# MACHINE LEARNING FOR SUSTAINABLE AGRICULTURE

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# Machine Learning For Sustainable Agriculture

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First Impression: January 2026

**Machine Learning For Sustainable Agriculture**

## ISBN: 978-93-49359-96-3

## Rs. 1000/- ($80)



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# Preface

Agriculture stands at a critical crossroads. Growing global food demand, climate variability, soil degradation, water scarcity, and rising input costs are placing unprecedented pressure on agricultural systems. In this context, sustainability is no longer an option—it is a necessity. The convergence of agriculture with advanced computational technologies, particularly machine learning, offers powerful tools to address these challenges in an efficient, data-driven, and scalable manner.

Machine Learning for Sustainable Agriculture explores how intelligent algorithms can transform traditional farming into a resilient, productive, and environmentally responsible system. By leveraging data from sensors, satellites, drones, weather stations, and field observations, machine learning enables precise decision-making across the agricultural value chain—from crop selection and yield prediction to pest management, irrigation scheduling, and soil health monitoring.

This book is designed to bridge the gap between agricultural science and artificial intelligence. It presents fundamental concepts, practical methodologies, and real-world applications of machine learning tailored to sustainable agricultural practices. Emphasis is placed on improving resource efficiency, minimizing environmental impact, enhancing productivity, and supporting farmer livelihoods.

The content is intended for students, researchers, academicians, professionals, and policymakers who seek to understand and apply machine learning techniques in agriculture. By integrating technological innovation with sustainability goals, this book aims to contribute to the development of smarter and more sustainable agricultural systems for the future.

# Acknowledgement

The successful completion of this book is the result of the support, guidance, and encouragement received from many individuals and institutions. I express my sincere gratitude to all researchers, scientists, and practitioners whose work in the fields of agriculture, data science, and machine learning has laid the foundation for this interdisciplinary domain.

I am deeply thankful to my mentors and academic colleagues for their valuable insights, constructive feedback, and continuous motivation throughout the preparation of this manuscript. Their expertise and encouragement played a vital role in shaping the content and direction of this book.

Special thanks are extended to my family and well-wishers for their patience, understanding, and unwavering support. Their encouragement provided the strength and inspiration necessary to complete this work.

I also acknowledge the contributions of farmers and agricultural professionals worldwide, whose real-world challenges and experiences continue to inspire technological innovation toward sustainable agriculture.

# About the Authors

**Ms. Gurpreet Kaur** currently serves as an Assistant Professor in the Department of Computer Applications at Gian jyoti Institute of Management and Technology, Sector-54,phase-2,Mohali. Her teaching and research interests include Programming languages, web designing, AI and Machine leaning with a focus on intelligent systems and full-stack web technologies. She actively participates in academic mentoring, research guidance, and curriculum enrichment activities. Her work emphasizes experiential learning, practical problem-solving, and the adoption of emerging digital technologies in higher education. She is committed to continuous professional development and aims to contribute meaningfully to academic research and technical education.

**Ms. Amandeep Kaur** is an Assistant Professor in the Department of Computer Applications at Gian jyoti Institute of Management and Technology, Sector-54,phase-2,Mohali. She holds strong academic interests in machine Programming, web designing, IOT and Machine learning with a focus on applying computational techniques to solve real-world problems. She is actively involved in teaching undergraduate and postgraduate students, curriculum development, and academic mentoring. Her professional interests include emerging technologies, interdisciplinary research, and the integration of theory with practical implementation. She is committed to continuous learning, scholarly research, and contributing to quality technical education.

**Professor Awadhesh Kumar Yadav** is a senior academician and researcher in Botany, specializing in plant genetics, cytogenetics, and mutation breeding. He has extensive experience in undergraduate and postgraduate teaching, research supervision, and curriculum development. His scholarly contributions include publications in national and international journals and active participation in international research collaborations. His research emphasizes genetic variability, mutagenesis, and cytological analysis of crop plants, with relevance to sustainable agriculture. As an author, he aims to integrate classical botanical foundations with modern experimental approaches, presenting clear, rigorous, and globally relevant content for students, researchers, and professionals across academia and applied plant sciences. Presently associated with Sri Krishna University, Chatterpur, Madhya Pradesh as Professor & Head of Department of biological Sciences. In this modern era of AI technology, Machine Learning for Sustainable Agriculture is must to learn and read for Wider Approaches in Science and Technology.

**Ms. Bhawna Sharma** is an Assistant Professor at Guru Nanak Khalsa College, Yamunanagar, and is UGC NET and HTET (PGT) qualified. Her teaching and research interests are primarily centred on Artificial Intelligence and Machine Learning, with a strong emphasis on intelligent systems, data-driven models, and adaptive computational techniques. She also works in the domains of Internet of Things (IoT) and programming languages as enabling technologies for intelligent and connected environments. Her academic focus involves the study and application of AI methodologies, machine learning model development, and the integration of intelligent decision-making frameworks to address real-world and interdisciplinary problem domains. She emphasizes theoretical depth, algorithmic thinking, and experimental learning to cultivate research aptitude and analytical skills among students. She actively engages in student mentoring, research-oriented teaching, and curriculum enrichment aligned with emerging AI paradigms such as responsible AI, automation, and data-centric intelligence. She is committed to continuous professional development and aspires to contribute meaningfully to AI-driven research, innovation, and advanced technical education.

**Dr. Abhisek Saha** is an Associate Professor in the Department of Chemistry, at Tufanganj College, Cooch Behar, India. The career of Dr. Abhisek Saha spans over twenty-three years of academic, Research, and administrative responsibilities at various colleges, school, and universities. Dr. Saha graduated from the University of North Bengal, India, and obtained a Master's degree in Chemistry from the same university. He completed his Ph.D. at the Department of Chemistry, Cooch Behar Panchanan Barma University, WB, India-736101. He qualified for the prestigious GATE (Graduate Aptitude Test for Engineers) examination in 2001 and CSIR-UGC-NET on Chemical Science in 2002. Dr. Saha acted as a SPOC in SWAYEM-NPTEL, X India since 2019 and faculty organizer of Spoken Tutorial, IIT Bombay, India. He acts as an Academic counselor (UG level) at Netaji Subhas Open University, India from 2015 to till date. Dr. Saha's research interests are focused primarily on single crystal X-ray Diffraction, Synthesis, characterization and reactivity of transition metal Complexes. He is experienced in the multi-step synthesis of organic compounds as well as organometallic compounds and their separation/purification by chromatographic techniques. Possess knowledge for interpreting data from IR, NMR, UV-vis and FAB-mass spectra. Wellversed in solving structures using single crystal X-ray diffraction and possess knowledge of various softwares related to crystal structure solutions and representations (SHELXS, SHELXTL-PLUS, DIAMOND etc.). IR and UV-vis spectrophotometers, electro chemistry system (PAR-VarsastatTM II cyclic voltametry and coulometry), HPLC, GC. He worked as a Principal Investigator in the UGCsponsored project on 'Application of platinum group metal complex to achieve C-H activation' in 2010- 2012. The research work was the regioselective or regiospecific C(aryl)-H bond activation using cyclometallation reaction.

Palladium(II), Platinum(II), Ruthenium(II), Rhodium(I) and Iridium(1) were used for C(aryl)-H bond activation. The cyclometallates were isolated and characterized. Single crystal X-ray crystallography has been used extensively for structure elucidation of the cyclometallates. The reactivity of the cyclometallates was also studied. Dr. Saha changed his research focus to Bioinformatics and Computational Biology, Next Generation Sequencing, DNA Sequence Analysis, XI Genome Sequencing, Comparative Genomics, DNA Analysis, DNA Sequence Alignment, and Sanger Sequencing. Dr. Saha published research papers (Twenty-four) in reputed National and International journals, edited book (Two), edited chapter in books (seven) published by National and International (WileyScrivener, Springer Publication) publishers.

Dr. Saha presented his research papers in many National and International seminars, conferences and symposia in India and abroad (Indonesia, Nepal). He also acted as Chairman, Co-Chairman, Rapporteur in technical sessions of many National and International seminar held in India and abroad. Dr. Saha also renders his service as an editorial panel of National and International Journals. He is an associate editor of 'International Journal of BioPharma Research journal' (ISSN: 2234-8638) and 'Anals of Pharma Research journal' (ISSN: 2347-1956). He acts an executive editor of 'International Journal of Current Science Research and Review' (ISSN: 2581-8341) and an editor of 'Asian Journal of Research in Chemistry (ISSN: 0974-4150; Online, ISSN: 0974-4169;Print). Dr. Saha is also a member of reviewer panel of 'International Journal of Chemical and Life Sciences' (ISSN: 2287-6898). He also acts as an editorial board member of 'International Journal of Pharmacognosy and Chemistry (Online ISSN:2582-7723) and 'Agricultural and Biological Research' (ISSN:0970- 1907).

Dr. Saha published patent from India and UK. The patents are Design patent (Design number6319356) from Intellectual Property Office, UK on Gas Chromatography-Mass Spectrometer Analyzer on 1st November, 2023. XII Dr. Saha was awarded National Scholarship of HRD, Govt. of India for his ranking in Higher Secondary Examinations conducted by the West Bengal Council of Higher Secondary Education. DPI, Govt. of West Bengal awarded him with Scholarship in 1997 for his performance at UG level. The Air India, Govt. of India has awarded him the prestigious BOLT Award for his teaching efficiency in 2007.

Dr. Saha was awarded the 'Excellent Teacher Award' on his overall contribution to the field of Chemistry at the International Conference on Sustainable Development Initiatives in South East Asia held in Nepal in 2022

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## ABOUT THE BOOK

*Machine Learning for Sustainable Agriculture* provides a comprehensive overview of how data-driven intelligence can be applied to achieve environmentally sustainable and economically viable agricultural practices. The book covers fundamental principles of machine learning and demonstrates their application in solving key agricultural challenges.

Key topics include crop yield prediction, soil and nutrient analysis, pest and disease detection, irrigation and water management, climate-smart agriculture, precision farming, and decision support systems. The book highlights how machine learning models can optimize resource use, reduce chemical inputs, improve productivity, and enhance resilience to climate change.

Structured in a clear and accessible manner, the book combines theoretical foundations with practical case studies and real-world applications. It serves as a valuable reference for undergraduate and postgraduate students, researchers, agronomists, data scientists, and professionals involved in smart farming and agricultural innovation.

By integrating machine learning techniques with sustainability principles, this book aims to support the transition toward intelligent, efficient, and sustainable agricultural systems that can meet present needs without compromising the ability of future generations to meet their own.


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ISBN 978-93-49359-96-3

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