ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue VII July 2025

A Comprehensive Survey on IoT-Based Smart Irrigation in Agriculture

Dr. Sumathy Kingslin[1], Ms. K. Vaishnavi[2]

[1]Associate Professor, PG Department of Computer Science, Quaide-E-Millath Government College for Women, Chennai – 02

[2]Research Scholar, PG Department of Computer Science, Quaide-E-Millath Government College for Women, Chennai – 02

DOI: https://doi.org/10.51244/IJRSI.2025.120700071

Received: 09 July 2025; Accepted: 15 July 2025; Published: 02 August 2025

ABSTRACT

The integration of the Internet of Things (IoT) in agriculture has revolutionized traditional farming practices by introducing smart irrigation techniques. IoT-based smart irrigation systems leverage real-time data collection, automation, and remote monitoring to enhance water efficiency and optimize crop growth. This survey explores the various IoT technologies applied in smart irrigation, including sensors, wireless communication protocols, and data analytics. It discusses different irrigation methodologies, their impact on sustainable agriculture, and the challenges involved in implementing IoT-driven solutions. The study also highlights emerging trends such as AI-powered decision-making, blockchain integration, and cloud computing in precision irrigation. By examining the advancements and potential of IoT in agricultural irrigation, this paper aims to provide insights into the future of smart farming.

Keywords: IoT, Smart Irrigation, Precision Agriculture, Sensors, Wireless Communication, Data Analytics, AI in Agriculture, Sustainable Farming, Cloud Computing, Automation, Smart Farming

INTRODUCTION

Agriculture plays a vital role in global food production, and irrigation is a crucial factor in ensuring crop growth and yield. However, traditional irrigation methods often lead to excessive water usage and inefficiency. The emergence of the Internet of Things (IoT) has revolutionized smart farming by integrating real-time data analytics, automated irrigation systems, and precision farming techniques. [1] IoT-based irrigation helps in optimizing water resources, reducing human intervention, and improving overall agricultural efficiency. By deploying smart sensors and AI-driven decision-making tools, farmers can manage their irrigation needs with greater accuracy. This survey aims to explore the various IoT applications in agriculture, particularly in smart irrigation, highlighting key technologies, challenges, and future trends. [2]

Iot In Agriculture: An Overview

IoT in agriculture involves the integration of digital technologies, such as wireless sensor networks, cloud computing, and artificial intelligence, to enhance farm productivity. The main goal is to monitor various environmental factors, such as soil moisture, temperature, humidity, and weather conditions, to optimize farming decisions. IoT enables precision farming, which involves the targeted application of water, fertilizers, and pesticides based on real-time data. Farmers can use IoT-enabled mobile applications to access farm data remotely, allowing them to take timely actions. The growing adoption of smart farming solutions is driven by the need for sustainable agriculture, reduced labor costs, and increased food production efficiency. [3]

Components of Iot in Smart Irrigation

IoT-based smart irrigation systems comprise multiple interconnected components that work together to ensure efficient water management.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue VII July 2025

Sensors: IoT irrigation systems rely on soil moisture sensors, temperature sensors, humidity sensors, and weather sensors to collect real-time data. These sensors help determine the precise amount of water required for crops, avoiding overwatering or under-watering. [4]

Actuators: These include irrigation valves, pumps, and sprinklers that are controlled automatically based on sensor data. Automated actuators eliminate the need for manual irrigation and improve water efficiency.

Communication Technologies: Wireless protocols such as LoRa, Zigbee, Bluetooth, NB-IoT, and 5G enable seamless data transmission between sensors, controllers, and cloud platforms. [5]

Cloud Computing & Edge Computing: Cloud-based IoT platforms store and analyze large volumes of data, providing farmers with real-time insights. Edge computing, on the other hand, processes data closer to the source, reducing latency and improving decision-making.

AI and Machine Learning: AI-driven analytics predict irrigation needs based on historical data, weather patterns, and soil conditions, ensuring optimal water usage. [6]

Smart Irrigation Techniques Enabled by Iot

IoT-based smart irrigation systems use advanced techniques to ensure efficient water management and conservation.

Automated Drip Irrigation: This method utilizes soil moisture sensors and automated valves to deliver water directly to the plant roots in controlled amounts. Drip irrigation minimizes water wastage and prevents soil erosion.

Precision Irrigation Systems: Precision irrigation uses GPS, remote sensing, and AI to determine the exact water requirements of different crop zones. It allows farmers to optimize irrigation schedules and conserve water resources. [7]

AI-Based Decision Support Systems: AI-driven algorithms analyze real-time data and predict irrigation requirements based on crop type, growth stage, and environmental factors. These systems enhance irrigation efficiency and crop health.

Weather-Based Smart Watering: Weather forecasting models are integrated with IoT-based irrigation systems to adjust watering schedules according to predicted rainfall and temperature fluctuations, reducing unnecessary water use. [8]

Iot Architectures for Smart Irrigation

IoT-based smart irrigation systems are built on different architectural models to ensure seamless connectivity and data management.

Cloud-Centric Architecture: In this model, all sensor data is transmitted to cloud servers, where it is stored and analyzed. Farmers can access real-time irrigation insights through web or mobile applications, enabling remote decision-making.

Edge and Fog Computing-Based Approaches: These architectures process data closer to the source, reducing dependency on cloud servers. By utilizing local gateways and edge devices, latency is minimized, and real-time control of irrigation systems is enhanced.

Hybrid IoT Architecture: A combination of cloud and edge computing, the hybrid model ensures efficient data processing while reducing network congestion. This approach balances scalability, efficiency, and responsiveness in smart irrigation. [9]

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue VII July 2025

Sensors and Data Acquisition in Smart Irrigation

IoT-enabled smart irrigation relies heavily on sensor networks that collect and transmit crucial data for decision-making.

Types of Sensors Used in Irrigation: The most common sensors include soil moisture sensors, temperature sensors, humidity sensors, pH sensors, and rain gauges. These sensors provide valuable data on soil health and environmental conditions. [10]

Sensor Calibration and Data Accuracy: To ensure reliability, sensors must be properly calibrated. Regular calibration prevents data inconsistencies and enhances decision-making accuracy.

IoT-Based Real-Time Data Monitoring: IoT platforms aggregate data from multiple sensors and present it through dashboards and mobile applications, allowing farmers to monitor and manage irrigation remotely. [11]

Wireless Communication Technologies for Iot in Smart Irrigation

IoT-based smart irrigation requires robust wireless communication technologies for seamless data exchange.

Short-Range Communication: Zigbee, Wi-Fi, and Bluetooth enable localized sensor networks, making them suitable for small-scale farms.

Long-Range Communication: LoRaWAN, Sigfox, NB-IoT, and 5G support large-scale deployments by offering extended coverage, low power consumption, and reliable connectivity.

Comparison of Wireless Protocols: Different protocols are evaluated based on factors like reliability, power efficiency, coverage range, and cost, ensuring the most suitable technology is chosen for agricultural applications. [12]

Data Analytics and Ai for Smart Irrigation

Predictive Analytics for Water Management: AI-driven predictive models analyze historical irrigation data and forecast water needs, preventing water wastage.

AI-Driven Irrigation Scheduling: Machine learning algorithms process real-time data to optimize watering schedules, ensuring efficient irrigation without human intervention.

Deep Learning for Crop Health Monitoring: AI-powered deep learning techniques analyze satellite and drone imagery to assess crop health, detecting diseases and nutrient deficiencies in real time. [13]

Energy-Efficient Iot Solutions for Smart Irrigation

Solar-Powered IoT-Based Irrigation Systems: Solar panels power IoT sensors and actuators, making irrigation systems more sustainable and cost-effective.

Low-Power IoT Devices and Optimization Techniques: Advanced power management strategies enhance battery life, reducing maintenance costs and improving device longevity.

Battery Life Considerations: Efficient energy consumption ensures continuous operation of IoT devices, minimizing downtime in irrigation management. [14]

CONCLUSION

IoT has proven to be a game-changer in agriculture, particularly in the domain of smart irrigation. By enabling precise water management, reducing resource wastage, and improving crop yields, IoT-driven irrigation systems contribute significantly to sustainable farming. The adoption of real-time monitoring, automation, and AI-powered analytics has further enhanced efficiency in agricultural practices. However, challenges such as

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue VII July 2025

high initial costs, data security concerns, and connectivity issues in rural areas still need to be addressed. With ongoing advancements in technology, including the integration of blockchain and edge computing, the future of IoT in smart irrigation looks promising. Continued research and development in this field will help farmers maximize productivity while minimizing environmental impact.

REFERENCES

1. Patel, K. & Patel, S. (2016). "Internet of Things–IOT: Definition, Characteristics, Architecture, Enabling Technologies, Application & Future Challenges," International Journal of Engineering Science and Computing, 6(5), pp. 6122-6131.
2. Jayashree, K., Mohanavalli, S., &Sundari, S. (2021). "IoT-based Smart Irrigation System using Machine Learning Techniques," Journal of Ambient Intelligence and Humanized Computing, 12, pp. 6101-6112.
3. Kumar, S. & Rani, S. (2019). "A Review on IoT Based Smart Irrigation System Using Machine Learning Approaches," International Journal of Engineering and Advanced Technology (IJEAT), 8(6S3), pp. 1587-1592.
4. Raut, R., Gaikwad, V., &Suryawanshi, S. (2017). "Smart Irrigation System using IoT," Proceedings of the International Conference on Computing, Communication and Control, ICCCC-2017, pp. 1-6.
5. Panda, D., Kumar, R., & Sharma, S. (2020). "Wireless Sensor Networks and IoT in Precision Agriculture: Survey and Challenges," IEEE Internet of Things Journal, 7(4), pp. 3053-3067.
6. Sharma, S., Gupta, B., &Koundal, D. (2021). "A Review on Energy-Efficient IoT-Based Smart Irrigation Systems Using Machine Learning Techniques," Computers and Electronics in Agriculture, 182, p. 106008.
7. Singh, P. & Gupta, R. (2018). "Role of Wireless Sensor Networks in Smart Irrigation: A Review," International Journal of Advanced Research in Computer Science, 9(3), pp. 45-51.
8. Zhang, X., Li, H., & Wang, J. (2020). "Cloud-based IoT for Smart Irrigation: Architecture and Implementation," IEEE Access, 8, pp. 182276-182289.
9. Gondchawar, N. &Kawitkar, R. S. (2016). "IoT Based Smart Agriculture," International Journal of Advanced Research in Computer and Communication Engineering, 5(6), pp. 838-842.
10. Iqbal, J., Khan, Z., & Kim, H. (2022). "IoT-enabled Smart Irrigation Systems: A Review and Future Trends," Sustainable Computing: Informatics and Systems, 35, p. 100762.
11. Rath, A., Priya, P., &Satapathy, P. (2021). "AI and IoT Integration in Precision Agriculture: A Survey," Neural Computing and Applications, 33, pp. 11123-11138.
12. Mishra, P., Poonia, R., & Kumar, N. (2020). "Blockchain for Smart Irrigation in Precision Agriculture: A Survey," Internet Technology Letters, 3(5), e158.
13. Shukla, A., Mishra, S., &Agrawal, N. (2021). "IoT and Big Data Analytics for Smart Agriculture: A Review," Journal of King Saud University - Computer and Information Sciences, 33(5), pp. 576-591.
14. FAO (Food and Agriculture Organization) (2021). "The Role of Digital Technologies in Sustainable Agriculture," United Nations Report on Smart Agriculture.