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

Smart Irrigation System

Ganesh H[1a], Veereshaiah H M[1b], Chandrika B[2a], K Gouthami[2b], Shashank S[2c], V Tarun Sai[2d]
Assistant professor, Department of Civil Engineering [1a,1b]
Students, Department of Civil Engineering [2a,2b,2c,2d]
Rao Bahadur Y Mahabaleswarappa Engineering College, Ballari, India

Abstract: *Water scarcity and inefficient irrigation practices pose major challenges to sustainable agriculture. This study presents the development and evaluation of a laboratory-scale smart irrigation system designed to optimize water usage through real-time soil moisture monitoring and automated control. The system employs a soil moisture sensor integrated with an ESP32 microcontroller integrated, relay module, and water pump to regulate irrigation based on predefined threshold values. Sensor calibration was performed using the standard oven-dry method on multiple soil samples to ensure accurate moisture measurement. The system was tested on red and black soils with different moisture requirements, and suitable threshold limits were established for each soil type. Integration with the Blynk IoT platform enabled real-time monitoring and remote control of the irrigation process. Experimental results demonstrated efficient water management, reduced manual intervention, and reliable system performance. The developed model proves to be a low-cost, scalable, and sustainable solution for smart irrigation, with potential applications in small and large-scale agricultural fields.*

Keywords*:* Smart irrigation system, Soil moisture sensor, Threshold limits, Water use efficiency, Sustainable agriculture

I. INTRODUCTION

Agriculture is the largest consumer of freshwater resources, and increasing water scarcity has become a critical global concern. Traditional irrigation practices often rely on fixed schedules or manual judgment, which can lead to excessive water usage, uneven distribution, and reduced crop productivity. These inefficiencies highlight the need for intelligent irrigation solutions that can optimize water use while maintaining adequate soil moisture for crop growth.

Recent advancements in sensors, microcontrollers, and Internet of Things (IoT) technologies have enabled the development of smart irrigation systems capable of real-time monitoring and automated decision-making. Soil moisture–based irrigation is particularly effective, as it directly reflects the water availability in the root zone and allows irrigation to be applied only when necessary. By defining suitable moisture threshold limits, irrigation can be controlled precisely according to crop and soil requirements.

This project focuses on the development and evaluation of a laboratory-scale smart irrigation system using a calibrated soil moisture sensor integrated with an ESP32 microcontroller. The system automatically controls a water pump through a relay module based on predefined soil moisture threshold values. A standard reference based calibration approach using the oven-dry method was adopted to define suitable soil moisture threshold values. The system was tested on red and black soils, which have different moisture retention characteristics, and appropriate threshold limits were established for each soil type.

Furthermore, the integration of the system with the Blynk IoT platform enables real-time monitoring and remote control, enhancing system usability and flexibility. The proposed system aims to reduce water wastage, minimize manual intervention, and promote efficient irrigation practices. Owing to its low cost, scalability, and simplicity, the developed model has the potential to support sustainable agriculture and precision irrigation in both small and large-scale farming applications.

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

II. PRESENT STUDY

The present study addresses the growing need for efficient and sustainable water management in agriculture by developing a laboratory-scale smart irrigation system based on sensor-driven automation and Internet of Things (IoT) technology. Rapid depletion of freshwater resources and inefficient conventional irrigation practices necessitate the adoption of intelligent irrigation solutions capable of delivering water based on real-time soil and environmental conditions.

A detailed review of earlier studies reveals that although smart irrigation systems have been widely implemented using soil moisture, temperature, and humidity sensors, several practical challenges persist. These include inaccuracies in sensor readings due to lack of proper calibration, dependence on complex system architectures, and high implementation costs that limit adoption by small and marginal farmers. The present study aims to overcome these limitations by emphasizing reference-based threshold definition, system simplicity, and cost- effectiveness.

In this work, a standard reference–based calibration approach was adopted under controlled laboratory conditions using measured soil water content to define suitable soil moisture threshold values, since the resistive soil moisture sensor used does not support precise absolute calibration. These threshold values form the basis for automated irrigation control. A laboratory-scale experimental setup was developed using soil and crop samples, an ESP32 microcontroller, relay module, water pump, and environmental sensors for temperature and humidity monitoring. The ESP32 was selected due to its low power consumption, built-in Wi-Fi capability, and suitability for IoT-based agricultural applications.

The system was programmed to automatically control irrigation by comparing real-time soil moisture values with predefined threshold limits derived from the reference-based calibration. When soil moisture fell below the threshold value, the water pump was activated through the relay module, and irrigation was terminated once adequate moisture levels were restored. Simultaneously, temperature and humidity data were recorded to provide additional insight into environmental conditions influencing crop water requirements.

To enhance accessibility and real-time monitoring, the developed system was integrated with a cloud-based IoT platform (Blynk). This integration enabled remote visualization of sensor data, pump status, and system performance through a mobile interface, allowing users to monitor irrigation activities without physical presence at the site.

The performance of the smart irrigation system was evaluated in terms of automation accuracy, response efficiency, and water-saving potential when compared to conventional manual irrigation practices. The results demonstrated that the proposed system effectively prevented over-irrigation and ensured timely water application. Overall, the present study establishes the feasibility of implementing a low-cost, sensor-based smart irrigation system at laboratory scale, providing a foundation for future expansion to field-scale and real-time agricultural applications

III. METHODOLOGY

The methodology adopted in the present study is designed to systematically develop, implement, and evaluate a laboratory-scale smart irrigation system using sensor-based automation and Internet of Things (IoT) technology. The approach is formulated based on insights obtained from previously published literature and is structured into sequential stages to ensure accuracy, reliability, and repeatability of results.

Calibration of Soil Moisture Sensor

Prior to system implementation, a standard reference–based calibration approach was adopted under controlled laboratory conditions to define suitable soil moisture threshold values. Soil samples with varying moisture levels were prepared, and the corresponding sensor readings were recorded. Since the resistive soil moisture sensor used in this study does not support precise absolute calibration, sensor output values were correlated with experimentally determined soil moisture content obtained using the standard oven-dry method. These reference measurements were used to establish appropriate threshold limits for irrigation control, thereby minimizing measurement uncertainty and ensuring reliable system operation.

Design and Development of Smart Irrigation System

Following reference-based calibration, a laboratory-scale smart irrigation setup was designed and developed. The system consists of soil and crop samples, a soil moisture sensor, temperature and humidity sensor, ESP32

DOI: 10.48175/IJARSCT-30664

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

microcontroller, relay module, water pump, and necessary power and connectivity components. The ESP32 microcontroller serves as the central processing unit, receiving sensor data, executing control logic, and communicating with the IoT platform. The relay module electrically isolates and controls the operation of the water pump.

Control Logic and Automation Strategy

The irrigation control algorithm was implemented by programming the ESP32 microcontroller to continuously monitor soil moisture levels. Predefined threshold values, derived from the reference-based calibration process, were used as decision parameters. When soil moisture fell below the threshold value, the relay module was activated, initiating irrigation. Once the soil moisture reached the desired level, the pump was automatically switched off. Environmental parameters such as temperature and humidity were simultaneously recorded to provide additional context for irrigation behaviour.

IoT Integration and Monitoring

To enable real-time monitoring and user interaction, the smart irrigation system was integrated with a cloud- based IoT platform (Blynk). Sensor data and pump status were transmitted wirelessly to the platform and visualized through a mobile dashboard. This integration allows remote monitoring and system observation, thereby enhancing usability and operational flexibility.

Performance Evaluation

The performance of the developed smart irrigation system was evaluated under laboratory conditions by analyzing automation accuracy, response time, and water usage efficiency. The results obtained from the automated system were compared with conventional manual irrigation practices to assess potential water savings and operational effectiveness. The evaluation confirmed the suitability of the proposed methodology for small-scale agricultural applications.

IV. SYSTEM ARCHITECTURE AND HARDWARE COMPONENTS

The proposed smart irrigation system is designed as an automated, sensor-based irrigation system for real-time monitoring and control. The overall system consists of sensing, processing, actuation, and communication units that work in coordination to regulate irrigation based on soil moisture conditions.

System Architecture

The system architecture follows a closed-loop control approach as shown in Fig no 1 , in which soil moisture and environmental parameters are continuously monitored and compared with predefined threshold values. The soil moisture sensor measures the moisture content of the soil and transmits the data to the ESP32 microcontroller. Based on the programmed control algorithm, the ESP32 determines the irrigation requirement and accordingly activates or deactivates the water pump through the relay module. System status and sensor data are simultaneously transmitted to a cloud-based IoT platform for remote monitoring.

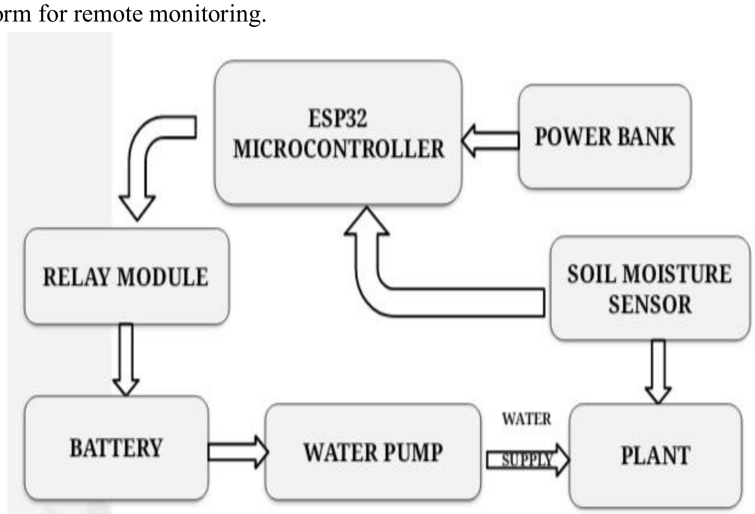


Fig no 1: Flow diagram of smart irrigation system

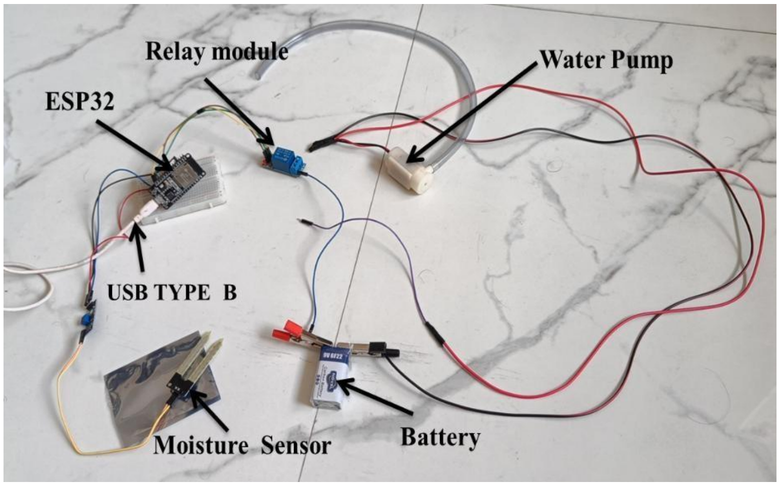


Fig no 2: Hardware Components of smart irrigation system

Hardware Components

ESP32 Microcontroller: The ESP32 functions as the central control unit of the smart irrigation system. It acquires sensor data, executes the irrigation control logic based on threshold values, and controls the relay module. Its built-in Wi-Fi enables real-time data transmission to the IoT platform.

Soil Moisture Sensor: The soil moisture sensor detects variations in soil water content through changes in electrical conductivity. The sensor output is continuously monitored by the ESP32 to determine irrigation requirements based on reference-defined moisture thresholds.

Relay Module: The relay module acts as an electrically isolated switch, allowing the low-power ESP32 to control the high-power water pump safely. It receives control signals from the microcontroller to turn the pump ON or OFF.

Water Pump: The water pump delivers water to the soil during irrigation. Its operation is automatically controlled by the ESP32 through the relay module to ensure timely and efficient watering.

USB Type-B Cable: The USB Type-B cable is used to supply power to the ESP32 and to upload the control program during system development and testing.

Battery: The battery provides an independent power source for the system, enabling uninterrupted operation and demonstrating the feasibility of portable deployment.

Jump Wires: Jump wires are used to establish electrical connections between the ESP32, sensors, relay module, and power supply components. They facilitate reliable signal transmission and flexibility in assembling the laboratory-scale setup.

V. EXPERIMENTAL SETUP

The experimental setup for the present study was developed under controlled laboratory conditions to evaluate the performance of the proposed smart irrigation system. The setup consisted of a soil container, a soil moisture sensor, ESP32 microcontroller, relay module, DC water pump, and supporting power and communication components.

Two commonly used agricultural soil types, namely red soil and black soil, were selected for the experiment to study the system response under different soil moisture retention characteristics. The soil moisture sensor was embedded at the root-zone depth to continuously monitor soil water content. Irrigation water was supplied through a small DC water pump, which was controlled by the ESP32 microcontroller via a relay module.

The ESP32 microcontroller was interfaced with the soil moisture sensor and relay module using jumper wires and powered through a battery and USB connection. The system was programmed to compare real-time soil moisture values with predefined threshold limits derived using a reference-based approach and to automatically

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

activate irrigation when moisture levels dropped below the threshold. The pump was switched off once adequate soil moisture was restored. A manual control option was also provided through the user interface to enable additional irrigation beyond the predefined threshold level when required.

The developed setup was integrated with a cloud-based IoT platform to enable real-time monitoring of soil moisture values and pump status through a mobile interface. Multiple irrigation cycles were performed for both soil types, and system performance was observed in terms of automation efficiency and irrigation response.

The user interface of the proposed smart irrigation system was developed using the Blynk IoT platform to enable real-time monitoring and control of irrigation based on soil type. The interface was designed to be simple and user-friendly, allowing selection between red soil and black soil and visualization of corresponding soil moisture conditions.

As part of the interface setup, virtual data streams were created in the Blynk application to display soil name, soil moisture percentage, pump status, and soil type selection. A segmented switch widget was provided for selecting the soil type, enabling the user to choose either Red Soil or Black Soil . Based on the selected soil type, predefined moisture threshold values were automatically applied within the system logic.

The Blynk dashboard also enabled remote access through a mobile device, allowing users to monitor soil moisture levels and pump operation from any location. This user interface effectively integrated soil type selection with threshold-based irrigation control, enhancing system flexibility and making it suitable for different soil conditions.

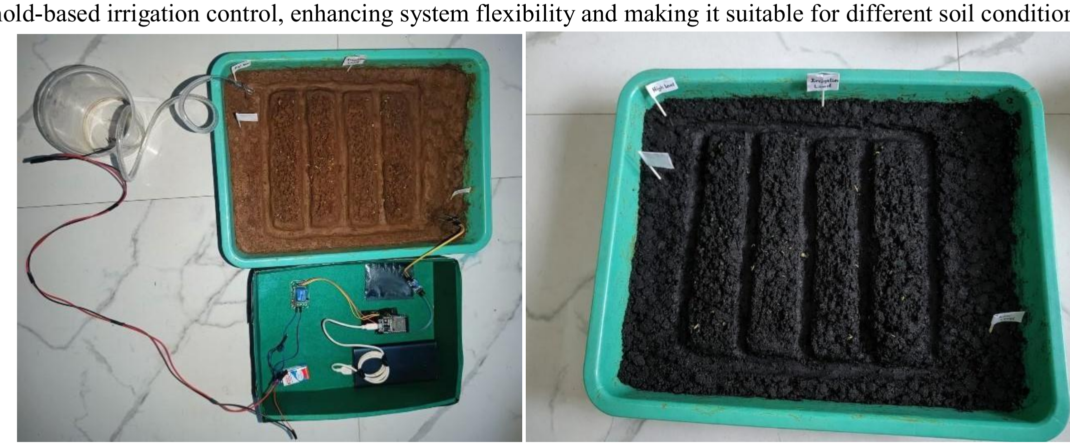


Fig no 3: Red and Black soil tray

VI. USER INTERFACE FOR SMART IRRIGATION SYSTEM & WORKING PROCESS

The user interface of the proposed smart irrigation system is developed using the Blynk IoT platform to enable real-time monitoring and control of irrigation based on soil type. The interface is designed to be simple and user-friendly, allowing selection between black soil and red soil and visualization of corresponding soil moisture conditions. As shown in the interface setup, virtual data streams are created in the Blynk application to display

soil name, soil moisture percentage, pump status, and soil type selection. A segmented switch widget is provided for selecting the soil type, allowing the user to choose either Black Soil or Red Soil. Based on the selected soil type, predefined moisture threshold values are automatically applied within the system logic.

For red soil, the interface displays the soil name as Red Soil (20%), indicating the threshold moisture level selected for irrigation. When the soil moisture falls below this threshold, the pump status is shown as ON, and irrigation is initiated. Once the moisture level increases beyond the threshold, the pump status changes to OFF, indicating that irrigation has stopped.

Similarly, for black soil, the interface displays Black Soil (60%) as the selected soil type, reflecting its higher water-holding capacity. The real-time soil moisture value is visualized using a circular gauge widget ranging from 0 to 100 percent. The pump status indicator updates dynamically based on the moisture condition, ensuring automated irrigation control without manual intervention.

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

The Blynk dashboard also enables remote access through a mobile device, allowing users to monitor soil moisture levels and pump operation from any location. This user interface effectively integrates soil type selection with threshold-based irrigation control, enhancing system flexibility and making it suitable for different soil conditions.

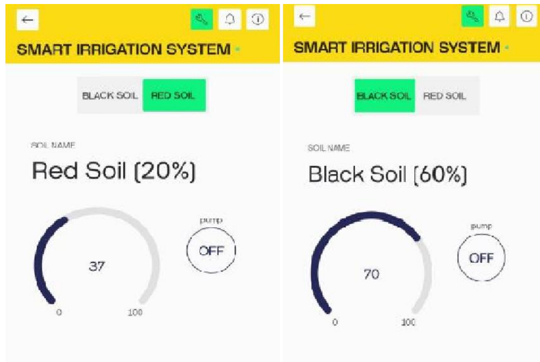
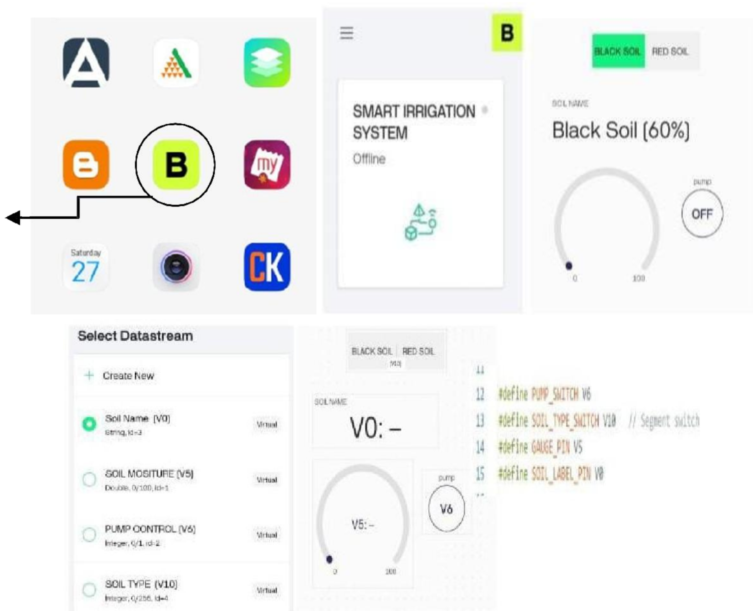


Fig no 4: Blynk app interface



BLYNK APP

Fig no 5: User interface of black and red soil

VII. RESULTS AND DISCUSSION

The laboratory-scale smart irrigation system was tested using red soil and black soil to evaluate its performance under different moisture retention characteristics. The soil moisture sensor provided real-time readings, which were processed by the ESP32 microcontroller to automatically control the water pump through the relay module based on predefined threshold values.

For red soil, the irrigation threshold was set at 20%, while for black soil, the threshold was set at 60%. The system successfully activated the water pump when the soil moisture level fell below the respective threshold and automatically turned it off once the desired moisture level was reached. A manual override option available through the Blynk interface allowed additional irrigation when required.

The experimental results indicated that the automated irrigation system reduced water usage compared to conventional manual irrigation practices. Red soil required more frequent irrigation cycles due to its lower moisture retention capacity, whereas black soil required fewer cycles because of its higher water-holding capacity. The ESP32 processed sensor data reliably, and the Blynk interface enabled effective real-time monitoring of soil moisture levels and pump status.

Minor variations in sensor readings were observed due to soil heterogeneity and environmental conditions; however, the overall performance of the system demonstrated efficient, flexible, and reliable irrigation control. These results confirm the suitability of the proposed smart irrigation system for small-scale agricultural applications

VIII. CONCLUSION

A laboratory-scale smart irrigation system was successfully developed and tested using red soil and black soil. The soil moisture sensor, ESP32 microcontroller, and relay-controlled water pump enabled automated irrigation based on predefined moisture threshold levels. Integration with the Blynk IoT platform allowed real-time monitoring of soil moisture conditions and manual override when required.

The experimental results demonstrated effective moisture-based irrigation control, efficient water usage, and reliable system performance under laboratory conditions. The study confirms that a low-cost, sensor-based smart irrigation system can be effectively implemented at small scale, providing a practical foundation for future field-scale applications and promoting sustainable water management practices in agriculture.

REFERENCES

[1] Manjula, A., 2024. Smart Irrigation System using IOT. EAI Endorsed Transactions on Internet of Things, 10.

[2] El Mezouari, A., El Fazziki, A. and Sadgal, M., 2022. Smart irrigation system. IFAC-PapersOnLine, 55(10), pp.3298-3303.

[3] Shobana, S., Pandey, B.S., Padmashri, R. and Triveni, U. (2021) IoT based smart irrigation system using soil moisture sensor and NodeMCU. International Journal of Computer Science and Information Technology Research, 9(2), pp. 52–58, April–June.

[4] Priyanka, M., Kumar, L.T., Teja, I.S. and Sai, I.N.S., 2023. IOT Based Smart Irrigation System. Journal of Engineering Sciences, 14(04).

[5] Ananthan, S.S. (2022) Smart Irrigation. International Journal for Research in Applied Science and Engineering Technology (IJRASET), 10(6), pp. 233–239. (Accessed: June 2022).

[6] Shreyash, S., Sharma, S., Nagar, S. and Priyadardshani, S. (2021) Smart Irrigation System. International Journal of Electrical, Electronics and Computers, 6(5), pp. 1–5. (Accessed: Sep–Oct 2021).