

Farmer's Eye: A Sustainable Crop-Field Monitoring System

Shubhankar Barui^{1*}, Animesh Arabinda Maity², Susomoy Saha³,
Priyanka Tamank⁴, Rudrajit Datta⁵

Abstract

This paper outlines the creation and implementation of an Internet of Things (IoT)-driven smart agriculture monitoring system. It aims to tackle major issues in agriculture, such as inefficient irrigation, excessive resource use, and a lack of real-time data. The system focuses on the Arduino Uno, which connects to a variety of sensors: soil moisture for measuring substrate conditions, DHT11 for monitoring ambient temperature and humidity, MQ135 for checking air quality, a rain sensor for detecting precipitation, and an ultrasonic sensor for monitoring water tank levels. A relay-controlled DC pump automates irrigation based on actual site data. It activates only when soil moisture falls below a certain level, no rainfall is detected, and there is enough water in the tank. An ESP-01 Wi-Fi module manages communication, sending live sensor data to the Blynk 2.0 IoT platform. This allows for remote access and control through smartphones or web dashboards. To maintain hardware stability, a buck converter controls voltage, and a 20×4 LCD module displays local environmental data in real time. System simulations and these field studies demonstrate that timely, data-driven irrigation may significantly reduce water usage, reduce human labor, and improve crop management. Through the integration of on-site automation and cloud-based analytics, this approach offers a scalable and affordable solution that promotes responsible resource management and precision agriculture. Furthermore, the proposed system can be easily adapted to different crop types and environmental conditions, making it suitable for small- and medium-scale farmers. Its modular design supports future expansion with additional sensors and advanced decision-support algorithms, enhancing long-term sustainability and agricultural productivity.

Keywords: Arduino Uno, automatic irrigation, Blynk, DHT11, ESP-01, IoT, MQ135, rain sensor, smart agriculture, soil moisture sensor, ultrasonic sensor

INTRODUCTION

The development of sustainable and precise agriculture is crucial to address global food security, water scarcity, and environmental damage. Traditional farming methods often lead to wasteful water use, inadequate environmental monitoring, and reliance on manual labor. These problems are particularly evident in developing countries, where agricultural productivity is closely related to climate change and resource availability [1].

Recent advancements in the Internet of Things (IoT) have provided new ways to modernize agriculture through real-time data collection, smart decision-making, and automated control systems. Efficient irrigation management is a critical requirement for agriculture. Under-irrigation can result in decreased crop yields, whereas over-irrigation wastes water, degrades soil, and wastes energy. For effective crop health and resource use,

*Author for Correspondence

Shubhankar Barui
E-mail: barui.subhankar007@gmail.com

¹⁻⁴Student, Department of Electrical Engineering, Greater Kolkata College of Engineering and Management, Dudhnai, Ramnagar-II, P.O. Piyali Town, Baruipur, South 24 Paragana, West Bengal, India

⁵Assistant Professor, Department of Electrical Engineering, Greater Kolkata College of Engineering and Management, Dudhnai, Ramnagar-II, P.O. Piyali Town, Baruipur, South 24 Paragana, West Bengal, India

Received Date: December 11, 2025

Accepted Date: December 29, 2025

Published Date: March 26, 2026

Citation: Shubhankar Barui, Animesh Arabinda Maity, Susomoy Saha, Priyanka Tamank, Rudrajit Datta. Farmer's Eye: A Sustainable Crop-Field Monitoring System. Journal of Agricultural Science and Technology. 2025; 15(1): 19–27p.

variable parameters such as temperature, humidity, air quality, rainfall, and water storage levels must be monitored regularly [2].

This study discusses a cheap, IoT-based smart agriculture monitoring system that combines sensing the environment with automated irrigation control. The two main components of this system are an Arduino Uno microcontroller and an ESP-01 Wi-Fi module for wireless communication. A diverse array, including a DHT11, soil moisture sensor, MQ135 air quality sensor, rain sensor, and ultrasonic sensor (HC-SR04) are used in this system. A 5 V relay-managed DC pump automatically regulates irrigation according to the logical conditions generated from real-time data. A 20×4 LCD module locally displays field status, while Blynk 2.0 allows for remote monitoring. A buck converter guarantees stable power distribution across all modules.

The proposed system supports sustainable farming practices by automating field operations and reducing water waste. It aids in the broader goals of smart agriculture by enabling data-driven decisions, lowering human involvement, and ensuring the efficient use of natural resources [3, 4].

Proposed Methodology

The proposed system has several layers, including sensing, controller, communication, monitoring, and power management modules, which all work together to monitor the environment and control irrigation automatically in real time (Figures 1 and 2).

- *Sensor layer*: Various sensors, including a soil moisture sensor, DHT11, MQ135, rain sensor, and ultrasonic sensor, collect real-time data on key field parameters and provide them for automated irrigation [5].
- *Control layer*: The Arduino Uno served as the control unit. A threshold-based decision algorithm is used to process the data.
- *Auto-irrigation*: A 5 V relay activates a DC pump to irrigate the field. To start irrigation, the following conditions must be met: low soil moisture content, no rainfall, and sufficient water in the tank [6].
- *Communication and monitoring layer*: The ESP-01 Wi-Fi module sends data to the Blynk 2.0 cloud, allowing remote access through smartphones or desktops. In addition, a 20×4 LCD shows local real-time sensor values [7].
- *Power management*: To improve power efficiency, protect components from voltage fluctuations, and improve voltage regulation, an LM2596s buck converter is used.

CIRCUIT DIAGRAM

Working Principle

The proposed IoT-based smart agriculture monitoring system continuously senses the environmental conditions and automates irrigation based on predetermined rules. It gathers data by using several sensors as shown in Figure 3.

- *Soil moisture*: Sensor measures soil hydration,
- *DHT11*: Sensor tracks temperature and humidity,

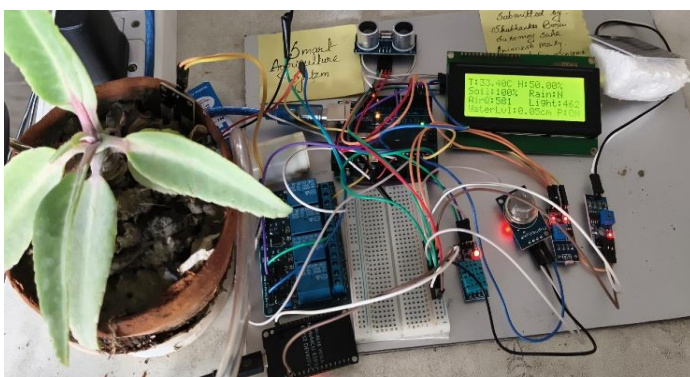


Figure 1. Basic prototype model.

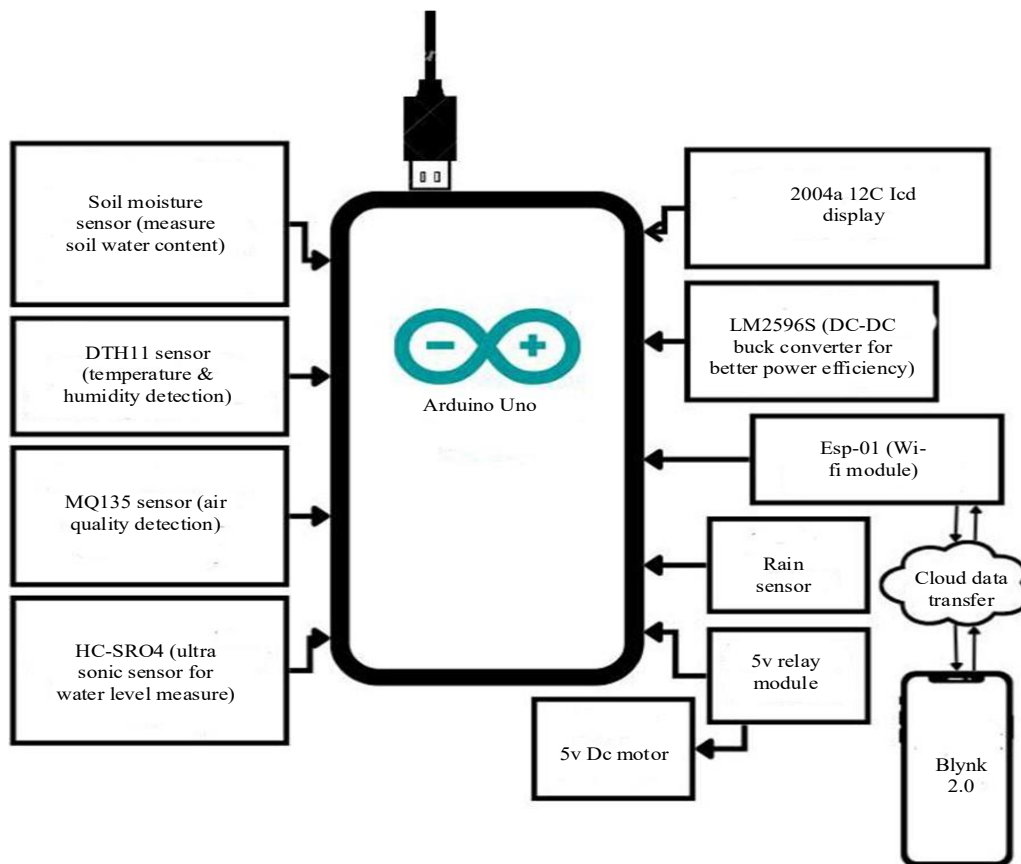


Figure 2. Block circuit diagram of the prototype model.

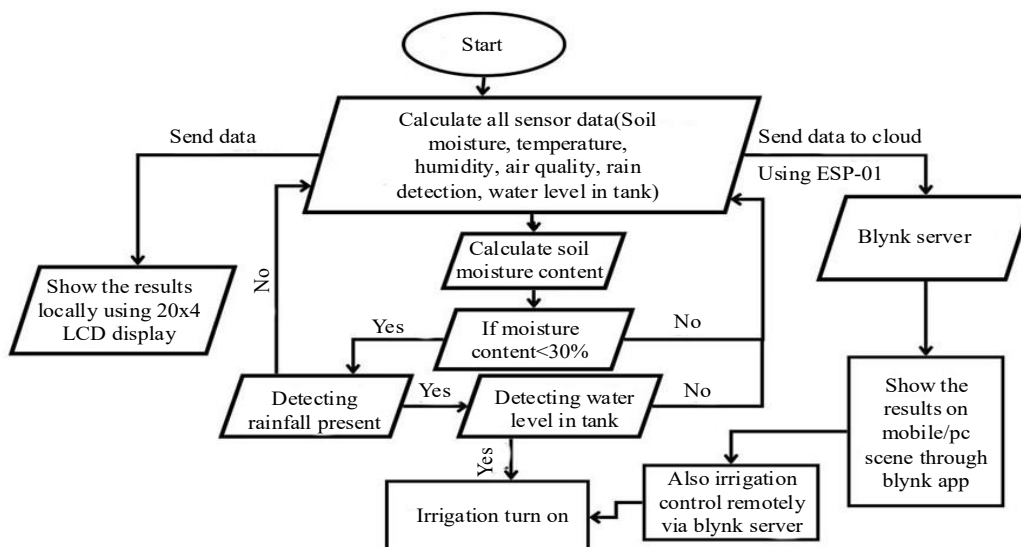


Figure 3. The working principle in the flowchart diagram describes the prototype model.

- *MQ135*: Sensor checks air quality,
- *The rain sensor*: Detects rainfall,
- *HC-SR04 (Ultrasonic sensor)*: Measures water levels in the tank [8].

The Arduino Uno microcontroller manages the system using a rule-based control algorithm. It analyzes the sensor data in real time to evaluate three main factors:

- *Soil moisture check*: Determines irrigation requirements.

- Rainfall detection prevents watering in the rain.
- Determines whether there is enough tank water available.

If these conditions are met, the microcontroller activates a 5 V relay module, which starts a DC water pump and automatically irrigates the field. This logic helps prevent overwatering, saves water, and lowers energy use [9].

A buck converter provides constant and efficient power to all electronic components. A 20×4 LCDs real-time data locally, and an ESP-01 Wi-Fi module sends environmental readings to the Blynk 2.0 cloud platform. Through this platform, farmers can monitor field conditions, receive alerts, and control irrigation using a smartphone or web interface [10]. This smart, sensor-driven automation framework encourages sustainable water management while reducing the need for manual labor. The system facilitates precision agriculture by coordinating data collection, decision-making, and cloud access, especially for small and medium-sized farms.

Results and Impact

- *Less manual work:* Field labor is significantly reduced when real-time monitoring systems are combined with automated irrigation. Automating repetitive and time-consuming tasks can help farmers manage their labor and time better, which will lower labor costs.
- *Optimizing water utilization:* Sensor-based irrigation control makes it possible to precisely regulate water supply in response to environmental variables and soil moisture. By avoiding over-irrigation, this strategy minimizes water waste and promotes ecologically friendly farming methods.
- *Benefits to the environment:* This system promotes environmental sustainability by reducing excessive resource consumption. By optimizing energy and water use, the ecological footprint is minimized, and long-term soil health and conservation are supported.
- *Less manual work:* Field labor is significantly reduced when real-time monitoring systems are combined with automated irrigation. Automating repetitive and time-consuming tasks can help farmers manage their labor and time better, which will lower labor costs.
- *Optimizing water utilization:* Sensor-based irrigation control makes it possible to precisely regulate water supply in response to environmental variables and soil moisture. By avoiding over-irrigation, this strategy minimizes water waste and promotes ecologically friendly farming methods.
- *Benefits to the environment:* This system promotes environmental sustainability by reducing excessive resource consumption. By optimizing energy and water use, the ecological footprint is minimized, and long-term soil health and conservation are supported.

These benefits contribute to a more resilient agricultural ecosystem, fostering biodiversity and improving crop yields over time. Additionally, farmers can adapt their practices to changing climatic conditions, ensuring food security for future generations.

Sensor Performance

Sensor accuracy and operational dependability are important for the system's decision-making effectiveness. The sensor-level performance is summarized as follows.

- *Soil moisture sensor (%):* Accuracy $\pm 5\%$; effective in detecting dry/wet soil conditions; appropriate for threshold-based irrigation logic. Figure 4 shows that the values rise significantly during the wet season, reflecting the increased ground moisture caused by regular rainfall.
- *DHT11 (temperature and humidity):* Temperature accuracy is $\pm 2^\circ\text{C}$; Figure 5 indicates high temperatures ($35\text{--}45^\circ\text{C}$) in summer and moderate temperatures ($28\text{--}35^\circ\text{C}$) during the rainy season. Humidity accuracy $\pm 5\%$ RH, with higher levels during rainy seasons ($70\text{--}90\%$ RH) than during summer ($30\text{--}50\%$ RH).
- *MQ135 (air quality sensor):* Semi-quantitative; detects air density and pollutants with an effective range of $\sim 70\%$ in open-field tests. Figure 6 shows improved air quality during the rainy season with lower pollutant readings.

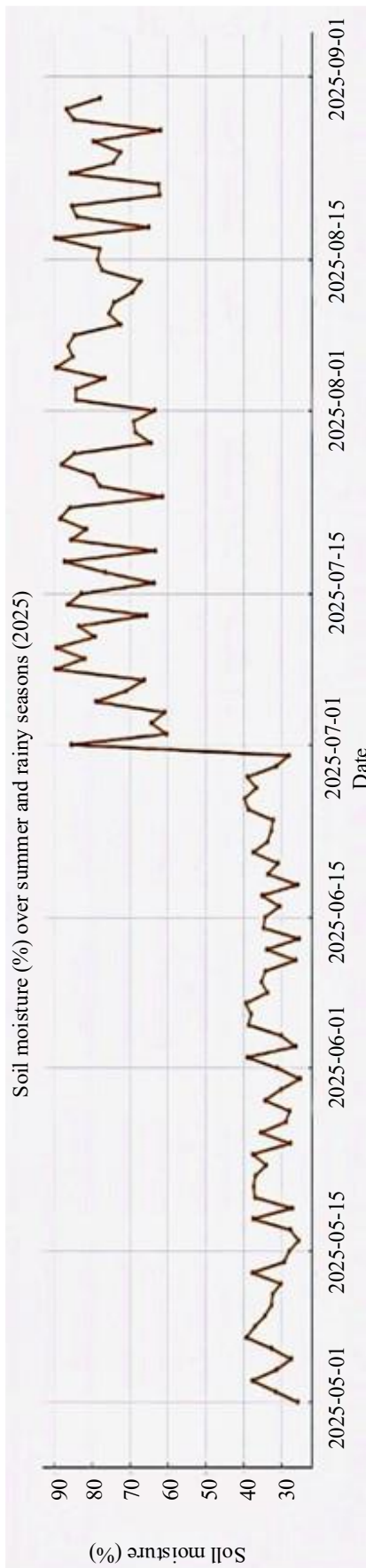


Figure 4. Soil moisture sensor graphical value during summer and rainy season.

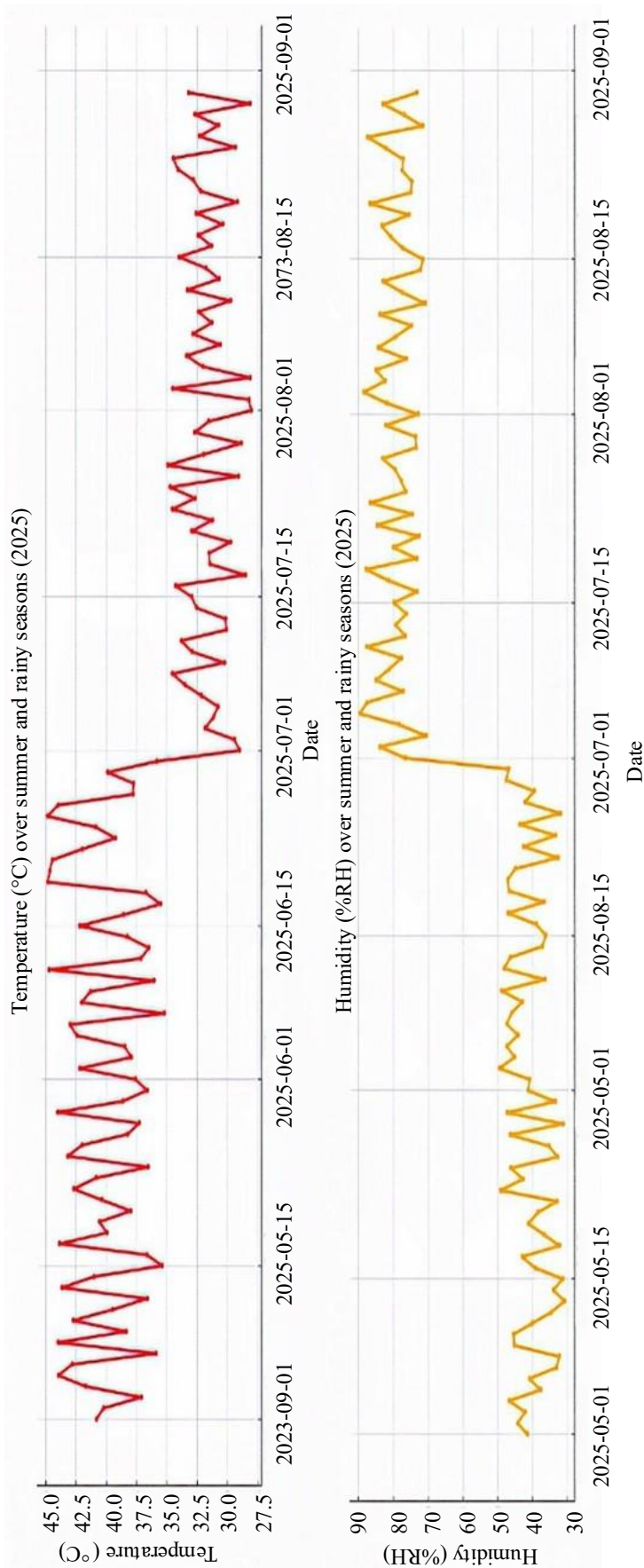


Figure 5. DHT11 (Temperature & Humidity) sensor graphical value during summer and rainy season.

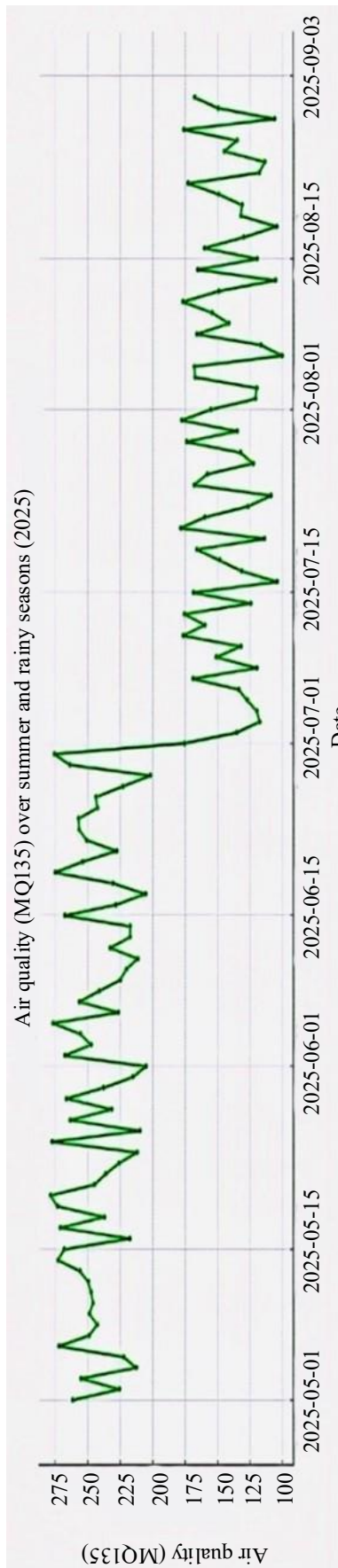


Figure 6. MQ135 sensor air quality values graphical value during summer & rainy season.

- *Rain sensor*: Accurately >95% detection of light to moderate rain. With a very fast response.
- *ESP-01 (Wi-Fi module)*: Wireless data transmission >90% packet success rate with delay: ~200–500 ms per transmission; reliable for Blynk-based monitoring.

CONCLUSION

The proposed IoT-based smart agriculture monitoring system is a budget-friendly and durable solution for improving irrigation methods through automation and real-time environmental monitoring. The system collects data from the field and makes irrigation decisions based on specific thresholds, using several low-power sensors. These include a DHT11 temperature–humidity sensor, an MQ135 air quality sensor, a rain detection sensor, and an ultrasonic water level sensor. It operates with an Arduino Uno microcontroller and ESP-01 Wi-Fi module.

The system uses a relay module to control a 5 V DC water pump. This ensured that irrigation occurred only when required. The proposed system aims to improve crop health, boost agricultural productivity, and support responsible resource management by optimizing water use, reducing waste, and extending the sensor life. A 20 × 4 LCD displays real-time data on-site, whereas the Blynk 2.0 cloud platform sends this information to farmers anywhere in the world, allowing them to monitor field conditions. Testing and simulations confirmed the system's durability, quick response to environmental changes, and reduced need for human involvement in irrigation. These features are especially useful in rural and semi-urban farming areas, where labor shortages and water mismanagement are common issues.

Future Scope

To enhance the practicality and scalability of the proposed system, the following developments are suggested:

- *Field-scale deployment*: extending the system for multi-zone irrigation in larger farms with varied soil and crop conditions.
- *AI-driven irrigation forecasting*: Employing machine learning to predict irrigation needs based on soil history, crop type, and weather data.
- *Solar power integration*: In remote off-grid farming areas, installing solar photovoltaic (PV) modules can guarantee a steady supply of power for sensor nodes and microcontrollers.
- *LoRa communication*: Replacing Wi-Fi with LoRa for long-range, low-power communication is suitable for rural deployment.
- *Weather API synchronization*: Adaptive irrigation based on anticipated rainfall, humidity, and temperature conditions is made possible by integrating dynamic weather forecast APIs (such as an Open Weather Map).
- *Edge computing deployment*: Using edge devices, such as the Raspberry Pi and NVIDIA Jetson Nano, to process data on-site can reduce the need for the cloud and the time it takes to perform important tasks.

REFERENCES

1. Sassenrath GF, Heilman P, Luschei E, Bennett GL, Fitzgerald G, Klesius P, Tracy W, Williford JR, Zimba PV. Technology, complexity and change in agricultural production systems. *Renew Agric Food Syst.* 2008;23(4):285–295. doi:10.1017/S174217050700213X.
2. Shah F, Wu W. Soil and crop management strategies to ensure higher crop productivity within sustainable environments. *Sustainability.* 2019;11(5):1485. doi:10.3390/su11051485.
3. Kumari K, Mirzakhani Nafchi A, Mirzaee S, Abdalla A. AI-driven future farming: achieving climate-smart and sustainable agriculture. *AgriEngineering.* 2025;7(3):89. doi:10.3390/agriengineering7030089.
4. Medrano-Hermosillo JA, Rodríguez-Mata AE, Djilali L, Suarez-Sierra OJ, González Huitron VA. Solar-powered electric vehicle charging station with fuzzy MPPT algorithm. 2024 IEEE Colombian Conference on Applications of Computational Intelligence (ColCACI), Pamplona, Colombia. 2024. p. 1–6. doi:10.1109/ColCACI63187.2024.10666570.

5. Awasthi A, Reddy SR. Monitoring for precision agriculture using wireless sensor network: a review. *Glob J Comput Sci Technol.* 2013;13(7):22–28.
6. Devika SV, Khamuruddeen S, Khamurunnisa S, Thota J, Shaik K. Arduino based automatic plant watering system. *Int J Adv Res Comput Sci Softw Eng.* 2014;4(10):449–456.
7. Patil KA, Kale NR. A model for smart agriculture using IoT. 2016 International Conference on Global Trends in Signal Processing, Information Computing and Communication (ICGTSPICC), Jalgaon, India. 2016. p.543–545. doi:10.1109/ICGTSPICC.2016.7955360.
8. Ayaz M, Ammad-Uddin M, Sharif Z, Mansour A, Aggoune EHM. Internet-of-Things (IoT)-based smart agriculture: Toward making the fields talk. *IEEE Access.* 2019;7:129551–129583. doi:10.1109/ACCESS.2019.2932609.
9. Manikandan A, Balasubramanian K. Smart irrigation system using IoT. *Int J Eng Res Technol.* 2020;9(5):588–592.
10. Gubbi J, Buyya R, Marusic S, Palaniswami M. Internet of Things (IoT): A vision, architectural elements, and future directions. *Future Gener Comput Syst.* 2013;29:1645–1660. doi:10.1016/j.future.2013.01.010.