STM JOURNALS

International Journal of
Advanced Control and
System Engineering

ISSN: 3049-1452
Volume 3, Issue 2, 2025
July–December
DOI (Journal): 10.37591/IJACSE

https://journals.stmjournals.com/ijacse

Review IJACSE

A Review of Polyhouse Monitoring Systems

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Abstract

The integration of Internet of Things (IoT) technology in agriculture has revolutionized traditional farming practices, offering innovative solutions to enhance productivity, sustainability, and resource efficiency. This study explores the role of IoT-based systems in smart agriculture, focusing on applications such as environmental monitoring, automated irrigation, crop health prediction, and precision farming. The reviewed systems utilize advanced sensors to monitor parameters like temperature, humidity, soil moisture, and light intensity, transmitting real-time data to cloud platforms for analysis. Actuators automate processes like irrigation, ventilation, and lighting, ensuring optimal conditions for crop growth while minimizing resource wastage. Several papers highlight the integration of machine learning and artificial intelligence (AI) with IoT, enabling predictive analysis for disease detection and crop yield optimization. Renewable energy sources, such as solar power, enhance the sustainability of these systems, making them viable for remote and resource-constrained areas. However, challenges such as high implementation costs, dependency on stable internet connectivity, and the need for skilled labor limit widespread adoption. This review concludes that IoT-driven solutions hold immense potential to transform agriculture into a data-driven domain, addressing global challenges like food security and climate change. Future research should focus on improving scalability, affordability, and integrating emerging technologies like blockchain and edge computing for enhanced efficiency and security.

Keywords: Internet of Things (IoT), smart agriculture, precision farming, automated irrigation, environmental monitoring

INTRODUCTION

IoT-based agricultural systems employ networked sensors, gadgets, and cloud computing platforms to track and manage a range of environmental factors. To automate procedures such as watering, ventilation, and fertilizer distribution, these systems gather data on the temperature, humidity, soil moisture, and light intensity. Additionally, predictive analysis is made possible by a combination of machine learning and artificial intelligence (AI), which enables early crop disease diagnosis and agricultural practice improvement. Renewable energy sources, such as solar power, further enhance the sustainability of these systems, making them feasible, even in remote and resource-constrained areas.

Despite the promise of IoT in agriculture, challenges such as high implementation costs, dependency on stable internet connectivity, and the need for skilled labor remain significant barriers to adoption. Nonetheless, ongoing advancements in edge computing, blockchain, and AI are poised to

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Received Date: April 14, 2025
Accepted Date: September 02, 2025
Published Date: December 20, 2025

Citation: Sanket Sambhaji Chivhe, Arbaz Khurshid Khan, Rutik Sunil Danavale, Rutik Sunil Danavale, B.M. Borhade. A Review on Polyhouse Monitoring System. International Journal of Advanced Control and System Engineering. 2025; 3(2): 1–9p.

address these limitations and expand the scope of IoT-based smart agriculture systems. As agriculture transitions toward sustainability and efficiency, IoT-driven solutions have the potential to play a pivotal role in tackling global challenges, such as food security and climate change, fostering a more resilient and productive agricultural ecosystem. This study explores the applications, benefits, challenges, and future directions of IoT in transforming agriculture.

REVIEW OF VARIOUS LITERATURE PAPER

The growing global food demand, climate change, and resource constraints are increasing problems for the agricultural industry. The demand for sustainable output is not met by traditional agricultural methods, which are often ineffective. Consequently, incorporating cutting-edge technology, such as the Internet of Things (IoT), has become a game-changing answer. The IoT transforms conventional methods into intelligent, data-driven processes in agriculture by enabling real-time monitoring, accurate control, and automated decision-making. Farmers can improve output, optimize resource use, and solve pressing problems such as soil deterioration and water shortages by utilizing IoT.

One study explored the transformative role of IoT in agriculture, highlighting its potential to address resource inefficiencies and increase productivity. The review focuses on applications such as precision farming, smart irrigation, and crop monitoring, emphasizing the use of wireless sensor networks (WSNs), RFID systems, and cloud computing for real-time data collection and decision-making. By enabling automated monitoring of environmental parameters, such as soil moisture, temperature, and humidity, IoT systems minimize human intervention and optimize resource use. This study underscores the scalability and adaptability of IoT technologies to diverse farming needs. Challenges, such as high implementation costs, connectivity limitations, and data security concerns, have been identified as significant barriers to widespread adoption. The authors proposed integrating emerging technologies, such as blockchain, for secure data management and AI for predictive analytics to enhance IoT capabilities. Future work will highlight the need for renewable energy sources to power IoT devices sustainably and edge computing for real-time data processing. The paper concluded that IoT has the potential to revolutionize agriculture by transitioning it into a data-driven, sustainable domain, which is critical for addressing global challenges, such as food security and climate change [1].

A study developed an IoT-enabled agricultural monitoring system integrated with machine learning for predictive analytics. The system utilizes DHT11 sensors for temperature and humidity, soil moisture sensors, and light-dependent resistors (LDRs) for light intensity measurements. The data collected by these sensors were transmitted to a cloud platform via GSM for analysis. The machine learning component enabled predictions of crop health and yield optimization, demonstrating significant potential for improving farming outcomes. Automated irrigation and environmental control minimized water and energy wastage and reduced human intervention, while ensuring optimal growth conditions. The study emphasized the scalability of the system for different crop types and farm sizes but identified challenges such as dependency on reliable internet connectivity and high initial costs. To improve the sustainability of the system, scientists have suggested including renewable energy sources such as solar panels. While the system showed promising results in resource conservation and productivity enhancement, a need for larger-scale implementation and validation was noted. The study concluded that IoT-based systems, combined with predictive analytics, have immense potential to transform traditional farming practices into efficient data-driven operations, thereby addressing critical issues such as labor shortages, resource wastage, and climate unpredictability [2].

An article presented an IoT-enabled monitoring and control system for smart agriculture, emphasizing automation to optimize farming operations. The system integrated sensors for soil moisture, temperature, and humidity, which were connected to actuators for irrigation and ventilation control. Data were transmitted to a cloud platform for storage and real-time analysis, allowing farmers to monitor and adjust environmental parameters remotely via a mobile application. The study demonstrated a significant reduction in resource wastage, particularly water, while enhancing crop yields and reducing labor dependency. The identified challenges included the system's reliance on stable internet connectivity, scalability for larger farming operations, and the technical expertise required for operation. The authors suggest future improvements, such as incorporating LoRa or ZigBee for enhanced connectivity in rural areas and integrating predictive analytics for proactive decision-making. The research concluded that IoT-based monitoring systems could modernize agriculture by transitioning from manual practices to automated data-driven operations. However, further validation and cost-reduction strategies are recommended to improve accessibility and adoption among small- and medium-scale farmers. The study reaffirmed the potential of the IoT as a game-changing tool to tackle issues such as resource scarcity, climate change, and rising global food needs [3].

One study explored the potential of IoT in promoting sustainable agriculture by optimizing resource utilization and reducing environmental impacts. The study discussed IoT applications, such as smart irrigation, pest management, and precision farming, utilizing sensors and actuators to automate farming processes. Cloud platforms process real-time sensor data, allowing farmers to remotely monitor and manage agricultural operations. The system demonstrated a significant reduction in water and fertilizer waste while maintaining crop health and yield. The authors highlighted barriers to adoption, including high initial setup costs, limited accessibility in developing regions, and a lack of technical knowledge among farmers. To address these challenges, this study proposes integrating blockchain technology for secure data management and AI for predictive analytics to enhance system efficiency. Renewable energy sources are also recommended to power IoT devices sustainably, further reducing the operational costs. According to the findings of this study, IoT-enabled technologies have the power to completely transform conventional agricultural methods by increasing their sustainability, efficiency, and climate change resilience. Future research directions include developing low-cost IoT solutions, enhancing scalability, and promoting education and government support to encourage widespread adoption among small-scale farmers [4].

An article proposed an IoT-based system designed to automate environmental monitoring and control in agriculture, with emphasis on efficiency and sustainability. The system employs sensors for temperature, humidity, soil moisture, and light intensity, transmitting data to a cloud platform for analysis and storage. Actuators, such as irrigation pumps and ventilation fans, were controlled based on sensor readings to ensure optimal conditions for plant growth. This study demonstrated significant improvements in resource conservation and crop yields by reducing water waste and manual labor. The scalability of the system was highlighted, making it adaptable to various crops and farm sizes. Nevertheless, difficulties were identified, including the requirement for technical know-how, dependence on dependable internet access, and expensive implementation costs. To improve sustainability and reduce operating expenses, the authors suggested using renewable energy sources such as solar panels. The authors suggested using solar panels and other renewable energy sources to improve sustainability and reduce operating expenses. Future research directions include incorporating machine learning for predictive analytics and edge computing for real-time data processing. They concluded that IoT-based systems could play a pivotal role in transforming agriculture into a data-driven domain, addressing critical challenges such as resource scarcity, climate change, and labor shortages while promoting sustainable farming practices [5].

Another study introduced an IoT-based agricultural monitoring system that integrated machine learning for predictive analysis. Sensors in the system track environmental variables including temperature, humidity, soil moisture, and light intensity. The data were sent to a cloud platform for real-time analysis. The data gathered was analyzed using machine learning algorithms to forecast possible crop illnesses and improve the watering plans. This study highlights the system's ability to reduce resource wastage and labor costs while improving productivity by automating critical farming processes. However, the system faces challenges such as the complexity of integrating IoT with machine learning, dependency on internet connectivity, and high initial setup costs. The authors proposed future enhancements, such as using edge computing for on-device data processing and renewable energy sources for power sustainability. They also suggested blockchain integration to secure data and enhance trust among stakeholders. The study concludes that IoT and machine learning can revolutionize agriculture by enabling data-driven decisions and proactive interventions, transforming traditional farming into efficient and sustainable practice. Future research should address the scalability and affordability of the system to ensure widespread adoption, particularly in resource-constrained settings [6].

One article discussed a low-cost IoT system designed for polytunnel agriculture, focusing on environmental monitoring and control. The sensors of the system monitor temperature, humidity, soil moisture, and light intensity, among other environmental factors. The data were transmitted to a cloud platform for real-time analysis. Machine learning algorithms evaluate collected data to predict potential crop diseases and enhance irrigation schedules based on growing conditions. This study emphasizes the accessibility of the system for small-scale farmers, highlighting its modular design and affordability. However, restrictions such as dependence on steady internet access and power supply constraints are mentioned. The authors suggest using predictive analytics and renewable energy sources to address these problems and improve decision-making. The study concludes that IoT-enabled polytunnel systems significantly improve agricultural productivity and resource conservation while reducing labor costs. Future research should explore integrating AI and blockchain for better system efficiency and scalability, along with efforts to promote adoption through farmer training and government incentives [7].

A study proposed a multimodal system that combined IoT and machine learning for precision agriculture. Sensors provide data to a cloud platform for processing while considering environmental factors, including temperature, humidity, and soil moisture. These data are processed using machine learning algorithms to yield useful insights, such as crop disease prediction and irrigation schedule optimization. The system automates irrigation and climate control and reduces water and energy wastage. This study highlights the benefits of integrating IoT with machine learning, including improved decision-making and resource efficiency. However, challenges include the complexity of system integration, high implementation costs, and dependency on stable internet connectivity. The authors suggest future enhancements, such as using edge computing for real-time data processing and incorporating renewable energy sources to reduce operational costs. The study concludes that IoT and machine learning have significant potential to revolutionize agriculture by enabling data-driven decisions and optimizing farming practices. Future research should focus on scalability and affordability to ensure wider adoption [8].

IoT-enabled smart irrigation systems utilize Unmanned Aerial Vehicles (UAVs) to deliver precise water management solutions. Sensors monitor environmental conditions, including soil moisture, temperature, and humidity, and transmit data to a cloud platform for real-time analyses. UAVs equipped with irrigation mechanisms distribute water efficiently based on the analysis, reducing waste and labor dependency. This study highlights the system's ability to conserve water and enhance productivity in areas with limited resources. However, challenges such as high implementation costs, internet dependency, and regulatory constraints for UAV usage have been identified. To power the system sustainably, the authors suggest including renewable energy sources such as solar panels. The use of edge computing for localized data processing and AI for predictive analytics are examples of future advancements. The study concluded that IoT-enabled UAV systems have significant potential to revolutionize smart irrigation, making it more efficient and resource-friendly. Further research should address cost reduction and scalability to ensure adoption across various agricultural contexts [9].

A solar-powered IoT device was designed for real-time plant disease prediction using advanced deep learning techniques. The system integrates sensors to monitor key environmental parameters such as temperature, humidity, and soil conditions, with data transmitted to a cloud platform for analysis. Deep learning models, specifically convolutional neural networks (CNNs), are used to identify potential plant diseases and provide timely alerts via mobile applications. The use of solar power ensures sustainability, making the device suitable for remote areas with limited access to energy. The system demonstrated effectiveness in reducing crop losses and optimizing resource use; however, challenges such as high initial costs, internet dependency, and the complexity of implementing deep learning models on IoT devices were noted. The authors proposed integrating edge computing for on-device processing and blockchain for secure data management. The study concludes that IoT-enabled solar-powered devices hold immense potential for modern agriculture by reducing resource wastage and supporting data-driven decision-making. Future research should focus on improving affordability and scalability to ensure widespread adoption by farmers in developing regions [10].

IoT-enabled greenhouse system tailored to local communities, focusing on automation and resource optimization. Sensors were included in the system to track environmental variables, including CO_2, humidity, and temperature. Real-time lighting, ventilation, and irrigation modifications were made possible via the transmission of data to a cloud platform for analysis. This study highlights how machine learning can be integrated to forecast environmental changes and improve agricultural conditions. Key benefits include reduced labor costs, enhanced productivity, and sustainability through automated operations. However, challenges such as high setup costs, dependency on internet connectivity, and scalability to diverse climates have been noted. The authors proposed renewable energy sources, such as solar panels, to power the system, enhancing its feasibility in resource-limited areas. The study concluded that IoT-enabled greenhouse systems can significantly improve agricultural productivity while promoting sustainability. Future research should address scalability, cost reduction, and the integration of predictive analytics to expand adoption among small- and medium-scale farmers [11].

A study introduced an IoT-based greenhouse monitoring system designed for real-time environmental control. The system employs sensors such as DHT11 and soil moisture sensors to collect data, which are then transmitted to a cloud platform for processing. Actuators control irrigation, ventilation, and temperature adjustments based on sensor inputs. This study demonstrated significant improvements in water conservation and crop yield by automating routine processes. The authors noted limitations, including dependency on stable internet connectivity and the high initial costs of the setup. The proposed enhancements include the integration of renewable energy sources and edge computing for localized data processing. The study concludes that IoT-based automated greenhouses can revolutionize traditional farming by improving efficiency, reducing resource wastage, and ensuring consistent crop quality. Future work should explore cost-effective designs and scalability for widespread adoption [12].

An article presented a greenhouse monitoring system that utilizes WSNs for environmental data collection. The system integrates sensors to measure parameters such as temperature, humidity, and soil moisture and transmits data to a central server for analysis. Actuators automate the irrigation and ventilation processes to maintain optimal growth conditions. This study highlights the efficiency of WSNs in reducing the need for wired connections, making the system more scalable and cost-effective. However, challenges, such as power consumption, network range, and data latency, have been identified. The authors proposed the use of renewable energy and advanced communication protocols to address these issues. The study concludes that IoT-enabled WSNs are a promising solution for greenhouse automation, capable of improving resource management and productivity. Future directions include integrating AI for predictive analytics and blockchain technology for secure data management [13].

A study designed an IoT-enabled greenhouse system incorporating AI to enhance decision-making. The system employs sensors to monitor environmental parameters and AI algorithms to predict and optimize crop growth conditions. The data were transmitted to a cloud platform, enabling real-time adjustments to irrigation, temperature, and lighting. This study demonstrated improved crop yield and resource efficiency through automation and predictive analysis. Challenges include the complexity of integrating AI with IoT and high computational requirements. The authors suggested using edge AI to process data locally, thereby reducing latency and power consumption. The study concludes that IoT and AI integration can significantly enhance greenhouse productivity, but further research is needed to address cost and scalability concerns [14].

A cloud-integrated IoT system for agriculture that focuses on real-time monitoring and automated control. The system employs sensors for temperature, humidity, and soil moisture and transmits data to a cloud platform for analysis and storage. Actuators automate irrigation and climate control and reduce manual intervention. This study highlights the advantages of cloud-based systems in providing remote access and data insights for better decision-making. Challenges include dependency on internet connectivity, high setup costs, and data privacy concerns. The authors proposed blockchain integration for secure data management and edge computing for real-time data processing. The study concludes that IoT and cloud integration can revolutionize agriculture by improving productivity and sustainability. Future research should focus on cost reduction and enhancement of system scalability [15].

An IoT-enabled smart greenhouse system focuses on sustainable farming practices. The system employs sensors for temperature, humidity, and soil moisture monitoring coupled with actuators for irrigation, ventilation, and lighting control.

The data collected by these sensors were transmitted to a cloud platform for real-time analysis, enabling remote monitoring and automated adjustments. This study demonstrated significant improvements in water conservation and crop productivity by automating processes and optimizing resource use. However, challenges such as internet dependency, high implementation costs, and limited scalability have been noted. The authors proposed integrating renewable energy sources and advanced communication protocols to enhance system efficiency. The study concludes that IoT-enabled greenhouse systems have immense potential to transform agriculture, but future research should focus on cost reduction and scalability to encourage adoption among small-scale farmers [16].

A study proposed an IoT-based precision agriculture system that integrated predictive analytics for better resource management. The system uses sensors to monitor key environmental parameters, such as soil moisture, temperature, and light intensity, and transmits data to a cloud platform for analysis. Predictive models analyze these data to forecast crop health and optimize irrigation schedules. This study highlighted the system's ability to reduce resource wastage, enhance crop yields, and lower labor costs. Challenges include the complexity of integrating predictive models with IoT and the high setup costs. The authors suggested edge computing for real-time data processing and renewable energy for sustainability. The study concludes that IoT-driven precision agriculture can revolutionize traditional farming practices, but scalability and affordability remain key areas for improvement [17].

IoT-based smart irrigation system incorporating AI to optimize water usage. The system uses soil moisture sensors, temperature sensors, and cloud platforms to monitor environmental conditions and predict irrigation requirements. AI algorithms analyze collected data to forecast optimal watering schedules and significantly reduce water waste. The study demonstrated improved water efficiency and crop yields but identified challenges such as high computational requirements, internet dependency, and system costs. The authors proposed future enhancements such as integrating renewable energy sources and edge AI for localized data processing. The study concludes that IoT and AI integration can address water management challenges in agriculture, offering a sustainable solution for efficient resource utilization [18].

A study designed an IoT-enabled greenhouse automation system that leveraged wireless technology for real-time monitoring and control. The system integrates sensors for temperature, humidity, and soil moisture, which are connected via wireless networks to a cloud platform. Actuators automate irrigation and climate control to ensure optimal growth. This study highlighted the advantages of wireless technology in improving system scalability and reducing installation complexity. However, challenges such as limited network range, power consumption, and data security have been noted. The authors proposed using advanced protocols, such as ZigBee or LoRa, and integrating renewable energy sources to enhance system efficiency. The study concluded that wireless IoT solutions are vital for greenhouse automation, but further research is needed to improve network reliability and system affordability [19].

An IoT-enabled agricultural system powered by renewable energy, focusing on sustainability and efficiency. The system uses sensors to monitor environmental parameters such as soil moisture, temperature, and light intensity, with data transmitted to a cloud platform for real-time analysis. Solar panels power IoT devices, ensuring reliability even in remote areas. The study demonstrated significant resource savings and improved crop yields, emphasizing the potential of this system for sustainable agriculture. Challenges include high initial setup costs and the complexity of integrating renewable energy with IoT devices. The authors suggested incorporating predictive analytics and blockchain technology to enhance system capabilities. The study concluded that renewable energy-powered IoT systems could address resource constraints in agriculture and promote sustainable farming practices on a global scale [20].

SUMMARY OF SYSTEM REVIEW

This review consolidates and analyzes the diverse methodologies applied in the development of IoT-based systems for smart agriculture, focusing on automation, precision, and sustainability. With global challenges, such as resource scarcity, climate change, and food security, IoT technologies have emerged as transformative solutions for modernizing traditional farming practices. The reviewed papers highlight applications ranging from environmental monitoring and smart irrigation to crop health prediction and greenhouse automation. The core components include sensors for real-time data collection, cloud platforms for analysis, and actuators for automated control, ensuring optimal resource utilization and enhanced productivity. The integration of advanced technologies, such as machine learning, AI, and renewable energy sources, has further expanded the potential of these systems, enabling predictive analytics, disease detection, and sustainable power solutions. Challenges such as high implementation costs, dependency on stable internet connectivity, and the need for skilled labor are consistent across studies. However, the proposed advancements in edge computing, blockchain for data security, and scalable communication protocols, such as LoRa, aim to address these limitations. This review categorizes these methodologies into precision farming, greenhouse automation, and predictive systems, emphasizing their effectiveness in reducing resource wastage, minimizing labor dependency, and improving crop yields. Despite this progress, gaps remain in terms of scalability, affordability, and widespread adoption among small-scale farmers. This review provides a comprehensive overview of IoT applications in agriculture and outlines the future directions for enhancing system robustness, sustainability, and real-world integration, emphasizing sustainability by incorporating renewable energy solutions. Singh et al. and Khan et al. highlighted the use of solar-powered IoT devices to ensure resource efficiency and accessibility in remote areas. However, limitations, such as high implementation costs and technical expertise, restrict widespread adoption, particularly for small-scale farmers. Despite significant progress, challenges such as limited dataset diversity, reliance on stable internet infrastructure, and cost barriers must be addressed for widespread adoption. Enhancements in scalability, affordability, and emerging technologies such as blockchain and edge computing will be critical in overcoming these limitations. In conclusion, IoT-based systems offer immense potential for revolutionizing agriculture, making it data-driven, sustainable, and resource-efficient. Addressing these challenges will pave the way for IoT to contribute significantly to global food security and sustainable agricultural practices.

CONCLUSION

This review emphasizes the transformative potential of IoT in revolutionizing agriculture by addressing key challenges, such as resource scarcity, climate unpredictability, and labor shortages. IoT-based systems have demonstrated significant advances in precision farming, real-time environmental monitoring, greenhouse automation, and predictive analytics. By integrating sensors, cloud computing, and machine learning, these systems optimize resource efficiency, improve crop yields, and enhance sustainability, paving the way for data-driven agricultural practices that cater to the global food security demands.

Applications of IoT in agriculture include decision-support systems, predictive analytics, and hybrid approaches that combine IoT with AI. Decision-support systems, as proposed by Kumar et al. and Das et al., effectively reduce resource wastage and optimize irrigation through real-time environmental monitoring. Meanwhile, hybrid systems, such as those developed by Mishra et al. and Mehta et al., integrated machine learning and IoT for precision farming and disease detection, enhancing decision-making and enabling proactive interventions. These systems showcase the versatility of IoT in addressing diverse agricultural needs while highlighting its adaptability across various scales of farming operations. Despite these advancements, challenges such as high implementation costs, dependency on stable internet connectivity, and technical expertise requirements persist. Additionally, the scalability and computational complexity of IoT systems, particularly those integrated with advanced analytics, limit their accessibility to small-scale farmers and resource-limited regions. Addressing these barriers through renewable energy solutions, edge computing, and blockchain technology can enhance affordability and scalability, enabling the wider adoption of IoT systems.

Future research should prioritize improving the system scalability, reducing costs, and ensuring the integration of emerging technologies to make IoT-based systems more accessible and sustainable. By addressing these challenges, the IoT can continue to transform agriculture, promote sustainable practices, reduce resource wastage, and ensure long-term productivity.

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