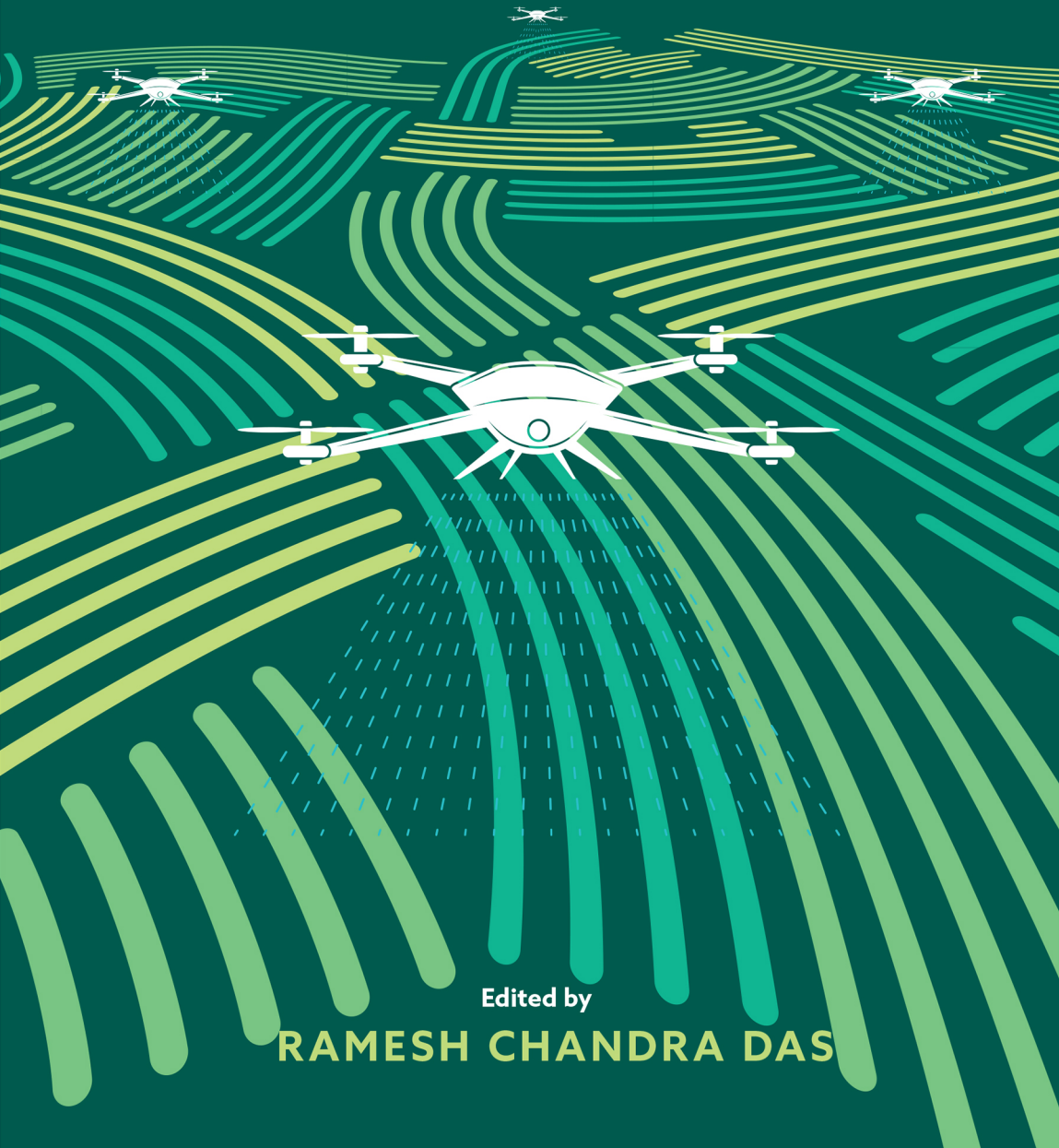


ARTIFICIAL INTELLIGENCE IN AGRICULTURE AND ENVIRONMENTAL SUSTAINABILITY

A GLOBAL PERSPECTIVE



Edited by

RAMESH CHANDRA DAS

Artificial Intelligence in Agriculture and Environmental Sustainability

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Artificial Intelligence in Agriculture and Environmental Sustainability: A Global Perspective

EDITED BY

RAMESH CHANDRA DAS

Vidyasagar University, India



United Kingdom – North America – Japan – India – Malaysia – China

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INVESTOR IN PEOPLE

The book is for my daughter, Anureema, and wife, Amrita

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List of Abbreviated Terms

Chapter 1

AI:	Artificial Intelligence
CAGR:	Compound Annual Growth Rate
GDP:	Gross Domestic Product
IoT:	Internet of Things
ML:	Machine Learning
SCI:	Supply Chain Integration
UN:	United Nations
UPL:	United Phosphorous Ltd

Chapter 2

AI:	Artificial Intelligence
AI4AI:	Artificial Intelligence for Agriculture Innovation
ANN:	Artificial Neural Networks
AR:	Augmented reality
CAGR:	Compound Annual Growth Rate
eNAM:	National Agriculture Market
GPS:	Global Positioning System
ICAR:	Indian Council of Agricultural Research
IIT:	Indian Institute of Technology
IoT:	Internet of Things
IoTAg:	IoT-enabled agricultural
LIDAR:	Light Detection and Ranging
ML:	Machine Learning
NIT:	National Institute of Technology
NITI:	National Institution for Transforming India
NLP:	Natural Language Processing
SLR:	Systematic Literature Review
SVM:	Support Vector Machines
VR:	Virtual Reality
VRT:	Variable Rate Technology

Chapter 3

AI:	Artificial Intelligence
DQN:	Deep Q-Networks

xii List of Abbreviated Terms

GIS:	Geographic Information Systems
KNN:	k-Nearest Neighbours
MSE:	Mean Squared Error
PCA:	Principal Component Analysis
SCRS:	Smart Crop Recommendation System
SVM:	Support Vector Machines
t-SNE:	t-Distributed Stochastic Neighbour Embedding

Chapter 4

AI:	Artificial Intelligence
AIPI:	Artificial Intelligence Preparedness Index
APAC:	Asia Pacific Accreditation Cooperation
cpl:	Cereals per land
ed:	environmental disaster
GDP:	Gross Domestic Product
IoT:	Internet of Things
ltp:	land temperature
rec:	renewable energy consumption
tp:	surface temperature

Chapter 5

AI:	Artificial Intelligence
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Chapter 6

AI:	Artificial Intelligence
NLP:	Natural Language Processing
GDP:	Gross Domestic Product
R&D:	Research and Development
IoT:	Internet of Things
ML:	Machine Learning
IT:	Information Technology
HR:	Human Resources
ROI:	Return on Investment
HEVC:	High Efficiency Video Coding

Chapter 7

AI:	Artificial Intelligence
CO ₂ :	Carbon Di-oxide
R&D:	Research and Development
SD:	Standard Deviation

Chapter 8

AECI:	Architecture-Engineering-Construction Industry
AI:	Artificial Intelligence
AIoT:	AI and IoT integration
AM:	Additive manufacturing

CCUS:	Carbon capture, utilization, and sequestration
CDR:	Corporate Digital Responsibility
CI:	Construction Industry
DTT:	Digital Twin Technology
PP:	Peer-to-Peer
UN SDGs:	United Nations Sustainable Development Goals

Chapter 9

AI:	Artificial Intelligence
AOC:	Air Operations Center
ICT:	Information and Communications Technology
JSAI:	Japanese Society for Artificial Intelligence
NSS:	National Security Strategy
OECD:	Organization for Economic Cooperation and Development

Chapter 10

AIDDEV's:	Artificial Intelligence Development Services
CI:	Continuous Integration
ESD:	Electrostatic Discharge
HED:	High Quality Energy Development
ML-XAI:	Machine Learning Explainable Artificial Intelligence
SVM:	Support Vector Machine

Chapter 11

AI:	Artificial intelligence
AQI:	Air Quality Index
EVs:	Electric vehicles
GHG:	Greenhouse gas
IoE:	Internet of Energy
IoT:	Internet of Things
IoV:	Internet of Vehicles

Chapter 12

AI:	Artificial Intelligence
CO ₂ :	Carbon Di-oxide
DL:	Deep Learning
ML:	Machine Learning
OECD:	Organization for Economic Cooperation and Development
SDGs:	Sustainable Development Goals
SoS:	System of Systems
SSA:	Sub- Saharan Africa

Chapter 13

AI:	Artificial Investment
BCSLM:	Bias-corrected scaled Lagrange Multiplier
BPLM:	Breusch–Pegan Lagrange Multiplier

xiv List of Abbreviated Terms

BRICS:	Brazil, Russia, India, China, South Africa
CD:	Cross-section Dependence
Chat-GPT:	Chat Generative Pte-trained Transformer
CO ₂ :	Carbon Dioxide
CO ₂ Eic:	Carbon dioxide emission from industrial combustion
CSD:	Cross-Section Dependence
DOLS:	Dynamic Ordinary Least Square
ECM:	Error Correction Model
ECT:	Error Correction Term
EDGAR:	Emissions Database for Global Atmospheric Research
EFT:	Ecological Footprint
FMOLS:	Fully Modified Ordinary Least Square
GDPpc:	Gross Domestic Product Per Capita
GFN:	Global Footprint Network
Gha:	Global Hectare
ICT:	Information and Communication Technology
IFDI:	Inward Foreign Direct Investment
IPCC:	Intergovernmental Panel on Climate Change
NITI:	National Institution for Transforming India
OSTP:	Office of Science and Technology Policy
PCCA:	Paris Climate Change Agreement
PCD:	Pesaran Cross-section Dependence
PMG/ARDL:	Pooled Mean Group Auto-Regressive Distributed Lag
PSLM:	Pesaran Scaled Lagrange Multiplier
R&D:	Research and Development
REG:	Renewable Energy Generation
TWh:	Terawatt-hour

Chapter 14

AI:	Artificial Intelligence
AR:	Assessment Report
C-D test:	Cross Sectional Dependence test
CO ₂ :	Carbon Dioxide
DCs:	Data Centres
ECT:	Error Correction Term
GDP:	Gross Domestic Product
GWP:	Global Warming Potential
IBM:	International Business Machines Corporation
ILO:	International Labour Organization
IPCC:	Intergovernmental Panel on Climate Change
L-M test:	Lagrange Multiplier test
LULUCF:	Land Use, Land-Use Change, and Forestry
OECD:	Organization for Economic Co-operation and Development
PMG-ARDL:	Polled Mean Group Autoregressive Distributed Lag
PTY:	Labour Productivity
R & D:	Research and Development

SME:	Small and Medium Enterprise
UAE:	United Arab Emirates
UK:	United Kingdom
USA:	United States of America
VC:	Venture Capital

Chapter 15

AI:	Artificial Intelligence
AII:	Artificial Intelligence Investments
CO ₂ :	Carbon Dioxide
DOLS:	Dynamic Ordinary Least Squares
ES:	Environmental Sustainability
FMOLS:	Fully Modified Ordinary Least Squares
LCF:	Load Capacity Factor
OECD:	Organization for Economic Co-operation and Development
SDGs:	Sustainable Development Goals
STIRPAT:	Stochastic Impacts by Regression on Population, Affluence, and Technology

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About the Editor

Ramesh Chandra Das, PhD, is presently Professor and Head of the Department of Economics, Vidyasagar University, India, with more than 25 years of teaching and research experience. He has published more than 100 articles in reputed journals and edited books, and more than 20 books in his credit. His research interests lie in applied macroeconomics, public economics, and environmental economics.

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About the Contributors

Henry Thomas Asogwa has MSc in Economics from the University of Nigeria and is currently a PhD student at Nnamdi Azikiwe University, Awka in Anambra State, Nigeria, and also an Assistant Research Fellow at the Institute of Development Studies, University of Nigeria, Nsukka.

Aparna Banerjee, PhD, is currently Assistant Professor in Economics at Serampore College, India. She has research interests in various fields of economics and several publications in reputed international/national journals/edited books are there in her credit.

Bappaditya Biswas, PhD, is presently working as an Assistant Professor in the Department of Commerce, University of Calcutta, India, with over 15 years of teaching experience in undergraduate as well as postgraduate courses. He has published more than 35 articles in different journals and edited volume of repute.

Kenneth Chilton, PhD, is Professor of Public Administration at Tennessee State University (TSU) in Nashville, TN. His research focusses on regional economic development, housing policy, and inequality. Prior to TSU, he was the CEO of the Ochs Center for Metropolitan Studies in Chattanooga, TN. He directed numerous studies that focussed on the state of the Chattanooga region that focussed on economics, criminal justice, education policy, and community development.

Sayantani Roy Choudhury, PhD, is presently Associate Professor and Chairperson, Students and Alumni Affairs at Praxis Business School, Kolkata, India. Her academic qualification are MSc, MPhil, PhD, PGDBA. She is a Visiting Professor at IIM Udaipur and IIM Amritsar. Her research area is quantitative studies on social issues of economy.

Ndubuisi O. Chukwu, is presently associated with the Department of Economics, University of Nigeria, Nsukka, Nigeria. His research and teaching interests lie within household studies, financial economics, and development economics.

Sourav Das is a Postgraduate Student of Business Administration at Praxis Business School, Kolkata, India. His research interest is in data analytics.

Ömer Esen, PhD, is currently serving as a Professor in the Department of Public Finance at Tekirdağ Namık Kemal University in Tekirdağ, Turkey. He received his PhD from Atatürk University in Erzurum, Turkey, where he focussed on Turkey's energy deficit in the context of sustainable growth. His research primarily encompasses macroeconomics, energy economics, the Turkish economy, and public finance, with a particular emphasis on economic growth, macroeconomic stability, sustainable development, environmental pollution, climate change, and public policy.

Imran Hussain is currently pursuing PhD in Economics at Vidyasagar University, India. He has qualified for the UGC-NET exam held in December, 2023. He was honoured with the 'Anundoram Borooah Award' in 2011 for his secondary education by the Secondary Education Department, Government of Assam. Additionally, he was selected for the 'Ishan Uday Scholarship' under the UGC (University Grants Commission) in 2015 for his undergraduate studies. He has published various empirical works in different Scopus-indexed journals and books.

Enrico Ivaldi is an Associate Professor of Demography and Social Statistics at the Free University of Languages and Communication IULM in Milan, Italy. He holds a PhD in Applied Economics and Quantitative Methodologies from the University of Genoa. He is a member of the Editorial Board of *Social Indicators Research* (Class A, SECS-S/05 sector), *Quality and Quantity* (Class A, SECS-S/05 sector), *Scientific Reports* (Class A, Area 13), *International Journal of Transport Economics*, *Revista de Estudios Andaluces*, *PLOS One*, *Sustainability*, the Scientific Committee of the National Nautical Observatory, the faculty board of the PhD programme in Social Sciences at the University of Genoa, the *Centro de Investigaciones en Econometría* at the University of Buenos Aires, Argentina, and the Pontifical International Marian Academy in Vatican City.

Biswapati Jana, PhD, is currently working as Professor and Head in the Department of Computer Science, Vidyasagar University, India. He received his BTech and MTech degrees in Computer Science and Engineering from the University of Calcutta and received PhD from Vidyasagar University. He has 22 years of teaching experience. He has made significant contributions to these fields, authoring or co-authoring around 130 research papers published in both national and international journals.

Sharmistha Jana, PhD, graduated from Calcutta University and completed her masters from Vidyasagar University, presently is working as a faculty member in the Department of Mathematics, Midnapore College [Autonomous], India. She achieved her PhD at National Institute of Technology Durgapur, India. She has teaching experience of nearly about 16 years. Her current research interests include the transportation problem, supply chain management, inventory problem, and travelling salesman problems.

Susobhan Maiti, PhD, is an Assistant Professor in the Department of Economics, School of Humanities and Social Sciences (SHSS), Jain (Deemed-to-be

University), Bangalore, India. He has published many research papers in the area of macroeconomics, development economics, industry, efficiency, and productivity in both national and international journals.

Souvanik Maity, PhD, serves as a Guest Faculty Member (ITEP-Geography) in the Department of Education at North Eastern Hill University. He has experience of four years of teaching experience in Geography in College and University. He possesses specialized knowledge in research concerning water pollution and is proficient in R Programming as well as GIS software such as ArcGIS, QGIS, and quantitative data analysis.

Prasenjit Makur is an Assistant Professor of Commerce at Calcutta Girls' College, Kolkata, West Bengal. He obtained his graduation and master's degrees from The University of Burdwan, India. He has more than seven years of teaching experience in the fields of accounting, finance, taxation, and economics and more than six years of research experience, with numerous publications in peer-reviewed national journals and books.

Sumita Manna has obtained MSc in Economics and Bachelor of Education degree from Vidyasagar University, India, respectively, in the years 2022 and 2024. She has qualified for the NET conducted by UGC, New Delhi, in 2023 and has worked as Research Assistant in the Project titled 'Has the Kanyashree Prakalpa Programme Effected a Permanent Change in Values and lead to Parents of Prospective parents Valuing Education of the Girl Child More?' at the Department of Economics, Jadavpur University, for one year, 2024–2025. She has research interests in the areas like economics of education, technological innovations, development economics, etc.

Tiyasa Mishra is currently a fourth-year PhD research scholar (Senior Research Fellow) at the Department of Humanities and Social Sciences, Indian Institute of Technology Kharagpur, India. She works in the broad area of Environmental Economics. She has qualified UGC-NET for Assistant Professorship (2020) and CAT (2022). She has been a gold medallist during her graduation and postgraduation courses in Economics under Vidyasagar University.

Saddam Hossain Mondal, PhD, is an Assistant Professor of Economics in the Department of Economics, Heramba Chandra College under Calcutta University, Kolkata. Previously he served Jalpaiguri Govt. Engineering College for almost one year. He did his doctorate degree from the University of Burdwan on Patterns of Foodgrains Production and Food Security in India. His research article has been published in various national and international peer-reviewed journals. His areas of interest include macroeconomics, agricultural economics, food economics, and environmental economics.

Snehangshu Mondal, PhD, research scholar at the School of Energy Science and Engineering in Indian Institute of Technology Kharagpur, India. He works

on building energy, air conditioning and ventilation, refrigeration, renewable energy, conventional energy, and waste management. He completed his MTech in Mechanical Engineering from the Indian Institute of Technology (Indian School of Mines) Dhanbad. He has worked in power sector (power generation) as an Operation and Commissioning Engineer for four years. He works in different academic and industrial projects.

Debjit Nag is a Postgraduate student of Business Administration at Praxis Business School, Kolkata, India. His research interest is in data analytics.

P. Nandeeswara Rao, PhD, an Assistant Professor at Jain University, holds a PhD in Quantitative Economics and a postgraduate degree in Mathematical Economics from Andhra University. With extensive teaching and research experience in India and abroad, he specializes in development economics, statistical methods, and quantitative economics. A passionate educator, he simplifies complex economic concepts, equipping students with a deep understanding of the subject. His research focusses on poverty alleviation, economic progress, and broader socio-economic issues, driven by a commitment to meaningful societal impact. He has published extensively in reputed journals.

Debasish Nandy, PhD, is Associate Professor in the Department of Political Science at Kazi Nazrul University, Asansol, India. He is the Coordinator of the Centre for Studies of South and South-East Asian Societies at the same university. He is a Visiting Faculty Member in the Department of Foreign Area Studies at Tajik National University, Dushanbe (Tajikistan), and the Indian Cultural Ambassador to Tajikistan. In 2022, Dr Nandy he served the Department of Japanese Studies at the University of Dhaka, Bangladesh, as the Visiting Faculty. He was the Visiting Faculty at the Frankfurt University of Applied Sciences, Frankfurt, Germany.

Divine Ndubuisi Oboodoechi is a Lecturer in the Department of Economics University of Nigeria. He obtained his MSc degree in Finance and Economics, Manchester Business School, United Kingdom. He is a consultant with Thinkwell global, United States of America.

Ambrose Nnaemeka Omeje is a Lecturer in the Department of Economics, University of Nigeria, Nsukka. He has published papers in both international and local peer-reviewed journals. He has also researched and consulted for SAVI-DFID, UNICEF and has facilitated research for Central Bank of Nigeria – South-East Entrepreneurship Development Centre Training on Entrepreneurship and Development, Nigeria.

Sabari Pramanik, PhD, is an Assistant Professor in the Department of Computer Science at Vidyasagar University, Midnapore, India. She received her BSc, MSc, and MTech degrees from the University of Calcutta, India. She received gold medal for standing first in MSc. She has teaching experience of nearly about 22 years. Her teaching and research interests include artificial intelligence, parallel

computing, and bioinformatics. She is a life member of Indian Science Congress Association.

Ramakrishna G. N., PhD, is an Assistant Professor at Jain University, a prestigious institution, boasting a wealth of knowledge and expertise acquired over 14 years in the realm of education, encompassing roles as a lecturer, researcher, and avid learner. Drawing from a background in economics, particularly in the domains of Finance, Insurance, and Banking, this analysis aims to elucidate the key facets of the development of young individuals.

Mouparna Samanta has obtained MSc in Economics from the Vidyasagar University in 2024. She has completed her dissertation at the masters' level on the role of artificial intelligence (AI) upon environmental pollution in countries and groups. Her research interests lie on AI, technological innovations, and environmental economics.

Palas Samanta, PhD, is Assistant Professor of Environmental Science at Sukanta Mahavidyalaya, India. He is Ex-DST INSPIRE Fellow, GoI and Ex-BK 21 Plus Fellow, Korea. His research focussed on fate and toxicity analysis of environmental contaminants on aquatic organisms, pollution monitoring, and risk assessment and environmentally sustainable aquaculture. One book, 27 book chapters, 82 international articles are in his credit.

Ayanangshu Sarkar, PhD, is an Assistant Professor of Economics in the Department of Economics, Heramba Chandra College under Calcutta University, Kolkata. Previously, he served in Pailan College of Management and Technology for almost 16 years. He earned his doctorate from Jadavpur University on Contagion, Volatility Spillover, and Stock Market Interdependence: A Comparative Study Between India and China. His research article has been published in various national and international peer-reviewed journals. His areas of interest include microeconomics, financial economics, and agricultural economics.

Shubhamita Sarkar has passed MSc in Economics from the Vidyasagar University in 2024. She has earned diploma in Data Science from the Department of Computer Science of the same university and possessed skills in handling complex data in the subjects like economics and business studies. She has research interests in artificial intelligence, technological innovations, and environmental economics.

Tarakeshwar Senapati, PhD, is presently working as faculty member (Assistant Professor) in Environmental Science at Department of Environmental Science, Sidho-Kanho-Birsha University, Purulia, India. He served as Assistant Professor at Department of Environmental Science, Directorate of Distance Education, Vidyasagar University, India. He was former Assistant Professor in Environmental Engineering at Poornima University, Jaipur, India. He has completed his PhD degree in Environmental Science from The University of Burdawn in the year 2013. He has published more than 45 research papers in international and

national journals of repute. His research area includes ecotoxicology, limnology, and climate change issues.

Gamze Yıldız Şeren, PhD, holds bachelor's, master's and PhD degree in Public Finance from Marmara University. Her areas of research are include public finance theory, public finance economics, public budgeting, and gender. Throughout her career, she has participated in various international and national congresses, seminars, and workshops and has contributed as an editor for national and international books. She currently serves as an Associate Professor at Tekirdag Namık Kemal University.

Begum Sertyesilisik, PhD, is Professor in the Department of Interior Architecture, Faculty of Architecture, at the Istanbul University. She has been awarded her MSc, MBA, and BSC degrees from the Istanbul Technical University, and her PhD degree from the Middle East Technical University. Her specialization areas include but not limited to: green marketing, strategic management, sustainability, and sustainable built environment.

Krishna Singh, PhD, is an Assistant Professor at the Department of Economics, University of GourBanga, Malda, West Bengal, India. He completed his MA in 2008 and PhD in 2015 from The University of Burdwan. He has published more than 15 papers in international and national journals of repute. His research interests include rural livelihood, health economics, corporate finance, etc.

Chinasa Ebere Urama is a Lecturer at Economics Department, University of Nigeria, Nsukka, where she obtained all her degrees. She has served as a Chief Planning Officer in the Academic Planning Unit before joining the Academia. She specializes in health and development economics where she has published enormously.

Ezebuilo Romanus Ukwueze, PhD, is a Senior Lecturer at the Department of Economics, University of Nigeria, Nsukka in Enugu State, Nigeria. He has published widely in both local and internationally recognized journals. He teaches and supervises graduate students.

José G. Vargas-Hernández, PhD, is presently a Research Professor, Instituto Tecnológico Mario Molina Pasquel y Henríquez, Unidad Académica Zapopan, Zapopan, México. He has a long career in Administrative and Management Sciences having more than 200 articles published in different journals and books, and reports.

Bhuman Vyas is a Senior Software Developer at Credit Acceptance, USA, with over 15 years of industry experience. A Fellow of the Royal Society of England, IAP, and RSA, he is a recognized thought leader, keynote speaker, and mentor. He has judged hackathons, chaired IEEE conference sessions, and conducted technical workshops for universities, showcasing his expertise in bridging academia and industry.

Foreword

Artificial intelligence (AI) has emerged as one of the most revolutionary forces of the 21st century, with a transformative potential that extends well beyond the boundaries of the technology industry. In particular, its impact on agriculture and environmental sustainability is set to redefine how we address the most pressing global challenges. With a continuously growing global population and increasing pressure on natural systems, the need for innovative solutions to ensure food security, optimize resource use, and reduce environmental impact has become an absolute priority. AI stands at the centre of this challenge, offering a range of tools and approaches capable of revolutionizing both agricultural practices and environmental management.

In the agricultural context, AI applications promise to significantly improve both productivity and sustainability. Sophisticated machine learning algorithms can analyse vast amounts of data to predict optimal planting periods, considering variables such as weather conditions, soil quality, and resource availability. AI-powered automated irrigation systems can monitor soil moisture and crop needs in real time, reducing water waste and optimizing water resource use. Precision agriculture, supported by AI, enables monitoring of soil health, early detection of pest infestations and diseases, and optimization of fertilizer use, leading to increased yields and reduced environmental impact. Drones and robots, guided by AI systems, are transforming harvesting processes, making them more efficient and reducing reliance on human labour. Furthermore, AI can enhance the efficiency of agricultural supply chains by optimizing logistics and minimizing food waste.

Environmental sustainability also benefits greatly from AI, with innovative solutions for deforestation monitoring, climate change prediction, and energy optimization. AI can be used to analyse satellite images and detect deforestation in real time, allowing timely interventions to protect forests and preserve biodiversity. AI models can more accurately predict climate changes, enabling governments and businesses to make informed decisions to mitigate the effects of global warming. AI systems can optimize energy use in buildings, transportation, and industrial processes, reducing greenhouse gas emissions and contributing to the fight against climate change.

However, the widespread adoption of AI raises important concerns regarding the energy consumption of data centres, electronic waste management, and the ethical implications of automation in the labour market. Data centres powering AI systems require enormous amounts of energy, contributing to greenhouse gas emissions. The production and disposal of electronic devices necessary for AI

generate toxic waste that can harm the environment and human health. AI-driven automation could lead to job losses in certain sectors, creating social inequalities. While AI offers extraordinary opportunities for sustainability, it also necessitates a critical reflection on its ecological and social effects.

The volume *Artificial Intelligence in Agriculture and Environmental Sustainability: A Global Perspective* aims to explore in depth the role of AI in these crucial areas, structured into two main sections.

Section I, titled 'Roles of Artificial Intelligence upon Agriculture Across the Globe', examines the economic impact of AI on agriculture, highlighting both challenges and opportunities. The chapters in this section analyse the role of AI in optimizing agricultural techniques, improving decision-making processes, and promoting sustainability. Case studies from various countries illustrate AI integration in agricultural practices, from crop recommendations to supply chain management.

Section II, titled 'Environmental Implications of Artificial Intelligence', delves into AI's contribution to environmental sustainability, examining its use in pollution control, climate change mitigation, and sustainable urban development. Comparative studies from Asia, Africa, and OECD countries offer diverse perspectives on AI's role in environmental resilience.

The research presented in this book highlights the dual nature of AI: while it provides powerful tools to improve efficiency and reduce waste, it also raises crucial issues related to environmental degradation, job displacement, and ethical implications. As AI becomes increasingly integrated into economic and environmental policies, finding a delicate balance between technological innovation and social responsibility is essential.

Ultimately, this book with a good editorial exercise by Ramesh Chandra Das, Professor at the Department of Economics, Vidyasagar University, India, provides a valuable framework for researchers, policymakers, and industry professionals, contributing to an informed debate on how AI can address global challenges and promote equitable and sustainable development. Offering diverse perspectives and in-depth empirical studies, the volume stimulates new research, guides policy decisions, and fosters collaborations for a future where AI supports both agricultural productivity and environmental conservation. The large-scale adoption of AI presents new challenges but also extraordinary opportunities to improve resource efficiency and develop smarter, more sustainable systems. A collaborative and multidisciplinary approach is essential to maximize AI's benefits and mitigate potential risks, ensuring that technology serves humanity and the protection of our planet.

Enrico Ivaldi, PhD
IULM University, Milan, Italy

Preface

Artificial intelligence (AI) has been the keyword in today's lives of the common citizens in the world. The history of AI is discernible by several key mileposts, beginning with Alan Turing's foundational concept of the Turing Test in 1950, followed by the coining of the term 'artificial intelligence' by John McCarthy in the 1950s, and later seeing significant advancements in machine learning, deep learning, and natural language processing, with recent breakthroughs in areas like generative AI and large language models. The world economy, society, and the nature have been continuing towards a complete operational phase of technological tools in the last two to three decades. The uses of physical capital induced growth and development of the nations is now the past events. The countries of today are welcoming newer technologies for fast development of the economies as well as social changes besides putting categorical impacts upon the agriculture sector and nature's preservation. One such tool is the AI which has the power of doing everything on its own without taking help of larger quantities of physical labour forces. There are so many good opportunities for this fast growth of technologies. Besides, there are black edges of it also. It might increase environmental degradation as running AI technologies might exploit the nature more. Therefore, its consequences might fall upon the agriculture sector in an economy as well as nature's quality.

With the rise in the global population size there has been a parallel increase in the food demand as well as increase in the business activities. The agricultural sector in most of the countries has now come up with the uses in the modern technologies resulting into high yield rates and growth rates of agricultural produces. AI has made a spectacular jump in the technological base of the countries where agriculture and the business sector are one of the largest beneficiaries. Besides, the AI has the potential of reducing environmental degradation as due to replacing the man-made physical capital, though there may be the instances of high magnitudes of e-pollutant generation due to the AI. With these good effects, there are negative aspects of AI in relation to agriculture and environment too. Smart farming makes use of high techs that require technical skill and precision to make it a success. It requires an understanding of robotics and ICT. However, many farmers do not have these skills. In addition, under certain conditions, automation in agricultural or the smart agricultural practices can dislocate rural labour and lead to negative environmental consequences such as land degradation and biodiversity loss. Again with respect to the environment, there are several negative sides to the explosion of AI and its related infrastructure. The booming data

centres that house AI servers produce electronic wastes which are the large consumers of water, which is becoming scarce and sometimes exacerbating pressure on already limited freshwater resources in many places so far as the global climate change conditions are concerned. The mining and production of the metals used in AI hardware can lead to soil erosion and pollution. Major electronic wastes are not properly recycled, leading to electronic waste that can cause further pollution. The materials which are used in recycling the e-wastes can contaminate soil and water when not disposed of properly.

Under the context, the present edited book titled *Artificial Intelligence in Agriculture and Environmental Sustainability: A Global Perspective* throws light upon assembling studies related to the AI and its impacts upon agricultural activities and environmental conditions from a global perspective. As the researches in AI in social sciences are relatively new and there are thus limited data availabilities on several indicators of AI vis-à-vis economy, society and environment, the present book has endeavoured to develop the book on the said contents as good as possible to palate it to the readers in the related fields.

The book contains 15 chapters which are divided into two broad sections. Section I captures the studies related to economic impacts of AI in agriculture with issues and challenges, containing six chapters, and Section II covers up the studies related to environmental implications of AI in countries and groups containing nine remaining chapters. The brief objectives and outcomes of all the chapters are outlined below.

Chapter 1 discusses the economic impacts of AI, in improving agricultural output and, therefore, farmer livelihoods, and the fact that India's farming issue requires attention on many levels. It also discussed about the contribution of startups in improving the AI in agriculture. Through content analysis, the article reveals that AI can boost farm output in India, ease supply chain constraints, and increase market access. It shows how the AI can be used to resolve all these issues in a sustainable way and to boost the farms productivity and farmer's income.

Chapter 2 examines various applications of AI in agriculture in India with a focus on how these applications might improve sustainability, production, and efficiency. By content analysis using secondary data it is found that AI tools give farmers the data-driven insights they need to make wise decisions, such as machine learning and data analytics. Thanks to AI, farmers can now tailor their approaches to crop performance, soil health, and meteorological conditions in real time through precision agriculture. This reduces the hazards brought on by variables like climate change and maximizes the use of resources.

Chapter 3, stating the scenario that the farmers often grapple with the challenges of making informed decisions regarding crop selection, particularly in the face of fluctuating environmental conditions and soil compositions, explores the development and deployment of the Smart Crop Recommendation System, a pioneering solution aimed at alleviating this prevalent issue by harnessing the power of predictive modelling techniques.

Chapter 4 aims to establish the relevance of AI in agricultural practices for maintaining food security in Asian countries. Using the data on AI and other agricultural indicators and statistical tools and the Box-Whisker model, it observes

a positive association between AI and cereals productivity in Asian countries. A strong correlation between GDP and AI is also observed in the continent. The higher use of pesticides and renewable energy consumption also improved the productivity of cereals in Asian countries. Given limited arable land, sustainable production of food grains for such a huge population is going to be insufficient in the near future so implementation of AI-based technologies and machine learning is inevitable. The government must take proactive steps towards this direction.

Chapter 5 highlights the socio-economic implications of AI on the agricultural, industrial, and service sectors. In spite its complex dynamic structure including privacy threats, it can help in efficiency increase with proper planning. Using the content analysis on the basis of some secondary data the study finds that AI can also increase income and wage inequality while aiming for achieving sustainable development goals. USA stands first in both AI implementation and its effectiveness showcasing the most progressive technology in the country. It can be observed that in spite of increase in large-scale AI, the AI-based employment has increased but not proportionately.

Chapter 6 explores the global impact of AI on society, economy, and the environment, focussing on the transformative effects of AI technologies, identifying both opportunities and challenges. Specifically, it investigates how AI reshapes employment dynamics, drives innovation, and influences socio-economic structures and environmental footprint of AI technologies. Major results include insights into AI's role in job creation in the fields like data science and its impact on sectors prone to automation. AI is found to foster growth through innovation but raises concerns regarding income inequality and the concentration of wealth. Environmental considerations highlight AI's potential to optimize resource use and climate change mitigation, though it also presents challenges such as high energy demands and e-waste.

Chapter 7 seeks to investigate whether investments in AI have strong correlation with environmental pollution like CO₂ emissions in selected countries of the world. Using the correlation and regression analysis for the individual as well as pooled data for the listed countries for the period 2010–2020 it is observed that all the countries have maintained rising levels of investment in AI where China is leading the list as the individual countries in most of the heads while Singapore records the lowest CO₂ emission followed by Germany, France, and UK. There are negative and significant correlations between the two and their regression coefficients are negative for the developed countries in the list and they are statistically significant too meaning to the fact that AI has good impacts upon the nature.

Chapter 8 examines the trade-off and potential opportunity cost of the AI in the architecture–engineering–construction industry (AECI) from the sustainability and sustainable development perspective through highlighting the need for integrated thinking of and relationship among AI, sustainability and sustainable development in the AECI. It reveals that use of AI in AECI has not only the sustainability pillar-based effects on sustainability but also on their interactions. As challenges related with the use of AI can affect outputs of trade-off and opportunity cost assessments of companies in AECI, challenges need to be addressed

strategically and effectively at the strategic management level of the AECI companies and in countries' sustainable development plans covering and enhancing their impacts on sustainable development, and sustainability.

Chapter 9 investigates whether Japan's reliance on an AI-centric state system undermines human cognitive abilities in general form but in particular it has three main objectives: first, to examine the impact of AI on Japan's socio-economic landscape; second, to investigate the various factors that influence the implementation of AI in Japan; and third, to evaluate the initiatives taken by the Japanese government to facilitate the effective integration of AI. To accomplish these goals, the study utilizes content analysis as its methodological approach. It finds that integration of AI across various sectors in Japan significantly influences the landscape which yields a diverse range of effects in the areas like employment, environment, education, health, fairness, ethics, etc.

Chapter 10 aims to analyse the effectiveness of the latest application of AI for the development of energy and economy through exhaustive reviews of the existing studies in the area. The analysis exhibits that AI can reduce adverse environmental affects and can thus promote green growth in the long run. With the rising usage of AI in the last decade, superior outcomes with higher efficiency have been obtained in some cases. However, this approach requires proper coordination, integration and selection of the most important strategy. The future scope of the study includes government intervention to strengthen the application of AI in the developing countries of the world.

Chapter 11 explores the comprehensive environmental and economic impacts arising from the widespread adoption of electric vehicles (EVs), especially in Indian context, utilizing the AI, particularly machine learning algorithms. It also includes a diverse dataset encompassing environmental metrics and economic indicators. Preliminary findings demonstrate the effectiveness of AI in predicting reductions in greenhouse gas (GHGs) emissions, identifying patterns in consumer behaviour, and highlighting regional variations. From this study, it is drawn that the integration of AI in forecasting the impacts of EV will deliver a promising avenue for proactive decision-making for policymakers, industries, and researchers to navigate the evolving landscape of sustainable transportation.

Chapter 12 aims to investigate the potential of AI applications in addressing the energy consumption and CO₂ emissions challenges faced by countries in Sub-Saharan Africa (SSA) and their implications for economic growth by employing a theoretical approach towards examining how AI mitigate CO₂ emissions and optimize energy use in SSA countries. The findings were observed through a comprehensive analysis of systematic reviews, and desk reviews of documents on energy use in SSA countries which revealed that technologies such as machine learning algorithms analyse real-time data to predict energy demands, leading to more efficient usage and reduced waste in SSA countries.

Chapter 13 investigates the effect of AI, economic development, renewable energy (REG), and inward foreign direct investment (IFDI) on carbon emission from industrial combustion (CO₂Eic) and ecological footprint (EFT) in Asia during 2013–2023 in the long and short run. Using the pooled mean group autoregressive distributed lag model, the panel fully modified least squares methods

and dynamics least squares attested that combustion significantly shortens due to AI and REG over time. It also reveals that economic development and IFDI have significantly positive contributions to combustion in major Asian economies in the short and long run. The outcomes also confirmed that AI in the case of India and Japan subtract combustion in the short run. Finally, it exhibits that that economic development led to improve the ecological footprint, whereas REG negatively impacted overtime to footprint except for Japan.

Chapter 14 investigates empirically the pairwise long-term equilibrium relationships and short-term dynamics between AI and labour productivity, AI and GDP, and AI and CO₂ emissions over the period from 2012 to 2023, using panel data econometric techniques for the world's top 20 AI-investing countries. The correlation coefficients reveal that most countries show a positive relationship between AI and labour productivity, as well as AI and GDP. Conversely, there was a negative relationship between AI and CO₂ emissions in these countries. The Westerlund cointegration test results indicate that long-term stable relationships exist between AI, labour productivity, GDP, and CO₂ emissions in the selected countries. Furthermore, the PMG-ARDL model reveals that AI does not have impacts upon labour productivity, GDP, and CO₂ emissions in the short run. However, in the long run, AI significantly boosts labour productivity and GDP, while not contributing to CO₂ emissions.

Chapter 15, the final chapter of the book, examines the effect of private investments in AI on environmental sustainability focussing on a panel of 32 OECD countries over the period 2013–2021. To analyse the long-term dynamics among variables, Pedroni panel cointegration tests are employed and dynamic ordinary least squares (DOLS) and fully modified ordinary least squares (FMOLS) estimation methods are utilized to estimate the long-run coefficients. The findings reveal a positive and statistically significant relation between AI investments and environmental sustainability in the long run, indicating that increased investments in AI contribute to enhanced environmental quality.

The essences of all the covered studies show that AI has many positive impacts upon the agricultural sector in terms of smart agricultural practices using machine learning, deep learning techniques and reduces environmental hazards by means of the uses of sophisticated AI-based technologies to replace the traditional physical capital with the green and automated technologies. The studies covered the countries and groups in the world where most of the studies recommended that the countries and groups should focus and invest more upon AI to boost up agricultural productivity to solve the food crisis problem and to reduce environmental pollution to attain sustainable development goals, particularly the SDG 7. But there are worries too behind using AI-based technology. Primarily it hurts the human beings, their sentiments and ethics. Smart farming makes use of high techs that need technical skill and precision to make it a success. However, many farmers do not have these skills. In addition, smart agricultural practices can dislodge rural labour. Again with respect to the environment, the growing data centres that stock AI servers produce electronic wastes which are the large consumers of water which sometimes worsening pressure on already limited freshwater resources in many places so far as the global climate change conditions are concerned. The

mining and production of the metals used in AI hardware can lead to soil erosion and pollution. Major electronic wastes are not properly recycled, leading to electronic waste that can cause further pollution. Thus, the AI, though might help in the short run, the long-run effects might be dangerous to the agricultural sector such as in reducing employment, distressing human brains and activities, human rights, among others. Thus, the studies recommended sustainable use of such a high-quality technology in agriculture sector through proper managements from the parts of the governments in the countries in associations with private bodies to mitigate the resource crisis and the issues of environmental pollution so that sustainable development goal can be achieved in these regards.

The contents of the book may provide thought provoking solutions to the existing prospects and problems of the use of AI in agriculture and its consequences with the nature and there may be the possibilities of value addition to the existing literature in this area. The readers and policy makers in the related disciplines would be immensely benefitted from the contents and materials of the book.

While carrying out the book project the editor got tremendous supports from different corners of the academic and social world. The editor acknowledges the supports of the entire Emerald Team, the contributing authors and the Foreword writer. In addition, the editor is indebted to his parents, wife, daughter and other members of the family for their sacrifice and supports to unveil the title. However, the editor is solely responsible for any error still left in the book.

Ramesh Chandra Das
Editor

Section I

Roles of Artificial Intelligence upon Agriculture Across the Globe

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Chapter 1

Economic Impact of Artificial Intelligence in Agriculture: Issues and Challenges

Bappaditya Biswas

Department of Commerce, University of Calcutta, India

Abstract

The global population is increasing day by day; however, the traditional method of cultivation is not sufficient to cater the increasing demand for food. Precision agriculture, often known as artificial intelligence (AI) systems, is assisting in enhancing the overall quality and accuracy of harvests in many ways. Indian agriculture faces several unique issues like lack of mechanization, low productivity, soil erosion, unavailability of water for cultivation, price of the produces, low income of the farmers, etc. To promote innovation and entrepreneurship in agriculture, the agricultural industry is increasingly looking at ways to harness technology for increased crop yields. This chapter emphasizes the economic impacts of AI in improving agricultural output and, therefore, farmer livelihoods, and the fact that India's farming issue requires attention on many levels. It also discussed about the contribution of startups in improving the AI in agriculture. Through content analysis, the chapter reveals that AI can boost farm output in India, ease supply chain constraints, and increase market access. It shows how the AI can be used to resolve all these issues in a sustainable way and to boost the farms productivity and farmer's income.

Keywords: Artificial intelligence; agriculture; farm productivity; sustainability; farming; startups

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Introduction

Agriculture is one of the major occupations in many countries worldwide. United Nations (UN) has projected that the world's population will increase from 7.5 billion now to 9.7 billion by 2050 but during this period only 4% extra land will be available for cultivation that will lead to more pressure on the land. As a result, to feed this additional two billion people, the firm's productivity should be increased by 60% which is a gigantic task with the existing traditional methods of cultivation. By providing food producers with much greater access to data about their operations, AI in agriculture have revolutionized the way that farming operations throughout the world operate. According to Markets & Markets, spending on AI technology will increase from \$1 billion in 2020 to \$4 billion in 2026, representing a compound annual growth rate of 25.5%. AI is the most notable of the new technologies that can address issues in agriculture. Robotics, computer vision, machine learning (ML), etc., are all part of AI. AI is essential to the agricultural sector's fight for food sustainability in the face of climate change, from agricultural robots to soil and crop surveillance to predictive analytics.

By leveraging new solutions and acquiring the results in a few days as opposed to months and years together using conventional methods, AI platforms enable crop and livestock producers and processing units to quickly and simply increase the efficiency, improve decisions, and realize more revenue. They also significantly minimize discrepancies in manual control, quantification, and analysis, increase processing efficiency, and yields.

Real-time information regarding crop conditions, animal activities, and the whereabouts of agricultural equipment is sent to farmers via AI. Many academics predict that AI in agriculture will play a significant role in boosting food production throughout the world, especially in regions where food poverty is the norm. UN statistics on population and hunger predict a 2 billion increase in global population by 2050. To feed everyone on the planet, food production will need to grow by 60%. Agriculture technologies powered by AI and ML developments have the potential to enhance food production supply chains in more sustainable, cost-effective ways. Here lies the need of AI to bring technological evolution in agricultural industry to improve farmer's efficiency and to increase the quantity and quality of farm production and faster marketing of the crop.

India is an agriculture-based economy as 54.6% of the population depends on agriculture for living and the sector contributed 19.91% in India's gross domestic product in 2020–2021 (Economic Survey, 2020–2021). But the average annual income of the farmers and farms output-to-input ratio in India are significantly low comparing to the global standard. Indian agriculture faces some specific issues like lack of mechanization, soil erosion, small landholding, lack of good quality seeds and fertilizers, dependency on monsoon for cultivation, etc., and many of the problems can be resolved with the help of AI.

By the year 2019, the application of AI in agriculture has reached to a valuation of \$852.2 million globally, which is estimated to reach at \$8.38 billion by 2030 (Singh, 2020). The present valuation of Indian agri-tech market is \$204

million and is expected to grow exponentially with the help of AIs and supportive government policies.

Literature Review

The rise of AI and its ever-greater impacts on numerous industries needs an assessment of its effect on the accomplishment of the Sustainable Development Goals (Vinuesa et al., 2020). Both corporate procedures and policy makers are all seeing tremendous advancements to AI as welfare to the society. Deep learning-capable robots and machine intelligence have had a profoundly disruptive and enabling influence on industry, governments, and society (Goralski & Tan, 2020). Along with other cutting-edge computer technologies, the Internet of Things (IoT) and AI have been used in agriculture for a long time worldwide. However, the use of such smart technologies is now receiving more focus in India (Alreshidi, 2019). AI delivers radical change with cutting-edge methods that will disrupt the conventional pattern and boundaries of agriculture. An agricultural revolution will be led by AI at a time when the world has to produce more food with fewer resources (Liu, 2020).

In a sustainable manner, this technology-based farming might affect crop productivity and guarantee the purity and safety of seeds (Shelar et al., 2021). Sustainable agriculture is developed using ML methods, namely supervised, unsupervised, and reinforcement learning. Policymakers are anticipated to support investments in digital technologies and make them more accessible so that they may be used broadly considering the high cost of doing so and improving ML capabilities (Sharma et al., 2020). Das (2025) discusses the necessity of sustainable agricultural practices to be adopted by the countries in the world where ill effects of agricultural upon the nature are to be mitigated properly.

Farmers may apply crop protection more effectively through targeted use by utilizing current breakthroughs in AI. This improves the production and financial success of the farmer while also lessening the impact on the environment (Shankar et al., 2020). AI is largely being used to boost output and efficiency, with labor shortages and environmental sustainability issues coming in second. The results show active AI adoption in North America and Europe, with rising initiatives in Asia and Africa at the regional level (Lakshmi & Corbett, 2020).

AI adoption is significantly influenced by process characteristics, information exchange, and supply chain integration, and AI has a favorable impact on agricultural sustainability and farmer income (Nayal et al., 2022). AI can create advanced agricultural practices to minimize losses for farmers and increase yields for them to improve the socioeconomic position of Indian agriculture (Giri et al., 2020). AI contributes to the Indian agriculture sector's increased socioeconomic and environmental sustainability. The production, efficiency, and revenue of Indian farmers with small- and medium-sized agricultural holdings are increased by AI approaches (Anitha Mary et al., 2022). AI completely altered the Indian agricultural landscape and economic strategy. Precision farming, ML, and demand forecasting are some of the primary applications of

AI in agriculture that will be crucial to the sustainability of Indian agriculture (Panpatte & Ganeshkumar, 2021).

Objectives of the Study

The objectives of the study are:

- (i) To examine the economic impact of AI in agriculture for boosting farms productivity and farmer's income.
- (ii) To evaluate the contribution of startups and companies in promoting AI in agriculture.
- (iii) To discuss the issues and challenges in implementation of AI in agriculture.

Methodology Adopted

The present study is exploratory and descriptive in nature and is based on secondary data. It goes for content analysis to examine how the AI can be used to resolve all these issues in a sustainable way and to boost the farms productivity and farmer's income. Different working papers, case studies, analytical reviews, journals, newspaper reports, magazines and websites are being consulted and reviewed to fulfill the objectives of the study.

Economic Impact of AI in Agriculture

Over the centuries, water, fertilizers, and pesticide have been considered as the important agricultural input and the farmers used to apply them on the basis of their knowledge and experience to gain most out of these. Now a day, "data" can be added to the list as with the help of satellites, drones, and IoT devices collectively; critical data about agriculture can be collected and supplied to the farmers so that they can sow the right crops, use water and fertilizers optimally, and improve yields. The data collected are matched with weather data, soil health-card data, mandi prices and help build predictive models that can greatly enhance decisions about seeds, fertilizers, pesticides that are of critical importance in both pre-harvest and post-harvest stages.

AI can transform the way we think about agriculture by bringing about several advantages and allowing farmers to produce more with less work. However, AI is not a self-contained technology. AI is the next phase in the transition from conventional to creative farming. AI may support already-used technology. Most of the procedures and steps involved in agriculture are manual. AI can simplify the most difficult and common activities by enhancing already-adopted technology. When used in conjunction with other technologies, it can collect and analyze large amounts of data on a digital platform, determine the optimal course of action, and even start that action.

Majority of the AI models are cheap in cost, and mobile phone penetration among the Indian farmers has allowed the companies to develop apps that can help the farmers in taking decision like procuring the inputs at low cost to sell the

produces at the best available prices. AI can be used in agricultural sector for solving multiple issues like detection and controlling of pests and weeds, monitoring and improving soil health, producing healthier crops, precision farming, forecasting weather, reducing wastages and costs, price forecasting of the produces, etc.

The World Economic Forum India's Center developed the AI4AI program (AI for Agriculture Innovation) in partnership with the state of Telangana and the Union Ministry of Agriculture, India, to support small-holder farmers by utilizing emerging technologies like blockchain, drones, and AI. In the Khammam area of Telangana, India, they conducted a test of the AI4AI framework with 7,000 farmers. Three crop cycles and 18 months were needed to finish the pilot project. Farmers reported an astounding increase in net revenue during this period: \$800 per acre in a single crop cycle (six months), which is essentially double the typical income. The production of chilies per acre is increased by 21% because of the digital advising services. Fertilizer and pesticide usage is decreased by 5% and 9%, respectively ([The Batch, 2024](#)).

For the time being, technology providers must consider a few things: how to make their products better, how to assist farmers in overcoming their difficulties, and how to clearly and simply explain how ML better at coping actual problems, such as lowering manual labor. AI in agriculture will undoubtedly have a bright future. The different applications of AI in agriculture are discussed in the following paragraphs.

Sowing Advisories

Farmers need to know the proper timing of sowing to get a productive crop and get the best return. When it comes to crop sowing, AI is mostly utilized to drive predictive analytics to identify when and how to seed. Based on climate data, historical conditions, market trends for inputs and outputs, private details, and other factors, it assists in creating forecasts about the best time to plant, apply fertilizers, harvest, bale, till, and so on. Crops can also be sown at equidistant intervals and at appropriate depths utilizing AI-assisted machinery. Microsoft and ICRISAT collaborated to create an AI seeding app that utilizes Power BI and ML from the Microsoft Cortana intelligence suite. Farmers who use this app to receive sowing advisories can seed on the best date, increasing crop yields. Simple feature phones may get these alerts via text messaging, so even small-holder farmers can access them and they do not need to install any sensor for this. By using AI-based showing advisories farmers can increase their yield by 30% ([Nagpal, 2017](#)).

Soil Analysis and Monitoring

By using the sensors, cameras, and infrared rays for scanning the nutritional properties in soil, AI may be used to analyze and monitor the soil health. This also aids in determining how individual seeds react to different soils, the impact of weather changes on the soil, and the likelihood of disease and insect dissemination. With this information, farmers may improve the efficiency of their agricultural inputs, resulting in cost savings and increased output. There are different

software based on AI available in market such as OneSoil – It a free app that can be used by the farmers to save seed and fertilizer costs, boost yields, and remotely monitor crops. Again, Research Prototype is a software for mobile soil analysis that uses the phone's camera, which is a research prototype software program installed on a commercially accessible smartphone takes a picture of the output layer of soil sensors. To evaluate soil qualities, the software carries out analysis processes such as image segmentation and color extraction.

Optimal Mixture of Agricultural Products

Cognitive computing gives advice to farmers on the simplest choice of crops and seeds based on many characteristics such as soil condition, weather forecast, type of seeds, and infestation near a certain location. The advice is further customized based on the needs of the farm, local conditions, and past data. AI can also consider external aspects such as market trends, prices, and consumer needs to provide the optimal mix. There are many softwares available for the farmer that can help them with the optimal mixture of agriculture products such as Farm ERP, PanAgro, eAgronom, CSWS software by Random Soft Solutions, Aahaar ERP, etc.¹ These software programs make use of AI, cognitive computing, and data analytics to offer customized crop-selection recommendations using market trends, soil quality, and meteorological conditions into account. Their goal is to increase farm profitability and productivity by offering advice on the best seeds and crops.

Weed and Pest Control

Weed infestations have been observed to cause losses of up to 90% of overall crop productivity. Pests have also been observed to cause average losses of up to 19% (Kubiak et al., 2022). As a result, pesticides are used more frequently, damaging the land and groundwater even more. Insecticides and pesticides account for about 5% of total agricultural input costs, and these costs are rising both in percentages and absolute terms. AI techniques are used in precision farming to detect disease, pests, and malnutrition in the field. AI sensors can detect and target weeds, and then calculate which pesticides and weedicides should be deployed in the buffer zone. This allows farmers to use the least quantity of pesticides and weedicides possible. Again, Microsoft with collaboration of United Phosphorous Ltd. developed Pest Risk Prediction app that will inform the farmers in advance about the common pest attacks such as Aphids, Jassids, Thrips, and Whitefly. During the initial phase, automated voice calls are being made to approximately 3,000 marginal farmers who own less than five acres of land in 50 villages located in Telangana, Maharashtra, and Madhya Pradesh, regarding their cotton crops. In addition to the sowing advice, the calls also identify the risk of insect assaults

¹Top 15 agriculture software solutions providers in India: For better farm management and crop yield (agrifarming.in).