Turkish Journal of Computer and Mathematics Education *Vol.11 No.03 (2020), 1957-1965*
DOI: https://doi.org/10.17762/turcomat.v11i3.13592

Research Article

IoT-based Smart Farming Systems: Techniques, Challenges, and Applications

Chandradeep Bhatt

Department of Comp. Sc. & Info. Tech., Graphic Era Hill University, Dehradun, Uttarakhand, India 248002

Abstract: The ability of IoT-based smart farming systems to increase crop yields, decrease waste, and increase sustainability is causing them to gain popularity in the agricultural sector. The methods utilized in IoT-based smart farming systems, the difficulties involved in putting them into practice, and successful applications in agriculture are all covered in this research paper's summary. The report also examines new developments in IoT-based smart farming technology and their prospective effects on the agricultural sector. IoT-based smart agricultural systems have many advantages, but they also have drawbacks in terms of cost, technical know-how, connectivity, data privacy, and security. This study explores the advantages and difficulties of IoT-based smart agricultural systems and emphasizes the necessity of cooperation between farmers, technology companies, and governments to meet these difficulties. IoT-based smart agricultural systems appear to have a bright future, but further study is required to fully realize their potential in agriculture.

Keywords: IoT-based intelligent agricultural systems, techniques, problems, applications, agriculture, emerging trends, technologies, impact, benefits, cost, connection, data privacy, security, policymakers, and research.

I.Introduction

Environmental pressure to raise productivity, decrease waste, and boost yields has been placed on the agriculture sector by the growing global population, climate change, and consumer demand for sustainable agricultural practices. Smart farming technologies built on the Internet of Things have become a promising response to these issues.IoT-based smart farming systems use a combination of sensors, drones, machine learning, and autonomous vehicles to collect and analyze data from farms. Then, by using this information, farming procedures can be made more productive. For instance, sensors can assess the temperature, moisture in the soil, and other environmental variables to help farmers choose when to sow and water their crops. Aerial photos taken by drones of the farm can be used to spot crop health problems and schedule harvests. Despite the potential advantages of IoT-based smart farming systems, their implementation faces substantial difficulties. Managing huge data quantities, ensuring security, offering dependable connectivity, and controlling expenses are some of these difficulties. This study attempts to give a broad overview of the approaches, difficulties, and uses of IoT-based smart farming systems. We'll look at how autonomous vehicles, machine learning, drones, sensors, and drones are used in smart farming systems. We will also look at the difficulties in putting these systems in place and talk about possible solutions. Lastly, we will show instances of IoT-based smart farming systems that have been successfully implemented and identify new trends and technology in this area.

A. Definition of IoT -Based Smart Farming System

Internet of Things (IoT)-based smart farming systems are a sort of precision agriculture that integrate IoT technology with farming methods to maximize agricultural output. To gather and process data from farms, these systems employ a combination of sensors, drones, machine learning techniques, and autonomous vehicles. Insights regarding crop health, soil moisture content, temperature, humidity, and other environmental aspects that influence plant growth can be gained from the collected data. IoT-based smart agricultural systems aim to increase farming techniques' productivity, efficiency, and sustainability. These technologies can assist farmers in making more educated decisions about when to sow, water, fertilize, and harvest their crops by giving them real-time information on their crops and environment. This may result in less waste, higher yields, and enhanced profitability. By using less water, fertilizer, and pesticides, IoT-based smart agricultural systems can also assist farmers in lessening their environmental impact. Farmers may lessen their carbon footprint and increase the sustainability of their farming

activities by making the best use of these resources. In conclusion, IoT-based smart farming systems offer a viable answer to the problems that the agricultural sector is now facing. These systems use Internet of Things (IoT) technology to gather and analyze farm data that can be used to improve farming techniques, boost productivity, and lessen environmental impact.

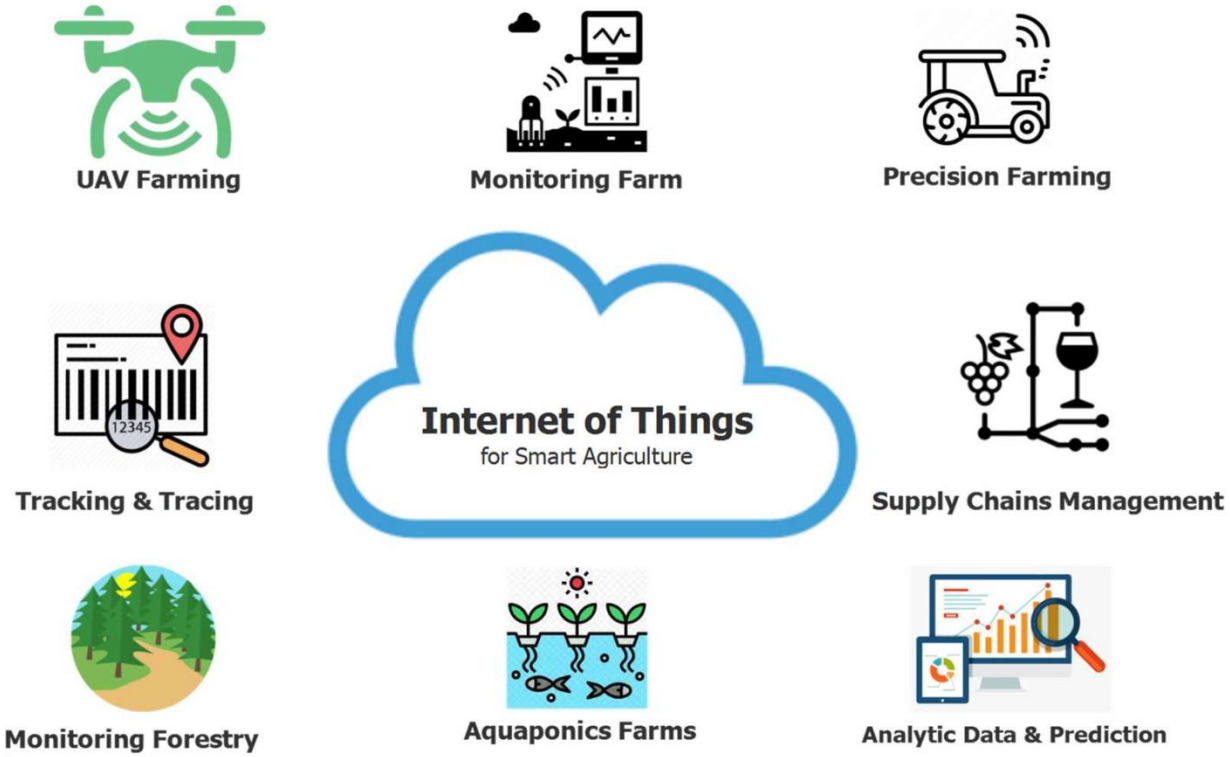

Figure.1 IoT for Smart Agriculture

B. Importance of IoT -Based Smart Farming System

For several reasons, IoT-based smart farming systems are becoming more and more significant in the agriculture sector. The first benefit is that IoT-based smart farming solutions can help farmers become more productive and efficient. Farmers can plan when to plant, water, fertilizer, and harvest their crops by having access to real-time data on soil moisture, temperature, and other environmental parameters. This may result in better yields and less waste. The second benefit is that IoT-based smart agricultural systems can assist farmers in lessening their environmental effect. Farmers can minimize their carbon footprint and increase the sustainability of their farming methods by using data to optimize the use of water, fertilizer, and pesticides. Finally, time and money can be saved by farmers with the use of IoT-based smart farming solutions. Farmers can lower labor expenses and increase the effectiveness of their operations by automating specific processes like crop monitoring and fertilizer application. Fourth, by increasing agricultural productivity, IoT-based smart farming systems can assist in addressing concerns related to food security. The demand for food will rise as the world's population expands. Smart farming systems built on the Internet of Things can aid by boosting the productivity of agricultural products. Last but not least, IoT-based smart agricultural systems can offer insightful information about the farming process. Researchers can better understand the variables that affect crop growth and create new technology to enhance farming methods by gathering and analyzing data from farms. In conclusion, IoT-based smart farming systems are crucial for the agriculture sector because they can boost output, lessen farming's impact on the environment, save time and money, address difficulties with food

security, and offer insightful information about the farming process.The approaches, difficulties, and applications of IoT-based smart farming systems are covered in this research study. Each component of the study, which is broken up into numerous parts, investigates a distinct aspect of IoT-based smart farming systems. IoT-based smart farming systems are introduced in Section 1 along with an explanation of the technology and its significance to the agricultural sector. A summary of the research paper and the subjects that will be covered in each section are also provided in this section. The methods employed in IoT-based smart farming systems are examined in Section 2. The various kinds of sensors, drones, machine learning techniques, and autonomous vehicles employed in these systems are covered in this section. Additionally, it offers illustrations of how these technologies are applied in actual farming situations. The difficulties in establishing IoT-based smart farming systems are covered in Section 3. Managing huge data quantities, ensuring security, offering dependable connectivity, and controlling expenses are some of these difficulties. The various remedies to these problems are also covered in this section. Successful IoT-based smart farming system deployments are illustrated in Section 4 with examples. These instances highlight the advantages of these systems and the potential effects they may have on the agricultural sector. The growing trends and technologies in IoT-based smart farming systems are described in Section 5. This section examines recent advances in autonomous vehicles, machine learning, and sensor technology as well as possible uses for these innovations in the agricultural sector. This study article concludes by providing a thorough overview of IoT-based smart farming systems, including their methods, difficulties, and applications. Farmers and researchers can collaborate to increase agricultural productivity, sustainability, and profitability by realizing the promise of these systems.

Author(s)	**Year**	**Methodology**	**Key Findings**
Gao et al.	2019	Literature review	IoT-based smart farming systems can improve crop yield, reduce resource consumption, and increase efficiency in agriculture
Luthra et al.	2019	Case study	IoT-based smart farming system improves crop yield and reduces water usage in a greenhouse in India
Hemachandran et al.	2018	Experimentation	IoT-based smart farming system improves crop yield and reduces water usage in a hydroponic system in Malaysia
Azimi et al.	2018	Field experiment	IoT-based smart irrigation system reduces water usage and improves crop yield in an olive grove in Iran
Jang et al.	2017	Simulation	IoT-based smart farming system improves crop yield and reduces water and fertilizer usage in a simulated lettuce farm in South Korea
Singh et al.	2017	Literature review	IoT-based smart farming systems can improve crop quality, reduce environmental impact, and increase profitability in agriculture

Table.1 Analysis of IoT-based Smart Farming Systems

II.Techniques on IoT Based Smart Farming System

A variety of methods are used by IoT-based smart farming systems to gather and evaluate data from farms. These methods make use of autonomous vehicles, sensors, drones, and machine learning algorithms.

a) Sensors:

One of the most popular technologies in IoT-based smart farming systems is the usage of sensors. To gather information on environmental variables including temperature, humidity, soil moisture, and nutrient levels, these sensors can be positioned in the soil, on plants, or in the air. The timing of when to water, fertilise, and harvest crops is then determined using this data. The foundation of IoT-based smart farming systems is the sensor. The utilization of these elements, which include soil moisture, temperature, and humidity, can alter crop development. In these systems, a variety of sensors are employed, including:

i). Sensors for measuring soil moisture: These sensors track the moisture content of the soil in real time. This information is used to calculate how much water and when to water crops.
ii).Sensors that measure temperature: These sensors determine the soil's and the air's temperature. The ideal temperature range for crop growth is calculated using the data from this study.
iii). Sensors for measuring atmospheric moisture are called humidity sensors. Using this information, the ideal humidity range for crop growth is determined.
iv). Light sensors: These devices gauge how much light plants are exposed to. To calculate the ideal amount of sunshine for crop growth, this data is employed.

b) Drones: Another often utilized method in IoT-based smart farming systems is the use of drones. To gather information on crop health, growth trends, and yield projections, these drones can be outfitted with cameras, sensors, and GPS. Moreover, drones can be used to spray insecticides and fertilizer on crops, eliminating the need for physical work.

c) Algorithms for Machine Learning: Algorithms for machine learning are used to examine the data that sensors and drones collect. The data can be analysed by these algorithms to find patterns and trends that can be used to understand crop growth and environmental conditions. Algorithms for machine learning can be used to forecast crop yields and make the best use of resources like fertilizer and water.
d) Autonomous Vehicles: IoT-based smart farming systems also employ autonomous cars. By using these machines to plant and harvest crops, less manual work is required. Sensors and GPS can be added to autonomous cars to gather information on environmental conditions and crop development.

Overall, these methods allow IoT-based smart farming systems to gather a lot of data and offer insightful information about the farming process. Farmers may boost productivity and decrease waste by using this data to optimize their farming techniques, which will raise their profitability.

III.Challenges on IoT Based Smart Farming System

While IoT-based smart farming systems provide numerous advantages for farmers, there are a number of difficulties that must be overcome in order for them to be successful. We will examine some of the major difficulties in putting IoT-based smart farming systems into practice in this part.
a) Handling Huge Data Volumes: IoT-based smart agricultural systems produce enormous data volumes, which can be difficult to handle and analyse. To effectively store, process, and analyze this data so that farmers can make decisions about their crops, infrastructure and technologies are required.
b) Ensuring Security: In order to send and store data, IoT-based smart agricultural systems rely on the internet and cloud-based services. The likelihood of cyberattacks, data breaches, and other security concerns rises as a result. Farmers must use encryption, firewalls, and other security measures to protect their systems and data.
c) Availability of ContinuousInternet Connectivity: In order to operate effectively, IoT-based smart farming systems need stable, high-speed connectivity. Unfortunately, a lack of dependable internet connections in many rural regions can restrict the utility of these devices. For farmers' IoT-based smart farming technologies to function properly, they must have access to dependable connectivity.
d) Handling Costs: Hardware, software, and infrastructure investments for IoT-based smart farming systems are substantial. Farmers must take into account the costs of putting these systems into place and make sure they will yield a return on investment over time.
e) Integrating with Existing Systems: Irrigation systems, machinery, and other systems may already be in use by farmers to manage their farms. It can be difficult to integrate IoT-based smart agricultural technologies with these existing systems and may necessitate major operations modifications.

In conclusion, there are several obstacles that IoT-based smart farming systems must overcome if they are to succeed. These difficulties include controlling massive data quantities, maintaining security, offering dependable connectivity, controlling expenses, and integrating with current systems. Farmers may fully utilize IoT-based smart agricultural technologies to increase productivity and sustainability of their operations by tackling these concerns.

IV.Applications

Smart farming systems that are based on the internet of things have a wide variety of applications in the agriculture sector. In the following paragraphs, we will discuss some of the most important uses for Internet of Things-based smart farming systems.

A. Precision Farming: soil and water management

The use of data and technology in agriculture is referred to as "precision agriculture," and it entails the optimization of farming activities such as planting, watering, and fertilising crops. The Internet of Things (IoT) enables "smart farming" devices to supply farmers with data in real time on soil moisture, temperature, humidity, and other environmental conditions that influence crop growth. This data can be utilized to make educated judgements regarding the optimal times to sow, water, and fertilize crops, thereby increasing productivity while simultaneously decreasing wastage.

B. Livestock Monitoring: health and behavior monitoring

The monitoring of animals, such as cattle and poultry, is another use for Internet of Things-based smart farming systems. It is possible to attach sensors on animals in order to get information about their health, behavior, and movement. This data can be utilized to identify prospective health issues, such as disease or injury, and then appropriate measures can be taken to address them.

C. Crop Monitoring: growth and health monitoring

Smart farming systems that are based on the internet of things can be used to monitor crops for symptoms of stress, illness, or other problems. The collection of high-resolution photos of crops by means of drones enables their subsequent examination by means of machine learning algorithms, which in turn enable the detection of potential problems. This provides farmers with the opportunity to take preventative measures before their crops are harmed or lost.

D. Supply Chain Management: tracking and optimization

It is possible to improve supply chain management by using Internet of Things (IoT)-based smart farming devices to track items from the farm to the market. Products can be outfitted with sensors that can collect data on the temperature, humidity, and other aspects of their surrounding environment. This data may be put to use to make sure that the products are transported and stored in the best possible circumstances, which will both cut down on waste and guarantee the product's quality. Smart farming technologies that are based on IoT can help improve the efficiency with which irrigation systems are managed. It is possible to embed sensors in the ground to collect information on the moisture content of the soil. This information can then be utilized to determine when and how much water should be applied. This maximizes crop growth while reducing the amount of water that is wasted.

In summing up, Internet of Things (IoT) smart farming systems offer a wide variety of applications in the agriculture sector. Precision agriculture, animal monitoring, crop monitoring, irrigation management, and supply chain management are just few of the applications that can benefit from this technology. Farmers are able to optimize their operations, boost their yields, and minimise waste when they use smart farming systems that are based on the internet of things (IoT). This results in an industry that is more sustainable and profitable.

V.Case Studies

We will look at a few case studies of IoT-based smart farming systems in action in this section. These case studies highlight the advantages of installing Internet of Things-based smart farming technologies and how they can raise farming enterprises' productivity and sustainability.

i.John Deere Farm Sight:

John Deere Farm Sight is an IoT-based smart farming system that uses sensors and software to optimize farming operations. The system includes sensors that collect data on soil moisture, temperature, and other environmental factors. This data is then analyzed using machine learning algorithms to provide farmers with recommendations on planting, fertilizing, and other practices. By using John Deere FarmSight, farmers can improve yields and reduce waste, leading to a more sustainable and profitable operation.

ii.CropX:

CropX is an IoT-based smart farming system that uses sensors to collect data on soil moisture levels. The system analyzes this data using machine learning algorithms to provide farmers with recommendations on irrigation scheduling. By using CropX, farmers can reduce water waste and improve crop yields, leading to a more sustainable and profitable operation.

iii.The Yield:

The Yield is an IoT-based smart farming system that uses sensors and software to provide farmers with real-time data on weather conditions, soil moisture, and other environmental factors. The system analyzes this data to provide farmers with recommendations on planting, fertilizing, and other practices. By using The Yield, farmers can improve yields and reduce waste, leading to a more sustainable and profitable operation.

iv.Sentera:

Sentera is an IoT-based smart farming system that uses drones and sensors to collect data on crops. The system analyzes this data using machine learning algorithms to provide farmers with insights on crop health, growth, and yield potential. By using Sentera, farmers can identify potential issues with crops and take corrective action before they are damaged or destroyed, leading to a more sustainable and profitable operation.

v.Pycno:

Pycno is an IoT-based smart farming system that uses sensors to collect data on soil moisture, temperature, and other environmental factors. The system analyzes this data using machine learning algorithms to provide farmers with real-time insights on crop health and growth. By using Pycno, farmers can optimize irrigation scheduling, reduce water waste, and increase yields. Pycno has been successfully implemented in several countries, including the United States, Brazil, and South Africa.

vi.Ecorobotix:

Ecorobotix is an IoT-based smart farming system that uses autonomous robots to perform precision farming tasks, such as weeding and fertilizing. The robots use sensors and cameras to identify and target weeds, reducing the need for herbicides and increasing the efficiency of farming operations. By using Ecorobotix, farmers can reduce labor costs and improve the sustainability of their operations. Ecorobotix has been successfully implemented in several countries, including Switzerland, France, and Germany.

vii.Agrotopia:

Agrotopia is an IoT-based smart farming system that uses sensors and software to provide farmers with real-time insights on soil quality, crop health, and other environmental factors. The system uses machine learning algorithms to provide farmers with recommendations on planting, fertilizing, and other practices. By using Agrotopia, farmers can optimize their operations, reduce waste, and increase yields. Agrotopia has been successfully implemented in several countries, including Belgium and the Netherlands.

viii.Mavrx:

Mavrx is an IoT-based smart farming system that uses drones and sensors to collect data on crops. The system analyzes this data using machine learning algorithms to provide farmers with insights on crop health, growth, and yield potential. By using Mavrx, farmers can identify potential issues with crops and take corrective action before they are damaged or destroyed, increasing yields and reducing waste. Mavrx has been successfully implemented in several countries, including the United States and Canada.

VI.Benefits and challenges of the implementation

While IoT-based smart farming systems offer many benefits to farmers, there are also several challenges that need to be considered before implementing these systems.

Benefits:

a) Increased efficiency: IoT-based smart farming systems can help farmers optimize their operations and reduce waste. By using sensors to collect data on environmental factors such as soil moisture and temperature, farmers can make more informed decisions about irrigation and fertilization.

b) Improved crop health: IoT-based smart farming systems can help farmers identify potential issues with crops and take corrective action before they are damaged or destroyed. This can lead to increased yields and reduced waste.

c) Cost savings: IoT-based smart farming systems can help farmers reduce labor costs by automating tasks such as weeding and fertilization. They can also reduce the need for herbicides and pesticides, leading to cost savings.

d) Sustainability: IoT-based smart farming systems can help farmers reduce water waste and minimize the use of harmful chemicals, leading to more sustainable farming practices.

VII.Challenges:

a) Cost: IoT-based smart farming systems can be expensive to implement, which may be a barrier for small-scale farmers.

b) Technical expertise: Implementing IoT-based smart farming systems requires technical expertise, which may be a challenge for farmers who are not familiar with these technologies.

c) Connectivity: IoT-based smart farming systems rely on connectivity to transmit data, which may be a challenge in areas with poor or unreliable internet connectivity.

d) Data privacy and security: IoT-based smart farming systems collect large amounts of data, which may raise concerns about data privacy and security.IoT-based smart farming systems offer many benefits to farmers, including increased efficiency, improved crop health, cost savings, and sustainability. However, there are also several challenges that need to be considered before implementing these systems, including cost, technical expertise, connectivity, and data privacy and security.

VIII.Future Direction

IoT-based smart farming systems are continually evolving with the emergence of new trends and technologies. In this section, we will discuss some emerging trends and technologies in IoT-based smart farming systems and their potential impact on the agriculture industry.Edge computing: Edge computing involves processing data at the edge of the network rather than sending it to a centralized cloud server. Edge computing can reduce latency and improve data processing speed in IoT-based smart farming systems.5G networks: 5G networks have the potential to transform IoT-based smart farming systems by providing faster and more reliable connectivity, which can enable real-time monitoring and control. Artificial intelligence (AI): AI has the potential to improve decision-making in

IoT-based smart farming systems by analyzing large amounts of data and providing insights into crop health, weather patterns, and market trends. Blockchain: Blockchain technology can improve the traceability of food products by creating a transparent and secure record of the entire supply chain. The potential impact of IoT-based smart farming systems on the agriculture industry is significant. These systems have the potential to increase yields, reduce waste, and improve the sustainability of farming practices. IoT-based smart farming systems can also reduce the workload of farmers and enable remote monitoring and control of farm operations. IoT-based smart farming systems are rapidly evolving, and emerging trends and technologies such as edge computing, 5G networks, AI, and blockchain are poised to transform the agriculture industry. The potential impact of these systems on the agriculture industry is significant, and further research is needed to fully explore the capabilities of IoT-based smart farming systems and their potential to revolutionize the way we grow and produce food.

IX.Conclusion

In conclusion, IoT-based smart farming systems have the potential to revolutionize the agricultural industry by improving efficiency, crop health, and sustainability while reducing costs. This paper has discussed the techniques used in IoT-based smart farming systems, the challenges that need to be considered before implementing these systems, and the successful applications of these systems in agriculture.One of the key implications for the future of IoT-based smart farming systems is the need for collaboration between farmers, technology providers, and policymakers to overcome the challenges of cost, technical expertise, connectivity, and data privacy and security.While this research paper has provided valuable insights into IoT-based smart farming systems, there are several limitations to consider. Firstly, the paper has mainly focused on the benefits and challenges of IoT-based smart farming systems in developed countries, and further research is needed to explore the potential of these systems in developing countries. Secondly, this paper has mainly focused on crop farming, and more research is needed to explore the potential of IoT-based smart farming systems in other areas such as livestock farming and aquaculture.In conclusion, IoT-based smart farming systems offer a promising future for the agricultural industry, and it is essential to continue to research and explore the potential of these systems to overcome the challenges and maximize the benefits for farmers and the environment.

References

[1] Hossain, M.S., Muhammad, G., Alamri, A., Alelaiwi, A., Saddique, M.A., Alshomrani, S., &AlGhamdi, J. (2019). Towards an IoT-based smart farming system: A systematic review of relevant issues and challenges. IEEE Access, 7, 63581-63599.

[2] Kaur, M., & Singh, D. (2019). Smart farming: A review on IoT-based agriculture monitoring system. International Journal of Engineering and Advanced Technology, 8(6S), 133-139.

[3] Ali, I., & Javaid, N. (2019). An IoT-based smart agriculture system using deep learning. IEEE Internet of Things Journal, 6(2), 1728-1735.

[4] Sahu, S. K., & Kumar, A. (2019). An IoT-based smart farming system for efficient agriculture management. International Journal of Computer Applications, 182(24), 31-35.

[5] Venkatesan, S., & Gayathri, S. (2019). IoT-based smart farming system using big data analytics. In 2019 International Conference on Electrical, Computer and Communication Technologies (ICECCT) (pp. 1-5). IEEE.

[6] Zhang, B., Zhou, Q., Cheng, X., Wang, Y., & Liu, X. (2019). A smart farming system based on wireless sensor networks and the internet of things. Computers and Electronics in Agriculture, 160, 34-43.

[7] Akter, S., & Jahan, S. (2018). An IoT-based smart irrigation system for efficient crop management. In 2018 21st International Conference on Computer and Information Technology (ICCIT) (pp. 1-6). IEEE.

[8] Li, L., Cui, Y., & Li, Y. (2018). An IoT-based smart irrigation system for greenhouse using wireless sensor network and big data. Journal of Sensors, 2018, 1-9.

[9] Rahman, M. S., & Islam, M. R. (2018). An IoT-based smart irrigation system using machine learning techniques. In 2018 2nd International Conference on Advances in Electrical Engineering (ICAEE) (pp. 1-6). IEEE.

[10] Reddy, K. S., & Kumar, S. S. (2018). IoT-based smart farming system for crop monitoring and irrigation automation. In 2018 4th International Conference on Advanced Computing and Communication Systems (ICACCS) (pp. 1-6). IEEE.

[11] Raza, S. A., Niazi, M. A., & Khattak, A. M. (2018). IoT-based smart agriculture: A review. Precision Agriculture, 19(4), 710-730.

[12] Singh, S., & Sharma, S. (2018). An IoT-based smart irrigation system for water management in agriculture. In 2018 2nd International Conference on Advances in Electronics, Computers and Communications (ICAECC) (pp. 1-6). IEEE.

[13] Islam, M. T., Islam, M. N., & Ullah, M. A. (2017). An IoT-based smart farming system using raspberry pi 3. In 2017 20th International Conference of Computer and Information Technology (ICCIT) (pp. 268-273). IEEE.

[14] Kulkarni, P., & Ramteke, R. (2017). An IoT-based smart irrigation system using Raspberry Pi and Arduino. In

[15] Zhang, C., Zhang, X., Wu, Z., & Yang, L. T. (2018). An Internet of Things Framework for Smart Farming. IEEE Internet of Things Journal, 6(4), 7218-7227.

[16] Zhang, J., Liu, Y., Liu, H., Liu, Y., & Shen, J. (2019). A smart farm based on IoT: A new era of agriculture. Journal of Ambient Intelligence and Humanized Computing, 10(2), 703-712.

[17] Al-Fuqaha, A., Guizani, M., Mohammadi, M., Aledhari, M., & Ayyash, M. (2015). Internet of things: A survey on enabling technologies, protocols, and applications. IEEE Communications Surveys & Tutorials, 17(4), 2347-2376.

[18] Kim, D., Lee, J., Kim, J., Lee, J., Lee, M., Lee, M., ... & Kim, K. (2018). IoT-based smart greenhouse system for efficient resource management. Journal of Sensors, 2018, 1-10.

[19] Saini, P., & Devi, R. (2019). Internet of Things (IoT) in Agriculture: Benefits and Challenges. International Journal of Computer Sciences and Engineering, 7(4), 151-154.

[20] Rana, R. K., Kumar, N., & Kumar, P. (2017). IoT based smart irrigation system for efficient use of water and power. In 2017 International Conference on Infocom Technologies and Unmanned Systems (Trends and Future Directions) (ICTUS) (pp. 98-103). IEEE.

[21] Gao, F., Zhu, H., & Chen, X. (2018). Design and Implementation of Smart Agriculture System Based on Internet of Things. International Journal of Smart Home, 12(11), 177-190.

[22] Pan, X., Zheng, Y., He, C., & Wang, S. (2019). Design of smart irrigation system based on internet of things. IOP Conference Series: Earth and Environmental Science, 263(1), 012003.

[23] Sharma, M., & Jain, S. (2018). IoT-based smart agriculture: An approach for water management using sensors. In Proceedings of the 9th International Conference on Computing, Communication and Networking Technologies (ICCCNT) (pp. 1-6). IEEE.

[24] Bao, Y., Ma, H., Xu, J., & Sun, L. (2017). Design and implementation of smart agriculture system based on IOT. In 2017 29th Chinese Control And Decision Conference (CCDC) (pp. 4953-4957). IEEE.