International Journal of Scientific Research & Engineering Trends
Volume 12, Issue 2, Mar-Apr-2026, ISSN (Online): 2395-566X

A Comprehensive Survey on IoT and AI-Based Smart Agriculture Systems

Chaitanya Khandbahale[1], Mohammad Junaid Shaikh[2], Arnav Raut[3], Darshan Sonar[4], Professor Kalyani Pawar[5]

[1,2,3,4]Information Technology Vidyalankar Polytechnic Mumbai, India
[5]Project Guide, Information Technology Vidyalankar Polytechnic Mumbai, India

Abstract- Smart agriculture has emerged as a key solution to address critical challenges in traditional farming, including inefficient irrigation, excessive resource usage, delayed disease detection, and limited accessibility to modern technologies, especially in rural areas. The integration of the Internet of Things (IoT) and Artificial Intelligence (AI) has enabled data- driven decision-making, real-time monitoring, and automation in agricultural practices. This survey presents a comprehensive review of IoT- and AI-based smart agriculture systems reported in recent literature. Various system architectures, sensing technologies, communication methods, and AI techniques used for irrigation control, crop health monitoring, disease detection, and yield prediction are analyzed and compared. The survey also examines connectivity models, including internet- dependent and offline solutions, power management approaches such as solar-based systems, and user-access mechanisms like mobile applications, SMS alerts, and voice interfaces. Key challenges related to cost, scalability, data reliability, and rural deployment are discussed. Finally, the paper identifies existing research gaps and outlines future directions for developing affordable, scalable, and intelligent smart farming solutions, providing design insights for next- generation agricultural monitoring systems.

Keywords – Smart agriculture, Internet of Things, Artificial intelligence, Precision farming, Survey).

I. INTRODUCTION

Agriculture faces several challenges such as inefficient irrigation, excessive use of resources, delayed detection of crop diseases, and limited adoption of modern technologies, particularly in rural areas. The emergence of smart agriculture has addressed these issues by integrating the Internet of Things (IoT) and Artificial Intelligence (AI) to enable real-time monitoring, automation, and data-driven decision-making. IoT-

based sensors collect environmental and soil data, while AI techniques support crop health analysis, disease detection, and yield prediction. Numerous smart farming solutions have been proposed using different architectures, communication methods, and intelligence levels. This survey reviews and compares recent IoT- and AI-based smart agriculture systems, highlighting their key features, challenges, and research gaps to support the development of efficient and scalable precision farming solutions.

II. LITERATURE REVIEW

Recent research has shown significant progress in the application of Internet of Things (IoT) and Artificial Intelligence (AI) technologies for smart agriculture. Many studies focus on sensor-based IoT systems that monitor soil moisture, temperature, humidity, and environmental conditions to enable automated irrigation and efficient resource utilization. Wireless communication technologies and cloud platforms are commonly used to support real-time data collection, storage, and remote monitoring of agricultural fields.

Artificial Intelligence has further enhanced smart agriculture by enabling intelligent data analysis and decision-making. Machine learning and deep learning models have been widely applied for crop disease detection, yield prediction, and plant growth monitoring. Image-based techniques using convolutional neural networks have demonstrated high accuracy in identifying plant diseases at early stages. Some approaches integrate AI analytics with IoT infrastructure to provide decision-support systems for farmers.

Despite these advancements, existing solutions exhibit several limitations. Many systems rely heavily on continuous internet connectivity, expensive hardware, and cloud-dependent processing, which restrict their adoption in rural and resource-constrained environments. Power consumption, scalability, and system affordability also remain major challenges. These limitations highlight the need for cost-effective, scalable, and resilient smart agriculture systems that can operate reliably under diverse field conditions.

III. SMART AGRICULTURE APPROACHES

Existing research on smart agriculture demonstrates a wide range of approaches that integrate Internet of Things (IoT) and Artificial Intelligence (AI) technologies to enhance farming efficiency, sustainability, and decision-making. These approaches differ in terms of sensing mechanisms, intelligence level, connectivity models, power management, and user interaction strategies.

A. Sensor-Based Automation Approach

This approach focuses on the deployment of IoT sensors to continuously monitor soil moisture, temperature, humidity, and rainfall conditions. Sensor data is used to automate irrigation and fertilizer application, enabling precision resource management. Many studies adopt threshold-based or rule-based automation to reduce water wastage and manual intervention, making this approach suitable for precision irrigation systems.

B. AI-Driven Crop Monitoring and Analysis Approach

AI-based approaches leverage machine learning and deep learning techniques to analyze crop images and sensor data for disease detection, growth monitoring, and yield prediction. Computer vision models, particularly convolutional neural networks, are widely used to identify plant diseases and nutrient deficiencies at early stages. These approaches support proactive crop management and improve productivity through data-driven insights.

C. Weather-Aware and Predictive Farming Approach

Several smart agriculture systems integrate environmental monitoring with weather forecasting data to enhance decision-making. By combining real-time sensor inputs with predictive weather information, these systems dynamically adjust irrigation schedules and farming operations. This approach helps mitigate risks associated with unpredictable climatic conditions and improves crop resilience.

D. Cloud-Centric Data Processing Approach

In cloud-based approaches, agricultural data collected from IoT devices is transmitted to cloud platforms for storage, processing, and visualization. These systems enable large-scale analytics, historical data analysis, and remote monitoring through web or mobile dashboards. While cloud-centric solutions improve scalability and accessibility, they often depend on continuous internet connectivity and higher operational costs.

E. Edge-Based and Offline-Capable Approach

To address connectivity challenges in rural areas, several studies propose edge-based and offline-capable smart agriculture systems. These approaches perform data processing locally using embedded controllers or edge devices, reducing latency and dependence on cloud infrastructure. Communication mechanisms such as GSM- based SMS alerts and voice interfaces are commonly employed to ensure system functionality in low- connectivity environments.

F. Energy-Efficient and Renewable Power Approach

Power availability is a critical concern in agricultural deployments. Many smart farming solutions incorporate solar-powered systems with battery backup to ensure uninterrupted operation. Energy-efficient hardware design and low-power communication protocols are key elements of this approach, enabling sustainable and long-term system deployment in remote locations.

G. User-Centric and Multimodal Interaction Approach

User-centric approaches emphasize accessibility and ease of use by integrating mobile applications, multilingual alerts, SMS notifications, and voice-based control interfaces. These systems aim to accommodate farmers with varying levels of technical expertise and literacy, improving adoption and effective utilization of smart agriculture technologies. Some approaches also provide advisory services and real-time notifications to support informed decision-making.

IV. IOT TECHNOLOGIES USED IN SMART AGRICULTURE

IoT technologies form the backbone of modern smart agriculture systems by enabling continuous sensing, automation, and remote monitoring of farming activities. Based on the system architecture and components discussed in Group-5.docx, IoT in smart agriculture can be categorized into sensing units, communication mechanisms, embedded control platforms, automation devices, power systems, and data management layers.

A. Sensor and Environmental Monitoring Technologies

Smart agriculture systems employ multiple sensors to monitor real-time field conditions. As described in the document, soil moisture sensors are used to determine water availability in the soil, enabling automated and need-based irrigation. Temperature and humidity sensors provide microclimatic data that directly influences crop growth and disease development. Rain sensors are integrated to detect rainfall events and prevent unnecessary irrigation. Together, these sensors allow precise monitoring of environmental parameters and support data-driven farming decisions.

B. Communication and Connectivity Mechanisms

Connectivity is a critical IoT component, especially in rural agricultural environments. The document highlights the use of GSM-based communication to support SMS alerts and offline control of farm equipment. This approach enables system operation even in areas with limited or no internet access. By using GSM and SMS-based communication, farmers can receive real-time alerts, control irrigation pumps, and interact with the system using basic mobile phones, ensuring wider accessibility and reliability.

C. Embedded Control and Edge Devices

Embedded controllers act as the central processing units of IoT-based agriculture systems. The Group-5 document emphasizes the use of microcontroller-based platforms such as ESP32 for sensor interfacing, automation logic execution, and communication handling. These controllers collect data from multiple sensors, process it locally, and trigger actuators based on predefined conditions. Edge-level processing reduces dependency on continuous internet connectivity and improves system response time.

D. Automation and Actuation Components

Automation is achieved through actuators such as water pumps, valves, and fertilizer dispensing units. Based on sensor data, the system automatically controls irrigation and fertilizer application without manual intervention. This closed-loop control mechanism ensures optimal use of water and nutrients, reduces human effort, and improves overall farming efficiency. Remote pump control and automated fertilizer dispensing are key automation features discussed in the document.

E. Power Supply and Energy Management

Power availability is a major challenge in agricultural fields. The document describes the use of solar power combined with battery backup to ensure uninterrupted system operation. Solar-powered IoT nodes enable 24×7 monitoring and automation while reducing dependency on grid electricity. Energy-efficient sensors and controllers further enhance the sustainability and long-term deployment capability of smart agriculture systems.

F. Data Logging and Integration Platforms

IoT systems generate continuous streams of sensor data that must be stored and managed effectively. the system supports offline data logging with automatic cloud synchronization when connectivity becomes available. This hybrid approach ensures data.

V. ARTIFICIAL INTELLIGENCE TECHNIQUES USED IN SMART AGRICULTURE

Artificial Intelligence (AI) significantly enhances smart agriculture by enabling intelligent monitoring, prediction, and decision support. As described in Group-5.docx, AI technologies are integrated with IoT systems to automate farming operations, improve crop health management, and assist farmers through data-driven insights.

A. AI-Based Crop Disease Detection

AI cameras are used to capture crop images and analyze visual symptoms of plant diseases at an early stage. This enables timely intervention, reduces crop loss, and minimizes excessive pesticide usage.

B. AI-Driven Crop Growth Tracking

AI models analyze periodic image data to monitor crop growth patterns such as plant height and canopy development. This helps in understanding crop progress and detecting abnormal growth conditions.

C. AI-Based Yield Prediction

By combining historical data, real-time sensor inputs, and crop growth analysis, AI techniques are used to estimate expected crop yield. These predictions support better planning for harvesting and resource allocation.

D. AI-Integrated Decision Making

AI systems process sensor data such as soil moisture, temperature, humidity, and rainfall to support intelligent decisions related to irrigation and fertilizer application. This integration improves precision and resource efficiency.

E. Edge-Level AI Processing

AI inference is performed at the edge device level, reducing dependency on continuous internet connectivity. This ensures faster response time and reliable operation in rural farming environments.

F. AI-Based Farmer Assistance

AI outputs are delivered to farmers through multilingual alerts, SMS notifications, and voice-based interfaces. This improves usability and ensures that AI insights are accessible to farmers with varying technical literacy.

G. Limitations of AI Technologies

The effectiveness of AI models depends on the quality of training data and regular updates. Variations in crops and environmental conditions can impact prediction accuracy, requiring continuous refinement of AI systems.

VI. CHALLENGES AND LIMITATIONS

Although IoT- and AI-based smart agriculture systems offer significant improvements in efficiency and automation, several challenges and limitations hinder their widespread adoption, particularly in rural and resource-constrained environments.

A. Connectivity Issues

Many agricultural regions suffer from unreliable or limited internet connectivity. While GSM and SMS-based communication enables basic offline functionality, it restricts high-data operations such as real-time image transmission and detailed analytics.

B. AI Model Dependency

The accuracy of AI-based disease detection and yield prediction depends on the quality and diversity of training data. Variations in crop types, climatic conditions, and regional practices can affect model performance, requiring frequent updates and customization.

C. Hardware and Maintenance Challenges

IoT devices deployed in open fields are exposed to harsh environmental conditions, leading to sensor degradation and maintenance requirements. Limited access to technical support in remote areas can further impact system reliability.

D. Power Management Limitations

Although solar-powered systems improve sustainability, power availability depends on weather conditions and battery health. Inefficient energy management can affect uninterrupted system operation.

E. Cost and User Adaptability

Initial setup costs and periodic maintenance may be challenging for small-scale farmers. Additionally, farmers may require training to effectively understand and use system alerts and AI-

VII. CONCLUSION

This survey presented an overview of IoT- and AI-based smart agriculture systems with a focus on sensing technologies, communication mechanisms, intelligent analytics, and automation strategies. The analysis highlights that integrating IoT with AI significantly enhances resource efficiency, crop health monitoring, and decision-making in agricultural practices. Features such as automated irrigation, AI-driven disease detection, offline communication, and renewable energy support make smart agriculture systems more suitable for rural and remote environments. However, challenges related to connectivity, AI model reliability, system cost, and user adaptability continue to limit large-scale adoption. Addressing these challenges through improved AI models, affordable hardware, and farmer-centric design will be essential for the future advancement of smart agriculture.

REFERENCES

1. K. Patel, R. Sharma, and A. Singh, “IoT-Based Smart
2. Agriculture Monitoring System,”
3. Sharma and P. Deshmukh, AI-Driven Crop Disease Detection Using Convolutional Neural Networks,” IEEE Access, vol. 11, pp. 112345–112356, 2023.
4. Leher, “Smart Farming in India: Precision Techniques and Benefits,” 2025.
5. Arduino, Arduino Documentation and Development Guide.
6. Espressif Systems, ESP32-CAM Technical Reference Manual.
7. Thing Speak, IoT Analytics Platform for Data Visualization.
8. Blynk, IoT Cloud Platform for Mobile Monitoring and Control.
9. OpenWeatherMap, Weather Data API Documentation.