IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Integrated Smart Farming Approaches for Sustainable Agriculture

Padmaja Musunuri[1*], Sai Sudha Kella[2], Sravani Nidamanuri[3]

1. Department of Biochemistry, Government College for Women (A), Guntur-522001, Andhra Pradesh

2. Department of Biotechnology, Government College for Women (A), Guntur-522001, Andhra Pradesh

3. Department of Microbiology, Government College for Women (A), Guntur-522001, Andhra Pradesh

Abstract

Indian agriculture continues to face challenges like low productivity, inefficient resource use, and unpredictable climatic conditions due to its dependence on traditional farming practices. As the nation's economy heavily depends on crop production, strengthening agricultural systems has become increasingly important. The integration of Artificial Intelligence (AI) and the Internet of Things (IoT) has emerged as an effective smart farming strategy to overcome these limitations. AI-based applications, combined with real-time data from sensors, drones, and satellite imaging, aid in agricultural activities like fertilizer selection, water management, crop selection, soil fertility prediction, and much more. Despite its potential, the adoption of smart farming is limited by high initial costs, insufficient rural infrastructure, data management issues and the need for continuous technological upgrades and training. Nevertheless, smart farming offers a sustainable and innovative approach to meeting the growing food demand, improving resource efficiency, and promoting environmental and human health. This review offers a glimpse of how digital-agriculture innovations can transform the sector toward greater productivity and ecological sustainability.

Key words: Smart farming, Artificial Intelligence, Internet of Things, ecological sustainability.

Introduction

In India, most farmers still depend on conventional farming methods that rely heavily on manual labor, traditional knowledge, and unpredictable weather patterns. These practices often lead to reduced productivity, inefficient resource utilization, and financial losses. The integration of Artificial Intelligence (AI) and the Internet of Things (IoT) in farming—known as smart farming offers modern solutions to these challenges [1].

AI-based tools analyze data from sensors, drones, and satellite imagery to predict crop health, soil conditions, and weather changes, while IoT devices monitor irrigation, temperature, and nutrient levels in real time. Together, AI and IoT enable farmers to make data-driven decisions, reduce wastage, optimize input use, and ultimately increase crop productivity and profitability [2].

Crop productivity can be significantly improved by identifying which crop varieties yield the highest output under similar soil, climatic, fertilization, and irrigation conditions. This data-driven approach to crop selection not only enhances efficiency but also helps address major agricultural challenges such as climate change, limited natural resources (including water, labor and energy), and societal concerns related to animal welfare, fertilizer use, and environmental sustainability. By leveraging smart technologies and informed decision-making, farmers can achieve higher yields while promoting sustainable and responsible agricultural practices [3, 4].

Digital integration in agriculture

To observe crop growth under varying conditions such as soil quality and environmental factors, studies often include phenotyping to identify key parameters like soil pH and nitrogen depletion rates that influence plant development. These studies are typically carried out in natural outdoor environments, where irrigation and fertilizer application are varied to assess their effects.

The integration of the Internet of Things (IoT) with sensor networks has revolutionized such studies by enabling the collection of real-time data on soil, weather, and crop health, enhancing the precision and efficiency of such studies. IoT technologies, coupled with imaging sensors and mobile applications, not only reduce research costs but also expand the scale and accuracy of data collection, supporting better decision-making in modern agriculture [5]. The data collected from various IoT devices and sensors can be stored in the cloud and used in predictive analysis to optimize the farming practices.

Unmanned Aerial Systems (UAS), commonly known as drones, further strengthen the smart farming by facilitating crop monitoring, irrigation management, pest and disease detection, livestock tracking, and detailed field mapping [6, 7]. Alongside IoT devices and sensors used in smart farming range from simple weather sensors to advanced precision agriculture system that utilize Global Positioning System (GPS) technology for systematic tracking of crop growth and health. These devices can be integrated with irrigation systems, enabling farmers to remotely access and control water usage based on real-time soil moisture data [8].

Artificial Intelligence (AI) algorithms work in tandem by analysing the large volumes of data gathered from sensors, drones, and weather stations to identify optimal strategies for crop cultivation and management [9]. For example, IoT devices can capture time-series data on soil pH levels and nitrogen depletion rates, sharing this information among researchers and farmers to improve farming practices.

Another important aspect of smart farming is the monitoring of pesticide and fertilizer application. Excessive application of these chemicals not only results in environmental contamination but also degrades crop quality and poses serious health hazards [10]. Smart farming involves the use of real-time data by farmers to optimize the use of agricultural chemicals. By integrating IoT technologies and smart sensors with existing agricultural devices, farmers can achieve precise monitoring and control of chemical usage. These technologies also help in accurate diagnosis of crop diseases and promoting sustainable agricultural practices [11,12].

Limitations

The upfront cost of implementing smart farming technologies can be too expensive for small and medium-sized farms. The substantial expenses involved in acquiring and maintaining advanced tools such as drones and autonomous tractors often hinder their widespread adoption. Farmers need proper training to accurately interpret data gathered from sensors and to efficiently operate automated machinery. The successful implementation of smart farming technologies depends on adequate infrastructure, like reliable internet connectivity and electricity which is often insufficient or entirely absent in many rural regions, particularly in developing countries [13]. Smart farming needs continuous innovations and upgradation to stay aligned with emerging challenges [14]. Additionally, effective data maintenance and information sharing among agriculturists remain significant challenges [15].

Conclusion

In conclusion, the growing concerns over global food security and the rise of agricultural infections have emphasized the need for modern, technology-driven farming solutions. Smart farming technologies have become the backbone of modern agriculture. Overall, smart farming offers an innovative and sustainable approach to food production, effectively addressing the growing food demand while ensuring efficient use of limited agricultural resources, improving food quality, and enhancing human wellbeing and environmental sustainability.

References

1. Sharma, A., Sharma, A., Tselykh, A., Bozhenyuk, A., Choudhury, T., Alomar, M.A. and Sánchez-Chero, M., Artificial intelligence and internet of things oriented sustainable precision farming: Towards modern agriculture. Open Life Sciences, 2023; 18(1), :0220713.
2. A review of decision support system using mobile applications in the provision of day to day information about farm status for improved crop yield, Per. Eng. Nat. Sci., 2018; 6: 89-99.
3. Wolfert, S.; Ge, L.; Verdouw, C.; Bogaardt, M.J. Big data in smart farming—A review. Agric. Syst, 2017;153:69–80.
4. Karunathilake, E.M.B.M., Le, A.T., Heo, S., Chung, Y.S. and Mansoor, S., 2023. The path to smart farming: Innovations and opportunities in precision agriculture. Agriculture, 2023;13(8):1593.
5. Salehi, A.; Jimenez-Berni, J.; Deery, D.M.; Palmer, D.; Holland, E.; Rozas- Larraondo, P.; Chapman, S.C.; Georgakopoulos, D.; Furbank, R.T. SensorDB: A virtual laboratory for the integration, visualization and analysis of varied biological sensor data. Plant Methods, 201;11, 53.
6. Aqeel-Ur-Rehman and Z. A. Shaikh, "Smart agriculture," Applications of Modern High Performance Networks, 2009; 120–129.
7. Bolo BG, Mpoeleng D, Zlotnikova I. Application of unmanned aerial vehicle UAV for small scale precision farming in Botswana. In Southern space studies. 2019; 91–100.
8. A. Saleh, P. Joshi, R. S. Rathore, and S. S. Sengar, "Trust-Aware Routing Mechanism through an Edge Node for IoT-Enabled Sensor Networks," Sensors, 2022; 22(20): 1-22.
9. R. H. Ip, L. M. Ang, K. P. Seng, J. C. Broster, and J. E. Pratley, "Big data and machine learning for crop protection," Computers and Electronics in Agriculture, 2018;151:376–383.
10. S. Sarkar, P. Rajak, S. Roy Toxicological evaluation of a new lepidopteran insecticide, flubendiamide, in non-target drosophila melanogaster Meigen (Diptera: drosophilidae) Iran J. Toxicol, 2018; 12 (3): 45-50.
11. E. Navarro, N. Costa, A. Pereira A systematic review of IoT solutions for smart farming Sensors, 2020; 20: 4231, 10.3390/s20154231
12. BB Sinha, R. Dhanalakshmi, Recent advancements and challenges of Internet of Things in smart agriculture: A survey, Futur Gener Comput Syst, 2022; 126:169–184.
13. Glaroudis, D., Iossifides, A., & Chatzimisios, P., Survey, comparison and research challenges of IoT application protocols for smart farming. Computer Networks, 2020; 168:107037.
14. Darnhofer I, Bellon S, Dedieu B, Milestad R. Adaptiveness to enhance the sustainability of farming systems. A review.Agronomy for Sustainable Development. 2010; 30:545-555.
15. Ali I, Govindan K. Extenuating operational risks through digital transformation of agri-food supply chains.Production Planning & Control. 2023; 34(12):1165-1177.