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The role of AI in modern agriculture

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Abstract

The global population is growing, and soon be reaching 10 billion by 2050, and with it, the pressure on the agricultural sector to increase crop production (FAO, 2017; Hoque & Padhiary, 2024). AI is emerging as a critical solution to this challenge, offering a new wave of digital automation to overcome traditional obstacles like limited land, labour shortages, climate change and declining soil fertility (Basa, 2025). AI-driven technologies, combined with other innovations like IoT sensors, drones and big data analytics are transforming farming from a traditional manual practice into a data-driven, highly efficient industry and soon would be overtaking the traditional practices and design each season with new technologies.

Keywords: Artificial intelligence, agriculture, crop production, digital farming, IoT, drones

Introduction

Agriculture has been the backbone of human civilization and also in contributing to economic development (Bongiovanni & Lowenberg-DeBoer, 2024) [2]. In the recent years the world has witnessed rapid advancements in agricultural technology- making it a big revolution in farming practices and facing challenges caused due to climate change, extensive growth in the population causing drastic resource scarcity thus causing food scarcity and sustainability. Introducing AI helps in solves the challenges and the disadvantages of traditional farming (Hoque & Padhiary, 2024) [4]. AI-powered predictive analytics enable farmers to process vast amounts of data in a short time (Basa, 2025) [1]. This data provides insights into everything from soil health and weather conditions and market demand (IJRASET, 2024; Springer Discover Robotics, 2025) [6]. This allows for informed decisions at every stage of the crop cultivation process, AI can analyze market demand, forecast prices and also help in providing optimal time for sowing and harvesting (Basa, 2025; Journal of Agriculture and Food Research, 2025) [1, 7]. AI in agriculture can help explore the soil health and recommend the application of fertilizer and pesticides that could boost the production and gain profitability (IJRASET, 2024; ScienceDirect, 2023). AI-driven precision agriculture directly impacts a farmer's bottom line through several key methods:

- **Optimizing Resource Allocation:** Instead of uniformly applying resources across an entire field, AI algorithms can pinpoint specific areas that require attention (AIoT for Precision Agriculture, 2025). This can reduce the use of water by up to 50% and chemical pesticides by as much as 90%, according to some studies (Bongiovanni & Lowenberg-DeBoer, 2024) [2]. This not only lowers material costs but also minimizes environmental impact (Journal of Agriculture and Food Research, 2025) [7].
- **Predictive Analytics:** By analyzing historical data and real-time conditions like weather forecasts and soil moisture, AI can predict potential issues like pest infestations or crop diseases before they become widespread (Springer Discover Robotics, 2025; MDPI Drones, 2024). This early detection allows for targeted, proactive treatments, avoiding the cost of larger-scale interventions and preventing significant crop loss (Science Direct, 2023).
- **Automation and Efficiency:** AI-powered robotics and autonomous machinery can perform labour-intensive tasks like planting, weeding, and harvesting with high precision (IAEME, 2022; Science Direct, 2023). This automation reduces the need for manual labour, lowering labour costs and increasing overall operational efficiency

(Hoque & Padhiary, 2024) ^[4]. AI provides a solution to labour shortages by automating laborious and time-consuming tasks (IAEME, 2022). Automated farm machinery, smart irrigation systems, and AI-based robots are more efficient and accurate than human workers (PubMed, 2024).

- **Task Automation:** AI and robotics can perform repetitive, manual tasks like weeding, planting, and harvesting (ScienceDirect, 2023). This frees up the human workforce for more complex or supervisory roles, shifting the focus from physical labour to technology management (Hoque & Padhiary, 2024) ^[4].
- **Improved Efficiency:** Automated systems can work around the clock in all weather conditions, ensuring tasks are completed more quickly and consistently (IAEME, 2022). For example, AI-powered systems can monitor and adjust watering schedules in real time based on soil moisture and weather forecasts, optimizing resource use and reducing the need for constant human oversight (AIoT for Precision Agriculture, 2025).
- **Precision and Accuracy:** AI-based robots, such as those used for targeted weeding, can differentiate between crops and weeds, applying herbicides or removing them mechanically with extreme accuracy (ScienceDirect, 2023). This reduces waste and damage to crops, something that is difficult to achieve with manual labor alone (Basa, 2025) ^[1].

In places like Japan, where the agricultural workforce is aging, autonomous rice-planting robots are being used to maintain stable food production (IAEME, 2022). Similarly, in the US, companies are developing robotic harvesters to address the scarcity of seasonal farm workers (Science Direct, 2023).

Applications of AI in Agriculture

The AI in agriculture market is projected to grow significantly, indicating a rapid adoption of these technologies. The text highlights several key applications:

- **Optimizing Automated Irrigation:** AI algorithms, combined with IoT sensors, can autonomously decide the precise amount of water needed for crops in real-time, conserving water and promoting sustainable practices.
- **Detecting Leaks and Damage:** AI can analyze data from irrigation systems to identify patterns and anomalies that indicate leaks, preventing water waste and crop damage.
- **Crop and Soil Monitoring:** AI, particularly through computer vision, can accurately monitor soil conditions and analyze nutrient levels. It can also track crop growth and predict yields with a high degree of speed and accuracy.
- **Disease and Pest Detection:** Computer vision models can scan images to detect pests, diseases, mold, or rot, allowing farmers to take swift action to prevent the spread of threats.
- **Livestock Health Monitoring:** AI-powered systems using drones, cameras, and computer vision can monitor livestock remotely, detecting atypical behavior and providing insights into the impact of diet and environmental conditions on animal well-being.

- **Intelligent Pesticide Application:** AI-powered drones can use computer vision to determine the precise amount of pesticide to be sprayed on specific areas, combining the precision of manual application with the speed of automation.
- **Yield Mapping and Predictive Analytics:** AI and machine learning algorithms analyze large datasets from drones and sensors to predict future yields, helping farmers plan and allocate resources for the best return on investment.
- **Automatic Weeding and Harvesting:** Computer vision and machine learning can distinguish weeds from crops, allowing robots to perform automatic weeding and harvesting tasks with high precision.
- **Sorting Harvested Produce:** After harvesting, AI can sort produce more accurately than manual methods, grading items based on shape, size, and color, which helps in quickly categorizing and pricing produce.
- **Surveillance:** AI-based video surveillance systems can help with farm security by identifying security breaches and distinguishing between employees and unauthorized visitors.

Challenges of AI Adoption in Agriculture

Despite the clear benefits, there are several hurdles to the widespread adoption of AI in agriculture:

- **High Upfront Costs:** The initial investment in AI solutions can be very expensive, making it difficult for small-scale farmers and those in developing countries to adopt the technology.
- **Reluctance to Embrace New Technologies:** Many farmers are more familiar with traditional methods and may be hesitant to adopt new technologies, especially due to a lack of understanding.
- **Lack of Practical Experience:** The technological advancement varies across the world. In some regions, a lack of infrastructure and experience with next-gen technology makes implementation difficult.
- **Lengthy Technology Adoption Process:** The agricultural sector often lacks the necessary infrastructure for AI to work seamlessly. A gradual approach, starting with simpler technologies, may be required.
- **Technological Limitations:** AI still has constraints, such as the need for diverse, high-quality data, which can be scarce in agriculture. Additionally, robots may struggle to adapt to changing farming environments.
- **Privacy and Security Issues:** The use of AI in farming raises legal questions, and there are risks of cyber attacks and data leaks that could disrupt food supplies. The lack of clear regulations is a significant concern.

The Future of AI in Agriculture

The future of AI in agriculture is promising. Technology has always been a driver of progress in farming, and AI is the next logical step (FAO, 2017). The integration of AI with big data, sensors, and robotics will continue to increase efficiency and productivity while reducing the traditional challenges of farming. Public and private sector collaboration is crucial to overcome the adoption challenges (Hoque & Padhiary, 2024) ^[4]. Technology providers must work on educating farmers and offering training and support. Governments can also play a vital role by providing funding and developing regulations to build trust and ensure

the responsible use of AI. The text mentions a market size of USD 1.7 billion in 2023, projected to grow to USD 4.7 billion by 2028, showcasing the immense potential and expected growth in this sector. Based on the provided text, here is a detailed summary of the role of AI in agriculture, its benefits, applications, challenges, and future outlook. More importantly, the benefits of AI in agriculture are undeniable. Smart farming tools, intelligent automation, and AI-powered products perform repetitive time-consuming tasks so workers can use their time for more strategic operations that require human judgment. Increasingly affordable computer vision alongside agricultural robotics has the potential to accelerate AI advancement in farming. AI has the tools to address the challenges posed by climate change, environmental concerns, and an increasing demand for food. It will revolutionize modern agriculture by improving efficiency, sustainability, resource allocation on top of real-time monitoring for healthier and higher-quality produce.

However, you can't just buy AI and start using it. AI is not something tangible - it's a set of technologies that are automated through programming. In essence, an AI algorithm mimics the way people think — it learns first, and then solves problems based on data. AI-driven transformation of agriculture will require changes in the industry. Farmers need to be educated and trained in how to use AI-powered solutions. AI is likely to change the role of farmers from manual workers to the planners and overseers of smart agricultural systems. An understanding of IT solutions and agribusiness intelligence will potentially become more useful than the ability to use conventional tools or carry out physical labour. Despite AI and machine learning together with MLOps services having the potential to radically transform farming, they need other technologies to work in sync. To reap all the benefits of AI, farmers first need a technology infrastructure. It could take years to develop that infrastructure, but doing so could result in a robust, future proof technology ecosystem. Understanding how AI works and how best to integrate technical knowledge into real-life processes is vital for maximizing its benefits. Providers of AgTech solutions have an important role to play. Each must consider how they can improve their tools, address challenges, and clearly convey the measurable benefits of AI and machine learning. If this can be achieved, the future of AI in agriculture is bound to be fruitful. The success of human society is essentially dependent on the optimization of its agricultural systems. Traditional farming methods are becoming outdated, need for advanced technological solutions. Worldwide, the impact of automation on industries has always been considerable. Digital technology is now playing a huge role in transforming agriculture and the impact of artificial intelligence in agriculture is set to be vast.

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