Original Article

Check for updates

Available online at
https://jiicet.gnt.com.pk/index.php/jiicet/

Journal of Innovative Intelligent Computing and Emerging Technologies (JIICET)

Vol. 1, No. 1, 2026

Leveraging IoT for Crop Health Monitoring: A Perspective

Mushtaque Ahmed Rahu[1], Sayed Mazhar Ali[2]

[1] Department of Electronic Engineering, QUEST Nawab Shah, 67450, Pakistan, email: rahumushtaque@gmail.com (M.A.R)
[2] Department of Mechatronics, Air University Karachi Campus, Pakistan, email: mazharlakyari@gmail.com (S.M.A)

* Correspondence: rahumushtaque@gmail.com

Article History

Received 05 December 2025
Revised 21 Jan 2026
Accepted 01 April 2026
Available Online 07 April 2026

Keywords:
IoT
AI
Crop Management
Agriculture
Communication Protocols

Abstract

The implementation of the Internet of Things (IoT) technologies in the agricultural sector has led to the beginning of the new era of monitoring the health of plants, offering the opportunities to obtain real-time data and fully analyze it like never before. The IoT systems can monitor key parameters, including soil moisture, temperature, humidity, and stress indicators of plants by using a variety of sensor technologies. This potential will support early detection of diseases, effective pest control measures and optimal irrigation systems that will improve crop productivity and sustainability. This review summarizes the latest developments in IoT-based plant health monitors with particular focus on the most important technological features such as wireless communication protocols and data analytics. It also analyses the major issues like sensor longevity, connection limitations, cost implications and data safety issues that hinder the greater usage. Last but not the least, the new trends that include edge computing, artificial intelligence, and multi-sensor fusion are discussed, highlighting the potential to revolutionize the IoT in the field of precision agriculture and sustainable crop management.

1. Introduction

Modern agriculture and environmental management is largely concerned with plant health monitoring [1]. It is a systematic monitoring and evaluation of plants in order to identify the evidence of stress, disease, deficiency of nutrients or other variables that impact on the health of the plants. Plant health is important in enabling optimum crop production [2], land management sustainability and early detection of. Prospective challenges to food production. The technological revolution in the recent years transformed the manner in which the preferred health of plants is scrutinized. Remote sensing tools, data analytics and machine learning [14] algorithms have been used to supplement or substitute the traditional visual inspection and manual sampling methods. Through these innovations [3], it is possible to monitor plant health with increased efficiency, precision, and timeliness over a sizeable area and in a wide range of landscape types. Remote sensors, satellites, drones, ground sensors, etc. record many details of plant physiology and the environment. An example is the spectral imaging, which is a measure of the reflection of light on plant tissues giving valuable information about chlorophyll concentration, structure of the leaf, and indicators of stress. The multispectral and hyperspectral imaging methods are used to provide specific insights into the parameters of plant health and provide an opportunity to detect diseases, pests, or lack of nutrients in time [7]. Adoption of plant health monitoring in the practice of precision agriculture has revolutionized the management of crops by ensuring the allocation of resources is optimized, the impact on the environment is minimized and improvement in productivity is realized. Plant health monitoring helps farmers and land managers to reduce risks, losses and achieve sustainable food production and environmental stewardship by being proactive in their approach to monitoring [6].

IoT paradigm has shifted the fundamental paradigm of the Internet of Things [8]. Created many industries through facilitation of the interconnection of. Physical devices that have sensors, software and communication potential to gather and trade information without hitches. Agri culture, which is traditionally based on labor-intensive and subjective moniorating, is one of the fields where the IoT [15] can be of great use. Offer automated, intelligent, and live monitoring services. By outfitting farms with a system of computers that constantly record and monitor the data. Farmers to make decisions based on environmental and plant-specific information, which is provided by IoT. Informed decisions that enhance the health of crops and productivity of the crops. Reducing resource wastage. The ability to be perpetual and remote sensing does not only make the detection of plant stressors fast, diseases, and outbreaks of pests but also enables accurate interventions. Specific to the requirements of crops. This review dwells on the recent. Innovations in IoT technologies [13] used in the health monitoring of plants, describing the nature of sensors used, communication structures, and statistics methodologies. Also, it talks about present-day. Mechanisms such as technological, environmental and economic constraints. Obstacles and considers future innovations that can help to beat these. Problems to facilitate sustainable production of agriculture in a global approach.

2. Significance of Plant Health Surveillance

The importance of plant health monitoring has attracted a lot of interest in agricultural research [5] and practice as it is essential in the achievement of crop productivity and sustainability. Plant health monitoring literature is found across different methodologies and technologies such as conventional field methods, remote sensing methods, and sensor-based systems [6].

Monitoring systems are sensor-based and attached to the Internet of Things (IoT) [19] technology, as a result of which real-time monitoring of the parameters of plant health is possible, such as the moisture content of the soil, temperature, humidity, and nutrient content. Field sensors that are IoT based. Constantly gather information, and it is wirelessly transferred to central databases or cloud platforms to be analyzed and visualized. These systems can give farmers and agronomist's practical information on the condition of crops [20] and the environment, facilitating the prompt action and efficient use of resources. Also, sensor technology has improved, which has resulted in specialized sensors to identify certain plant pathogens or pests, and they are quick and accurate diagnosis in the field. Visual inspection, scouting, and sampling are traditional approaches to plant health monitoring and have historically been the basis of the methods of disease, pest, and nutrient deficiency identification, enabling the researcher and the farmer to utilize the data. Although these approaches are labor intensive and are subjective at times, they are still useful in ground based evaluation and confirmation of the health of plants. Inspection and laboratory tests are still essential in diagnosing diseases and pests. Nevertheless, technological developments in remote sensing, including satellite imagery and drones, provide the most significant prospects of tracking large-scale crop health indicators. Moreover, real-time is allowed by sensor-based systems that have IoT devices. Measuring of environmental conditions such as the moisture content of the soil and nutrient content. Although there are tremendous developments in the technology of monitoring plant health and methodology, there are some challenges. The data combination and interoperability problems create an obstacle to the smooth flow of data across various monitoring systems. And platforms. Moreover, data privacy and security is of utmost importance, especially when passing sensitive data through wireless networks, or when storing data at the cloud. Plant health monitoring technologies are effectively used in their operations through standardization of the protocols and data [6].

Modern agri plants health monitoring is also effective. Culture, which is part of the early detection of diseases, effective pest manage. Mind, and effective use of water and nutrients. Historically, plant health has been assessed in the past relying on manual field. Time consuming, subjective and usually inadequate inspections. Client to identify the physical physiological changes that manifesting visible symptoms. With the use of IoT-related monitoring, objectivity is added. And continuity through time to this process by implementing different sensors. That are capture parameters so as soil moisture, temperature, humidity, and this intensity of light in the real time. This is a goal and perpetual. Data collection does not only increase the accuracy of health assessment. But also facilitates forward intervention measures that reduce losses of crops and benefit the management of sustainable resources.

3. IoT based Sensors for Plant health monitoring

IoT systems in plant are based on a number of sensor technologies. Moisture sensors on soil offer vital information on the timing of irrigation so that plants can get sufficient water without waste. Microclimate is monitored using temperature and humidity. Microclimaticmatic conditions around plants, which have direct impact on pathogen stress and development of plants. The high-tech optical sensors, include recording multispectral and hyperspectral imaging devices, take finer [9]. Data on reflectance and coloration of plants displaying evidence of invisible nutrient deficiencies or stresses. The incorporation of these heterogeneous sensors in wireless networks develops the platform of holistic monitoring that is able of providing granular information on crop conditions.

4. Communication Protocols

The IoT does not represent a single technology, but it is a combination of different technologies. The hardware and software technologies, wireless technologies, including 2G/3G/4G/LTE/5G, Bluetooth (IEEE 802.15.1 standard), Wi-Fi (IEEE 802.11 standard), ZigBee (IEEE 802.15.4 standard), RFID, cloud computing and big data analytics are all types of technology that are used in various layers of the IoT networks. IoT is attributed to hardware and software technologies in many aspects [10].

It takes reliability to transmit the large volumes of sensor data that are accumulated. Wireless communication technologies that are able. Protocols such as ZigBee, Narrowband IoT (NB-IoT) and LoRa WAN [11] are usually used. Based on the application needs in respect of range, power consumption, and data rate. An example is the LoRa WAN which is preferred in agricultural [12] locations of its long range communication and low power. Usage, which renders it highly adapted to the large fields. The selection of a proper communication protocol is very important in sustaining. Real-time data flow, and it is based on timely decision-making. High quality control of flora condition.5G networks, while still emerging in rural areas, enable ultra-low latency for real-time autonomous machinery and drone control.

5. Data Processing and Analysis

Sensor data that will be collected will require capability data processing. Computing and storage in the cloud computing platforms is scalable. All functionalities which are needed to work with big datasets and execute their intricate operations. Analytics. Algorithms [18] of machine learning and artificial intelligence [17] have been useful in sensor interpretation by classifying. Prediction of stress conditions, predicting plant diseases, and recommending remedial actions. These smart analysis tools convert unstructured data into. Actionable insights, which allow accuracy of agriculture where. Interventions are designed based on a real time crop demands thereby increasing the yield. Becoming less harmful to the environment.

6. Applications in Plant Health Monitoring

i. Irrigation Management

Water management: Water is necessary in the health of plants, particularly. In water-scarce regions. Based on IoT, soil moisture sensing makes it possible to control dynamic irrigation scheduling, avoiding water stress, as well as waters excess. Watering. Programmed irrigation systems based on IoT plat. Forms are real-time reacting to sensor feedback, maximising water consumption, reducing consumption, and improving the health of crops.

ii. Pest Management

Crops are highly endangered by pest infestations. IoT facilitates pest management using sensors which identify plant stress associated with pest attacks and traps that have cameras to track pest populations directly. Instant messages enable the farmers to implement aimed control measures, in which the indiscriminate use of was minimized. Pesticides, preventing the resistance of pests, and conservation of beneficial insect’s populations.

iii. Early disease Detection

The use of IoT in agriculture has had one of the most significant effects through the use of one of the applications, which is the early detection of diseases. Physiological diseases are caused by many plant diseases reacts much earlier than symptoms manifest, and this is a significant advantage down for intervention. IoT image pro augmented systems. Pattern recognition and cessation can be used to identify minute changes in leaf col. shape, texture, and our, allowing timely reactions which decrease yield degradation of crops and the fact that large amounts of pesticides are required.

7. Current Trends and Techniques in IoT

The last years have seen the invention of a number of IoT contemplated based plant health monitoring offerings such as basic sensor mobiles with sophisticated platforms combining to applications drones, multi spectral imaging and AI analytics. For example, drones with sophisticated sensors are able to survey wide areas very quickly agricultural fields, de-IoT networks with feeding high-resolution data. Production-monitored crop health. Such innovations are additive to greater scalability, effectiveness and accuracy in surveillance undertakings.

8. Challenges in IoT Adoption

The agricultural IoT adoption is challenging with a number of challenges notwithstanding its potential Lenges. Extreme environmental sensor durability and accuracy. Conditions are still acute problems, sensor degradation may com. promise quality and system reliability. Connectivity Limitations particularly in the remote and expansive fields of agriculture [16] make real-time difficult. Data communication and require data processing both hybrid and localized. Solutions. Besides, there are issues of data security and privacy. Because of the sensitivity of the agricultural data, there is need to have a strong measure to have a secure transmission, storage and ownership control. the economic aspects also contribute greatly; the price of the IoT infra. Smallholder farmers may be prohibited by structure and maintenance, emphasizing the importance of affordable and easy to use solutions.

9. Global Case Studies

1. India - Irrigation using IoTs saved 30% of water and boosted wheat production by 12 percent.
2. Spain - IoT sensors were applied to vineyard management and the increase in pesticide use was decreased by 18% and the grape improved quality.
3. Kenya - Dairy monitoring in livestock had a 15 percent reduction in mortality and enhanced breeding efficiency
4. Australia - IoT-based frost alerts have resulted in saving of 5 million dollar of crop loss every year [4].

10. Current & Future Trends in IoT

Figure 1 shows that the number of Internet of Things (IoT) connections in the world is set to increase in 2022-2024, and the project is projected to reach 2033. The number of IoT devices in the globe is expected to almost grow by 2030 to more than 32.1 billion devices as compared to 15.9 billion devices in the year 2023. There will be the greatest number of IoT devices in China by 2033 with about 8 billion of these devices being consumer devices. The IoT devices are used in different industries and consumer markets, of which the consumer market in 2023 represents approximately 60 percent of all IoT or connected devices. This percentage is expected to be steady within the next ten years [4].

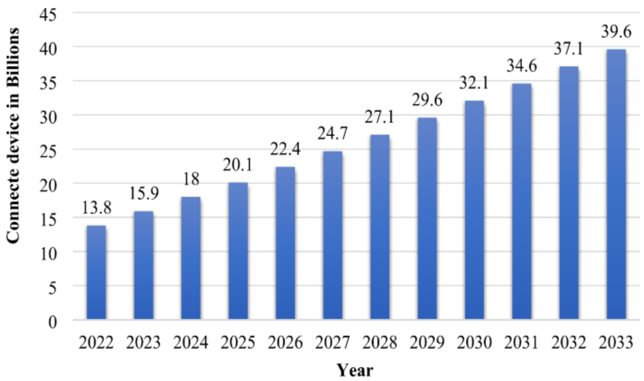

Figure 1. Global IoT Connections in 2024 and Projections 2033 [4]

11. Conclusion and Future Perspective

The introduction of internet of things (IoT) in monitoring plant health. Systems is a significant development of agricultural science, presenting unmatched chances of improving crop management. By accurate, punctual, and evidence-based interventions. By enabling on-going objective observation of environmental and physiological. Plant parameters, IoT enables the identification of disease early, successful pest efficiency, and good management of resources, and thus contributing to enhanced performance and profitability. Nonetheless, challenges associated with sensor dependability, connection, data integrity and accessibility problems in the economy still hinder mass implementation. Ad it is a task that needs the concerted efforts of researchers to dress these issues. To create resilient industry, stakeholders, policymakers and farmers will be involved. Scalable and cost-effective IoT solutions. Future directions are offering, with new developments on edge computing, that makes it possible. Processing at sensor level to minimize the latency and bandwidth. Requiring, artificial intelligence to improve interpretation of data, and combination of various sensor modalities that provide global knowledge into plant health. These technologies will promote the as they become mature. Development of smart environmentally friendly farms that can produce food to the entire world is resourceful and environmental-friendly, a new era of demands. Novice era of accuracy agriculture.

Author Contributions: "Conceptualization, M.A.R. and S.M.A.; methodology, M.A.R; and S.M.A writing—original draft preparation, M.A.R.; writing—review and editing, S.M.A.; visualization, M.A.R.; supervision, S.M.A.; All authors have read and agreed to the published version of the manuscript."

Funding: "This study does not receive external funding."

Ethical Clearance: "Not applicable".

Informed Consent Statement: "Not applicable".

Data Availability Statement: "Not applicable".

Acknowledgments: Thanks Co-author for support and help.

Conflicts of Interest: "All the authors declare that there are no conflicts of interest."

References

1. Kaler, Blossom, and Amandeep Kaur. "A systematic survey on explainable artificial intelligence (XAI) for plant health monitoring: challenges and opportunities." Applied Intelligence 55, no. 12 (2025): 889.

2. Xing, Yingying, Xiukang Wang, and Adnan Mustafa. "Exploring the link between soil health and crop productivity." Ecotoxicology and environmental safety 289 (2025): 117703.

3. Padhiary, Mrutyunjay, Avinash Kumar, and Laxmi Narayan Sethi. "Emerging technologies for smart and sustainable precision agriculture." Discover Robotics 1, no. 1 (2025): 6.

4. Irfan, Engr Faiza, Engr Rukhsar Zaka, Engr Sidra Rehman, Bushra Sattar, and SA Haiderand MA Hayat. "An IOT-Driven Smart Agriculture Framework for Precision Farming, Resource Optimization, and Crop Health Monitoring." ACADEMIA International Journal for Social Sciences 4, no. 3 (2025): 3329-3342.

5. Duguma, A.L., Bai, X. How the internet of things technology improves agricultural efficiency. Artif Intell Rev 58, 63 (2025). https://doi.org/10.1007/s10462-024-11046-0

6. Venkatesh, N., S. Maheswari, and P. Triveni. "Harnessing IoT for Real-Time Plant Health Monitoring: Challenges and Opportunities." (2024).

7. Szechyńska-Hebda, Magdalena, Ryszard Hołownicki, Grzegorz Doruchowski, Konrad Sas, Joanna Puławska, Anna Jarecka-Boncela, Magdalena Ptaszek, and Agnieszka Włodarek. "Application of Hyperspectral Imaging for Early Detection of Pathogen-Induced Stress in Cabbage as Case Study." Agronomy 15, no. 7 (2025): 1516.

8. Semarajana, I. Nyoman Gede, Kadek Ayu Wiswapawani, Ida Bagus Yorky Brahmantya, and I. Gusti Ngurah Putra Eka Santosa. "Implications of Changing the Health Paradigm from the Medicine 1.0 to 4.0 Era." Journal of Ethnomedicine and Medical Wellness 1, no. 1 (2025): 9-11.

9. Mendoza, Princess Tiffany D., Paul R. Armstrong, and Kaliramesh Siliveru. "Hyperspectral Imaging." In Emerging Non-destructive Technologies for Food Quality Analysis, pp. 159-185. Cham: Springer Nature Switzerland, 2025.

10. Das, Sangjukta, and Suyel Namasudra. "Introducing the Internet of Things: Fundamentals, challenges, and applications." Advances in Computers 137 (2025): 1-36.

11. Waseem, Muhammad, Alicia Lopez, Pedro Luis Carro, Maria Angeles Losada, Dwight Richards, and Abdul Aziz. "Understanding the potentials of narrowband internet of things (NB-IoT) cellular technology: Salient features, architecture, smart applications and quality of service (QoS) challenges." IEEE Open Journal of the Communications Society (2025).

12. Rahu, Mushtaque Ahmed, Pardeep Kumar, Sarang Karim, and Azeem Ayaz Mirani. "Agricultural Environmental Monitoring: A WSN Perspective." University of Sindh Journal of Information and Communication Technology 2, no. 1 (2018): 17-24.

13. Rahu, Mushtaque Ahmed, Sarang Karim, Rehan Shams, Ayaz Ahmed Soomro, and Abdul Fattah Chandio. "Wireless Sensor Networks-based Smart Agriculture: Sensing Technologies, Application, and Future Directions." Sukkur IBA Journal of Emerging Technologies 5, no. 2 (2022): 18-32.

14. Rahu, Mushtaque Ahmed, Abdul Fattah Chandio, Khursheed Aurangzeb, Sarang Karim, Musaed Alhussein, and Muhammad Shahid Anwar. "Toward design of Internet of Things and machine learning-enabled frameworks for analysis and prediction of water quality." IEEE Access (2023).

15. Rahu, M.A., Shaikh, M.M., Karim, S. et al. "Water Quality Monitoring and Assessment for Efficient Water Resource Management through Internet of Things and Machine Learning Approaches for Agricultural Irrigation". Water Resource Management (2024). https://doi.org/10.1007/s11269-024-03899-5.

16. Rahu, Mushtaque Ahmed. "Transforming Farming with Technology: A Smart Novel Agriculture Framework and Infrastructure." Sukkur IBA Journal of Computing and Mathematical Sciences 8, no. 2 (2024): 53-69.

17. Karim, Sarang, Kashif Hussain, Muhammad Bux Alvi, Mushtaque Ahmed Rahu, Mumtaz Ali Kaloi, and Halar Haleem. "Artificial Intelligence in Sustainable Smart Agriculture: Concepts, Applications, and Challenges." VAWKUM Transactions on Computer Sciences 13, no. 1 (2025): 307-342.

18. Sayed Mazhar Ali shah, Assadullah Soomro, Kashif Hussain, Mushtaque Ahmed Rahu, and Sarang Karim. "Innovative Machine Learning Solutions: Investigating Algorithms and Applications." Journal of Applied Engineering & Technology (JAET) 8, no. 1 (2024): 32-51.

19. Rahu, Mushtaque Ahmed, Muhammad Mujtaba Shaikh, Sarang Karim, Abdul Fattah Chandio, Safia Amir Dahri, Sarfraz Ahmed Soomro, and Sayed Mazhar Ali. "An IoT and machine learning solutions for monitoring agricultural water quality: a robust framework." Mehran University Research Journal of Engineering and Technology 43, no. 1 (2024): 192-205.

20. Das, Bhagwan, Syed Mazhar Ali, Muhammad Zakir Shaikh, Abdul Fattah Chandio, Mushtaque Ahmed Rahu, Jitander Kumar Pabani, and Mujeeb Ur Rehman Khalil. "Linear Regression Based Crop Suggestive System for Local Pakistani Farmers." In 2023 Global Conference on Wireless and Optical Technologies (GCWOT), pp. 1-6. IEEE, 2023.