



Original Article

Integrating Geography and AI in Precision Agriculture: A Study of Soil Health and Crop Stress

Shyamal N. Sonone¹ Dr. Vijay K. Tompe²

¹Research Scholar, M.A., B.Ed., SET G.S. Tompe Arts, Commerce & Science College, Chandur Bazar, Dist. Amravati

² Associate Professor, M.A., Ph.D.G.S. Tompe Arts, Commerce & Science College, Chandur Bazar, Dist. Amravati

Manuscript ID:

IBMIIRJ -2025-020631

Submitted: 20 May 2025

Revised: 30 May 2025

Accepted: 20 June 2025

Published: 30 June 2025

ISSN: 3065-7857

Volume-2

Issue-6

Pp 130-133

June 2025

Correspondence Address:

Shyamal N. Sonone
Research Scholar, M.A., B.Ed., SET
G.S. Tompe Arts, Commerce &
Science College, Chandur Bazar, Dist.
Amravati
Email: shyamalsonone75@gmail.com



Quick Response Code:



Web: <https://ibrj.us>



DOI: 10.5281/zenodo.17083174

DOI Link:

<https://doi.org/10.5281/zenodo.17083174>



Creative Commons

Abstract

Precision farming, an advanced agricultural practice, leverages technologies such as Artificial Intelligence (AI), Remote Sensing, and the Internet of Things (IoT) to maximize yield and resource efficiency. Among its many applications, AI plays a crucial role in monitoring soil health and detecting crop stress. This paper explores the integration of AI in precision farming, focusing on how machine learning, deep learning, and image processing techniques are used to assess soil conditions and identify crop stress factors such as nutrient deficiency, pest attacks, and water scarcity. The study further investigates the benefits, limitations, case studies, and policy recommendations for AI adoption, particularly in the context of Indian agriculture.

This paper investigates the transformative role of Artificial Intelligence (AI) in advancing precision agriculture, with a specific focus on soil health monitoring and crop stress detection. By integrating AI technologies such as machine learning, deep learning, image processing, and geospatial analytics, the study demonstrates how modern agriculture can overcome traditional limitations related to soil degradation, resource inefficiency, and environmental challenges. Drawing upon case studies from Indian regions like Vidarbha and the Cauvery delta, the paper examines practical applications of AI tools—ranging from drone imagery and satellite data to mobile applications—for early disease detection, nutrient analysis, and irrigation management. It also discusses the socio-economic benefits, barriers to adoption, and policy recommendations for inclusive AI implementation in rural farming communities. The findings underscore AI's potential to drive sustainable, scalable, and data-driven agricultural practices essential for food security in the era of climate change.

Keywords: Precision Farming, Artificial Intelligence (AI), Soil Health Monitoring, Crop Stress Detection, Sustainable Agriculture, Precision Farming, Artificial Intelligence (AI), Soil Health Monitoring, Crop Stress Detection, Sustainable Agriculture, Indian agriculture, Remote sensing, Deep learning.

Introduction

Agriculture, the backbone of rural economies and food security, is under immense pressure due to population growth, climate change, soil degradation, and water scarcity. Traditional farming methods, while time-tested, often lack the capacity for real-time decision-making and precise interventions. Precision farming, also referred to as site-specific crop management, has emerged as a solution to these challenges. Artificial Intelligence (AI), one of the key enablers of precision farming, allows farmers and researchers to monitor environmental conditions, soil properties, and crop health with high accuracy. By applying AI algorithms to spatial and temporal datasets, it becomes possible to optimize the use of fertilizers, pesticides, irrigation, and other inputs. This research focuses on how AI is revolutionizing two critical areas of precision agriculture—soil health monitoring and crop stress detection.

Conceptual Framework: AI and Precision Agriculture

Precision agriculture is a modern, data-driven farming approach that addresses variability within fields to enhance productivity and sustainability.

Creative Commons (CC BY-NC-SA 4.0)

This is an open access journal, and articles are distributed under the terms of the [Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International](https://creativecommons.org/licenses/by-nc-sa/4.0/) Public License, which allows others to remix, tweak, and build upon the work noncommercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

How to cite this article:

Sonone, S. N., & Tompe, V. K. (2025). Integrating Geography and AI in Precision Agriculture: A Study of Soil Health and Crop Stress. *In Sight Bulletin: A Multidisciplinary Interlink International Research Journal*, 2(6), 130–133. <https://doi.org/10.5281/zenodo.17083174>

It shifts from traditional uniform practices to targeted interventions by utilizing advanced technologies. Artificial Intelligence (AI) serves as the core enabler of this transformation, integrating real-time data from satellite imagery, drones, sensors, and mobile applications to generate actionable insights.

Machine Learning (ML), a key AI component, analyzes soil, weather, and crop data to predict yields, identify nutrient needs, and suggest optimal sowing times. Deep Learning (DL), a subset of ML, excels in processing complex data like multispectral images to detect early signs of crop stress, diseases, or pests. Computer Vision aids in monitoring plant health through drone-captured images, allowing for precise, geotagged field interventions.

Natural Language Processing (NLP) enhances farmer interaction by translating AI outputs into local languages via apps and chatbots, ensuring inclusive access to technology. Robotics and automation, driven by AI, revolutionize tasks like sowing, irrigation, and harvesting with high precision, reducing input waste and labor intensity.

Together, these AI technologies create a robust framework that empowers precision agriculture, making it more adaptive, efficient, and sustainable for the future of global food security.

Soil Health Monitoring Using AI

Soil health is a foundational element of agricultural productivity, influencing water retention, nutrient availability, and crop resilience. Traditional methods of soil assessment—manual sampling and lab testing—are often costly, slow, and inaccessible to smallholder farmers. The integration of Artificial Intelligence (AI) offers a transformative solution, enabling accurate, real-time, and scalable soil health monitoring through remote sensing, sensor networks, and predictive analytics.

AI systems can evaluate key soil parameters such as moisture, pH, organic carbon, nitrogen, and texture using data from IoT-enabled sensors and satellite imagery. Deep learning algorithms like Convolutional Neural Networks (CNNs) analyze spectral reflectance from satellites (e.g., Sentinel-2, Landsat 8) to map soil moisture and nutrient content. Additionally, machine learning models, including Random Forests and Support Vector Machines, process sensor data to generate high-resolution soil fertility maps.

In Vidarbha, Maharashtra, cotton farmers use AI-based soil mapping to detect micronutrient deficiencies like zinc and boron. This site-specific management has reduced fertilizer costs and improved yields. AI also optimizes irrigation and fertilizer use, reducing waste and environmental impact. As digital access improves in rural areas, AI-driven soil health monitoring is becoming a key tool in building climate-resilient, sustainable, and efficient agricultural systems.

Crop Stress Detection with AI

Crop stress, caused by biotic factors like pests and diseases or abiotic factors such as drought, heat, and poor soil, significantly impacts agricultural productivity. Early detection is crucial to mitigate yield losses and support timely interventions. Artificial Intelligence (AI) offers advanced tools to monitor and diagnose crop stress with high accuracy, enabling precision farming solutions.

AI-powered image classification techniques using drone and satellite imagery, processed through deep learning models like Convolutional Neural Networks (CNNs) and ResNet, can identify visual symptoms such as leaf discoloration or curling. Hyperspectral imaging enhances this process by detecting subtle physiological changes—like chlorophyll loss or moisture variation—before visible symptoms emerge. Predictive analytics leverages historical climate, soil, and crop data to forecast stress risks, allowing preemptive action.

Mobile apps like Plantix and Farmonaut make AI accessible to farmers, enabling image-based disease diagnosis and treatment advice in local languages. A notable success example is from Tamil Nadu's Cauvery delta, where AI models detected nitrogen deficiency in paddy fields. Targeted urea application based on the AI output led to a 12% yield increase.

AI-driven crop stress detection empowers farmers with proactive, data-informed decisions, promoting higher productivity, sustainability, and resilience against environmental and biological challenges.

Benefits of AI in Precision Farming

Artificial Intelligence (AI) brings transformative benefits to precision farming, enhancing efficiency, sustainability, and inclusivity across economic, environmental, and social dimensions. Economically, AI enables farmers to reduce input costs through targeted application of fertilizers, pesticides, and irrigation, optimizing resource use while maximizing yields. Early detection of crop stress through AI-driven models helps prevent losses and improves productivity. Automation technologies such as drones and autonomous tractors reduce labor dependency, streamlining field operations.

Environmentally, AI supports sustainable agriculture by minimizing the overuse of chemicals. By accurately diagnosing nutrient deficiencies or pest infestations, AI limits unnecessary chemical application, reducing pollution and preserving ecological balance. Smart irrigation systems use real-time soil and weather data to conserve water and improve soil health, while AI-guided nutrient management helps prevent runoff into water bodies.

Socially and institutionally, AI empowers smallholder farmers by offering real-time, data-based decision-making support through user-friendly mobile applications in local languages. This enhances access to modern agricultural tools, fosters confidence, and bridges knowledge gaps. AI also strengthens extension services by delivering timely, personalized guidance, improving farmer outreach and support systems.

Overall, AI in precision farming not only boosts farm productivity and profitability but also promotes environmental conservation and inclusive rural development, marking a shift toward sustainable, tech-driven agriculture.

Limitations and Challenges

Despite its transformative potential, the adoption of Artificial Intelligence (AI) in precision farming faces several limitations and challenges. Technological barriers, such as poor internet connectivity in rural areas, hinder real-time data transfer

essential for AI functionality. High costs of AI tools—like drones, IoT sensors, and satellite imagery—make them inaccessible for many small and marginal farmers. Additionally, the lack of localized datasets for specific crops, soil types, and climatic conditions limits the accuracy and effectiveness of AI models across diverse regions.

Socio-economic challenges include low digital literacy and limited awareness among farmers, leading to hesitation in adopting unfamiliar technologies. Land fragmentation, particularly in countries like India, further complicates large-scale implementation of AI tools, as small, scattered farms reduce the efficiency of precision interventions.

Ethical and policy concerns also pose significant challenges. Issues surrounding data ownership, consent, and privacy raise questions about who controls farm-level data and how it's used. The growing dependence on private agri-tech firms fosters fears of monopolistic practices and exploitation. Moreover, many AI systems operate as "black boxes," offering recommendations without explanation, reducing transparency and trust.

Overcoming these challenges requires collaborative efforts—investing in rural infrastructure, developing affordable tools, enhancing farmer education, and ensuring transparent, ethical AI governance in agriculture.

Policy Recommendations

To effectively integrate Artificial Intelligence (AI) into Indian agriculture—particularly in agrarian yet distressed regions like Vidarbha and Marathwada—a comprehensive and inclusive policy approach is essential. Government support should be the cornerstone, with subsidies provided for AI-enabled tools such as drones, soil sensors, and satellite-linked devices, making them accessible to small and marginal farmers. Moreover, flagship rural schemes like PM-KISAN and eNAM should include dedicated AI components to ensure technology penetration at the grassroots level. Capacity building is equally crucial, as digital literacy remains low among rural communities. Targeted training programs should be launched to empower farmers with the necessary skills to use AI platforms effectively. Krishi Vigyan Kendras (KVKs), which serve as rural knowledge hubs, should be equipped and trained in AI technologies to provide hands-on guidance and demonstrations.

On the research and development front, public-private partnerships must be encouraged to create region-specific AI models tailored to local crops, soils, and climatic conditions. Establishing AI centers of excellence in state agricultural universities would further stimulate innovation and create a pool of agri-tech professionals. Data on soil health, crop yields, climate conditions, and pest outbreaks should be made publicly available to researchers, startups, and farmers. Promoting open-source AI tools would reduce dependence on proprietary software and ensure equitable access. Finally, a robust agri-tech startup ecosystem should be nurtured through incubators, seed funding, and market linkages, especially for startups working in the fields of soil diagnostics, pest and disease detection, crop stress monitoring, and predictive analytics. These combined policy measures can lay the groundwork for a smart, sustainable, and inclusive AI-driven agricultural revolution in India.

Future Prospects

The future of AI in agriculture is poised for rapid and transformative growth, driven by advancements in computing, data integration, and automation. One of the most promising developments is the integration of AI with blockchain technology, which can enhance traceability and transparency in the agricultural supply chain—from farm to fork—ensuring food safety, reducing fraud, and increasing consumer trust. Cloud computing is set to further democratize access to large-scale AI models, allowing even smallholder farmers to benefit from sophisticated analytics through mobile devices and rural service centers. Meanwhile, robotics and automation are evolving to support autonomous vehicles, drones, and machines capable of real-time field surveillance, precision spraying, and mechanical weeding with minimal human intervention.

A revolutionary area of development is Geospatial AI (GeoAI), which blends geographic information systems (GIS) with artificial intelligence to interpret spatial data and generate high-resolution, map-based insights on soil variability, crop health, and stress zones. Furthermore, the advent of Edge AI—where AI computations occur on local devices like smartphones or drones instead of remote servers—will empower real-time, on-site decision-making even in regions with poor internet connectivity. This is particularly vital for remote Indian villages where cloud infrastructure may be inconsistent.

In the coming years, AI-driven innovations will likely shift the paradigm from reactive to proactive and predictive farming, where stress, disease, or nutrient imbalances are addressed even before visible symptoms appear. With continued investment in infrastructure, research, and inclusive policy support, AI has the potential to create a more resilient, productive, and equitable agricultural system for India and the global South.

Conclusion

AI in precision farming represents a transformative shift in agriculture, addressing long-standing challenges such as declining soil fertility, increasing crop stress, and resource inefficiencies. Through data-driven interventions, AI enables timely decisions that enhance productivity, reduce costs, and promote sustainability. While limitations exist, the path forward lies in collaborative action by governments, researchers, tech developers, and farmers to make AI accessible, affordable, and inclusive. For regions like rural Maharashtra, where climate variability and socio-economic vulnerabilities are high, the fusion of AI and agriculture offers not just innovation, but hope.

Acknowledgment

We extend our sincere gratitude to the faculty and administration of G.S. Tompe Arts, Commerce & Science College, Chandur Bazar, for their academic support and encouragement throughout this research endeavor. We also thank Sant Gadge Baba Amravati University for providing a research-friendly environment and access to relevant academic resources.

We are especially grateful to the farmers, field experts, and technology facilitators who shared valuable insights and real-world data that enriched the practical dimension of our study. Our heartfelt appreciation goes to our mentors and colleagues for their constant guidance, critical suggestions, and moral support during the writing process.

Lastly, we acknowledge the contributions of researchers and developers whose pioneering work in AI and agriculture served as a foundation for this study. Their efforts continue to inspire innovation in creating more equitable and sustainable food systems.

Financial support and sponsorship

Nil.

Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

References

1. Zhang, Y. et al. (2020). "Deep Learning for Agricultural Image Analysis: A Review." *Computers and Electronics in Agriculture*.
2. Patil, M., & Jagtap, R. (2021). "AI-enabled Irrigation System in Cotton Fields of Vidarbha." *Indian Journal of Agricultural Research*.
3. Khosla, R., et al. (2019). "Machine Learning Applications in Soil Nutrient Mapping." *Precision Agriculture Journal*.
4. FAO (2022). *Digital Agriculture and AI: Global Experiences*. Food and Agriculture Organization.
5. Kumar, S. (2023). "Crop Stress Detection using UAV and CNN in Tamil Nadu." *Remote Sensing Applications: Society and Environment*.
6. ISRO-NRSC (2021). "Geospatial AI for Crop Health Monitoring in India."
7. World Bank (2020). *Artificial Intelligence in Agriculture: Trends and Opportunities*.
8. ICAR (2022). *Smart Farming: The Role of Digital Technologies*.
9. Plantix App. (2023). www.plantix.net
10. Farmonaut. (2024). www.farmonaut.com