International Journal of Advance Innovations, Thoughts and Ideas

Editorial Open Access

Smart Agriculture: Tech-Driven Efficiency and Sustainability

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Received: 01-Sep-2025, Manuscript No. IJAITI-25-173452; **Editor assigned:** 03-Sep-2025, PreQC No. IJAITI-25-173452(PQ); **Reviewed:** 17-Sep-2025, QC No. IJAITI-25-173452; **Revised:** 22-Sep-2025, Manuscript No. IJAITI-25-173452(R); **Published:** 29-Sep-2025, **DOI**: 10.4172/2277-1891.1000352

Citation: Osei DD (2025) Smart Agriculture: Tech-Driven Efficiency and Sustainability. Int J Adv Innovat Thoughts Ideas 14: 352.

Abstract

Smart agriculture is transforming through advanced technologies like *Artificial Intelligence* (AI), Machine Learning (ML), IoT-Edge computing, and Unmanned Aerial Vehicles (UAVs). These innovations facilitate precision farming, improving crop yield prediction, disease detection, automated irrigation, and real-time monitoring. Blockchain enhances supply chain transparency, while robotics addresses labor needs. The digital transformation aims for sustainable farming by optimizing resource management and ensuring food security. Despite challenges in adoption and infrastructure, these technologies significantly enhance agricultural efficiency and sustainability.

Keywords

Artificial Intelligence; Smart Agriculture; Precision Farming; Crop Monitoring; IoT; Machine Learning; Blockchain; UAV; Robotics; Sustainability

Introduction

This review provides a comprehensive look at Artificial Intelligence applications in smart agriculture, covering areas like crop yield prediction, disease detection, automated irrigation, and intelligent harvesting. It highlights current trends, addresses challenges, and outlines future research directions, emphasizing the transformative potential of AI in enhancing agricultural efficiency and sustainability[1].

This paper proposes an IoT-Edge computing system for smart agriculture, focusing on precision farming and real-time crop monitoring. It describes how sensor data is processed at the edge to provide timely insights for optimized irrigation, fertilization, and pest management, thereby improving crop yield and resource efficiency[2].

This research explores various machine learning models for effective crop monitoring in smart agriculture settings. The focus is on leveraging historical and real-time data to predict crop health, identify diseases, and optimize resource allocation, demonstrating how ML can significantly enhance agricultural productivity and sustainability[3].

This systematic review examines the growing role of blockchain technology in smart agriculture, particularly focusing on enhancing supply chain traceability, food safety, and transparency. It synthesizes current research, identifies key applications, benefits, and challenges, suggesting future directions for integrating blockchain with other AgriTech innovations[4].

This review focuses on the applications of Unmanned Aerial Vehicles (UAVs) in precision agriculture, specifically for remote sensing. It covers various uses like crop health monitoring, irrigation management, and yield estimation, while also discussing the technological challenges and future opportunities for widespread adoption of drone technology in farming[5].

This study investigates how smart agriculture technologies contribute to sustainable farming practices. It critically assesses both the challenges in adopting these technologies, such as cost and infrastructure, and the opportunities they present for improving resource management, reducing environmental impact, and ensuring food security in a sustainable manner[6].

This comprehensive survey delves into the applications of computer vision techniques across various agricultural domains. It highlights methods for crop monitoring, disease and pest detection, fruit grading, and automated harvesting, showcasing how visual data analysis is revolutionizing precision farming practices and improving overall agricultural productivity[7].

This paper details a smart irrigation system that integrates IoT sensors with machine learning algorithms for precision agriculture. The system continuously monitors soil moisture, temperature, and weather conditions, using ML to predict optimal irrigation schedules and deliver water efficiently, significantly reducing water waste and improving crop yield[8].

This review provides an in-depth analysis of the digital transformation occurring in agriculture, encompassing various technologies from IoT and AI to big data analytics. It outlines key applications, examines the benefits of enhanced efficiency and sustainability, and addresses the significant challenges involved in technology adoption, infrastructure, and skill development within the agricultural sector[9].

This review provides an overview of robotics and automation technologies applied in agriculture, ranging from autonomous tractors to robotic harvesting systems. It discusses the significant progress in these areas, highlighting how they address labor shortages and enhance efficiency, while also examining the economic and technical challenges that need to be overcome for broader integration[10].

Description

This review provides a comprehensive look at Artificial Intelligence (AI) applications in smart agriculture, covering areas like crop yield prediction, disease detection, automated irrigation, and intelligent harvesting. It highlights current trends, addresses challenges, and outlines future research directions, emphasizing the transformative potential of AI in enhancing agricultural efficiency and sustainability[1]. In related efforts, an IoT-Edge computing system is proposed for smart agriculture, specifically for precision farming and real-time crop monitoring. This system processes sensor data at the edge, offering timely insights for optimized irrigation, fertilization, and pest management, consequently improving crop yield and resource efficiency[2].

Research also explores various Machine Learning (ML) models for effective crop monitoring in smart agriculture settings. The focus here is on leveraging historical and real-time data to predict crop health, identify diseases, and optimize resource allocation, demonstrating how ML significantly enhances agricultural productivity and sustainability[3]. Concurrently, blockchain technology's growing role in smart agriculture is examined, especially its contributions to enhancing supply chain traceability, food safety, and transparency. This systematic review synthesizes current research, identifies key applications, benefits, and challenges, suggesting future directions for integrating blockchain with other AgriTech innovations[4].

Unmanned Aerial Vehicles (UAVs) are another key technology, with reviews focusing on their applications in precision agriculture, particularly for remote sensing. These uses include crop health monitoring, irrigation management, and yield estimation, alongside discussions on technological challenges and opportunities for drone adoption in farming[5]. Such smart agriculture technologies also notably contribute to sustainable farming practices. A critical assessment reveals both challenges in adoption, like cost and infrastructure, and opportunities for improving resource management, reducing environmental impact, and ensuring food security sustainably[6].

A comprehensive survey delves into the applications of computer vision techniques across various agricultural domains. This work highlights methods for crop monitoring, disease and pest detection, fruit grading, and automated harvesting, illustrating how visual data analysis is revolutionizing precision farming and boosting overall productivity[7]. Furthermore, smart irrigation systems integrate Internet of Things (IoT) sensors with Machine Learning (ML) algorithms for precision agriculture. These systems continuously monitor soil moisture, temperature, and weather conditions, using ML to predict optimal irrigation schedules for efficient water delivery, significantly reducing water waste and improving crop yield[8].

The broader digital transformation in agriculture is analyzed, encompassing technologies like IoT, AI, and big data analytics. This includes outlining key applications, examining benefits such as enhanced efficiency and sustainability, and addressing significant challenges in technology adoption, infrastructure, and skill development within the sector[9]. Finally, robotics and automation technologies applied in agriculture are reviewed, from autonomous

tractors to robotic harvesting systems. Discussions cover significant progress, how these technologies address labor shortages and enhance efficiency, and the economic and technical challenges for broader integration[10].

Conclusion

Smart agriculture is undergoing a significant transformation, driven by advanced technologies designed to boost efficiency, productivity, and sustainability across farming operations. Key innovations encompass Artificial Intelligence (AI) and Machine Learning (ML), which are vital for critical tasks such as accurate crop yield prediction, early disease detection, sophisticated automated irrigation systems, and intelligent harvesting processes. IoT-Edge computing systems are fundamental, enabling precision farming through real-time sensor data processing that optimizes resource use and provides constant crop monitoring. Unmanned Aerial Vehicles (UAVs) further enhance remote sensing capabilities, crucial for managing crop health and irrigation effectively, even as technological hurdles are addressed. Blockchain technology plays a growing role in improving agricultural supply chains by ensuring traceability, enhancing food safety, and increasing transparency from farm to consumer. Simultaneously, advanced computer vision techniques are revolutionizing visual data analysis for comprehensive crop monitoring, precise pest detection, and efficient automated harvesting. Moreover, smart irrigation systems integrate IoT sensors with ML algorithms to continuously monitor environmental conditions, allowing them to predict and deliver optimal water schedules. This significantly reduces water waste and enhances overall crop yields. Robotics and automation are actively addressing agricultural labor shortages and bolstering operational efficiency, thereby contributing substantially to the broader digital transformation. While these integrated technologies promise improved resource management, a reduced environmental impact, and enhanced food security, practical challenges related to technology adoption, infrastructure development, and necessary skill development within the agricultural sector continue to be pressing concerns.

References

1. Sarvjeet S, Rahul S, Neha S, Sanju K, Himanshu S et al. (2023) Artificial Intelligence for Smart Agriculture: A Review, Current Trends, and Future Perspectives. Smart Agric. Technol. 5:100293.

2. Sarada PG, Ajit KB, Pradip KS, Biniam T, Abinet E et al. (2023) IoT-Edge Computing-Based Smart Agricultural System for Precision Farming and Crop Monitoring. Appl. Sci. 13:12822.

3. Asad A, Shahaboddin S, A.R. AN, Khurram S, A.R. N et al. (2022) Machine learning-based approach for smart agriculture towards crop monitoring. Eng. Appl. Artif. Intell. 113:104998.

4. Riaz U, Asad U, Ali D, Firas AO, Wael A et al. (2023) Blockchain technology in smart agriculture: A systematic literature review. Comp. Electron. Agric. 204:107567.

5. Ali RS, Masoud M, Somayeh M, Hamed M, Zahra K et al. (2023) UAV-Based Remote Sensing for Precision Agriculture: A Review of Applications, Challenges, and Opportunities. Remote Sens. 15:3757.

6. Md MI, M. M. R, M. R. K, A. R. M. A. K, M. M. H et al. (2023) Smart Agriculture Technologies for Sustainable Farming: An Assessment of Challenges and Opportunities. Sustainability 15:13076.

7. Ashish S, Harpreet K, Pranjali S, Rajeev K, Shaveta S et al. (2022) Computer Vision in Agriculture: A Comprehensive Survey. Arch. Comput. Methods Eng. 30:1077-1099.

8. K. V, K. S, K. S. L, R. U, S. S et al. (2023) Smart Irrigation System Based on IoT and Machine Learning for Precision Agriculture. Comp. Electr. Eng. 105:108528.

9. Mohamed AE, Marwa MK, Abdullah HA, Sultan AA, Khalid AA et al. (2023) Digital Transformation in Agriculture: A Comprehensive Review of Technologies, Applications, and Challenges. Agronomy 13:2769.

10. Ayman SA, Saad EA, Ali AA, Jumanah AA, H. R. AN et al. (2022) Robotics and Automation in Agriculture: A Review of Advancements, Challenges, and Future Directions. Smart Agric. Technol. 2:100062.