



International Journal of Research in Agronomy

E-ISSN: 2618-0618

P-ISSN: 2618-060X

© Agronomy

NAAS Rating: 5.20

www.agronomyjournals.com

2025; 8(6): 201-204

Received: 13-03-2025

Accepted: 17-04-2025

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AI-driven agricultural knowledge system: Empowering Indian farmers

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DOI: <https://www.doi.org/10.33545/2618060X.2025.v8.i6c.3017>

Abstract

India's agricultural sector, which is critical to food security and the economy, has a lot going against its productivity and access to modern technology: low productivity, lack of access to land and fragmented landholdings. The intention of this paper is to theorize how the use of artificial intelligence (AI) could help Indian agriculture close knowledge gaps and enhance productivity. New applications of AI such as in weather forecasting, crop recommendations, and pest control have already shown that the technology can greatly improve decision making and resource optimization. Moreover, it is equally led to knowledge dissemination transformation via AI powered real time advisories through mobile apps and IoT devices as well as making critical information easily accessible to farmers. Automation and Robotics, including tools for precision farming have made the jobs such as that much more efficient, profitable and resource exhaustive. Continued penetration of AI into supply chain optimization benefits consumers and farmers with improved market price forecasts and logistics modelled by predictive models. Widespread adoption of AI has been prevented by high costs, low digital literacy, and prohibitive infrastructure problems. Therefore, in this work, I propose that the government should support deploying AI by subsidizing it to implement AI on farms and helping the farmers adopt AI without any doubts or conflicts, and to work with the policymakers, researchers and technology companies tackle these barriers. These efforts will enable India to ensure equitable use of AI tools and also build a productive and more sustainable agriculture ecosystem in India.

Keywords: Precision farming, Artificial Intelligence (AI) in agriculture, crop yield optimization, digital agriculture tools, agricultural sustainability

Introduction

India's economy is largely supported by agriculture where it contributes about 18 per cent of its GDP and supports the livelihood of more than half our population. Food security, rural development and economic stability depend on it as a critical sector. As India with its vast and varied agricultural landscape brings a lot of challenges to this sector which has to be addressed at the gallop. Indian agriculture is important but productivity is low, resource use is inefficient, and there are poor practices.

Land holdings are fragmented, with the farm size of about two hectares very small to preclude economies of scale. At the same time, farmers have very low digital literacy and do not have access to modern knowledge and tools in modern agriculture. In addition, financial risks for smallholder farmers are exacerbated by market linkages inefficiencies and prices volatility. Climate variability threatens crop yields; sustainability.

Artificial Intelligence (AI) has become, in many ways, the vehicle that will allow us to tackle these problems. Combining such technologies as predictive analytics, Machine Learning and IoT, AI can fill the knowledge gaps bridging critical information to farmers to enable actionable insights. A notable example of that is AI driven tools that provide real time advisories on when to sow, what to spray and when to irrigate. On the other hand, AI driven platforms can improve market access by predicting price trends and smoothing supply chains.

AI holds the promise of being a bridge between current practices with traditional and modern technology in Indian agriculture. This is what will give the power to the farmers, increase the

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productivity, and will maintain sustainability, and hence it will be a key part of India's Agricultural future.

Objectives

India's agricultural sector is grinding with its fragmented landholdings, stale practices and a lack of access to actionable knowledge that keeps the small holder farmers from qualification to make informed decisions. Doing so enables the use of such solutions to be effectively and meaningfully deployed. The artificial intelligence (AI) can address these issues. Farm level decision making can benefit from the use of AI powered systems such as crop recommendation framework and predictive analytics crucial parameters such as soil health, climate pattern and crop suitability. For an instance, Mishra, and Gupta (2023) ^[19] mentioned that resources and wastage during cultivation can be reduced through the use of AI block crop advisory models. In addition, as Liu (2020) ^[6] posited, AI is useful in precision agriculture for pest control and optimization of irrigation. It thus supports AI as a disruptor that bridges knowledge gaps in agriculture (Ankush Ramrao Gaike *et al.*, 2024) ^[24].

To achieve widespread adoption, high costs, lack of digital literacy and scalability must be addressed by actionable strategies. According to Wadhe *et al* (2023) ^[22], AI will democratize market trends and supply chain optimization to empower the smallholder farmers with ready to use tools that bring more profitability in what they produce. Along the similar lines, Hota, and Verma (2022) ^[16] warned about the barriers posed by the digital divide, which limits access to some AI solutions for Indian farmers, while urging the use of customized AI solutions that account for the socio economic reality of Indian farmers. Siddiqui *et al.* (2023) ^[20] further argue that AI should be integrated with resource management to create both environmental sustainability and productivity gains at a time.

In this work, we identify knowledge gaps related to existing research, how AI can effectively cater to them, and suggest farmer centric and scalable solutions for AI adoption. This approach attempts to create a sustainable and inclusive agriculture ecosystem in India (Mahajan SK *et al*, 2024) ^[26].

Literature Review

Artificial Intelligence (AI) has come up as a breakthrough in agriculture to address complex challenges. AI applications across farming practices are reshaping the way farmers practice globally by using predictive analytics, robotics, and precision farming. Agriculture is the main provider of livelihood for most Indians but is associated with low productivity and poses challenging gaps in knowledge regarding new molecular or new crop varieties, which is a unique case for the application of AI.

V. Wadhe *et al.* (2023) ^[22] pointed out the beneficial uses of AI related to technologies like crop monitoring, market forecasting and supply chain optimization in reducing the workforce need for productivity enhancement. The study emphasized the value of having real time data when making decisions at different points in the agricultural process. Like Mishra and Gupta (2023) ^[19], AI based crop recommendation systems have also shown to optimise the allocation of land use and resources to enhance yield while reducing the environmental impacts.

As Liu (2020) ^[6] articulated with regards to AI on a broader scale, AI is used to predict pests and diseases, which saves both money and food security. This matches up with Siddiqui *et al.* (2023) ^[20] who showed how AI and machine learning models can augment resource efficiency by incorporating live sensor data and drone data. These acts may seem to have created edges

but J. Hota and V. K. Verma (2022) ^[16] observed that challenges still exist along the way such as affordability matters, low digital literacy and infrastructural gaps in India.

Advancements in IoT, big data analytics and machine learning led to AI adoption globally supporting farmers in realizing precision agriculture too and adopting sustainable practices. India though however, has unique features such as fragmented land holdings and lower penetration of technology in rural areas. These specific needs must be considered in solutions via localized AI tools and farmer training programs.

The literature identifies convergence around the possibility of AI to revolutionize agriculture, but leaves gaps in how this can be achieved for smallholder farmers in terms of scalability and accessibility. Combining learnings from global and India studies, this review calls for targeting the strategies on transforms that fully leverage the strengths of AI in agriculture to build a sustainable and inclusive agricultural ecosystem in India.

Methodology

This study employs an analytical approach to estimation of the role which Artificial Intelligence (AI) would potentially play to bridge the knowledge deficits in Indian agriculture. A combination of secondary data analysis and case study evaluations is used as the primary methodology. The current status of AI applications in agriculture will be analysed from the secondary data sources through Primary research using peer reviewed articles, conference papers and reports. Such an approach makes it possible to understand in detail how the use of AI driven technologies is affecting farming practices, decision making and resource management in Indian agriculture.

Data Sources

The secondary data used in this study is introduced from the research papers in references, realizing the impact of AI on different facets of the agricultural system. Further important finds on AI based systems for crop monitoring and resource efficiency are presented in papers by Wadhe *et al.* (2023) ^[22] and Siddiqui *et al.* (2023) ^[20] and for AI based crop recommendation systems, by Mishra and Gupta (2023) ^[19]. This is what Hota and Verma (2022) ^[16] put forth as information that should help with understanding the challenges and barriers to AI adoption in India, particularly with respect to infrastructure, cost, and digital literacy. In Liu (2020) ^[6], further possibilities of AI for pest management and agricultural optimization are presented.

Focus Areas

1. **Case Study Analysis:** The methodology revolves around looking at specific AI based projects occurring in India. For instance, Siddiqui *et al.*'s (2023) ^[20] projects encompass crop monitoring systems in which sensors are used in conjunction with artificial intelligence so as to virtually monitor crop health, soil moisture, and pest outbreaks. Such projects offer us a bird's eye view of how these AI models work in the real field.
2. **Predictive Tools:** Additionally, the study analyses predictive analytics tools used in AI applications such as forecasting weather patterns, pest infestations and optimal planting schedules. This analysis is based on insights from Mishra and Gupta (2023) ^[19] on machine learning crop yield prediction models. The study evaluates the effectiveness of these predictive tools in reducing uncertainty and enhancing farmers' decision making by examining the results of these tools in agricultural practices.

- 3. Technological Barriers and Challenges:** The study also discusses the barriers to AI adoption discussed by Hota and Verma (2022)^[16]. High costs, limited technological access in rural areas, as well as the digital divide — the inability of farmers to make good use of AI tools — are some of the major issues in these areas.

Given this, the methodology aims to transform insights gleaned from different sources to shed light on the application of AI in Indian agriculture and how it can fill the knowledge gaps of farmers themselves.

Applications of ai in bridging knowledge gaps

Knowledge gaps in Indian agriculture are addressed by artificial intelligence in transformative applications. The applications make decisions easier; they improve internal business efficiency and they enable the dissemination of important information. In what follow are explored key AI applications that are greatly bridging these knowledge gaps.

- **Predictive Analytics:** AI enabled Predictive analytics helps farmers to make better decision. AI algorithms can predict weather patterns, optimise sowing schedules, predict pest outbreaks allegedly, and advise crop varieties best suited to particular environmental patterns. This reduces farmers' uncertainties, with them more able to make more informed decisions. For example, as pointed out by Mishra and Gupta (2023)^[19], AI-based crop recommendation systems used, such as those in India that combine historical climate data along with soil conditions and other inputs to recommend the best crops for a certain region, are very apt. Not only is this predictive model able to improve yield, it also decreases the risk associated with failure of a crop due to poor sowing times or errors in picking a crop. Like weather, AI models can forecast better, facilitating the scheduling of irrigation for farmers in India's water scarce regions, for example.
- **Automation and Robotics:** Automation and robotics are also reshaping agriculture, especially in tasks that require precision and efficiency. AI-driven tools such as drones, autonomous tractors, and harvesting robots have made significant strides in Indian agriculture, particularly in resource-intensive tasks. These technologies help optimize the use of water, fertilizers, and pesticides, reducing waste and improving crop yields. Wadhe *et al.* (2023)^[22] noted the potential of robotics in tasks like weeding, planting, and pruning, which not only reduce labour costs but also ensure that resources are applied only where needed. For instance, autonomous tractors equipped with AI can perform tasks like tilling and seeding with minimal human intervention, significantly increasing farm efficiency. Similarly, drones equipped with AI-based imaging systems can monitor large fields, detect pests, and assess crop health, allowing farmers to target interventions more precisely.
- **Supply Chain Optimization:** For long, the inefficiencies in Indian agriculture's supply chain have resulted in loss of significant amounts and volatility in prices. Supply chains today are being optimized with real time market price predictions, and improved logistics using AI. AI driven platforms can then analyze data from weather forecasts, crop reports, or historical pricing trends to predict the best times for a farmer to sell their crop. It lets them make more profit and losing with the market fluctuations. The latter indicates that AI can also help streamline the logistics of crop transportation, by identifying the least wasteful routes to get the produce to the markets without compromising its

condition. According to Hota and Verma (2022)^[16], these AI applications create a more transparent, efficient and profitable agricultural supply chain, cutting out intermediaries, and giving fairer prices to both farmers and consumers.

Challenges

While there is a great potential of Artificial Intelligence (AI) in turning Indian agriculture around, there are many challenges to widespread adoption. However, one of the most urgent issues is that the cost and affordability of AI technologies for smallholder farmers. Because a large percentage of Indian farmers work on these small plots of land, all the initial investment of drones, sensors and even sophisticated software required for AI tools, make them prohibitively high. According to Wadhe *et al.* (2023)^[22], the cost associated with it and the lack of access in financing limit smallholder farmers from access to these technologies that can improve productivity.

Secondly, farmers are lacking in levels of digital literacy. Large segments of the agricultural workforce in India, and in rural areas more particularly, are lacking the capability and skills to use digital tools and platforms. While Hota and Verma (2022)^[16] argue that such digital divide of farmers reduces their capacity to completely benefit from AI powered solutions, like mobile applications for advising and managing their crops in real time. Farmers, generally speaking, may not be eager to trust, much less adopt, AI technologies without proper training.

But there are three massive barriers to AI adoption: infrastructure and policy hurdles. However, AI deployment is inhibited by poor internet connectivity, mainly in rural areas and a lack of agricultural infrastructure, for example, storage facilities and logistics networks. Mishra and Gupta (2023)^[119] argue for policy interventions that build and strengthen digital agriculture infrastructure, and supportive policy regimes to enhance the adoption of AI in agriculture.

Recommendations

To ensure the widespread adoption of AI in Indian agriculture, several key recommendations should be implemented:

1. **Government-led Subsidies for AI Implementation:** The government ought to subsidize and to offer financial support on the purchase and implementation of AI driven tools that can help overcome the financial barriers faced by smallholder farmers. It would also help reduce the high out of pocket costs associated with AI technologies. However, Wadhe *et al.* (2023)^[22] note that government backed financial assistance will likely support the uptake of AI tools, specifically for farmers in the rural areas that are typically cash limited.
2. **Training Programs for Farmers on Digital Tools:** However, for effective adoption of AI, digital literacy has to be improved. To encourage governments and NGOs to partner and provide training programs to teach farmers how to use AI powered mobile apps, IoT devices and crop monitoring system. To reach a wider audience Hota and Verma (2022)^[16] suggest that such programs must be localized and delivered through easily accessible formats, for example mobile based tutorials or community workshops.
3. **Collaborative Efforts Between Policymakers, Researchers, and Tech Companies:** What is needed is a collaborative approach to meet the unique needs of Indian agriculture. Therefore, policymakers, researchers and tech companies must come together to create AI solutions that

are cost effective, scalable and targeted at the local environment. This was achieved by Mishra and Gupta (2023) ^[19], who state that public-private partnerships can spur innovation while allowing technologies to be tailored to smallholder farmers' situations.

Through these combined efforts, AI would achieve the maximum impact and the Indian agriculture would become inclusive and sustainable.

Conclusion

An Artificial Intelligence (AI) can revolutionize Indian agriculture by providing it with the knowledge gaps that are needed to increase efficiency and productivity, as well as sustainability of the agriculture. AI applications, such as predictive analytics, crop recommendation systems and real time knowledge dissemination platforms can support farmers to take informed decisions, mitigate the risks of climate change, market volatility and resource management. Mishra and Gupta (2023) ^[19], Wadhe *et al.* (2023) ^[22] demonstrate how AI can be used to greatly improve agricultural outcomes in India by enhancing decision making and improving how farming is done.

But full potential has not been reached as yet, and to achieve that, better education, infrastructure and digital literacy must still be achieved, and it will still be costly. Siddiqui *et al.* (2023) ^[20] and Hota and Verma (2022) ^[16] suggest that targeted government policies and subsidies to aid in the acquisition of the AI tools should be channelled towards the benefit of smallholder farmers given the steep learning curve required to learn the use of such tools.

Finally, it is important to note that although all these possible transformative applications can be realized by AI, it's critical to make these technologies available to all the farmers. If India wants to create a more sustainable, more productive, more equitable agricultural future, it can if it fosters collaboration between the research community, policymakers, and tech companies, and implements inclusive policies.

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