6, which was followed by the fuzzy-based generated surface of the model-1 for Apple production in Algeria as shown in Figure 4.7.

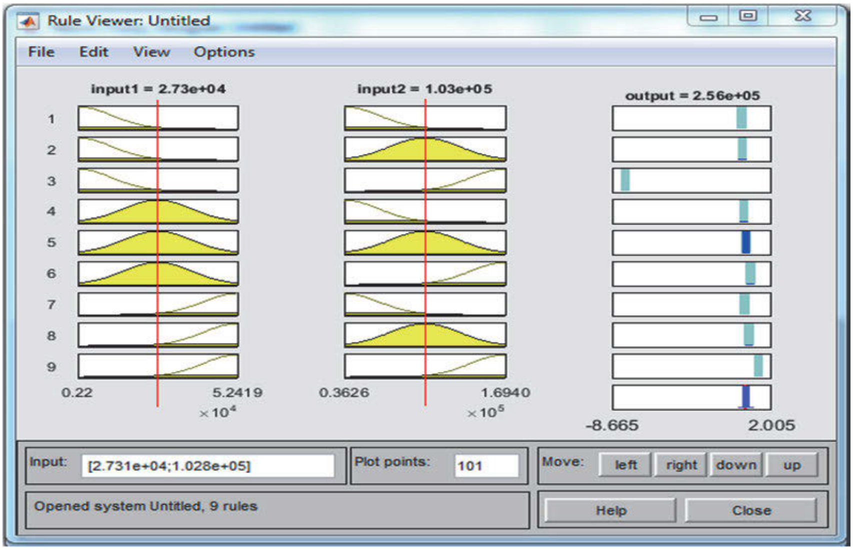

Fig. 4.6: Fuzzy-based rule-viewer of the ANFIS model-1 for Apple production in Algeria

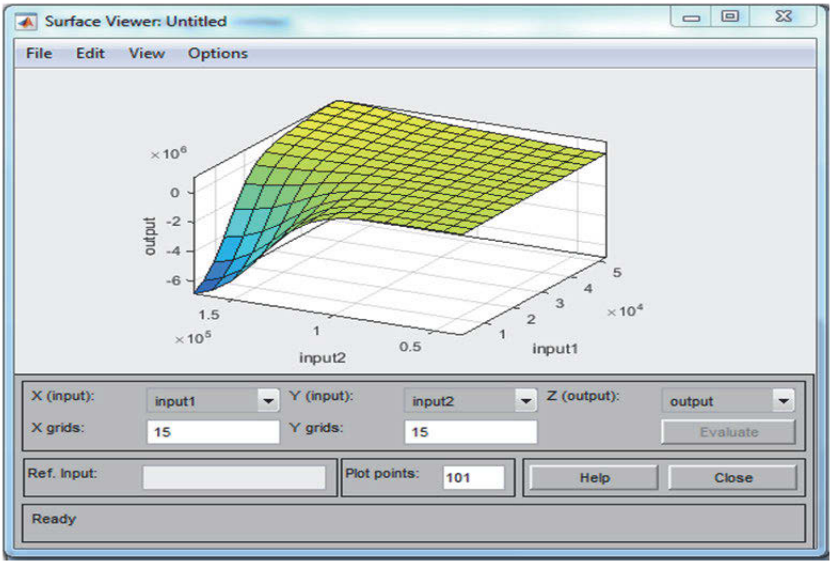

Fig. 4.7: Fuzzy-based generated surface of the ANFIS model-1 for Apple production in Algeria

The ANFIS information for model-1 included the followings: number of nodes to be 35; linear and nonlinear parameters' numbers to be 9 and 12, with total number of parameters to be 21; training data-pairs' numbers to be 59; checking data-pairs' numbers to be 0; and fuzzy-rules' numbers to be 9; respectively.

Further, based on the data obtained from FAO [21], the last ten years' statistics of dry-onions' cultivation in Algeria from 2010 to 2019 was illustrated in the Figure 4.8, which represented the area harvested in ha, yield in hg/ha, and the production in tonnes.

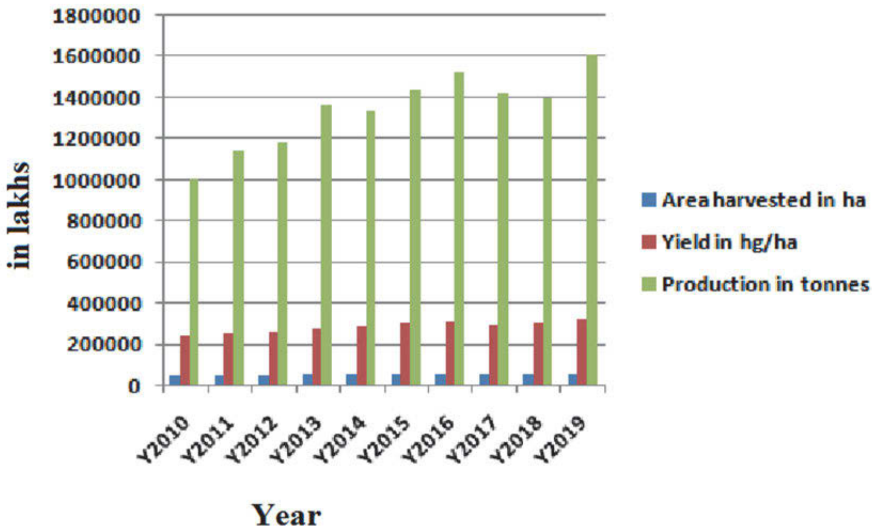

Fig. 4.8: Ten years' statistics of dry-onions' cultivation in Algeria from 2010 to 2019

The data from the year 1961 to 2019 for dry-onions' cultivation in Algeria was considered for subsequent prediction by ANFIS method. Two inputs included area harvested in ha as input-1, and yield in hg/ha as input-2, while the production in tonnes was considered as the output for the ANFIS model-2 (Figure 4.9). Further, with significant adjustments in the ANFIS network-structure, the most effective and the best-adjustment was obtained with minimal-errors in the ANFIS model-2, which included the number in addition to the different types of membership-functions like "triangular; Gaussian; bell-shaped; sigmoid; and trapezoidal", the output membership-function types like "linear or constant", the optimization-methods like "hybrid or back-propagation type", and the epoch-numbers, respectively. For the ANFIS model-2 for the dry-onions' production, bell-shaped membership function was considered to be more suitable.

Figure 4.10 illustrated the training-error for the ANFIS model-2 at five epochs for dry-onions' production in Algeria, which was further followed by the training-data and the FIS-output for the ANFIS model-2 shown in Figure 4.11. Similarly, Figure 4.12 illustrated the ANFIS model-structure for the model-2. It was found of the ANFIS in well predicting the dry-onions' productions in Algeria with minimal occurrences of errors.

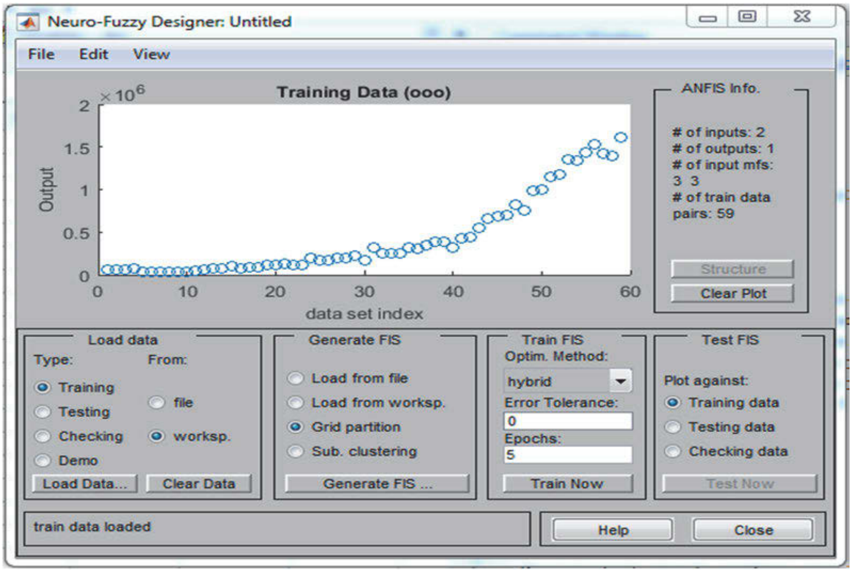

Fig. 4.9: Training-data for the ANFIS model-2 for dry-onions' production in Algeria

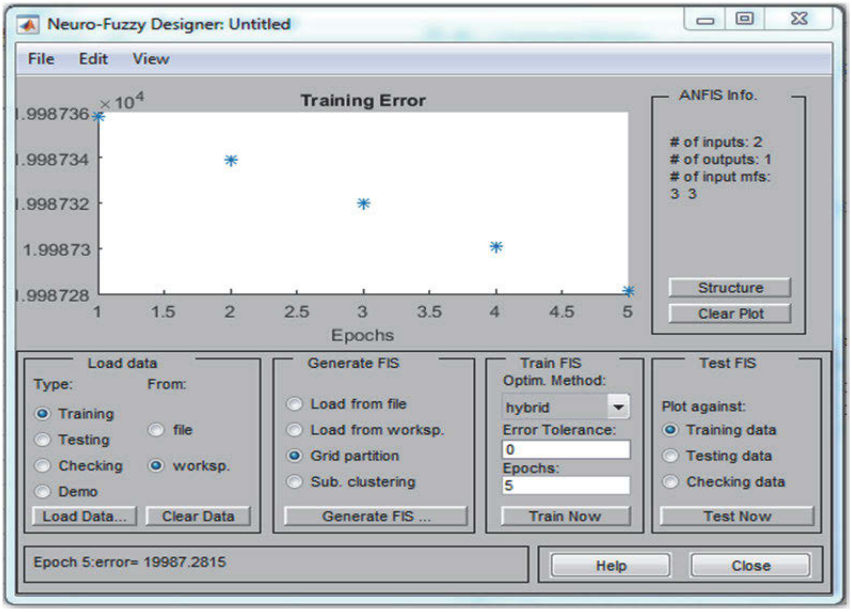

Fig. 4.10: Training-error for the ANFIS model-2 for dry-onions' production in Algeria

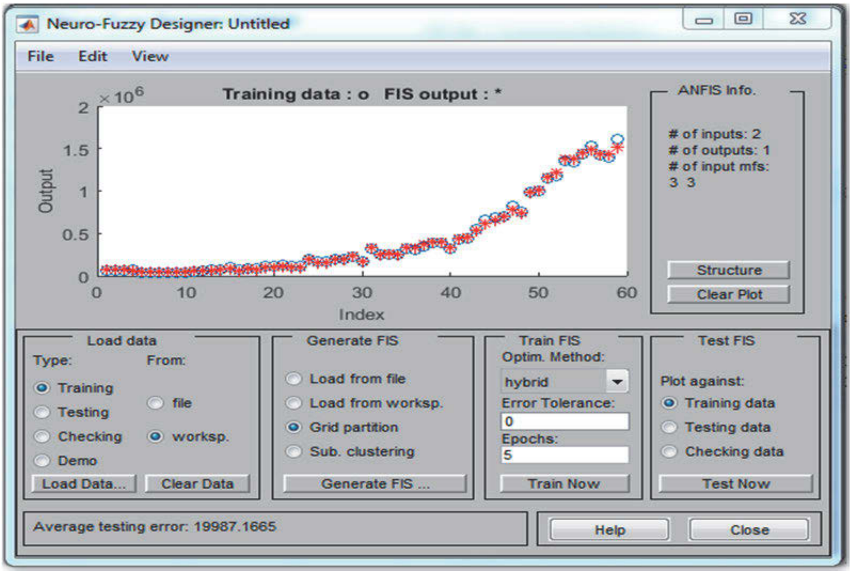

Fig. 4.11: Training-data and the FIS-output for the ANFIS model-2 for dry-onions' production in Algeria

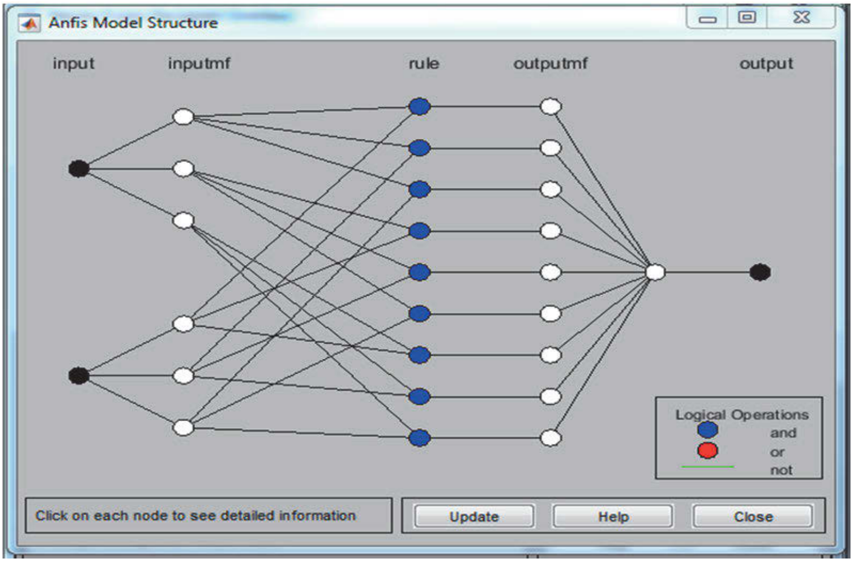

Fig. 4.12: The ANFIS model-structure for dry-onions' production in Algeria

The fuzzy-based rule-viewer of the ANFIS model-2 was shown in Figure 4.13, which was followed by the fuzzy-based generated surface of the model-2 for dry-onions' production in Algeria as shown in Figure 4.14.

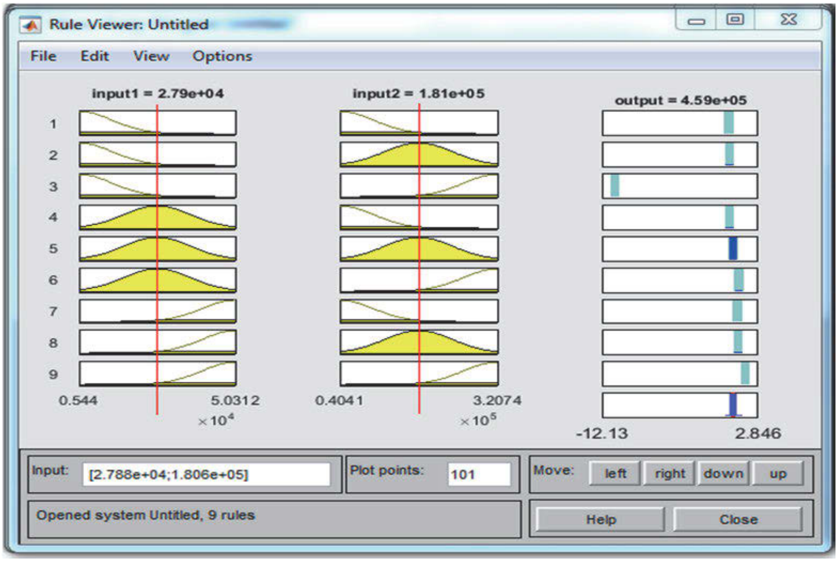

Fig. 4.13: Fuzzy-based rule-viewer of the ANFIS model-2 for dry-onions' production in Algeria

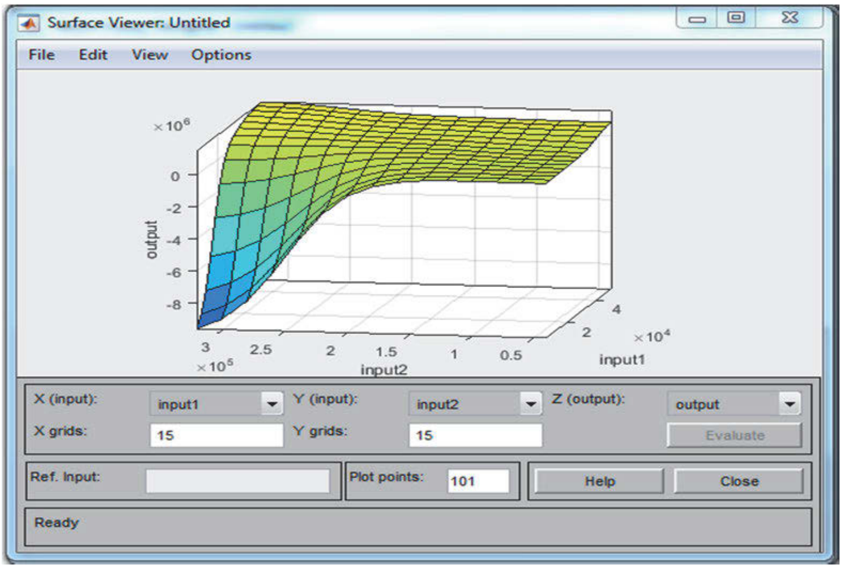

Fig. 4.14: Fuzzy-based generated surface of the ANFIS model-2 for dry-onions' production in Algeria

The ANFIS information for model-2 included the followings: number of nodes to be 35; linear and nonlinear parameters' numbers to be 9 and 12, with total number of parameters to be 21; training data-pairs' numbers to be 59; checking data-pairs' numbers to be 0; and fuzzy-rules' numbers to be 9; respectively.

4.4 Conclusion

Advancement in artificial-intelligence and soft-computing techniques has provided new opportunities to researchers for exploring their applications, which consist of several intelligent computing-paradigms, such as artificial neural-networks (ANN), support vector-machine (SVM), decision-tree, neuro fuzzy-systems (NFS), for successful modelling of various problems associated with the real-world [12]. Among the other soft-computing techniques, ANFIS has been revealed to be an effective-system with efficient-combination of ANN and fuzzy-logic for modeling of highly complex, non-linear, and dynamic-systems [3, 40].

The benefits of ANNs with their flexibilities as well as abilities for modelling of non-linear relationships enable them to be considered mathematically as universal-approximators [10]. However, the ANFIS-models combine both transparent as well as linguistic representations of fuzzy-systems with the learning-ability of ANNs. Therefore, the ANFIS can be trained for performing an input and/or output mapping like ANNs, but with the additional-features of providing the rules-set defining the model [36, 58]. But, the "standard back-propagation methodology" has been reported to be used by the ANFIS-models in order to adjust the parameters of membership-functions [29], where it becomes easier for the training-process in getting trapped to a local-minimum [39, 62].

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5 Agriculture-based risks measurement and control through metaheuristic approaches

Abstract: The agriculture-based risks may result in adverse consequences on the farmers and their community. In addition, the individuals involved in the farming business or activities may have significant outcomes on the long-run operating performances. The changing governmental policies as well as regulations may also impose considerable risks in agriculture, which may arise from alteration in policies from time-to-time. All the associated risks in the worldwide agricultural sectors reflect the individual-country's risk to economic-stability. Therefore, it becomes essential to evaluate the risk-levels in the agriculture, so that appropriate intervention strategies can be under-taken at different levels to enhance the stability as well as performances in the global agricultural sectors. The present study aimed at evaluating the agriculture-based risk-management in view of different risk-factors involved throughout the agricultural sectors of the world with the use of metaheuristic approaches like Particle-Swarm Optimization (PSO) and Genetic Algorithm (GA).

Keywords: Agriculture-based risks, Metaheuristic approaches, Particle-Swarm Optimization, Genetic Algorithm, PSO, GA, Worldwide, Agriculture; Management

5.0 Introduction

The agriculture-based risks occur as because the unmanageable events affect the agriculture that are found to be related to the weather-conditions, such as insufficient or excessive rainfalls, extreme-temperatures, uncontrollable insects, hail, and diseases. However, technology also plays a key-role in the production-related risks in agriculture. Although a higher potential for enhanced efficiency is provided with the substantial preamble of new varieties of crops and production-techniques, but it may result in poor-yields, particularly in the shorter duration of time-frame. In contrast, certain practices have been threatened of obsolescence, for instance, the use of machineries with no longer availability of spare-parts creating an added risk. These types of risks occur owing to the failures of the borrowers in making the agreed payments in-time. The agricultural productions are usually characterized by variability in seasons, which not only affects the specific settlements' circumstances, but also the cash-flow distributions in certain periods. Sometimes these agriculture-based risks may result from the events of divorces, deaths, injuries, or poor-health conditions of the farmers and their community. In addition, the individuals' varying objectives who are involved in the farming business or activities may have significant outcomes on the long-run operating performances.

https://doi.org/10.1515/9783110745368-005

The changing governmental policies as well as regulations also impose considerable risks in agriculture, which may arise from altering policies like the disposals of animal-manure, constraints in conservation-practices or land-use, or changing income-tax policies, credit-policies or subsidizing-policies. All the associated risks in the worldwide agricultural sectors reflect the individual-country's risk to economic-stability. Therefore, it becomes essential to evaluate the risk-levels in the agriculture, so that appropriate intervention strategies can be under-taken at different levels to enhance the stability as well as performances in the global agricultural sectors, which formed the basis of the present research work.

5.1 Literature review

Agriculture has been playing a key-role in the global-economy in recent years. With the continuous expansion in population, there occurred a global threat to the reduction in the area of cultivating lands in addition to pressures on the agricultural-system through urbanization [130]. There has been more demand for safe and effective agriculture-based food-production methods [80, 111]. The traditional agriculture-based management techniques need to be balanced by innovative-sensing as well as driving-technologies, and through better "information and communication technologies (ICT)" [14], for enhancing the productivity levels in agriculture in a more accurate and systematic way.

During the recent times, the use of computer-vision inspection-systems have increased to a greater-extent [41], and become imperative tools in agriculture-based applications [24, 94, 128], with considerably increasing the efficiency as well as productivity in agriculture [35, 79, 112]. Usually different risk-sources that affect the farming activities are included in the risk-management systems comprising of different strategies for risk-management, tools used by the farm workers, and all governmental-actions affecting farm-based risks. Moreover, a set of complex-relations exist in the risk-management system, which can be represented by three different axes involving the original risk-sources, the available strategies and tools, and the measures by government (Figure 5.1).

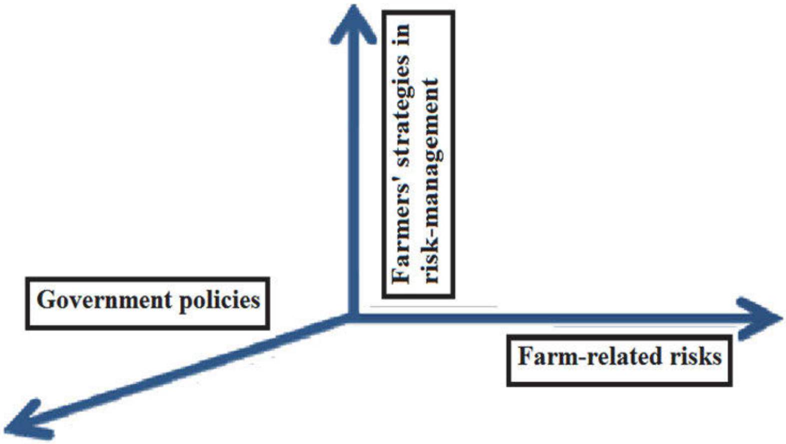

Fig. 5.1: Risk identification for risk-management systems

Owing to the biological-nature in addition to more dependency on agro-climatic situations, the agricultural productions are generally accomplished mostly in small-sized holdings. Therefore, in view of the extreme insecure and unstable circumstances, the farmers need to make decisions [98]. Hardaker Et al. and Komarek Et al. have discussed on the five major-types of agriculture-based risks such as production-related risks, market-related risks, institutional-related risks, personal-related risks, and financial-related risks, and also suggested for the need for probability-distributions and simulation-approaches [50, 76]. Being a developing country, Uganda has been vulnerable to climate-changes, and it also lacks expertise in adaptation to climate-changes. By the year 2020, the climate-change model was supposed to increase in temperature of 0.7–1.5^{0}C for Uganda [60]. In Uganda, the wetter regions around the "Lake Victoria-basin, East and North-west" were expected to experience more rainfalls in the upcoming years [43]. Agriculture-based risks inherently involve unfavourable outcomes that include lesser yields and earnings that may also involve catastrophic-events, such as financial-bankruptcy, food-insecurity and individual health-problems, although more expectations on returns occur as positive reward in taking such risks. The farmers were found to cope and manage constantly with different risks associated in agriculture [59, 127, 131]. The compound-effect may affect n decisions and outcomes in agriculture. The production-related risk owing to the 2007–2008 food-price crisis in the world was due to severely occurred droughts that pulled some governments to impose restrictions in exports [55]. In the period of this crisis, the farmers were reported in facing different risks within a shorter period, such as production-related risks (droughts), market-related risks (price-spikes), and institutional-related risks (surprising changes in government-policies). Thus, the outcome of risks can have cascade effects resulting in one consequence through the other, such as, excessive rainfalls during harvesting period may result in other kind of risks associated with financial-related risks by inability in loans' repayment [104] The farmers' resilience includes buffer, adaptive and transformative capabilities [25].

The unexpected events' continuance with significant impacts on the farmers was highlighted in a study [65]. According to Meuwissen Et al., owing to the probable occurrences of simultaneous agricultural risks, a number of policy-driven initiatives have been started for the examination of risk-management issues [90], as well as strategies concentrating on multi-risks' sources including the "SURE farm-project" and the "INFORM-index" for risk-management [17]. With regard to the risks faced by the farmers, the farmers' major-concerns were highlighted in a study as personal-illness and weather-variability in pre-modern Iceland [32]. Campbell Et al. have argued of the increasing studies on the linkage between crop-yields and weather-variability [19]. The IPCC indicated of possible solutions through policy-making by considering multiple-risks [61]. Based on the arguments of different researchers such as "Barrett and Constas, Darnhofer Et al., and Hansen Et al.", there has been a serious concern for the associated risks with regard to climatic-changes, globalization, economic-volatility, and political-instability [11, 26, 47].

Past studies have examined both theoretical-models in addition to empirical-methods for examining specific risk-types [12, 21, 67, 68, 84]. However, there exist limited studies on the handling and management of multiple risks' sources [20]. For instance, studies have focused on the risk-types found easier to analyze, such as weather-related shocks instead of the market-related or institutional-related risks in Africa [28]. The risk-based attitudes, perceptions and their dealings are the principal determinants in risk-management and act as its specific management-tools [65, 106, 107], but are associated with their non-observability and measuring difficulties [38, 123]. Thus, developing of most reliable-methods for measuring and understanding of farmers' risk-attitude, find more importance for researchers, advisory-offices and politicians [81,129]. In view of the impacts on other economy sectors, it has been crucial in the management of uncertainties as well as risks in agriculture [69], although with the availability of different management-tools for the farming community for the avoidance, prevention, sharing, transferring, spreading and/or taking agriculture-based risks [117]. However, selecting some particular tool relies on individual-situation in addition to the risk-bearing enthusiasm among the farming community. The agriculture-based risks have been a worldwide matter of concern and its analysis shows difficulties in the evaluation as well as management [30, 45, 50, 77]. The agricultural enterprises need of coping with a number of uncertainties. Different studies were based on the estimations of risk preferences of farmers [42, 62, 122], and providing models for the understanding of farmers' decisions among a set of arbitrary options [50]. In general, these studies were focused on limited set of risks' sources among several quantifiable and non-quantifiable risk-factors. In a study on cattle-farmers in Nebraska and Texas, Hall Et al. found of severe-drought in addition to meat-prices' variability as the most important risk-sources [44]. By considering the large-scale sugarcane-farmers in South Africa, Nicol Et al. found of land-reform regulations, labour-legislations, and crop-prices' variability as the most important risk-sources [97]. The US-based farmers dealing with livestock and crops were revealed of handling the risks by the key strategies of "placing investments, acquiring market-information, and enterprise-diversification" [16,103]. Baquet Et al. revealed of five distinct agriculture-based risk-factors, such as production-related risks, marketing-related risks, credit-related risks, personal-related risks, and environment-related risks [9]. Moreover, Hardaker Et al. expanded with additional risks i.e. political-related and business-related risks. Thus, on account of the viability of these risks, the farmers' decision-making process becomes very important in the evaluation and measurement of agriculture-based risks in an effective-manner [50].

With the adoption of advanced information-systems and internet-technology in agriculture, enormous farm-related data can be collected, analyzed and processed, such as meteorological-information, soil-conditions, marketing-demands, and land-uses, for making appropriate decisions by the farmers and in obtaining more profits [135]. Therefore, the use of decision-support systems in agriculture has gained wide attention in the research-community. Raghuvanshi and Ansari developed a scale based on "Likert's summated-rating technique" to help the academicians and researchers for the study of climate-change perceptions of farmers with its' agricultural impacts. Further, they suggested it to be useful for policy-makers in the development of risk-management strategies [108]. The agricultural sectors in India have been reported to be under threat owing to the climatic-changes [64], which affects the whole agricultural-systems in terms of "productivity, agricultural-practices, environmental-effects, and rural-livelihoods". Its' vulnerability to climate-change also poses negative-impacts on the prevailing food-security scenario in India in addition to other countries in the world [2, 109]. The climate-changes' risk judgment throughout the world fluctuate in different points of views [89]. On the other hand, the public refutation of climate-change has been revealed as associated to knowledge and education, and the environment as well as mass-media messages help in the determination of scepticism regarding climatic risks and uncertainties [132]. The agriculture-based risks are complex as well as pervasive [50, 54], affecting in the fluctuations of farm-level profitability in different seasons and years [31, 58]. The developing countries were revealed to be more prone to the risks owing to imperfect information by farmers in forecasting things that may impact the agriculture in the future, such as farm-input prices, product-prices, and weather-conditions [54, 99, 100]. Through different studies, it has been reported of the agricultural production systems in Thailand to be facing with many risks, such as yield-variabilities, fluctuations in product-prices and input-costs [70, 102, 115], and also due to poorer irrigation-systems, the Thai-based farmers were found to grow the crops in rain-fed conditions [72]. Teysseire Et al. have assessed the residential exposures to pesticides used in agriculture to help in preventing future exposures and possible improvements for public-health, regulatory and management strategies [120]. Tian Et al. have suggested for the computer-vision technology to be applied to all aspects of agricultural production-management by combining with intelligent-technology, such as deep-learning technology to solve the current agriculture-based problems [121]. Frischen Et al. have revealed of occurrences of frequent droughts with changing-patterns across Zimbabwe, and almost all districts have been affected with changing frequency and severity levels of droughts during the past thirty-years including the periods of "1991–1992; 1994–1995; 2002–2003; 2015–2016; and 2018–2019", respectively [36].

5.1.1 Application of metaheuristic approaches in agriculture

With the developments in the modern optimization methods, these are the most trending techniques used to solve optimization-problems and also, have been successfully applied to diverse-fields, such as engineering, sciences, finance, and so on. Usually, the metaheuristics deal with no mathematic-based information on the considered problems like first and/or second derivatives, but require proper-setting of different parameters concerned [9,18]. The most commonly used methods include "Genetic-Algorithm (GA)" developed by Holand [57]; "Simulated-Annealing (SA)" developed by Kirkpatrick Et al. [73]; "Differential-Evolution Method (DE)" by Storn and Price [118]; "Firefly-Algorithm (FA)" by Yang [133]; "Wind-Driven Optimization (WDO)" by Bayraktar Et al. [13]; "Brain-Storm Optimization (BSO)" by Shi [116]; "Flower-Pollinated Algorithm" by Yang [134]; Artificial Immune-Systems [33]; Taboo-Search [39,40]; and Particle-Swarm Optimization [71]; etc. GA has been regarded as the most accepted evolutionary-algorithm that evolves an individuals' population (moving through the fitness-landscape) on the basis of a set of rules, such as "selection, crossover, and mutation" [1]. Similarly, the PSO represents another algorithm based on population [6], which has been applied in a number of problems associated with the real-world [15].

In recent years, different models were developed and applied in order to solve problems related to crop-selection and land-management [8, 53, 83, 119]. Ramachandra Murthy Et al. determined suitable locations for capacitor with the help of power-loss based approach, and used "Index, GA and PSO" methods to find the fixed-capacitors' optimal-values in the distribution-networks [110]. Pant Et al. considered an optimization-model that was based on linear-programming in order to determine the most favourable crop-plan for command-area of "Pamba-Achankovil-Vaippar (PAV)" link-project of Kerala in India. The objective of the crop-plan model was to maximize net irrigation-benefits, and the optimization-model was solved by using four popular evolutionary-algorithms, such as GA, PSO, DE, and Evolutionary-Programming (EP), respectively [101]. Saeidian Et al. used GA for allocating different quantity of water to a number of farms [114]. Babatunde Et al. made a comparative examination for the classification-accuracy performances of both PSO and GA for some classifiers, and found the classification-accuracy with GA-based method to be better as compared to PSO-based approach [7]. Nazari Et al. have proposed of both "PSO and GA based energy-demand estimation-models (PSO-GEM and GA-DEM)" for estimating the future energy-demands of the commercial as well as residential sectors in Iran [96]. Memmah Et al. concluded the metaheuristics' success to be problem-dependent that enables searches in escaping from local-optima, and in attaining a satisfactory global approximation-solution [88]. Chen Et al. used "hybrid particle-swarm optimization and genetic-algorithms technique (HPSO-GA)" for estimating the indistinct internal-parameters of 'greenhouse energy-model', which was built on the basis of thermal-balance [22]. Cheraghalipour Et al. have considered rice supply-chain and proposed a bi-level optimization-model for rice supply-chain by using the metaheuristic algorithms such as GA and PSO with two hybrid-algorithms (GA-PSO and PSO-GA) in addition to a 'modified algorithm (GPA)' [23]. With the use of two computational-methods such as GA and PSO, Valim Et al. performed the 'thermogravimetric-analysis' in an inert-atmosphere of pure-nitrogen, and determined the involved kinetic-parameters in the 'lignin-pyrolysis' process with the aim of providing assistance in the design of "biomass conversion-reactors" for green-coconut [126]. For the analysis on benchmark-dataset on the "Maize and Mango", the "Particle-Swarm Optimization–Support Vector-Machine (PSO-SVM)" classification-algorithm was used [95]. Moayedi Et al. analyzed the land-slide susceptibilities in the "Ardabil-province of Iran", and for this analysis they synthesized two optimization-algorithms, such as GA and PSO with an "adaptive neuro-fuzzy inference-system (ANFIS)" for the creation of the ensembles of "GA-ANFIS and PSO-ANFIS". With regard to the calculated-area under the receiver-operating characteristic-curve index, the GA-ANFIS demonstrated best-performance in the phases of training as well as testing. Similarly, the ANFIS-PSO was demonstrated as the faster predictive method than the GA-ANFIS [93]. Thus, an attempt was made in this study to analyze the global agriculture-based risks by the use of both GA and PSO techniques.

5.2 Methodology

Initially literature-review was conducted to identify the agriculture-based risks common throughout the world. Then, with the help of suggestion of fifteen numbers of experts from different regions of the world, such as "Ethiopia, Kenya, India, and Europe (Chezch-Republic and Mexico) with agricultural, environmental and academic backgrounds, the parameters for the subsequent metaheuristic analysis with their range values were set for the evaluation of agriculture-based risk-management. The metaheuristic approaches such as PSO and GA were used for the analysis purposes, accordingly.

The participated experts with their domain expertise-areas, gender, educational-qualifications, and average-years of experiences for this study were illustrated in Table 5.1.

Tab. 5.1: Participated experts' characteristics

Domain expertise-areas	Gender		Educational-qualifications		Average-years of experiences
	Male	Female	Master-degree	Doctorate	
Agricultural	5	1	0	6	More than 15
Environmental	3	0	0	3	More than 15
Academic	4	2	1	5	More than 26

5.2.1 Terminologies for consideration of definitions related to risks and risk-types

For the purpose of appropriate considerations of risks and different risk-types associated with the agricultural-activities, due emphasis was given to the existing literature. For instance: according to Knight [74,75], risk may be a case with known distribution of effects either through experience and/or with uncertainties of quantifiable probabilities. This definition implied that the decision-makers have deficient information of possible effects associated to any occurrence of actions, but have sufficient knowledge about the probabilities of alternative circumstances of nature leading to different effects. However, unavoidable as well as subjective probabilities exist with the decision-makers [48]. The risks can have three commonly used interpretations, such as the chances of bad outcomes, and the outcomes' variabilities as well as uncertainties [49]. However, Urruty Et al. interpreted risks to be characterized in terms of resilience, vulnerability, and robustness, respectively [125]. These prior interpretations of risks were utilized in this research for the analysis of worldwide agriculture-based risks.

Moreover, the risk-management can be arranged into a number of steps to be taken in a cyclic as well as routine manner for considerations including risk-evaluation as a key-step [50]. The risk-concept has been reported to be broader and often confused with the concepts of dangers, harms, threats or uncertainties [113], while others argue this as an event or its' outcome-probability including both potential-benefits and potential-losses. However, in an earlier study, the risk-analysis concept has been considered as the key-step in decision-making process for pursuance of profit-oriented activities [63]. Based on the past studies on the agricultural sectors throughout the world, the five-types of agriculture-based risks along with their sources were illustrated in Table 5.2.

Tab. 5.2: The five-types of agriculture-based risks

Agriculture-based risks	**Sources**	**Reference**
Production-related risks	Weather and climate Pests and diseases Other yield reducing or yield limiting factors, such as excessive heavy-metals in soils or soil-salinity	[10, 92]
Market-related risks	Weather-shocks and their effects on yields Energy price-shocks and asymmetric-access to information International-trade, protectionism, and liberalization with their tendencies in increasing or decreasing market-access across multiple spatial-scales	[51, 56, 78]
Institutional-related risks	The factors having limited or no control of farmers, such as the government that may create-risks through unpredictable alterations in policy and regulations as a formal-institution Through informal institutions, such as unpredictable alterations in the activities of informal-trading partners, rural-producer organizations, and/or changing social-norms affecting the agricultural-systems	[4, 10, 52, 66]
Personal-related risks	Farm-machinery related injuries, illness or death of family-members because of diseases, harmful health-effects by using pesticides, and transmission of diseases between livestock and human-beings Fluctuation in incomes and concerns for farmers Death or divorce of a husband can result in appropriation of lands or livestock owing to the creation of institutional-related risks by the customary-laws	[3, 5, 29, 82, 86, 87, 124]
Financial-related risks	Changes in interest-rates or credit-availability Changes in credit-conditions	[27, 37]

5.3 Results

This study used both PSO and GA algorithm for the evaluation of agriculture-based risks' management in terms of five-types of agriculture-based risks, such as: Production-related risks; Market-related risks; Institutional-related risks; Personal-related risks; and Financial-related risks; respectively. The parameters for both the algorithms were set as follows: Production-related risks in the range of "0 to 3" representing "Nil, Low, Medium, and High"; Market-related risks in the range of "0 to 3" representing "Nil, Low, Medium, and High"; Institutional-related risks in the range of "0 to 3" representing "Nil, Low, Medium, and High"; Personal-related risks in the range of "0 to 3" representing "Nil, Low, Medium, and High"; Financial-related risks in the range of "0 to 3" representing "Nil, Low, Medium, and High"; respectively.

While, the fitness or objective function obtained by regression analysis using "MINITAB 17" was set as "Agriculture-based risk-management", which formed a maximization problem, i.e.

$$C6 = 0.526 + (0.374\ C1) + (-\ 0.041\ C2) + (0.097\ C3) + (0.02\ C4) + (0.581\ C5) \quad (1)$$

Where, C1= Production-related risks; C2= Market-related risks; C3= Institutional-related risks; C4= Personal-related risks; C5= Financial-related risks; and C6= Agriculture-based risk-management; respectively.

When this function [eq. (1)] was given as input to Particle-Swarm Optimization, the best value obtained for the agriculture-based risk-management was 0.403 as shown in Figure 5.2 for the PSO-output. The particle-swarm was reached the value 0.403000 after 21 iterations by using 2323 function evaluations.

When this function [eq. (1)] was given as input to Genetic Algorithm, the best value obtained for the agriculture-based risk-management was 0.403029 with a mean value of 0.403035 (Figure 5.3), which depicted the suitability and efficient-computation ability of the use of both these algorithms for the purpose of agriculture-based risks' evaluations.

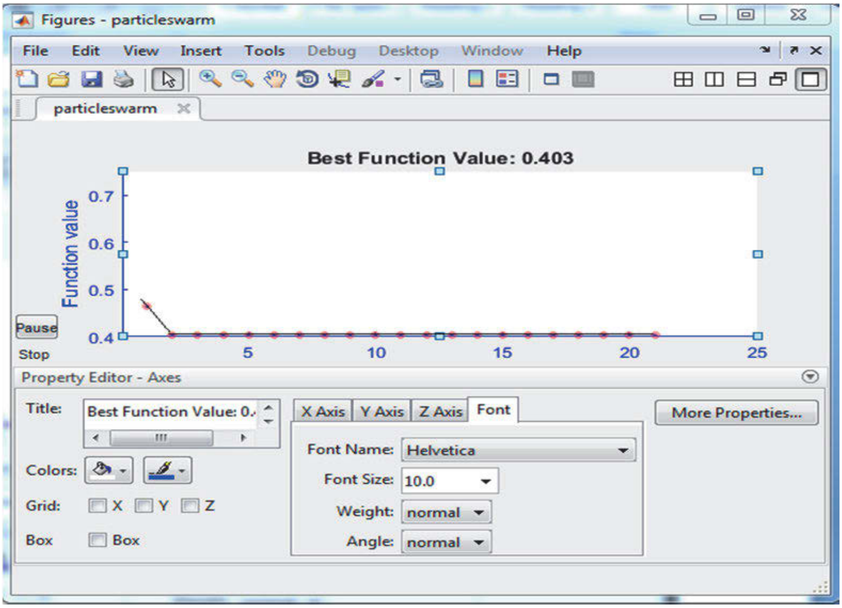

Fig. 5.2: PSO-output for the agriculture-based risk-management

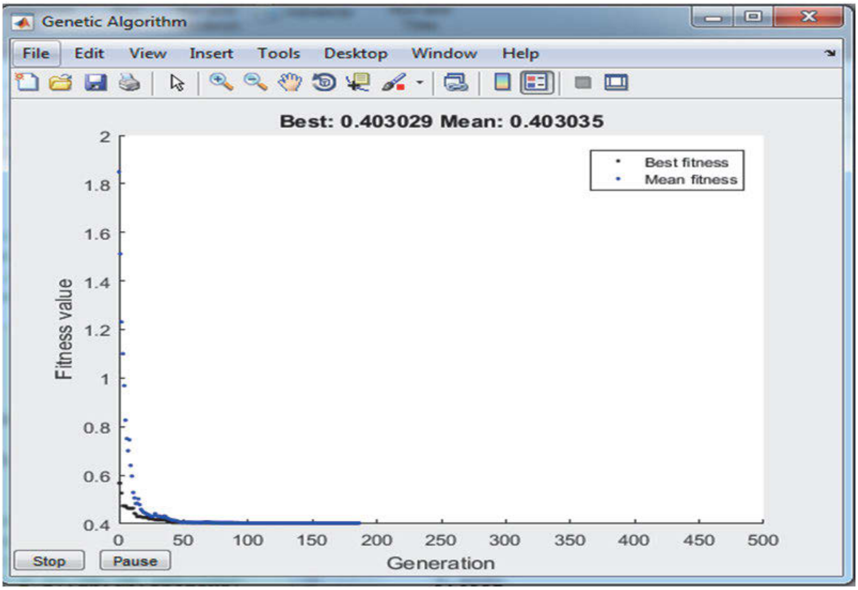

Fig. 5.3: GA-output for the agriculture-based risk-management

5.4 Discussion

5.4.1 Risk-management strategies in agriculture

The decision-making behaviours of farmers while facing with risky circumstances were revealed to be influenced by their perceptions in addition to their responses to such risks [34]. By asking the respondents about their perceptions of risks and accordingly to rank the risk-sources in addition to the risk-management strategies on the basis of the importance of each risk, a study was made to examine the farmers' awareness on risks associated in crop and livestock based productions in Northern-Florida and Southern-Alabama [16]. Through countrywide mail-survey, the risks' sources and their management strategies were examined for the farm workers in New Zealand by covering eight-types of farms, such as dairy, vegetables, flowers, cropping, sheep and beef, deer, pip-fruits, and kiwi-fruits, respectively.

The marketing-related risk was ranked as the most important risk-source by the farm workers including alterations in product-prices and input-costs [85]. The farmers' awareness of risk-sources was found to be varied depending on farm-sizes including large, medium, and small farms in Argentina, with more awareness of production-related risks among the small-size farm group than the others [105]. Meuwissen Et al. have revealed of price-related and production-related risks as the most imperative risk-sources for Netherlands based livestock farm workers [91].

Moreover, in order to manage the risks, an insurance-scheme was reported to be a suitable strategy. In contrast, the farmers of New Zealand were reported of using mixed risk-management strategies for the reduction of risks that varied among the farmers depending on products' nature, market conditions and structures, farmers' characteristics, dynamic risk-adjustment considerations, and the regulatory-situations [85]. Flaten Et al. compared the risk-perceptions and the risk-responses among the organic and conventional dairy-farmers in Norway, and found that the institutional-related risks like governmental supporting policies and the marketing-related risks to be important risk-sources for the organic dairy-farmers [34].

5.5 Conclusion

The Both risks and uncertainties are inseparable as with of occurrence of uncertainty, risk also occurs. Moreover, the risk-probability can be precisely measured, while the uncertainty measurement can only be done through the subjective possibility on the basis of individuals' marginal-utility [46]. In this context, the use of metaheuristic approaches such as GA and PSO in this study was found to be very useful in the agricultural sectors.

Moreover, it becomes a global concern to evaluate the farmers' risk-perceptions and responses to risk-management for getting an in-depth understanding of their risk-behaviours and managerial-decisions.

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6 Sustainable design of agriculture-based tools and equipment in view of ergonomic risks and safety: An Introduction

Abstract: Sustainable developments in agriculture have been most essential concern for the global advancement and have been acknowledged widely as an urgent requirement in the development of sustainable agricultural production-systems. In the present study, initially the "strength, weaknesses, opportunities as well as threats (SWOT)" analysis was used for the evaluation of the "existing agricultural systems without the aid of IoT" and the "IoT-based agricultural systems". Then, the "Step-wise Weight Assessment Ratio Analysis (SWARA)" method was used for ranking of the deficiencies in the existing agricultural systems without the aid of IoT, which revealed that the most important-variables with regard to the deficiencies in the existing agricultural systems without the aid of IoT in the descending order included: "Lack of adequate knowledge about the negative impacts by the use of existing agricultural tools and equipment; Inadequate expertise influencing the farm-activities; Lack of adequate awareness about latest technologies among the farmers; The noisy agriculture-based equipment that can cause hearing-problems; Inadequate supports from governmental and other agencies; Lack of appropriate training on emerging technologies; Hard and repetitive agriculture-based tasks resulting in musculoskeletal-disorders; Exposing to agro-chemicals and pesticides during fertilization process that can lead to occupational risks; In-correct working postures resulting in musculoskeletal-disorders; Getting in contact with plants and animals resulting in health-related problems; and Exposing to diesel-smells and dusts that can lead to respiratory-problems"; respectively. Further, by the use of the fuzzy-logic in fuzzy tool-box, the agricultural sustainability evaluation was done by considering the MSDs along with ergonomic OWAS scores as input, and the agricultural sustainability as the measuring output.

Keywords: Agriculture-based, Tools and equipment, Sustainability, SWOT, SWARA, Fuzzy-logic, Ergonomics, Musculoskeletal disorders, MSDs, OWAS score, Agricultural sustainability

6.0 Introduction

Despite of precautionary and preventive measures during the past-century, estimation has been made that accounted for 317-million non-fatal occupational-injuries with 321,000 cases of global fatalities occurring each year [64]. Based on the estimation by the "International Social Security Association (ISSA)", the associated costs with non-fatal work-place related accidents result in an approximate 4% of world's

https://doi.org/10.1515/9783110745368-006

"gross domestic-product (GDP)" per annum [66, 141]. Work-place environments, physical-exposures during job-tasks, usages of tools and appliances, machine-operations, and other machine-related works affect the workers in different sectors of occupational and employment groups [21, 165]. Because of seasonal aspects in farm-work that are more labour-intensive, the farm-workers are usually exposed to a variety of injuries and accidental risks due to adverse weather-conditions with considerable time-pressures, stresses, and fatigues. Most of these risk-factors include functioning of farm-equipment and machineries, working with animals, falling of objects, and performing tasks at heights, respectively [123].

Occupational injuries and accidents can be prevented by the implementation of the available methods and measures for eliminating the accidents causing factors [65], where the handle-diameter and handle-length play as key-factors in minimizing injuries at work-places [159]. Furthermore, determining the optimum tool-handle dimensions by the use of hand-anthropometry has been a common criterion [48, 71, 79, 143], and effective-way in the reductions of hand-tool injuries. By the use of ergonomic-principles, majority of ergonomic-strains associated with agriculture related tasks can be minimized [38]. The industrialized countries with farm mechanizations, such as the USA, UK, and Canada have been found of using power-operated machineries [89]. The improved crop-varieties also require the use of heavy-equipment like trucks, tractors, water-pumps, reapers, threshers, and combine-harvesters [115]. However, the design of these equipment and machines were focused on larger flat-land areas with higher crop-yield potentials [93]. As a result, small-sized as well as small-scale farmers in many developing countries are still suffering of lack of environmentally and socially responsible mechanizations through "technology-transfer" paradigm of sustainable agricultural developments [24]. It has been reported of most countries like Australia, Japan, UK, and India to be investing on smart-farming approaches with considerable developments in smart-technologies including robots, drones, and artificial intelligence [139].

Various goals are achievable through sustainable agriculture such as satisfaction of human needs for 'food and fibers', enhancement in environment-quality, and sustaining of economic-viability [106], which implies that sustainable agriculture needs to consider social, economic and environmental issues simultaneously. Besides these dimensions, sustainable development means to accomplish a compromise for overall achievement of different goals [32, 106]. Therefore, the main aim of this study was to develop and analyze sustainable agriculture-based tools and equipment in view of the requirements of the worldwide small-scale farmers engaged in agriculture.

6.1 Literature

Marchand Et al. have proposed two types of sustainability-assessment tools, such as rapid sustainability-assessment and full sustainability-assessment tools in order to support decision-making in agriculture. The rapid sustainability-assessment tools were found of more oriented toward communication and learning, and more suitable for larger farmers' group. Further, the authors suggested that with the increased commitments to 'on farm sustainability' by the farmers, an additional-insight to full sustainability-assessment can be obtained [86]. A study in the United States revealed of about 27% of operational adults to be exposed to repetitive motions, 10% to restricted working spaces requiring for awkward-postures, and 2.7% to vibrations in whole-body, and 25% to be spending more than half-time at work by either bending and/or twisting postures [158]. Owing to the higher rates of both fatal and non-fatal injuries with more fatality-rates in agricultural production compared to other industries, agriculture has been regarded to be hazardous the North America and Europe [11, 40, 169]. Pretty Et al. have tried through their work to scale up and spread: (i) the science and farmers' input into practices as well as technologies, which combine animals-crops with agronomic and agro-ecological management; (ii) the concept of creating novel social-infrastructure, which develops trust among agencies and individuals; (iii) farmers' knowledge as well as capacity improvements through farmer field-schools, and modern "information and communication technologies"; (iv) the benefits of engaging with the private-sectors for the supply of 'goods and services'; (v) the focus on women's needs of educational, microfinance, and agricultural-technology; (vi) the focus on the availability of rural banking and microfinance; and (vii) the focus on agriculture-based public-sectors support [127]. The approaches related to sustainability in agricultural sectors around the globe have been regarded to be utmost important in the improvement of issues associated with food-security and nutrition [4]. In a study, the authors have analyzed the determinants for sustainable production of wheat in "Golestan Province (Iran)", and found the "technical-knowledge" as having maximum influence on sustainability. They further suggested for future policy-makings for the improvement in farming based processes leading to sustainability [145]. Over the last fifteen-years, a significant eagerness has been found among the research-communities, practitioners, and funding-agencies to use a "Human Centered Design" approach in order to guide in developing technology-based solutions for the developing civilization with regard to their socioeconomic difficulties [6, 46, 182]. Small-scale farmers in "sub Saharan Africa" account for about thirty-three million with 80% of regional farms, and contributing to 90% of food-production in some nations [181]. Efforts have been made earlier in the development of technologies to support the farmers' primarily focusing on mechanization by promoting animal-traction (e.g., use of oxen) or/and tractors [13]. An earlier study included a discussion of the methodological decisions with regard to sustainability in agriculture including the sustainability-assessment scale and data-collection instrument, the sub-indicators within each-dimension, the assessment criteria to sustainability-level of farms relating to each sub-indicator, and the information synthesizing modality [44]. The outcomes of sustainable agriculture can be positive in improving food-productivity, reducing pesticide-uses and maintaining carbon-balances [125].

Sustainable developments in agriculture have been most essential concern for the global advancement [160], and acknowledged widely as an urgent requirement in the development of sustainable agricultural production-systems [28]. However, different approaches are encompassed with this ambiguous term of sustainable agriculture [54], with several definitions indicating it to be varying with people's aspect to different things [153]. At present, the sustainable agriculture is regarded as a reality necessary aspect [168]. Although the sustainable agriculture does not refer to any arbitrary-concept, but requires the contextual adaption of sustainable agriculture's definition [60, 63, 125, 151]. It becomes essential in distinguishing "goal-prescription" and "system-description" concepts to reveal different sustainability based understandings [54], as it affects about the perception of sustainable agriculture, possible assessment approaches, and methods as well as indicators used. The current projection on the world's population was estimated to be '9.8-million in 2050' and '11.2-million in 2100' [162]. Thus, the planet should be capable of producing and delivering adequate, better quality-food to the coming humanity [173]. Although the agricultural productivity has been increased with the evolution of technology, but has significantly amplified the environment-related footprint in agriculture by resulting of a number of environmental-impacts with the extensive uses of pesticides, fertilizers, water, and alterations in land-use, etc. [12]. The environment-related issues in agricultures have drawn the attentions of the scientific-community towards the sustainability in agriculture without having yet reached any kind of compromises [9,27]. However, the sustainability in agriculture should at-least address three basic-pillars of 'sustainable-development' by appraising simultaneously economic, environmental, and social issues related to the practices involved in agriculture [164], although several tools and methodologies have been developed in this regard [19,28]. The participation of stakeholders helps to determine the sustainability levels [81]. For implementing sustainable agriculture in practices broader approaches addressing different dimensions and stakeholders are of major concern, with the requirements of different action areas including institutionalization, development in assessments and systems, building of education in addition to capacity, and political as well as social supports [148]. With the help of "Quality Function Deployment" technique in addition to the ergonomics principles' concept, Jain Et al. have investigated the hand-tools used in agriculture and other areas [67]. For the purpose of encouragement in adopting organic-farming practices, the promotion of natural-resource conservation acts as key-pathway in improving the environmental sustainability of agricultural-systems. However, the farmers' adoption of supplementary farming techniques was found to be influenced by their accessibility to information and resources [85, 134, 178], risk-perceptions and requirements in maintaining beneficial operations [25]. Thus, in order to increase the technology adoption practices in agriculture, a number of challenging pressures need to be managed with appropriate strategies. Though little-extent of workforces are utilized in cultivating, but higher percentages of all workplace related fatal-accidents occur in the farming sectors. The "occupational health and safety (OHS)" issues are largely dealt with varying ranges of 'health and safety' issues apparent to hazards in workplaces with miscellaneous associated programs, policies and practices. The surveillance programs in view of the occupational health issues in agriculture help in providing earlier recognition of work-related indications of infirmity among the farmers and their community, such that suitable anticipatory-measures can be under-taken for the improvement in health and safety [157]. For the moral, economic and legitimate purposes of perspectives, OHS has been regarded as one of the most essential issue requiring appropriate commencements for the working-groups, employers in addition to the government all around the world. In addition, in the modern-segments as well as in agriculture-based businesses, the OHS has turned into a notable agenda for the overall-concerns. Moreover, the ranking of agriculture has been among the top three occupational-groups representing major perilous in terms of work-related injuries, illnesses, and fatalities, as declared by the "Centers for Disease Control and Prevention" earlier [18]. Thus, for ensuring of the farmers' prosperity as well as the agricultural sustainability, more emphasis has been a prime-requirement on the OHS issues within these sectors to have a long-haul positive-effect on nation's economy-levels [72]. With regard to the qualitative and community based participatory-approaches of small-scale women vegetables' cultivating farmers, it was proposed for a culturally suitable as well as sustainable intervention strategy for the improvement in the productivity in view of OHS practices in West-Africa provinces [166].

Agriculture has been unexpectedly a dismissed division throughout the world. Usually, everyone inclines more and more towards pleasant and mechanized life. The human-centred improvements are progressively pulled-in towards the mechanized divisions. Farming has been an old customary-business since the past-decades, yet simultaneously it has enormous non-beneficial business-fragments. However, the work-related security and safety has become significant issue for the cultivating experts' conversation. The systems associated in field-related works in extraordinary climates, exposures with synthetic-compounds like pesticides and composts, exposing to soils, dusts, and animals, bacterial contaminations, injuries owing to the un-safe use of hand-tools, and musculoskeletal disorders (MSDs) have been becoming more significant issues for every agrarian-specialists. In executing various agriculture-based operations, starting from preparation of lands to post-harvest operations, the agriculture workers play more crucial roles throughout the world. The farm-workers are normally found of utilizing different types of farm-related tools and equipment in order to accomplish different activities associated with crop-growing. However, the efficient use of these devices requires a good-knowledge of usage, in addition to proper design of all the equipment to enhance the work-related efficiency and safety-levels' of farmers. Although, the farmers working on farms have adequate understanding of the fact that the tools and equipment they use may pose serious and dangerous impacts on them if not used properly, but unfortunately, a lot of farmers are getting injured due to their carelessness, lacking-of-knowledge about the utilizations of tools. In some cases, the injuries or accidents are beyond the control of the farm-workers, which are caused owing to the defective as well as in-effective design of farm-based tools and equipment. The exposures to agro-chemicals, poor-physical working-conditions, psychosocial stresses and poor-ergonomics, the farmers have been reported of attributed to various work-hazards (White and Cessna, 1989). The farm-workers need to work on a daily-basis in out-doors for nourishment creations, and all the more frequently they perform rehashed and relentless physical-exercises for extended time-periods in both un-comfortable and awkward work-postures [128]. Giuffrida Et al. have revealed that heavy physical-related workloads in addition to ergonomically poorer work-conditions act as the pre-dominant factors causing in MSDs and work-related injuries [45].

Farming has been characterized as the occupation relying on farm-related awareness-skills of individuals and capabilities of doing repetitive and complicated jobs [102], which skills are essential for the improvement in the performances and abilities of individuals, in addition to the associated safety-levels in workplaces. Non-appearance of any of these expertises can lead in injuries of the farm-workers [174]. The farm-related accident-rates have been revealed of not diminishing, but with the occurrences of similar accidents every-year [59]. A number of conservative farm-related devices have been revealed of locally produced by the use of accessible materials, such as woods, stones and/or irons [77]. Nilsson Et al. have investigated the feedbacks obtained from "223 injured farmers", who were assembled by the "Swedish Farm-Registry" as a component of a survey sent to 7,000 farms by the "Swedish University of Agricultural Sciences and Statistics", Sweden in 2004. This data indicated no huge contrast of injuries achieved between the age groups, yet that senior farmers seemed to encounter the evil impacts of their injuries. This investigation uncovered the hugeness of urging senior farmers to hold-up under at the top of the priority list that their bodies are never again as young and strong as before-hand. All age group of farmers ought to clearly be cautious and consider the risks drew in with their work, yet since developing bodies expect longer to recover, senior farmers probably ought to be substantially more attentive and review their work condition and work environment, remembering the ultimate objective to keep-up a vital good way from injuries during the keep going extensive stretches of their working life. By then, it was endorsed to instruct senior farmers about the threats of injuries causing hurt as a result of their age [108]. The absence of ergonomic contemplations in the design of hand-tools and equipment, lack-of-skills, absence of the information on well-being measures, negligence of farmers, and un-favourable conditions can result in agriculture-based injuries as well as accidents [94,95]. Although, a number of studies exist by considering the injuries in the agricultural sectors worldwide, but the studies on agriculture-based injuries due to hand tools and equipment in particular are limited to a few. For instance, different perceived body effects with the use of a hand-tools by any person within an environment that were suggested as comfort, discomfort or no feelings [171]. MSDs were reported of occurring due to the perceived discomfort in using hand-tools for longer-term [52]. Patel Et al. have stated that owing to the non-availability of compiled information on agricultural injuries in nationwide, currently there was a lack of study on agricultural injuries from developing countries [121]. The awkward working postures, high rate of doing work, and deficiencies in the design of hand tools, were reported to cause cumulative musculoskeletal strains and injuries in farm activities [176]. Caffaro Et al. have investigated the knowledge of safety-pictograms used in agricultural machinery in a sample of farmers, and recommended of specific training-programs to draw-attention to safety-pictograms and to ingrain their significance [16].

The lesser technically advanced sector workers (i.e. handicrafts, agricultures, constructions etc.), especially involved in consistent postures and repetitive manual tasks, were reported of suffering of various work-related problems because of the factors such as individual, work characteristics and tool-related factors [26, 37, 68, 91, 113, 137, 180]. Although different social-ecological system's frameworks for complex-problems exist, but they differ mainly with respect to the structural as well as contextual criteria, including the social and ecological system's conceptualizations and interrelations among them [10]. In the Indian context, the waste-generation rates have been reported to be increasing with the emerging "inhabitants and urbanization" [118]. The positive impacts can be achieved on "environment, society and human-capital" through sustainable agro-ecosystems, while diminishing of such assets occur through unsustainable systems [126]. For the sustainable-development, the need-based agricultural tools and equipment design based on the ergonomic aspects would have a direct multiplier-effect on the socio-economic farmers' transformation [120]. A study was made by considering the main-causes of agriculture-based injuries with the farmers in "Panchagarh (Bangladesh)", and it was found of about 67% injuries due to hand-tools, and remaining 33% due to machinery as well as other sources [117]. Based on the investigation made on different harvester's vibrations at both idle and full-load conditions, it was observed of the "traumatic-vasospastic-diseases" to be appeared after 0.7-7.1 years for the left-hands, in 10% of the exposed population, and it appeared after 1.0 to 4.7 years in the right-hands' of operators who used on continuous-basis [17]. Based on a study, an ergonomic-mismatch prompts numerous item dissensions and disappointments with the present agricultural segments requiring of greater comprehension of ergonomics. Dominant-part of the provincial population was actively associated with farming sectors, and at the same time the farmers having little possessions were found to do a large portion of the farming exercises by utilizing manual-techniques, which resulted in huge wastage of human-work, and thus bringing-down the yield-per-capita-workforce [34]. Authors have revealed that the farm machineries and tools associated vibrations make the farmers to more often suffer from back pains, and pains in their shoulders, arms, and hands, respectively. Moreover, it has been accounted for 33% of the injuries that makes farmers to avoid cultivate works were sprains and strains, while a quarter were due to back injuries [170]. From a study focused on the women workforce engaged in tea industry in Assam, the musculoskeletal issues were reported at different body parts because of repetitive and awkward postures by utilizing the existing basket. Subsequently, with the modification of the basket in light of anthropometric information, a noteworthy decrease in inconvenience at various body parts were reported [7]. An investigation was made on farm women during the weeding activities on hill-farms by using traditional tools as well as three modified and improved weeding tools according to anthropometric information. Further, the improved tools were provided with convenient handles and made light in weight with sharp inward edges. The relative-appraisal between the utilization of conventional and enhanced apparatuses demonstrated better outcomes as far as pulse-esteems [69].

The agricultural sectors not only supplies food and nourishment as well as help in utilizing various labourers [103]. Agri-business has been perceived as the most perilous industry with a high-rate of MSDs in all over the countries. The utilization of ergonomic methodologies in agricultural appliances configuration was reported to be additionally restricted to a couple [177]. As a result, the misuse in the accessible-assets in addition to the innovations at ideal-level by proper utilization of best ergonomic-practices in the farming sectors has been an exceptional requirement to improve the efficiency. In a study, the issues of the utilization of power-tillers for various agricultural activities by the farmers was considered, and it was seen that abnormal-state of vibrations from the power-tillers was transmitted from the handles to hands, arms and shoulders, and thus by making early-exhaustion of the operators. However, for decreasing the magnitude of vibrations, three materials were utilized for mediation improvement like polyurethanes, rubbers, and blend of polyurethanes and rubbers. It was additionally discovered that the greatest decrease in vibrations were accomplished with the use of elastic when contrasted with polyurethanes, and blend of polyurethanes and rubbers [20]. Three sorts of hazard-factors has been distinguished, which can be considered in the survey of the work-related MSDs as: "Physical factors e.g. continuous & un-comfortable postures, repetitive-movements, forceful-activities, vibrations of hand and arms, vibrations of entire-body, mechanical-pressure, and cold"; "Psychosocial factors e.g. work-rate, work or rest cycles, task-demands, social-support and job-uncertainty"; "Individual factors e.g. age, sexual-orientation, sport-exercises, proficient-exercises, recreational-exercises, residential-exercises, tobacco or liquor utilizations, and earlier period work-related MSDs", respectively [111].

Distinctive ergonomic assessment tools are utilized to assess the ergonomic danger of work or task. For example, the “Quick Exposure Check (QEC)”, “Rapid Upper Limb Assessment (RULA)”, and the “Rapid Entire Body Assessment (REBA)” are all the more prevalently utilized ergonomic risk assessment tools that measure the ergonomic dangers/risks of both lower and upper parts of the human body. The RULA is utilized to delineate the acceptability of different tasks as well as postures, and recommends whether the assignment or posture is worthy or should be explored further or should be changed before long in light of RULA score values. Considering various variables and user data, RULA makes the postures examination in light of the parameters such as distance, weight and frequency. RULA was developed to show a quick measure of work-related musculoskeletal disorders (WRMSDs) in which the worker performs work with constant postures, and the work related upper limb issue were for the most part reported. RULA was broadly used to evaluate the postures, forces and movements related with different tasks and the outcomes were shown as risk scores going from one to seven, where more prominent levels of clear risk were demonstrated by higher score values [88]. In order to optimize different human-postures, the RULA analysis technique was discussed for accomplishing better designs, satisfactory items and workplaces [132,142]. Dube Et al. have used RULA tool for an ergonomic evaluation of working postures of Indian farmers. The different processes considered were seeding, fertilization, and weeding, and moreover, based on the obtained RULA scores, different activity-levels were recommended accordingly for the working methods [35]. For the evaluation and analysis of the postures in working and the workloads, the method by the “Finish steel industry” such as the “Ovako Working-Posture Analysing-System (OWAS)” has been developed [75,76], and this method was found its successful application in the ergonomic field [58]. In six tea-factories, forty-eight workers were considered to analyze their postures by the use of methods such as “REBA and OWAS”. Moreover, 75% of different postures of the workers were reported of needing corrective measures. Whereas, 34% of different postures were reported of at high and very high risk levels on the basis of results obtained by OWAS [155].

The multi-criteria decision-aid methods are generally used to assess decision-options in agricultural-systems and to design models for assessing sustainability [90], but few studies explain the use of fuzzy-based approaches for sustainability assessment. Transition towards sustainable development is very much essential to achieve agricultural-systems’ sustainability [112]. For this purpose, the assessment of sustainability provides a significant-aid [124], which has been developed for supporting in agricultural decision-making [41]. These developments have resulted in different-tools, ranging from the farm-levels to other emerging-levels [9]. A number of studies were based on meta-analysis, or categorization of tools for sustainability assessment [9, 29, 41, 42, 43, 51, 92, 107, 150]. Liu Et al. have reported of groundwater depletion as the prime environmental problem especially in “Shandong Province in China” to be warning for sustainable development [84]. The understanding difficulties in the relationships between agriculture and sustainability have made the researchers for conceptualization and evaluation of agricultural sustainability from various research-perspectives [47, 54, 133, 134, 136, 152, 153]. Despite of diverse thoughts, the definitions of agricultural sustainability lies with the consistency and denotes three key features to be achieved: social-acceptability, environmental-soundness, and economic-viability [130, 184, 185]. Different studies on the establishment and achievement of farm-level's sustainability in agriculture have found of various significant factors influencing the agriculture, such as inorganic-fertilizer patterns and chemical-pesticide uses, availability of ground-water, land-cultivation modes, and farmers' environmental-consciousness [1, 30, 140]. Owing to the agricultural importance in providing foods, fibers, oils, fuels and shelters for human-beings, the sustainable development of these sectors is very much essential [55,56,116,119]. The 'sustainable intensification' by the use of smart-technologies helps in agricultural productivity enhancement with lesser environmental damages and more social advantages [50], and have been widely promoted in "Sub-Saharan Africa and South Asia" in order to support the small-scale farm community [73,149]. In the developing countries, two types of farm mechanization have been observed, such as incumbent-mechanization characterized by the use of large machineries suitable for flat-lands, and alternative-mechanization characterized by smaller machineries like locally or/and household-owned animal-traction, and hand-tools suitable to reduce drudgery on hill-side farms [8]. Related to the technology-transfer paradigm of agriculture-based innovations, very few studies were found in assessing innovation in agricultural mechanizations [5, 100, 154]. Moreover, four-dimensions with regard to responsible-innovation, such as "anticipation, inclusion, reflexivity and responsiveness (AIRR)" have been revealed to be more common in guiding the developments related to technology [15, 36, 114]. The economic and social determinants of farm-based systems' sustainability are significant in various developing countries, as one of the major livelihood source-of-supports in these countries is agriculture [129]. For the prevention of farm-related injuries, proper designs of ergonomically fitting agricultural hand-tools are essential [117]. The barriers in the path development towards sustainable agriculture that requires more efforts include pressures of population, subsistence-agriculture, rural-poverty, depletion of natural-resource with importance on deforestation, land-degradation, decreased productivity, resource-rich/urban-biased policies, and gender-disparities [131]. The emerging developments of "artificial intelligence (AI)" need to be supported by the necessary regulatory-insights to the AI-based technologies for enabling in sustainable developments [172]. Devkota Et al. have focused on the small-scale agriculture mechanization for sustainable-development of agricultural sectors in Nepal's hill-sides as well as mountains, and revealed that the mechanization of small-holder farms in the hill-sides and mountains in Nepal to be neglected since the late 1960's with the mechanization policy based on the flat-areas only [31].

6.2 Reduction of physical-stresses in workplaces through minimization of ergonomic risks and work-related MSDs by the application of "Internet of Things (IoT)" in agriculture

In view of the work-related stresses and fatigues involved in workplaces, several modernized tools and agriculture-based equipment have been produced by considering the prime necessity as well as requirements of farm-workers for the reduction in the operators' drudgery-levels. By applying the features of "Internet of Things (IoT)" in the agriculture-based tools and equipment, diverse range of significant improvements can be further enhanced. For example, most of the crop-collections in the agricultural fields are normally carried out with the help of manual-labour by using sickles differing in shapes and sizes with the concerned regions' in the world. Nag Et al. have given emphasis on the design-parameters of nine different types of sickles, and observed the cutting-edge geometry to be effectively contributing in their implementations [104]. Mishra Et al. examined the weeding-effectiveness of devices along with weeding-actions performed by the farm-ladies who used the traditional as well as newly introduced tools. They reported of higher field-capacity of 0.07 ha/h with the use of the improved-sickles in comparison to normal-sickles [98]. By developing a manually operated reaper that required 20 man-h/ha, Chavan Et al. have found the cost of harvesting to be Rs. 1250.4/ha as compared to the traditional method of harvesting that accounted for a cost of Rs 2000/ha [22]. With the concept of a reaper for cutting the soybean-plants for two-consecutive rows, Shalini Et al. have designed a self-propelled reaper including a 3.5-hp diesel-engine, pulley and belt drive, collective mechanism with a cutting-bar. The transmission of engine-power was to the cutter was obtained through pulley and belt arrangements with scissoring type of motion for crop-cutting. The labour requirement was reported to be 20% in comparison to manually harvesting techniques [144]. In an investigation, the author improved brush-cutter that was initially operated by internal-combustion engine, into an electric brush-cutter with a DC-motor as power-source. Additionally, a Li-ion battery and an electronic control-board was used for speed-control of DC-motor in addition to circuit-protections' provisions [23]. Vora Et al. have reported of financial savings of "63.30% and 43.84%" associated with costs by the use of "mini-tractor mounted reaper as well as self-propelled reaper" over the conventional-methods of crop-harvesting by sickles [175]. Similarly, Hossain Et al. have revealed of savings about 97.50% of average-time, 35.00% of associated costs, and 2.75% of grains' saving by the use of combined harvesters over manual-methods [61]. Noby Et al. reported of better technical and economical performances of a modified-BAU self-propelled reaper than the existing-BAU self-propelled reaper [110].

Most of the objects gets connected with sensors and/or controlled remotely through the use of IoT across existing-networks improving the overall efficiency in addition to resulting in more accuracy as well as economic-benefits with considerable reduction in human-interventions. The applications of IoT can be evolved "between the peoples, between people and things in addition to between things and things". Higher accuracies in agriculture can be obtained through IoT enabling the items to be controlled remotely over the framework of existing-systems, thus bring-about improved-effectiveness and financial-advantages. Different studies have been carried out in context with the successful application of IoT in agricultural sectors [33, 70, 80, 99, 109, 122, 146, 163, 167, 183]. The merits associated with IoT-based agricultural machineries are as illustrated in Figure 6.1.

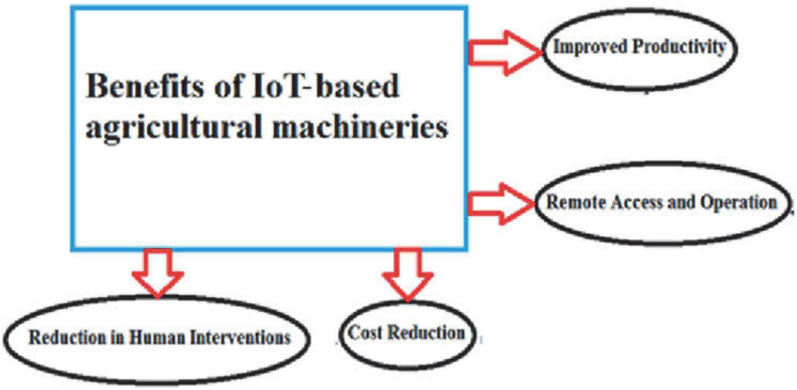

Fig. 6.1: Merits associated with IoT-based agricultural machinerie

6.3 Methodology of Research

This research was carried-out by in-depth review of literatures based on the existing agricultural systems and possible innovative benefits of utilizing IoT in agriculture, and discussing with the experts from various fields of expertise.

On the basis of the opinions of six-experts from different regions of the world (Table 6.1), subsequent decisions were taken for further analysis of the agriculture-related risks associated with ergonomic as well as MSDs with regard to the agricultural tools and equipment, and the benefits of utilizing IoT in agriculture to avoid or minimize such deficiencies.

Tab. 6.1: The participated experts in decision-making

Area of expertise	Gender		Education-level		Country
	Female	Male	Doctorate	Non-Doctorate	
Agriculture-based sectors	0	3	3	0	Odisha (India)-2; Nepal-1
Industrial-engineering	0	2	2	0	France-1; Czech-Republic (Europe)-1
Environment-sector	1	0	1	0	Nepal

Initially, the "strength, weaknesses, opportunities as well as threats (SWOT)" analysis was used for the evaluation of the "existing agricultural systems without the aid of IoT" and the "IoT-based agricultural systems", on the basis of the experts' opinions. Moreover, the "Step-wise Weight Assessment Ratio Analysis (SWARA)" method was used for ranking of the deficiencies in the existing agricultural systems without the aid of IoT.

Further, by the use of the fuzzy-logic in fuzzy tool-box using "MATLAB Version-2013" [87], the agricultural sustainability evaluation was done by considering the MSDs along with ergonomic OWAS scores as input, and the agricultural sustainability as the single-output. The sequences of steps followed were as shown in Figure 6.2.

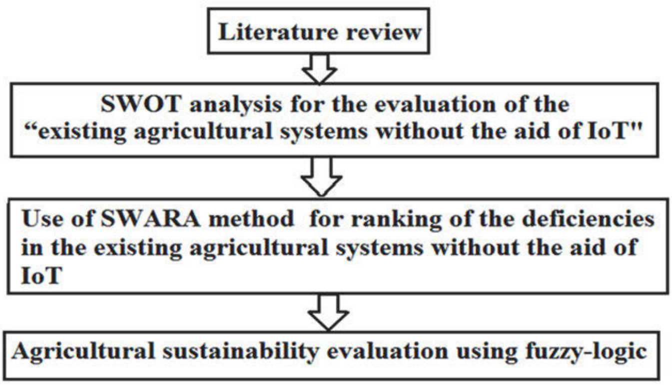

Fig. 6.2: Sequences of steps followed

6.3.1 Strength, Weaknesses, Opportunities and Threats (SWOT) Analysis

SWOT analysis has been used as an evaluating approach for strength, weaknesses, opportunities in addition to the threats in different studies, such as for developing as well as implementing of eco-systems [14], in energy-based corporate governance-systems [161], in the analysis of the development-process of urban transportation-systems [57], in Bangladesh based integrated aqua-farming systems [147], and so forth. In this study, the SWOT analysis was used for the evaluation of the "existing agricultural systems without the aid of IoT" and the "IoT-based agricultural systems", on the basis of the experts' opinions.

6.3.2 Use of SWARA method

The "Step-wise Weight Assessment Ratio Analysis (SWARA)" method was developed by Keršuliene Et al., which helps to determine the weight values in a decision-making process [78,97]. Different studies have likewise prescribed the SWARA strategies that can be utilized not exclusively to decide the weight of criteria, yet additionally to totally tackle MCDM issues. The SWARA method was suggested for practical implementation of specialized decision support systems, to solve legislative tasks and to assess dispute resolution from economic, social and others perspective [78]. Zolfani Et al. have proposed an extended version of SWARA for criteria evaluation in decision making process [186]. As SWARA analysis included two important steps such as prioritization of the criteria by experts as first step and calculation of relative weights as second step; hence in order to achieve a qualitative decision-making process, the reliability evaluation of the ideas of experts into the first step of SWARA analysis was recommended. The "simple multi-attribute ranking-technique (SMART)" and the SWARA method were used in a case study of "Swiss Re Tower" to assess its vulnerability to blast [105]. The combination of both the Delphi technique and the adapted SWARA method was effectively applied in view of the sales managers to create a set of evaluation criteria as well as to define the relative weights of such criteria [74].

Considering the deficiencies in the existing agricultural systems without the aid of IoT leading to the occurrences of ergonomic as well as MSDs risks in the agricultural sectors of the developing countries, the SWARA method was utilized in the present analysis for positioning of the criteria and sub-criteria based on the relative-importance, and also to compute their weights. Moreover, as the SWARA method was used for ranking of the deficiencies in the existing agricultural systems without the aid of IoT.

Based on the experts' opinion on the significance of criteria involved in the present decision making process, the list of criteria was formed. Subsequently, the following steps were followed as defined by Keršuliene Et al. (2010) and Stanujkic Et al. [78, 156].

Step-1: Criteria were sorted in accordance with their significance.

In this step the criterions were ranked by the experts according to their relative-significance; where the most-significant was placed in the first-place, while the least-significant was placed in the last-place.

Step-2: The average values' relative-importance (R_j) were determined.

In this step the significant-values were determined, which was started from the second ranked criterion, i.e. how much the criterion (D_j) was more important than the criterion (D_{j+1}).

Step-3: The coefficients (c_j) were calculated as follows:

$$c_j = \begin{cases} 1, & j = 1 \\ R_j + 1, & j > 1 \end{cases} \tag{6.1}$$

Step-4: The recalculated weights (w_j) were determined as follows:

$$w_j = \begin{cases} 1, & j = 1 \\ \frac{w_{j-1}}{c_j}, & j > 1 \end{cases} \tag{6.2}$$

Step-5: The relative-weights (W_j) of the evaluation criteria were determined as follows:

$$W_j = \frac{w_j}{\sum_{k=1}^{n} w_k} \tag{6.3}$$

Where, n denoted the number of criteria.

The criteria and sub-criteria obtained from the review of literature and experts' views were illustrated in Table 6.2.

Tab. 6.2: Selection of items under different dominant-factors (criteria)

Factor (Criteria)	Source	Sub-criteria details
Technological-aspects (D_1)	[53]	Lack of appropriate training on emerging technologies ($D_{1\text{-}1}$)
		Lack of adequate knowledge about the negative impacts by the use of existing agricultural tools and equipment ($D_{1\text{-}2}$)
		Lack of adequate awareness about latest technologies among the farmers ($D_{1\text{-}3}$)
Environmental-	[138]	Exposing to agro-chemicals and pesticides during fertilization

Factor (Criteria)	Source	Sub-criteria details
aspects (D_2)		process that can lead to occupational risks ($D_{2\text{-}1}$)
		Getting in contact with plants and animals resulting in health-related problems ($D_{2\text{-}2}$)
		Exposing to diesel-smells and dusts that can lead to respiratory-problems ($D_{2\text{-}3}$)
Health-aspects (D_3)	[138]	Hard and repetitive agriculture-based tasks resulting in musculoskeletal-disorders ($D_{3\text{-}1}$)
		In-correct working postures resulting in musculoskeletal-disorders ($D_{3\text{-}2}$)
		The noisy agriculture-based equipment that can cause hearing-problems ($D_{3\text{-}3}$)
Personal-aspects (D_4)	[53]	Inadequate expertises influencing the farm-activities ($D_{4\text{-}1}$)
		Inadequate supports from governmental and other agencies ($D_{4\text{-}2}$)

6.3.3 Fuzzy-model development by the use of fuzzy-logic

Vagueness is usually described by fuzzy-logic in the control and decision-making that involves uncertainties. Fuzzy-logic has been successfully applied in several applications involving evaluation of pain-intensity rating-scales [3], soil-assessments [49], life-cycle impact-assessment [39], fitness classification of crops and agriculture-based lands [101], soil quality-index as well as landfill-siting in agricultures [135], and in sustainability-evaluation of winter-based Iranian wheat [62], etc.

Moreover, a modified "Likert-scale" based on fuzzy-set theory was developed in earlier studies in which the data-collection process and the assignment of concerned respondents can be made based on the degree of membership associated with the agreement-levels or disagreement-levels [82, 83]. Similarly, authors have developed a fuzzy expert-system in a study by the use of MATLAB software, for the diagnosis as well as treatment of MSDs in wrists [2]. In this study, the associated MSDs and ergonomic OWAS scores were considered as inputs, while the agricultural sustainability was taken as output for the development of fuzzy-model.

6.4 Results and Discussion

6.4.1 SWOT analysis

In this study the SWOT analysis was done for the evaluation of the "existing agricultural systems without the aid of IoT" and the "IoT-based agricultural systems", on the basis of the suggestions of experts (Table 6.3).

The possible strengths associated with the IoT-based agricultural systems included "increased efficiency; increased farm-productivity; operational by less skilled operators once trained properly; reduced overall-weights; lesser human-intervention; and noise-less operations; respectively.

Tab. 6.3: SWOT analysis of the "existing agricultural systems without the aid of IoT" and the "IoT-based agricultural systems"

Existing agricultural systems without the aid of IoT	Strength	Wider availability More accessibility Some small products manufactured by local manufacturers
	Weaknesses	Requirement of skilled operators for large and heavy machineries Higher initial-cost for more sophisticated machineries Higher depreciation-costs for majority of agriculture-based machines and equipment
	Opportunities	Farmers friendly More productivity with the use of more sophisticated machineries Lesser overall operational-time
	Threats	Consumption of more fuels Un-affordable by small-scale farmers
IoT-based agricultural systems	Strength	Increased efficiency Increased farm-productivity Can be operated by less skilled operators once trained properly Reduced overall-weights Lesser human-intervention needed Noise-less operations
	Weaknesses	Lesser awareness among the farming community in the developing countries Lesser supports by respective governments and competing authorities
	Opportunities	Can be used in remote areas

	Reduced operational time and efforts Possibilities of remote operations More coverage in lesser time Higher incomes to the farming community
Threats	May have higher initial-costs Requirement of adequate training and awareness

6.4.2 SWARA based ranking of the deficiencies in the existing agricultural systems without the aid of IoT

The four most important-criteria with regard to the deficiencies in the existing agricultural systems without the aid of IoT that were obtained for this study included: "Technological-aspects (D_1), Environmental-aspects (D_2), Health-aspects (D_3), and Personal-aspects (D_4)", respectively (Table 6.2). Based on the SWARA method, different associated weights of all the concerned criteria as well as sub-criteria were illustrated in Table 6.4, Table 6.5, Table 6.6, Table 6.7, and Table 6.8, respectively.

Moreover, as suggested by the participated experts, the arrangement of all the criteria as well as sub-criteria were made followed by the calculations of the average values' relative-importance $(R|\quad|j)$ for all concerned criteria and sub-criteria.

Tab. 6.4: Measured weights of four-criteria

Criteria	Average values' relative-importance $(R\|\quad\|j)$	Co-efficient $(c_j = R_j + 1)$	Re-calculated weight $\left(w_j = \frac{w_{j-1}}{c_j}\right)$	Weight $\left(W_j = \frac{w_j}{\Sigma w_j}\right)$
D_1		1	1	0.315
D_3	0.19	1.19	0.840	0.265
D_2	0.18	1.18	0.712	0.224
D_4	0.15	1.15	0.619	0.195

Tab. 6.5: Measured final-weights for the sub-criteria of 'Technological-aspects'

Sub-Criteria	Average values' relative-importance	Co-efficient	Re-calculated weight	Weight	Final-weights
D_{1-2}		1	1	0.389	0.122
D_{1-3}	0.18	1.18	0.847	0.329	0.103
D_{1-1}	0.17	1.17	0.724	0.281	0.088

Tab. 6.6: Final-weights for the sub-criteria of 'Environmental-aspects'

Sub-Criteria	Average values' relative-importance	Co-efficient	Re-calculated weight	Weight	Final-weights
D_{2-1}		1	1	0.381	0.085
D_{2-2}	0.16	1.16	0.862	0.328	0.073
D_{2-3}	0.13	1.13	0.762	0.290	0.064

Tab. 6.7: Final-weights for the sub-criteria of 'Health-aspects'

Sub-Criteria	Average values' relative-importance	Co-efficient	Re-calculated weight	Weight	Final-weights
D_{3-3}		1	1	0.385	0.102
D_{3-1}	0.17	1.17	0.854	0.328	0.086
D_{3-2}	0.15	1.15	0.743	0.286	0.075

Tab. 6.8: Final-weights for the sub-criteria of 'Personal-aspects'

Sub-Criteria	Average values' relative-importance	Co-efficient	Re-calculated weight	Weight	Final-weights
D_{4-1}		1	1	0.541	0.105
D_{4-2}	0.18	1.18	0.847	0.458	0.089

Subsequent to all calculations made by using SWARA method, weights of criteria and sub-criteria along with relative-ranking of all the criteria as well as sub-criteria on the basis of their final-weight values were obtained as summarized in Table 6.9.

Tab. 6.9: Summary of the weights of criteria and sub-criteria of the model

Criteria and Sub-criteria	**Final-weights**	**Ranking of Criteria based on final-weights**	**Ranking of Sub-Criteria based on final-weights**
Technological-aspects (D_1)	0.315	1	
Lack of appropriate training on emerging technologies (D_{1-1})	0.088		6
Lack of adequate knowledge about the negative impacts by the use of existing agricultural tools and equipment (D_{1-2})	0.122		1
Lack of adequate awareness about latest technologies among the farmers (D_{1-3})	0.103		3
Environmental-aspects (D_2)	0.224	3	
Exposing to agro-chemicals and pesticides during fertilization process that can lead to occupational risks (D_{2-1})	0.085		8
Getting in contact with plants and animals resulting in health-related problems (D_{2-2})	0.073		10
Exposing to diesel-smells and dusts that can lead to respiratory-problems (D_{2-3})	0.064		11
Health-aspects (D_3)	0.265	2	
Hard and repetitive agriculture-based tasks resulting in musculoskeletal-disorders (D_{3-1})	0.086		7
In-correct working postures resulting in musculoskeletal-disorders (D_{3-2})	0.075		9
The noisy agriculture-based equipment that can cause hearing-problems (D_{3-3})	0.102		4
Personal-aspects (D_4)	0.196	4	
Inadequate expertise influencing the farm-activities (D_{4-1})	0.105		2
Inadequate supports from governmental and other agencies (D_{4-2})	0.089		5

*Final-weights of sub-criteria, $D_{4-1} = 0.541 \times 0.195 = 0.105$; and $D_{2-1} = 0.381 \times 0.224 = 0.085$

The SWARA ranking revealed that the most important-variables with regard to the deficiencies in the existing agricultural systems without the aid of IoT in the descending order included: "Lack of adequate knowledge about the negative impacts by the use of existing agricultural tools and equipment; Inadequate expertise influencing the farm-activities; Lack of adequate awareness about latest technologies among the farmers; The noisy agriculture-based equipment that can cause hearing-problems; Inadequate supports from governmental and other agencies; Lack of appropriate training on emerging technologies; Hard and repetitive agriculture-based tasks resulting in musculoskeletal-disorders; Exposing to agro-chemicals and pesticides during fertilization process that can lead to occupational risks; In-correct working postures resulting in musculoskeletal-disorders; Getting in contact with plants and animals resulting in health-related problems; and Exposing to diesel-smells and dusts that can lead to respiratory-problems"; respectively.

6.4.3 Fuzzy-logic Modeling for agricultural sustainability in context with MSDs and ergonomic OWAS Scores

The obtained "multi input and output (MIMO)" mamdani-type fuzzy-model as shown in Figure 6.3 consisted of two-inputs and a single-output for the evaluation of agricultural sustainability. The inputs were related to the risk factors associated with agriculture that included: "MSDs of farmers and ergonomic OWAS scores for performing different undesirable, awkward and stressful activities in agriculture" and the output was the agricultural sustainability. The MSDs of different-parts of the farm-workers' body were evaluated in-terms of "very-low, low, nil, high, and very-high" in the range of "1 to 5" depending on "standardized Nordic-questionnaire" used with a "five-point rating-scale" for the risk-levels' assessment of farmers [96].

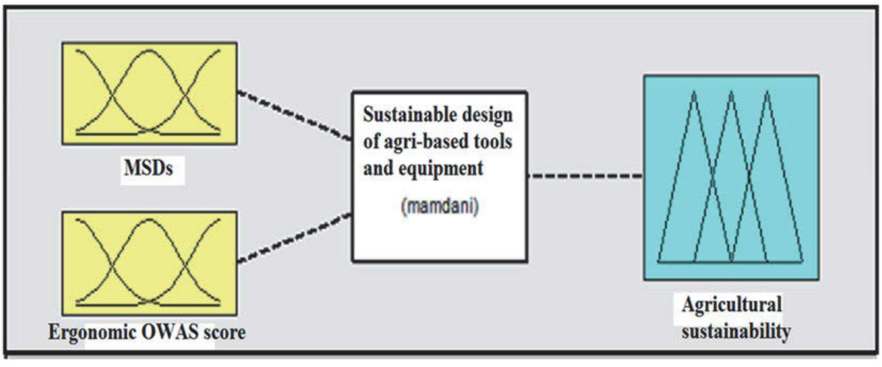

Fig. 6.3: Fuzzy-model with six-inputs and single-output

The input-data's fuzzification was accomplished with the assignment of linguistic-variables and each of the membership function's range-values for all the two-inputs constituting of the risk factors associated with agriculture that including "MSDs of farmers and ergonomic OWAS scores" for performing different agricultural activities, and the output as the agricultural sustainability. Based on the content in literature and suggestion of experts, trapezoidal-type membership-functions in the range-values of "1 to 5 (1= Very-Low, 2= Low,3= Nil, 4= High, 5= Very-High)" for MSDs, and in the range-values of "1 to 4 (1= No-Actions, 2= Actions in Near-future, 3= Actions as-soon-as possible, 4= Immediate-actions)" for ergonomic OWAS scores were taken for the two-inputs. Similarly, for the agricultural sustainability as output, triangular-type membership-functions in the range-values of "0 to 1" were taken that represented 0 as No and 1 as Yes. Then, the fuzzy-based rules for the development of the fuzzy-model were created accordingly.

The fuzzy-rules created were as follows:
1. If MSDs was "Very-low" and Ergonomic OWAS score was "No-action", then Agricultural sustainability was "Yes".
2. If MSDs was "Very-low" and Ergonomic OWAS score was "Action in Near-future", then Agricultural sustainability was "Yes".
3. If MSDs was "Very-low" and Ergonomic OWAS score was "Actions as-soon-as possible", then Agricultural sustainability was "No".
4. If MSDs was "Very-low" and Ergonomic OWAS score was "Immediate-actions", then Agricultural sustainability was "No".
5. If MSDs was "Low" and Ergonomic OWAS score was "No-action", then Agricultural sustainability was "Yes".
6. If MSDs was "Low" and Ergonomic OWAS score was "Action in Near-future", then Agricultural sustainability was "Yes".
7. If MSDs was "Low" and Ergonomic OWAS score was "Actions as-soon-as possible", then Agricultural sustainability was "No".
8. If MSDs was "Low" and Ergonomic OWAS score was "Immediate-actions", then Agricultural sustainability was "No".
9. If MSDs was "Nil" and Ergonomic OWAS score was "No-action", then Agricultural sustainability was "Yes".
10. If MSDs was "Nil" and Ergonomic OWAS score was "Action in Near-future", then Agricultural sustainability was "Yes".
11. If MSDs was "Nil" and Ergonomic OWAS score was "Actions as-soon-as possible", then Agricultural sustainability was "No".
12. If MSDs was "Nil" and Ergonomic OWAS score was "Immediate-actions", then Agricultural sustainability was "No".
13. If MSDs was "High" and Ergonomic OWAS score was "No-action", then Agricultural sustainability was "No".

14. If MSDs was "High" and Ergonomic OWAS score was "Action in Near-future", then Agricultural sustainability was "No".
15. If MSDs was "High" and Ergonomic OWAS score was "Actions as-soon-as possible", then Agricultural sustainability was "No".
16. If MSDs was "High" and Ergonomic OWAS score was "Immediate-actions", then Agricultural sustainability was "No".
17. If MSDs was "Very-high" and Ergonomic OWAS score was "No-action", then Agricultural sustainability was "No".
18. If MSDs was "Very-high" and Ergonomic OWAS score was "Action in Near-future", then Agricultural sustainability was "No".
19. If MSDs was "Very-high" and Ergonomic OWAS score was "Actions as-soon-as possible", then Agricultural sustainability was "No".
20. If MSDs was "Very-high" and Ergonomic OWAS score was "Immediate-actions", then Agricultural sustainability was "No".

The rule-viewer for the fuzzy-model was obtained as shown in Figure 6.4, which was further followed by the MATLAB-based final generated-surface of the model shown in Figure 6.5.

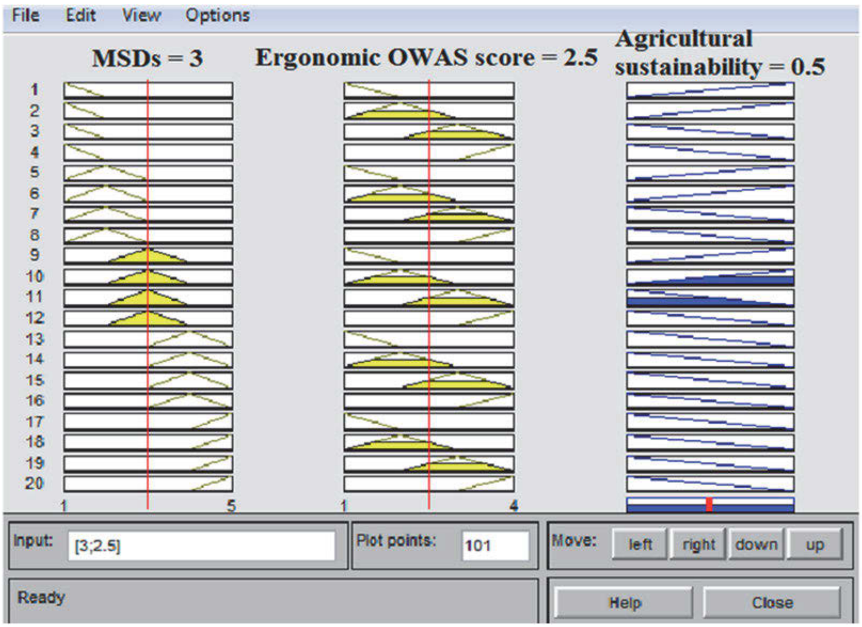

Fig. 6.4: Rule-viewer for the developed rules

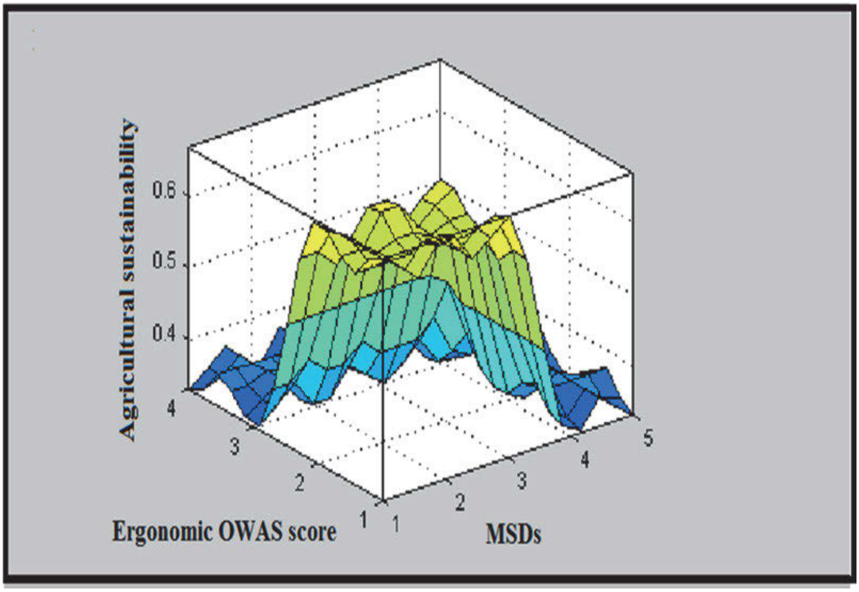

Fig. 6.5: Final generated-surface of the fuzzy-model of agricultural sustainability

6.5 Conclusion

Augmenting the farmers' connection with their corresponding workplaces is highly desirable. The enhancements in productivity, work-comforts as well as efficiency of farm-workers with considerable emphasis on their safety and well-being can be achieved by properly considering various ergonomic-aspects in the design-and-use of the agriculture-based tools and equipment. For the prevention of farm-related injuries, proper-designs of ergonomically fitting hand-tools are essential. The barriers in the path development towards sustainable agriculture that requires more efforts include pressures of population, subsistence-agriculture, rural-poverty, depletion of natural-resource with importance on deforestation, land-degradation, decreased productivity, resource-rich/urban-biased policies, and gender-disparities.

The emerging developments of "Internet of Things (IoT)" and "artificial intelligence (AI)" need to be supported by the necessary regulatory-insights to the IoT and AI based technologies for enabling in sustainable developments. Moreover, in view of the work-related stresses and fatigues involved in workplaces, several modernized tools and agriculture-based equipment have been produced by considering the prime necessity as well as requirements of farm-workers for the reduction in the operators' drudgery-levels. By applying the features of IoT in the agriculture-based tools and equipment, diverse range of significant improvements can be further enhanced.

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7 Conclusion

7.0 Introduction

One of the major sustainable foundation of economy has been regarded as agriculture [24], which plays significant-role for the economic-development on a long-term basis in addition to the structural-based transformations [23, 28, 39]. Most of the agriculture-based activities in the past were limited to productions of “crops and foods” [12]. On the other hand, the agriculture has been involved in the last two-decades for productions, processing, marketing and distributions related activities for “crops as well as livestock based products”, which serves as the basic-source of livelihood with subsequent GDP improvements [34]. Agriculture not only acts as national-trade source, but also helps in the reduction of un-employment, and provides raw-materials for other industrial-production activities by increasing the overall economy-levels [4, 7].

A variety of choices in addition to uncertainties are greatly concerned with agriculture. On account of the weather-variation from season-to-season, occurrences of fluctuations in the farm-based material-prices, soil-degradations, unviable-crops, crops’ suffocation by weeds, damages of crops by the use of pests, and climatic-changes, the farm-workers are required to cope with such incurred uncertainties. However, with the technological-advancements in this digital-world, the individuals have an extended thinking-process and are associated actively to combine normal-brains with artificial-brains through the application of different soft-computing techniques in agriculture leading to more accurate and faster computational results.

7.1 Benefits of the use of soft-computing techniques

The use of soft-computing techniques helps in modeling and analyzing of very complexity-based problems for which the conventional methods find difficulties in producing analytical, cost-effective, or complete-solutions [18]. The integration of both biological-structures and computing-techniques occur in case of soft-computing. Further, among different soft-computing techniques, the fuzzy-logic has been revealed to be an established method as one of the fundamental idea of soft-computing [46, 47]. For the achievement of robustness, tractability, the soft-computing techniques are mainly used, further it also provides low-cost solutions with a tolerance of uncertainty, imprecision, partial-truth, and approximation, which enables the soft-computing in solving problems in an analytical, cost-effective, or complete-manner than that of conventional methods. The improvements in soft-computing involve “combination or cascading or fusion” of different soft-computing techniques for improving system-performances over any conventional-technique like the neuro-fuzzy systems [20, 21, 41], which provides cost-

https://doi.org/10.1515/9783110745368-007

effective, high-performance, and reliable computing-schemes with more innovative-solutions [33].

In view of the present and future food-security, the sustainable crop-production has become most significant factor worldwide that can be achieved through innovative-technologies, more design-strategies for higher crop-yields with fewer resources and on lesser-occupied lands. For the sustainable food-systems, one of the major components is crop-production, but it is more sensitive to climatic-change. However, based on the present prediction of climate-based models, an increased level in temperatures as well as carbon-dioxide in atmosphere, changing-patterns in regional and global precipitations, and rise of the frequency and intensity of extreme-weather events will affect both quality as well as quantity of crops significantly over the next hundred-years [31]. Moreover, the advancement in the scientific-visualization together with computational modeling help the researchers in exploring and interacting with complex-agricultures, nutritions, and different climatic-data for the prediction of crops' response in diverse environments. This also helps in the design and development of strategies in order to meet the future yields as well as nutritional demands [8]. However, the soft-computing has been successfully applied in agricultural-and-biological engineering applications [10, 45]. The soft-computing based interests have also a steady increment in the last-decade. Higher advantages can be obtained with the application of the new technologies at the farm-levels, such as saving of 'work and money', enhanced productions, cost-reductions with minimal-efforts, and this in turn can produce more quality-foods with environment-friendly practices and procedures [9].

Considerable transformation processes have been occurring in the agricultural sectors through the introduction and use of latest-technologies, which will enable these sectors to move to the next-level of improved productivity in addition to higher farm-related benefits [17]. With the modern revolutions in agriculture throughout the world, the precision-agriculture has become an essential requirement for subsequent growth of agriculture [48]. In this context, the utilization of soft-computing techniques in agriculture-based analysis in addition to latest machineries with the aid of "Artificial Intelligence (AI) and/or Internet of Things (IoT)" can be more beneficial to the whole agricultural-systems.

7.2 IoT and AI applications for agriculture-based improvements

With the help of sensors and remotely operated devices, IoT help across the existing networks for the improvement in efficiency and resulting in more accuracy, economic-benefits and considerable reduction of human-interventions [2, 3, 5, 15, 19, 25, 36, 37, 38, 44]. The IoT based applications can be evolved "between the peoples"; "between people and things" and "between things and things". Moreover, higher accuracies in agriculture can be obtained through the utilization of IoT that can enable different items to be remotely controllable over the framework of existing-systems, thus this can bring about more significant as well as improved effectiveness and financial-advantages. For instance, Vasisht Et al. have discussed about "Farm-Beats system-design" by implementing IoT based platforms for data-collection with the help of diverse "sensors, cameras and drones" in agriculture [43]. In a review study made by Jawad Et al., the functions of "Wireless Sensor Networks (WSNs)" in agriculture as well as the classification and comparison of different "wireless communication protocols" have been discussed. This study was further followed with the energy harvesting-techniques that can be used in agriculture-based monitoring-systems [22]. Similarly, Lakshmi and Gayathri made combination of "image-processing as well as IoT" for monitoring the plant, and for subsequent collection of the environment-related factors, such as temperature and humidity [26]. Other studies included: IoT based smart-irrigation systems [35]; use of IoT and "Information and Communication Technologies (ICT)" for management of farms and conservation of resources [29]; smart-greenhouse promoting in crop-cultivation with least human-interventions [6]; smart-farming with the implementation of IoT [42]; and IoT-based sensor-nodes powered by solar-energy for monitoring and controlling of the agricultural-fields [40].

The AI based systems are associated with both classical as well as modern approaches to solve problems related to the technologies of precision-agriculture. The expert systems are included with the typical classical approaches to AI for solving the problems. However, some of the modern approaches to AI include "artificial neural-networks (ANN), genetic-algorithms (GA), evolutionary-computing (EC), and agent-architectures (AA)", respectively [13]. Moreover, for optimal performances as well as to enhance the agriculture-based production and productivity with minimized human-interventions, the use of IoT and AI based implements in agriculture have been found to provide more intelligent-machines for different activities. Therefore, the application of soft-computing techniques along with the farm tools and equipment coupled with IoT and AI features become important contributions in agricultural sectors in view of the management of "soils, crops, diseases and pests-controlling activities" [14, 16, 32]. It also becomes imperative with the substantial global population-growth to review the agriculture-based activities with the goal to extend innovative-approaches for the sustainable as well as improved agriculture-based practices. Further in the worldwide agricultural sectors, introducing the IoT and AI can be enabled through more technological-advancements with the efficient use of soft-computing techniques for providing predictive-insights for agricultural activities like "interpretation and analysis of plantation as well as harvesting information by the utilization of soil-management data-sources including data based on weather-variability, temperature, soil and moistures, and crop performance-history [1, 11, 27, 30, 49].

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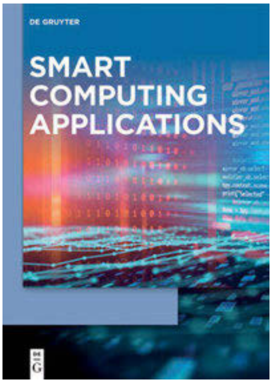

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