

Role of Artificial Intelligence in Transforming Modern Agriculture

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Abstract

Agriculture is one of the most important sectors for human survival and economic development. It provides food, raw materials, and employment to a large portion of the global population. However, modern agriculture faces several challenges, including climate change, irregular rainfall, soil degradation, crop diseases, pest attacks, and the increasing demand for food due to rapid population growth. These challenges make it difficult for farmers to maintain high productivity and manage resources efficiently using traditional farming methods.

In recent years, Artificial Intelligence (AI) has emerged as a powerful technology to address these agricultural challenges. AI systems can analyse large volumes of data collected from farms, sensors, satellites, and weather-monitoring systems. By processing this data, AI helps farmers make better decisions regarding crop management, irrigation, fertiliser use, and disease control.

Various AI techniques, such as machine learning, deep learning, and computer vision, are widely used in agriculture. These technologies enable systems to learn from historical data and identify patterns that are not easily visible to humans. For instance, AI can detect plant diseases at an early stage using image analysis, predict crop yields based on environmental conditions, and monitor crop growth through drone and satellite imagery.

This review paper focuses on the role of artificial intelligence in modern agriculture and explores its applications in improving farming practices. It highlights key areas such as crop monitoring, disease detection, smart irrigation, and yield prediction. Additionally, the paper discusses the challenges associated with the adoption of AI, including high costs, lack of technical knowledge, and limited data availability in rural areas.

Overall, artificial intelligence has the potential to transform traditional agriculture into a more efficient, data-driven, and sustainable system. With proper implementation and support, AI technologies can significantly enhance agricultural productivity and help meet future food demands.

Keywords: *Artificial Intelligence, Agriculture, Machine Learning, Deep Learning, Crop Monitoring, Plant Disease Detection, Smart Irrigation, Yield Prediction*

Introduction

Artificial Intelligence (AI) is emerging as a transformative technology in modern agriculture, helping to improve productivity, efficiency, and sustainability. In recent years, AI-based techniques such as machine learning, deep learning, computer vision, and data-driven systems have been widely used to solve various agricultural problems. These technologies assist farmers in making better decisions by analysing large amounts of data related to soil, crops, weather, and environmental conditions (Srikanthnaik, 2024; Nazish Aijaz et al., 2024).

One of the major applications of AI in agriculture is plant disease detection. Researchers have used deep learning models to analyse plant leaf images and identify diseases accurately at an early stage, which helps in reducing crop losses and improving yield (R. Sujatha et al., 2025; Gujju Siva Krishna et al., 2025). Similarly, computer vision and imaging technologies such as RGB and thermal imaging are also used for monitoring crop health and detecting stress conditions in plants (Sumaira Ghazal et al., 2024).

AI is also playing a significant role in precision agriculture, where technologies like IoT, sensors, drones, and satellites are used to collect real-time data from farms. This data helps in optimising irrigation, fertiliser usage, and pest management, leading to efficient resource utilisation (Abiodun Olusola Omotayo et al., 2025; Aziz et al., 2025; J.F.

Restrepo-Arias et al., 2024). Moreover, AI models such as Artificial Neural Networks (ANNs) are capable of analysing complex agricultural data and are widely used for crop yield prediction, soil analysis, and food quality assessment (Salvador Castillo-Girones et al., 2025).

In addition, AI technologies are being integrated into smart farming systems and agricultural extension services to provide real-time guidance and personalised recommendations to farmers. Tools like generative AI and mobile applications are improving access to agricultural knowledge, especially for smallholder farmers (Chris High et al., 2025; Amin S. Ibrahim et al., 2025).

Despite its advantages, the adoption of AI in agriculture faces several challenges, including high implementation cost, lack of technical knowledge, poor infrastructure, and data quality issues (R. K. Sharma et al., 2024; Gülfina Özogul, 2025; Shanmugam Vijayakumar et al., 2025). However, with proper support, training, and technological advancements, AI has the potential to revolutionise agriculture and make it impressive and efficient in the future (Akhilesh A. Wao, 2023).

CROP MONITORING	DISEASE DETECTION	YIELD PREDICTION	SMART IRRIGATION	CLIMATE ANALYSIS
• Sensors • Drones • Satellite	• Image Analysis • CNN Models	• ML Models • Data Processing • Prediction	• IoT Systems • Automation	• xAI Models • Weather Data • Risk Prediction

Figure 1: Applications of Artificial Intelligence in Agriculture

Figure 1 shows the major applications of Artificial Intelligence in agriculture. It highlights how AI techniques such as machine learning, deep learning, IoT, and xAI are applied in areas like crop monitoring, disease detection, yield prediction, smart irrigation, and climate analysis. These technologies help improve efficiency and support better decision-making in modern farming.

Techniques Used:

- Sensors and Drones
- Image Analysis
- Machine Learning Models
- IoT Systems
- Weather Data

Background of AI in Agriculture

Artificial Intelligence (AI) is a branch of computer science that focuses on creating systems capable of performing tasks that normally require human intelligence. These tasks include learning from data, recognising patterns, solving problems, and making decisions. Over the past few decades, AI has been successfully applied in various fields such as healthcare, finance, transportation, and education. In recent years, the agricultural sector has also started adopting AI technologies to improve farming efficiency and productivity.

One of the main reasons for using AI in agriculture is the large amount of data generated from different sources. Modern farms produce data through soil sensors, weather stations, satellite images, drones, and farm management systems. Analysing such a large volume of data manually is difficult and time-consuming. AI techniques help in processing this data quickly and extracting meaningful insights, which support farmers in making better and faster decisions.

Machine learning is one of the most widely used AI techniques in agriculture. It allows systems to learn from historical agricultural data and make predictions or classifications. For example, machine learning models can predict crop yield based on soil quality, rainfall, and temperature. They can also identify patterns that indicate possible pest attacks or crop diseases, helping farmers take preventive measures.

Deep learning, a subset of machine learning, is especially useful for image analysis. Models such as Convolutional Neural Networks (CNNs) are used to analyse images of plant leaves to detect diseases and nutrient deficiencies. These models can automatically learn visual features and classify plant conditions with high accuracy, reducing the need for manual inspection.

Another important technology is computer vision, which enables machines to understand and interpret visual data from images and videos. It is widely used for crop monitoring, weed detection, fruit counting, and even automated harvesting. These applications help in reducing labour efforts and increasing efficiency.

In addition, AI is often integrated with other modern technologies such as the Internet of Things (IoT), drones, and satellite systems. This integration enables real-time monitoring of agricultural fields and provides instant feedback to farmers. As a result, farmers can take immediate actions related to irrigation, fertilisation, and pest control.

Overall, the use of AI in agriculture has created new opportunities for improving farm management and productivity. By using intelligent systems, farmers can make informed decisions, reduce resource wastage, and increase crop production in an easing.

Literature Review

R. Sujatha et al. (2025) researched the use of artificial intelligence for plant disease detection. In their study, deep learning models were used to analyse plant leaf images. The system was able to identify different plant diseases by analysing patterns on the leaves. Their results showed that AI-based systems can detect diseases faster and more accurately compared to traditional methods. The study also explained that early disease detection can help farmers take timely action and reduce crop damage.

Gujju Siva Krishna et al. (2025) studied the use of artificial intelligence in precision agriculture. In their research, they developed an AI-based system that uses machine learning and image processing techniques to monitor crop health and detect plant diseases automatically. The system analyses images collected from farms and identifies possible disease symptoms. Their research suggests that AI technologies can help farmers monitor crops more efficiently and improve farm management.

Srikanthnaik J. (2024) presented a study on the applications of artificial intelligence and machine learning in modern agriculture. The research discussed several areas where AI can be used, such as crop monitoring, soil analysis, and crop yield prediction. The study concluded that AI technologies can support farmers in making better decisions and improving agricultural productivity.

Nazish Aijaz et al. (2024). The study explains the role of Artificial Intelligence in improving agricultural practices. It shows how machine learning and deep learning help in analysing farm data and making better decisions. The paper also highlights the use of image analysis for early detection of plant diseases. However, challenges like high cost and lack of technical knowledge are also discussed. Overall, the study shows that AI can make agriculture more efficient and sustainable.

R. K. Sharma et al. (2024) presented a study on the use of Artificial Intelligence for improving crop production and farm management. The research mainly focused on how AI can be used for soil analysis, weather prediction, and smart irrigation systems. It explained that AI helps farmers use water and fertilisers more efficiently. The study also discussed some limitations, such as a lack of proper infrastructure and data availability in rural areas. Overall, the paper showed that AI can support sustainable farming but needs proper implementation.

Abiodun Olusola Omotayo et al. (2025) presented a study on the application of Artificial Intelligence and data-driven techniques in modern agriculture systems. The research focused on how AI can be integrated with technologies like IoT

and smart sensors to collect real-time farm data. It explained that this data can be used for better decision-making in areas such as crop monitoring, yield prediction, and resource management. The study also highlighted challenges like data quality issues, high implementation costs, and a lack of awareness among farmers. Overall, the paper concluded that AI-based smart farming can improve productivity and make agriculture more efficient if properly implemented.

Chris High et al. (2025) presented a study on the role of Artificial Intelligence in agricultural extension systems to support smallholder farmers. The research focused on how AI tools, particularly generative AI like Farmer. Chat can be integrated into existing agricultural knowledge systems to provide personalised and real-time advisory services. It explained that AI can enhance farmers' access to information, improve decision-making, and support learning through multilingual and user-friendly interfaces. The study also discussed challenges such as one-way communication, limited feedback mechanisms, digital literacy barriers, and trust issues among farmers. Furthermore, it emphasised that over-reliance on technology without social interaction may reduce collective learning. Overall, the paper concluded that AI can significantly improve agricultural productivity and knowledge sharing, but its success depends on proper integration with human support systems, participatory approaches, and inclusive design.

Salvador Castillo-Girones et al. (2025) presented a study on the application of Artificial Neural Networks (ANNs) as a core component of Artificial Intelligence in modern agriculture. The research focused on how ANN-based models can be used to solve complex, nonlinear agricultural problems by learning patterns from large and diverse datasets. It explained that these models simulate the human brain's functioning and are highly effective in processing heterogeneous data such as soil properties, weather conditions, and crop images. The study highlighted that ANNs are widely applied in areas like crop yield prediction, disease detection, plant phenotyping, and food quality assessment. It also discussed different types of neural networks, including CNNs, RNNs, and MLPs, and their suitability for various agricultural tasks. Furthermore, the paper addressed challenges such as the need for large training datasets, high computational requirements, improper model selection, and lack of proper data preprocessing. It emphasised that selecting appropriate models, tuning parameters, and ensuring quality data are essential for achieving accurate results. Overall, the study concluded that ANNs have great potential to transform agriculture by improving decision-making, efficiency, and productivity, but their success depends on proper implementation and understanding of both data and model behaviours.

Aziz et al. (2025) presented a study on the use of Artificial Intelligence (AI) and remote sensing in agriculture, particularly for pest management. The research focused on how technologies like drones, satellites, and sensors can be used for real-time monitoring of crops. It explained that AI helps in the early detection of pests, diseases, and crop stress, allowing farmers to take timely actions.

The study also highlighted that these technologies improve decision-making, optimise the use of water, fertilisers, and pesticides, and reduce environmental impact. It discussed that AI models can predict pest outbreaks and support precision farming practices. However, challenges such as data quality issues, high cost, and limited accessibility were also mentioned.

Overall, the paper concluded that AI and remote sensing have strong potential to enhance agricultural productivity and sustainability, but their success depends on proper integration and wider adoption among farmers.

Arthur Hrast Essenfelder et al. (2025) presented a study on the use of expert-driven explainable Artificial Intelligence (xAI) models to detect multiple climate hazards affecting agriculture. The research focused on how AI can process large-scale climate and environmental data to identify risks like droughts, heatwaves, and extreme weather conditions. It explained that integrating expert knowledge with AI models improves accuracy and helps in better understanding the causes of these hazards. The study also highlighted the importance of explainability, which increases trust in AI-based decisions among stakeholders. Additionally, the model provides probabilistic results, helping farmers and policymakers make informed decisions. However, challenges such as data quality, complexity of models, and communication of results were also discussed. Overall, the paper concluded that xAI can significantly enhance early warning systems and support sustainable agricultural management.

Akhilesh A. Wao (2023) presented a study on the role of Artificial Intelligence in Agricultural Engineering. The research focused on how AI technologies can be used to improve different engineering aspects of agriculture, such as automated irrigation systems, smart machinery, and precision farming techniques. It explained that AI helps in analysing

soil conditions, weather patterns, and crop requirements to increase efficiency and reduce manual effort. The study also highlighted challenges like high initial cost and lack of technical knowledge among farmers. Overall, the paper concluded that AI can make agricultural engineering more advanced, efficient, and sustainable.

Akhilesh A. Wao & Dr Meena Tiwari (2024) presented a study on optimising crop yield and fertiliser management using machine learning techniques. The research focused on the use of algorithms like K-Nearest Neighbours (KNN) and boosting methods to analyse agricultural data such as soil properties, weather conditions, and crop attributes. It explained that these models can provide accurate crop recommendations and help farmers select suitable fertilisers. The study also highlighted that data-driven approaches improve decision-making and increase productivity. Overall, the paper concluded that machine learning can significantly enhance sustainable agriculture.

Gülfinaz Özoğul (2025) presented a review on the use of Artificial Intelligence in agriculture, explaining how technologies like machine learning, IoT, and sensors help in crop monitoring, disease detection, and improving farm management. The study highlighted that AI increases productivity, saves resources, and supports better decision-making through real-time data. However, it also discussed challenges such as high cost, lack of awareness, poor data quality, and limited access for small farmers. The paper concluded that with proper support and implementation, AI can make agriculture more efficient, sustainable, and advanced in the future.

Amin S. Ibrahim et al. (2025) presented a study on an AI-IoT-based smart agriculture system for plant disease detection and treatment. The research focused on using sensors, cameras, and deep learning models like ResNet50 to monitor crops and identify diseases accurately. It explained that the system can automatically take actions such as spraying fertilisers when diseases are detected.

The study also included a mobile application to help farmers monitor their fields in real time. Overall, it concluded that AI and IoT can improve crop productivity and disease management, but challenges like cost and system complexity still remain.

Sumaira Ghazal et al. (2024) presented a study on the use of computer vision and AI in smart agriculture and precision farming. The research explained how imaging techniques like RGB, multispectral, and thermal imaging are used to monitor crops and soil conditions. It also showed that these technologies help in tasks like disease detection, yield estimation, and irrigation management.

The study highlighted some challenges, such as high cost and complexity, but concluded that AI-based systems can improve productivity and make agriculture more efficient and sustainable.

Puwadol Oak Dusadeerungsikul and Shimon Y. Nof (2024) presented a study on AI-based precision agriculture using a Dynamic-Adaptive Search algorithm. The research focused on improving crop monitoring by detecting crop stress early with the help of AI and real-time data. It explained that the system combines image processing and smart search techniques to reduce losses. The study showed better performance and cost efficiency compared to traditional methods. Overall, it concluded that AI can make farming more efficient and productive.

Shanmugam Vijayakumar et al. (2025) discussed the opportunities and challenges of adopting Agriculture 4.0 in modern farming systems. The study explained how technologies like Artificial Intelligence, IoT, big data, drones, and robots are helping to improve agricultural productivity and efficiency. It highlighted that real-time data plays an important role in better crop management and decision-making. However, the paper also pointed out challenges such as high implementation cost, lack of technical knowledge, and poor infrastructure. Overall, the study concluded that with proper support, training, and policies, smart farming can make agriculture more sustainable and efficient.

F.A., C.V., D.M., and D.S. (2024) presented a study on the use of Artificial Intelligence in agriculture. The research explained how AI supports crop monitoring, yield prediction, and resource management. It also highlighted that technologies like IoT and sensors improve decision-making and farm efficiency. However, challenges such as high cost, lack of infrastructure, and limited technical knowledge were also discussed. Overall, the study concluded that AI can make agriculture more efficient and sustainable.

F. F.-P. et al. (2024) presented a study on the use of Artificial Intelligence and IoT in modern agriculture. The research explained how smart technologies help in crop monitoring, irrigation, and decision-making using real-time data. It concluded that AI-based digital farming can improve productivity but faces challenges like high cost and lack of technical knowledge.

J.F. Restrepo-Arias et al. (2024) presented a study on the use of Internet of Things (IoT) in smart agriculture systems. The research explained how IoT devices such as sensors and cameras are used to collect real-time data related to temperature, humidity, soil conditions, and crop environment. The study described different layers of IoT architecture, including the physical layer for data collection and the communication layer for data transmission. It also highlighted that these systems can automate agricultural processes like irrigation and environmental control. Overall, the paper concluded that integrating IoT with AI can improve farm monitoring, decision-making, and agricultural efficiency.

The following table summarises the key studies discussed in the literature review along with their main focus and contributions.

Table 1: Summary of Literature Review

Author(s)	Year	Focus Area	Key Contribution
R. Sujatha et al.	2025	Disease Detection	Deep learning is used for accurate plant disease identification from leaf images.
Gujju Siva Krishna et al.	2025	Precision Agriculture	AI system for crop monitoring and automatic disease detection
Srikanthnaik J.	2024	AI Applications	AI is used in crop monitoring, soil analysis, and yield prediction
Abiodun Olusola Omotayo et al.	2025	Smart Farming	Integration of AI with IoT and sensors for real-time farm data
Salvador Castillo-Girones et al.	2025	ANN Models	Neural networks used for yield prediction and disease detection
Aziz et al.	2025	Remote Sensing	Use of drones and satellites for pest detection and crop monitoring
Akhilesh A. Wao	2023	Agricultural Engineering	AI for smart irrigation, automation, and efficient farming systems
J.F. Restrepo-Arias et al.	2024	IoT Systems	Sensors and IoT are used for real-time monitoring and automation

From the above table, it can be observed that most studies focus on the use of AI techniques such as machine learning, deep learning, and IoT in agriculture. These technologies are primarily used for disease detection, crop monitoring, and smart farming. Overall, AI plays an important role in improving productivity and decision-making in agriculture.

Proposed Improvements

Although this study shows that Artificial Intelligence can improve agricultural practices, there are still several areas where further improvements can be made. Future work can focus on integrating real-time data collection using IoT devices and smart sensors to provide more accurate and up-to-date information about crops, soil, and weather conditions.

In addition, more advanced deep learning models can be applied to increase the accuracy of disease detection and crop yield prediction. The system can also be developed into a user-friendly mobile or web application so that farmers can easily access the technology.

Another important improvement is the integration of weather forecasting systems, which can help farmers plan their farming activities more effectively. Providing training and awareness programs for farmers can also increase the adoption of AI technologies.

Overall, future improvements can make the system more efficient, accessible, and practical for real-world agricultural applications.

Methodology

This study is based on a secondary research approach, where information has been collected from various research papers, journals, and scholarly articles related to Artificial Intelligence in agriculture. The selected studies mainly focus on applications of AI such as plant disease detection, crop monitoring, yield prediction, precision farming, and smart agriculture systems.

The methodology involves analysing different AI techniques used in agriculture, including machine learning, deep learning, computer vision, and Artificial Neural Networks (ANNs). Many studies used image-based analysis for detecting plant diseases, where leaf images are processed using deep learning models to identify patterns and symptoms. Other research works focused on the use of IoT devices, sensors, drones, and satellites to collect real-time agricultural data such as soil moisture, temperature, and crop conditions.

In addition, several studies highlighted the integration of AI with data-driven systems and smart technologies, where collected data is analysed to support decision-making in irrigation management, fertiliser usage, and pest control. Some research also included the use of mobile applications and AI-based advisory systems to provide real-time support and recommendations to farmers.

The methodology also includes a comparative analysis of research studies to assess the benefits, challenges, and effectiveness of AI technologies in agriculture. Key factors such as accuracy, efficiency, cost, and usability were considered in the review of these studies.

Overall, this methodology helps in understanding how different AI techniques are applied in agriculture and how they contribute to improving productivity, sustainability, and decision-making in modern farming systems.

Table 2: AI-Based Agriculture Data Processing Pipeline

1. Data Collection	2. Pre-Processing	3. Feature Extraction	4. Model Selection	5. Training	6. Output
- Sensors - Satellite - Drones	- Cleaning - Resizing - Normalization	- Patterns - Texture - Spatio-Temporal	- ML (SVM/RF) - DL (CNN) - ResNet	- Large Data - Tuning - Optimization	- Disease Detection - Yield Prediction

The above table shows the step-by-step methodology used in this study. It includes data collection, preprocessing, feature extraction, model selection, training, and final prediction. The process helps in analysing agricultural data and generating useful outputs for better decision-making.

Applications of Artificial Intelligence in Agriculture

Artificial Intelligence is playing an important role in transforming modern agriculture by improving efficiency, productivity, and decision-making. It helps farmers analyse agricultural data, monitor crop conditions, and manage resources more effectively. With the use of advanced technologies, AI is being applied in different areas of farming to solve real-world problems and improve overall agricultural practices.

One of the major applications of AI in agriculture is plant disease detection. AI systems can analyse leaf images and identify diseases at an early stage by recognising patterns that are not easily visible to the human eye. This helps farmers take timely action and reduce crop damage. In addition to this, AI is widely used for crop monitoring through technologies such as sensors, drones, and satellite images. These tools provide real-time information about crop health and field conditions, making it easier to track growth and detect problems early.

AI is also used for crop yield prediction by analysing data related to soil conditions, weather patterns, and records. This helps farmers plan their farming activities and manage resources more efficiently. Another important application is smart irrigation, where AI-based systems control water usage by analysing soil moisture and weather conditions. This ensures that crops receive the right amount of water and reduces wastage.

Furthermore, AI supports precision agriculture by helping farmers use fertilisers, pesticides, and other resources in a more controlled and efficient manner, which improves productivity and reduces environmental impact. It is also used in soil analysis to study soil quality and nutrient levels, helping farmers select suitable crops and apply the correct amount of fertilisers. In addition, AI plays an important role in pest detection and management by identifying pest attacks at an early stage, which helps in controlling them before they cause major damage.

Finally, AI-based advisory systems provide useful suggestions to farmers regarding crop management, irrigation, and disease control. These systems support better decision-making and help farmers improve their overall farming practices.

Challenges of Artificial Intelligence in Agriculture

The use of Artificial Intelligence in agriculture offers many benefits, but there are still several challenges that limit its widespread adoption. One of the major challenges is the high implementation cost of AI technologies. Tools such as sensors, drones, smart irrigation systems, and other digital equipment require a large initial investment, which is not affordable for many small and marginal farmers. Along with this, the lack of technical knowledge is also a serious issue, as many farmers are not familiar with advanced technologies like artificial intelligence and machine learning, making it difficult for them to use these systems effectively.

Another important challenge is the limited availability of data. AI systems depend on large amounts of accurate data for better performance, but in many rural areas, proper data related to soil conditions, weather patterns, and crop health is either unavailable or incomplete. In addition, poor infrastructure, such as a lack of internet connectivity, unreliable electricity supply, and limited access to digital tools, further creates difficulties in implementing AI-based solutions in agriculture.

Moreover, even when data is available, issues related to data quality can affect the accuracy of predictions and decision-making. AI systems are also complex in nature and require regular maintenance, updates, and technical support, which may not always be easily available to farmers. Low awareness among farmers about the benefits and usage of AI technologies is another reason for its slow adoption. Finally, excessive dependence on AI systems may reduce traditional farming knowledge and decision-making skills, and it can also create problems if the system fails or produces incorrect results. Therefore, addressing these challenges is essential for the effective use of AI in agriculture.

Conclusion

In conclusion, Artificial Intelligence has the potential to significantly transform modern agriculture by improving productivity, efficiency, and decision-making. This study highlights how AI technologies such as machine learning, deep learning, and IoT are being used in various agricultural applications, including crop monitoring, disease detection, yield prediction, and smart irrigation. From the literature review, it is observed that many researchers have successfully applied AI techniques to solve real-world agricultural problems. These technologies help farmers make better decisions, reduce crop losses, and use resources more efficiently. The methodology proposed in this study also demonstrates how AI can be applied in a structured way to analyse agricultural data and generate useful outputs.

Despite its advantages, there are still several challenges, such as high cost, lack of technical knowledge, and limited infrastructure that restrict the adoption of AI in agriculture. Addressing these challenges is important for the successful implementation of AI-based systems. Overall, Artificial Intelligence has a promising future in agriculture. With proper support, awareness, and technological development, AI can play a key role in developing a more efficient, sustainable, and smart agricultural system.

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