IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.67
Volume 5, Issue 7, March 2025

Edge Intelligent for Agricultural IoT AI Driven Crop Monitoring and Management

Kaushal Kumar Kori[1] and Mr. Pranjal Khare[2]
Research Scholar, Department of Computer Science & Engineering[1]
Assistant Professor, Department of Computer Science & Engineering[2]
Babulal Tarabai institute of Research and Technology, Sagar MP, India
3kverma2013@gmail.com and akashst133@gmail.com

Abstract: *The agricultural landscape is undergoing a transformative revolution with the integration of Intelligent Edge technologies in the context of the Internet of Things (IoT) and Artificial Intelligence (AI). This abstract explores three key aspects of Edge Intelligence applied to agricultural IoT, focusing on AI-driven crop monitoring and management. The convergence of edge computing, machine learning, and sensor technologies empowers farmers and stakeholders with real-time insights, enabling proactive decision-making and resource optimization. The first dimension delves into the deployment of edge devices for on-site data processing, reducing latency and enhancing responsiveness in crop monitoring. The second dimension explores the role of machine learning algorithms in analyzing data generated by IoT sensors, providing predictive analytics for crop health, yield estimation, and disease detection. The third dimension investigates intelligent decision support systems at the edge, facilitating automated and localized management strategies. These abstract lays the foundation for an in-depth exploration of each dimension, highlighting the potential and challenges of leveraging Intelligent Edge for AI-driven crop monitoring and management in modern agriculture*.

Keywords: Edge Computing in Agriculture, Agricultural IoT (Agri-IoT), AI-Driven Crop Monitoring, Precision Farming Solutions, Smart Agriculture Management

I. INTRODUCTION

In recent years, the intersection of agriculture, the Internet of Things (IoT), and Artificial Intelligence (AI) has ushered in a new era of smart and efficient farming practices. The integration of advanced technologies in agriculture holds the promise of addressing the challenges posed by a growing global population, changing climate conditions, and the need for sustainable resource management. Among these technologies, the convergence of Edge Intelligence with AI-driven approaches stands out as a transformative force in revolutionizing crop monitoring and management in the agricultural landscape.

Agricultural IoT, encompassing a network of interconnected sensors, devices, and machinery, has enabled farmers to gather vast amounts of real-time data from their fields. However, the sheer volume of data generated by these IoT devices presents challenges in terms of processing, analysis, and decision-making. Herein lies the significance of Edge Intelligence—a paradigm that involves processing data closer to the source, at the edge of the network. This proximity to the data generation points reduces latency, lowers the burden on central cloud servers, and empowers agricultural systems with real-time insights.

The crux of AI-driven crop monitoring and management lies in the application of sophisticated machine learning algorithms to the rich dataset acquired from agricultural IoT sensors. These algorithms, ranging from computer vision for image analysis to predictive analytics for yield forecasting, enable the system to autonomously analyze, learn, and adapt to dynamic agricultural conditions. By harnessing the power of AI at the edge, farmers can make data-informed decisions promptly, op

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.67
Volume 5, Issue 7, March 2025

Applications of Edge Intelligence in AI-Driven Crop Monitoring:

Edge intelligence enhances the capabilities of AI-driven crop monitoring systems by enabling real-time data analysis, adaptive decision-making, and autonomous operation at the network edge. Some key applications of edge intelligence in AI-driven crop monitoring include:

Real-time Sensor Data Processing: Edge devices can preprocess sensor data, such as temperature, humidity, soil moisture, and crop health metrics, in real-time before transmitting it to the cloud for further analysis. By performing data filtering, aggregation, and anomaly detection locally, edge intelligence reduces the volume of data transmitted over the network and minimizes latency in decision-making.

AI Model Inference at the Edge: Edge devices can execute lightweight AI models, such as convolutional neural networks (CNNs) or decision trees, to perform inferencing tasks directly on the sensor data. By deploying AI models at the edge, agricultural IoT systems can detect anomalies, predict crop yields, and classify crop diseases without relying on cloud-based servers, enabling faster response times and improved scalability.

Figure 1.1 Artificial Intelligence in agriculture

Adaptive Resource Allocation: Edge intelligence enables autonomous decision-making at the edge based on local sensor data and environmental conditions. For example, edge devices can adjust irrigation schedules, nutrient levels, and pest control measures dynamically based on AI-driven insights and predictive analytics. By adapting to changing field conditions in real-time, agricultural IoT systems can optimize resource utilization, minimize waste, and improve crop yields.

Benefits of Edge Intelligence in Agricultural IoT:

The integration of edge intelligence into agricultural IoT systems offers several benefits for crop monitoring and management:

- Reduced Latency and Improved Responsiveness: By processing data locally at the edge, agricultural IoT systems can achieve lower latency and faster response times compared to cloud-based approaches. This enables real-time monitoring, analysis, and control of agricultural processes, leading to more timely interventions and better crop management practices.
- Improved Data Privacy and Security: Edge intelligence reduces reliance on centralized cloud servers for data processing and analysis, minimizing the risk of data breaches, privacy violations, and cyber-attacks. By keeping sensitive data within the confines of the farm or field, agricultural IoT systems can ensure greater data privacy and security compliance.

- Enhanced Scalability and Reliability: Edge intelligence enables distributed computing architectures that can scale seamlessly to accommodate growing sensor networks and increasing data volumes. By decentralizing computation and decision-making, agricultural IoT systems can handle fluctuations in network traffic, device failures, and connectivity issues more gracefully, ensuring uninterrupted operation and reliable performance.

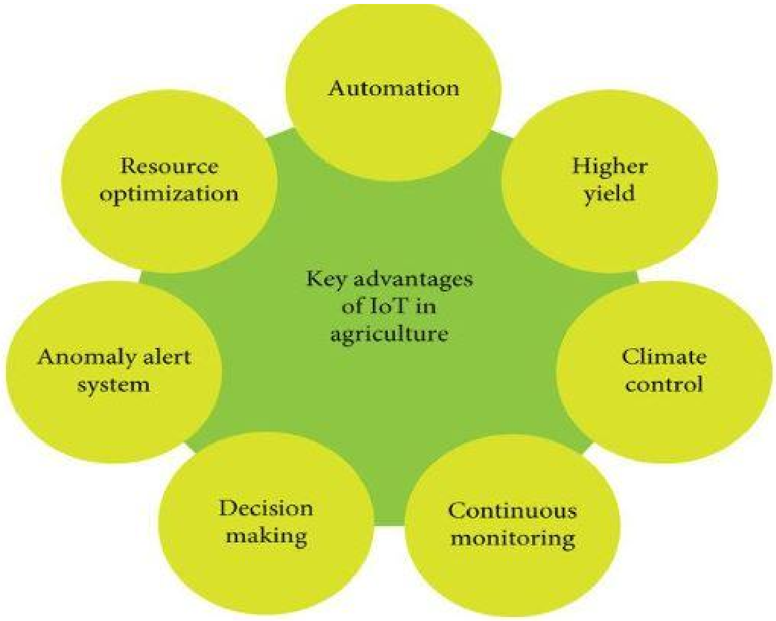

Figure 1.2 Key advantages of IoT in agriculture.

II. LITERATURE SURVEY

[1] Recent Advancements in Artificial Intelligence (AI) and Internet of Things (IoT) for Efficient Water Management in Agriculture, Chandan Kumar Deb,, Subeesh A, Samarth Godara, Asit Kumar Pradhan, Neetish Kumar ,MD AshrafulHaque, Madhu, Soam SK, Srinivasa Rao N, Ravisankar H,Sreekanth PD, Sumanth Kumar VV,

Climate change is a big challenge in agriculture globally. Improvement of the water use efficacy can reduce the effect of the global climate change. The injudicious use of water isnthe biggest challenge of global climate change. Agriculture and allied sectors are embracing new technologies for achieving sustainable developmental goals. Among the new technologies Artificial Intelligence (AI) and the Internet of Things (IoT) have the potential to play a significant role. This chapter discusses the modus operandi of AI and IoT in achieving the proper utilization of the water resources for combating the climate change. The significance of AI and IoT based water management system models has also been discussed here.The worldwide patent status of water management in the fields of IoT and AI has also been presented. Finally, an optimized water management system based on IoT and AI has been proposed which have a greater potential in solving water management..

[2] Fabrication and investigation of agricultural monitoring system with IoT & AI, P. Indira· I. Sheik Arafat, · R. Karthikeyan,· ShitharthSelvarajan, · Praveen Kumar Balachandran,2023.

Artifcial intelligence (AI) can be used in a variety of felds and has the potential to alter how we currently view farming. Due to its emphasis on efectiveness and usability artifcial intelligence has the largest impact on agriculture of all industries. We highlight the automation-supporting technologies such as Artifcial Intelligence (AI), Machine Learning, and Long-Range (LoRa) technology which provides data integrity and protection. We also ofer a structure for smart farming that depends on the location of data processing after a comprehensive investigation of numerous designs. As part of our future study we have divided the unresolved difculties in smart agriculture into two categories such as networking issues and technology issues. Artificial Intelligence and Machine Learning are examples of technologies whereas the Moderate Resolution Imaging Spectroradiometer satellite and LoRa are used for all network-related jobs.

The goal of the research is to deploy a network of sensors throughout agricultural felds to gather real-time information on a variety of environmental factors including temperature, humidity, soil moisture and nutrient levels. The seamless data transmission and communication made possible by these sensors' integration with Internet of Things technologies. With the use of AI techniques and algorithms the gathered data is examined.

[3] An Intelligent Agro-Cloud Framework For Efficient Crop Cultivation, Dr. S.Anitha , Dr. A.Muthusamy, Dr.T.Thiruvenkadam,2023

Agriculture is considered the backbone of the Indian economy. But, still, farmers are unable to get sufficient profit due to water scarcity,nflooding, storm, insufficient labor, and poor agro marketing. Moreover, modern technologies are not practiced efficiently in farming due to ignorance, high cost, and small land size. The proposed cloud-based framework consists of three key layers i) input layer ii) storage and processing layer iii) application layer. The input layer collects data from various IoT devices like sensors, meters, cameras, robots (for weeding & spraying), drones, and satellite data. The agro-cloud stores and processes the input data from IoT devices at regular intervals of time. Layer 2 aids smart farming namely soil monitoring, crop growth, irrigation management, and pesticide& fertilizer control. Soft computing technologies such as artificial intelligence, neural networks, and machine learning algorithms can be employed to select the appropriate irrigation method based on the type of soil, crop, quality of water, and rainfall. The application layer interacts with the farmers through various applications like graphical user interface systems (GUI), SMS alerts, and IoT-based mobile applications. A farmer advisor mobile App is designed based on the recommended framework for efficient crop cultivation which provides timely information to farmers like formulating land, choosing seeds, planting, plant protection, and plant insurance. Thus, the proposed research aids the farmers in improving crop yield and reducing the workforce and resources.

[4] Smart Agriculture: The Future of Agriculture using AI and IoT,Sapna Katiyar and Artika Farhana, 2021.

Agriculture sector contributing a significant share in World economy and in more than nine counties agronomy is the leading segment. Population is rising immensely therefore quality and quantity of food demand increases enormously. Agriculture segment is providing employment prospects to large population as well. Conventional farming styles used by farmers are not competent to fulfil the enlarged demand. To meet the growing demands, emerging innovative practices need to be introduced which can be observed as Agricultural Intelligence and can brought agriculture 4.0 revolution. Artificial Intelligence and Internet of Things like promising technologies convert traditional farming into smart agriculture by optimizing resources, reducing human labor, crop monitoring, weed handling, crop disease management, irrigation, harvesting and supply chain management. These technologies have proven for crop protection against climate changes, excess use of fertilizers, pesticides, herbicides and water for enhanced soil richness. This study presents the survey of researchers work of automation in agriculture with the support of sensors, Agricultural Robots and Drones and AI driven technologies to improve productivity. Moreover limitations, challenges and future scope of smart agriculture is also discussed in this study.

[5] IoT-Equipped and AI-Enabled Next Generation Smart Agriculture: A Critical Review, Current Challenges and Future Trends, SAMEER QAZI , (Senior Member, IEEE), BILAL A. KHAWAJA , (Senior Member, IEEE),AND QAZI UMAR FAROOQ , 2022.

Smart agriculture techniques have recently seen widespread interest by farmers. This is driven by several factors, which include the widespread availability of economically priced, low-powered Internet of Things (IoT) based wireless sensors to remotely monitor and report conditions of the field, climate, and crops. This enables efficient management of resources like minimizing water requirements for irrigation and minimizing the use of toxic pesticides. Furthermore, the recent boom in Artificial Intelligence can enable farmers to deploy autonomous farming machinery and make better predictions of the future based on present and past conditions to minimize crop diseases and pest infestation.

[6] A Critical Review, Current Challenges, and Future Trends of Next Generation Smart Agriculture using IoT and AI, DarojuAbhinaiKumar,EppiliJatin,Sarvade Keerthan, Dr.T.Venkat Narayana Rao,2023.

Farmers have recently demonstrated a strong interest in smart agricultural approaches. This is influenced by a number of variables, including the ubiquitous availability of inexpensive, low-powered Internet. Wireless Internet of Things (IoT)-based sensors are used to remotely monitor and report crop, weather, and field conditions. This makes it possible to manage resources effectively, for as by using fewer harmful pesticides and using less water for irrigation. Furthermore, owing to recent advancements in artificial intelligence, farmers may be able to deploy autonomous farming equipment and generate better future projections based on present and prior conditions, which would assist farmers minimize crop diseases and insect infestation. When utilized together, these two enabling technologies have changed traditional farming approaches. This research report offers: (a) A thorough instruction on the smart agricultural developments already available.

[7] Crop Management with the IoT: An Interdisciplinary Survey, Giuliano Vitali , Matteo Francia , Matteo Golfarelli and Maurizio Canavari ,2021 .

In this study, we analyze how crop management will benefit from the Internet of Things (IoT) by providing an overview of its architecture and components from agronomic and technological perspectives. The present analysis highlights that IoT is a mature enabling technology with articulated hardware and software components. Cheap networked devices can sense crop fields at a finer grain to give timeliness warnings on the presence of stress conditions and diseases to a wider range of farmers. Cloud computing allows reliable storage, access to heterogeneous data, and machine-learning techniques for developing and deploying farm services. From this study, it emerges that the Internet of Things will draw attention to sensor quality and placement protocols, while machine learning should be oriented to produce understandable knowledge, which is also useful to enhance cropping system simulation systems.

[8] Technology assisted farming: Implications of IoT and AI, N Aggarwal1 and D Singh, 2020 .

With the advancement of technologies, things became intelligent with the capabilities of self-communication between them. Internet of Things (IoT) connected daily household things to the Internet and make them able to make decisions like the human mind. Sensors collect the real atmospheric data and with the help of Artificial intelligence (AI) algorithms analysis of data takes place so that devices behave more smartly. The present article discusses how IoT revolutionized the agricultural community. According to the study, it is analyzed that 70% population is dependent on agriculture for their livelihood in India, but the status of agriculture is no more concealed from society. With the involvement of technology, it becomes easy to predict temperature, rainfall, humidity, the need for fertilizers, water requirements, etc. The introduction of modern agriculture techniques using IoT & AI is revolutionizing the traditional agriculture methodologies and are making farming a profitable venture also.

III. RESEARCH METHODOLOGY

1. Methodology

Design and Architecture of the Edge Intelligence System: Describe the design and architecture of the proposed edge intelligence system for agricultural IoT, including the components and modules involved.

Data Collection and Preprocessing Techniques: Discuss the methods for collecting sensor data from agricultural IoT devices and preprocessing the data to remove noise and anomalies.

AI Models for Crop Monitoring and Management: Outline the AI models and algorithms selected for crop monitoring and management tasks, such as anomaly detection, yield prediction, and disease identification.

Integration of Edge Computing with AI Algorithms: Explain how edge computing technologies are integrated with AI algorithms to enable real-time processing and analysis of agricultural data.

Evaluation Metrics and Performance Analysis Framework: Define the evaluation metrics and performance analysis framework used to assess the effectiveness and efficiency of the edge intelligence system.

2. AI Model Development:

Selection of AI Algorithms:

- Convolutional Neural Networks (CNNs) for image processing.
- Recurrent Neural Networks (RNNs) for time-series data analysis.
- Reinforcement Learning for decision-making optimization.

Training and Validation:

- Use of historical data for training AI models.
- Validation using a subset of real-time data to ensure accuracy and reliability.

3. Edge Intelligence Implementation:

Edge Device Deployment:

- Selection of edge devices suitable for agricultural environments.
- Integration of AI models onto edge devices for real-time analysis.

Edge-Cloud Collaboration:

- Establishment of a seamless communication protocol between edge devices and cloud infrastructure for data synchronization and updates.

Edge Intelligence Framework Development:

Design and Implementation of Edge Computing Infrastructure: Detail the design and implementation of the edge computing infrastructure, including hardware specifications, software components, and networking configurations.

Development of AI Models for Crop Monitoring: Describe the development process of AI models for crop monitoring tasks, including data preprocessing, feature selection, model training, and validation.

Integration of Sensor Data with Edge Devices: Explain how sensor data from agricultural IoT devices are integrated with edge devices for real-time processing and analysis.

Real-Time Data Processing and Analysis at the Edge: Illustrate the process of real-time data processing and analysis at the edge, including data ingestion, feature extraction, and model inference.

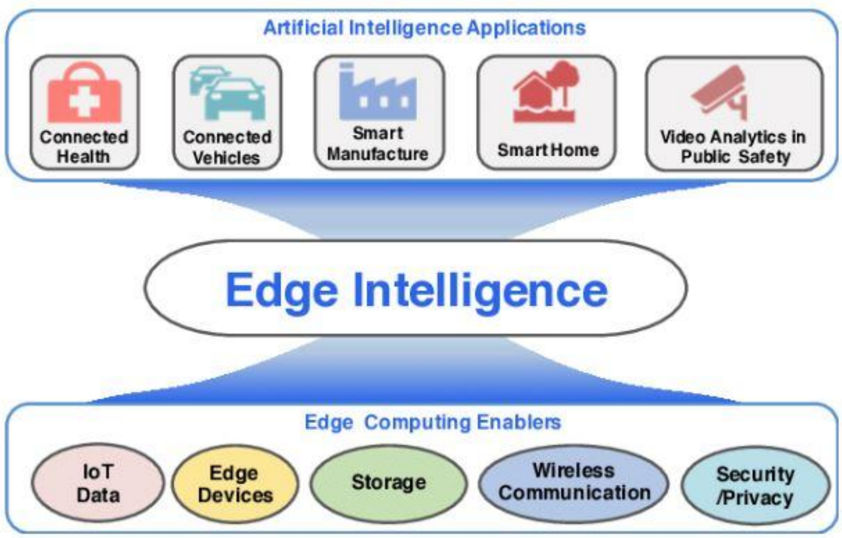

Figure 1.3 Motivation of Edge Intelligence

IV. CONCLUSION

In conclusion, the convergence of Artificial Intelligence (AI) and the Internet of Things (IoT) in the realm of agricultural practices marks a revolutionary stride towards precision farming and sustainable crop management. The three intelligent edge applications explored in this discussion—Smart Sensing, Edge Analytics, and Precision Actuation— collectively form a powerful framework for AI-driven crop monitoring and management in agricultural IoT.

Smart Sensing, as an integral part of the intelligent edge, empowers farmers with real-time and granular data about various environmental parameters. These sensors, deployed directly on the field or attached to agricultural equipment, provide continuous insights into soil health, crop growth, and climatic conditions. The data gathered forms the foundation for informed decision-making, allowing farmers to optimize resource usage, detect anomalies, and respond promptly to potential issues.

Edge Analytics, operating at the intersection of data processing and AI algorithms, brings computational intelligence directly to the source of data generation. By leveraging machine learning models, predictive analytics, and pattern recognition, edge analytics transforms raw sensor data into actionable insights. This localized processing not only reduces latency but also mitigates the challenges associated with transmitting vast amounts of data to centralized cloud servers. The result is a more responsive, efficient, and cost-effective approach to crop monitoring and decision support.

REFERENCES

[1] Programme, Water and Jobs, the United Nations World Water Development Report, UN World Water Develop. Rep. Arch., United Nations Educ., Sci. Cultural Org., Paris, France, 2016.
[2] M. S. Farooq, S. Riaz, A. Abid, K. Abid, and M. A. Naeem, ‘‘A survey on the role of IoT in agriculture for the implementation of smart farming,’’ IEEE Access, vol. 7, pp. 156237–156271, 2019, doi:m10.1109/ACCESS.2019.2949703.
[3] M. Ayaz, M. Ammad-Uddin, Z. Sharif, A. Mansour, and E. M. Aggoune, ‘‘Internet-of-Things (IoT)-based smart agriculture: Toward making the
fields talk,’’ IEEE Access, vol. 7, pp. 129551–129583, 2019, doi: 10.1109/ACCESS.2019.2932609.
[4] R.-A. Li, X. Sha, and K. Lin, ‘‘Smart greenhouse: A real-time mobile intelligent monitoring system based on WSN,’’ in Proc. Int. Wireless Commun. Mobile Comput. Conf. (IWCMC), Nicosia, Cyprus, Aug. 2014, pp. 1152–1156, doi: 10.1109/IWCMC.2014.6906517.
[5] R. Nalwade and T. Mote, ‘‘Hydroponics farming,’’ in Proc. Int. Conf. Trends Electron. Informat. (ICEI), Tirunelveli, India, May 2017, pp. 645–650, doi: 10.1109/ICOEI.2017.8300782.
[6] I. Idris and M. I. Sani, ‘‘Monitoring and control of aeroponic grow- ing system for potato production,’’ in Proc. IEEE Conf. Control, Syst. Ind. Informat., Bandung, Indonesia, Sep. 2012, pp. 120–125, doi: 10.1109/CCSII.2012.6470485.
[7] T. Nishimura, Y. Okuyama, A. Matsushita, H. Ikeda, and A. Satoh, ‘‘A compact hardware design of a sensor module for hydroponics,’’ in Proc. IEEE 6th Global Conf. Consum. Electron. (GCCE), Nagoya, Japan, Oct. 2017, pp. 1–4, doi: 10.1109/GCCE.2017.8229255.
[8] S. B. Saraf and D. H. Gawali, ‘‘IoT based smart irrigation monitoring and controlling system,’’ in Proc. 2nd IEEE Int. Conf. Recent Trends Electron., Inf. Commun. Technol. (RTEICT), Bengaluru, India, May 2017, pp. 815–819, doi: 10.1109/RTEICT.2017.8256711.
[9] M. C. Vuran, A. Salam, R. Wong, and S. Irmak, ‘‘Internet of underground things in precision agriculture: Architecture and technol- ogy aspects,’’ Ad Hoc Netw., vol. 81, pp. 160–173, Dec. 2018, doi: 10.1016/j.adhoc.2018.07.017.
[10] Singh S et al, "A Systematic Study on Big Data in IOT and Agriculture," JTGRS, vol. 21, no. 6, pp. 566-572, 2019.
[11] Patil V, Pathade S, "IOT based Agribot for Irrigation and Farm Monitoring," OAIJSE, vol. 4, no. 6, pp. 9-13, 2019.
[12] Kambar, Praveen S"A Study on the role of E-Technology to take over Agriculture Distress in India,"IJCAS, vol. 8, no. 12(A), pp. 335-341, 2018.
[13] Puranik V, Ranjan A, Kumari A, "Automation in Agriculture and IoT," in IEEE, 2019.
[14] Kumar S, Chowdhary G, Udutalapally V, Das D, Mohanty SP, "gCrop: Internet-of-Leaf-Things (IoLT) for Monitoring of the Growth of Crops in Smart Agriculture," in IEEE, 2019.
[15] David S, Anand RS, Sagayam M, "Enhancing AI based evaluation for smart cultivation and crop testing using agro-datasets," JAIS, vol. 2, no. 1, pp. 149-167, 2020.
[16] Raju BV, "An IOT based Low Cost Agriculture Field Monitoring System," JASC, vol. VI, no. IV, pp. 128-136, 2019.
[17] Ragavi B, Pavithra L, Sandhiyadevi P, Mohanapriya GK, Harikirubha S, "Smart Agriculture with AI Sensor by Using Agrobot," in IEEE, 2020.
[18] Lohchab V, Kumar M, Suryan G, Gautam V, Das RK, "A Review of IoT based Smart Farm Monitoring," in IEEE, 2018.
[19] Sujith AV, Sekhar KC, "Automated Agriculture as a Service Using IoT," IJARCSSE , vol. 7, no. 5, pp. 925-930, 2017.
[20] Dharmaraj V, Vijayanand C, "Artificial Intelligence (AI) in Agriculture," IJCMAS, vol. 7, no. 12, pp. 2122-2128, 2018.