

IOT – Based Smart Plant Irrigation System Using Soil Moisture Sensor

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Abstract - With efficient water use becoming more important to modern agriculture and home gardening, overwatering too often translates into wasted resources and poor plant health. This study proposes an intelligent irrigation solution based on continuous soil moisture measurements to determine the watering needs. The ESP32 controller reads the moisture sensor and if the reading is lower than the set threshold it turns on a relay to power the water pump. The operational data are wirelessly sent to a cloud-based platform for users to observe the irrigation status from anywhere. The experiments indicate that the prototype reduces the unnecessary watering and maintains the soil moisture for the healthy growth of the plant. Owing to its simple hardware configuration, low implementation cost, and automated operation, the developed system offers a practical approach for improving water-use efficiency in gardens and small agricultural fields.

Keywords - ESP32-based irrigation, IoT-enabled agriculture, precision farming, remote irrigation control, soil moisture monitoring

1. Introduction

Effective water management has become a critical requirement in agriculture and gardening due to increasing concerns about water availability and sustainable resource utilization. Conventional irrigation techniques generally depend on manual observation or scheduled watering patterns, which may not accurately represent the real moisture requirements of plants. Because of this limitation, irrigation may occur unnecessarily or insufficiently, resulting in water loss, additional human effort, and reduced plant growth performance. The integration of Internet of Things (IoT) technologies has provided a new approach for developing automated irrigation solutions with improved monitoring and control capabilities. This research focuses on the design of an IoT-enabled plant irrigation system that uses an ESP32-based controller along with a soil moisture sensing unit. The sensor continuously measures the moisture condition of the soil, and the controller analyzes the collected values to decide the requirement for irrigation. When the moisture content decreases below the predefined level, the system automatically activates the pump through a relay mechanism to supply the required amount of water.

In addition, the system utilizes wireless communication to share irrigation-related information, including soil conditions and pump activity, with a remote monitoring platform. This feature allows users to access system updates

without direct physical inspection. The experimental results show that the proposed approach can minimize unnecessary irrigation, reduce manual involvement, and maintain appropriate moisture levels for better plant development. Due to its affordable components, simple architecture, and automated functionality, the system provides a feasible solution for domestic gardening, greenhouse applications, and small-scale agricultural practices. and home gardening.

2. Literature Survey

Historically, watering practices depended largely on the experience and visual assessment of cultivators rather than measurable information about soil conditions. The absence of continuous moisture monitoring made it difficult to determine the exact amount of water required by plants, often resulting in inefficient irrigation and possible stress to plant growth. Later, automated systems based on fixed schedules were introduced to minimize human involvement, but these systems followed predefined intervals without considering changes in the surrounding environment. This limitation created the need for advanced irrigation methods that can sense field conditions, make informed decisions, and provide water according to the actual requirements of plants.

2.1. Traditional Irrigation Methods

In earlier agricultural practices, farmers or gardeners performed irrigation manually. They supplied water based on their observations instead of actual soil moisture conditions. While this method was easy, but it often led to overwatering or underwatering, which harmed plant growth and wasted water resources. To lessen manual labor, pre-programmed irrigation methods were introduced later. These systems automatically supplied water at set intervals. However, they couldn't tell if the soil actually needed water. As a result, irrigation continued even when the soil had enough moisture. This showed the need for next-generation irrigation solutions that provide precise and condition-based water management.

2.2. Interconnected IoT Systematic Frameworks for Efficient Irrigation Control

The application of connected technologies in agriculture has opened new possibilities for improving the way irrigation decisions are made in field environments. IoT-based solutions provide continuous access to information collected from agricultural areas, allowing irrigation activities to be adjusted according to actual field requirements rather than relying only on predefined schedules. These frameworks combine sensing components, embedded computing units, communication networks, and data handling platforms to observe changes in soil characteristics and initiate suitable watering actions. Various researchers have investigated such automated irrigation approaches to overcome challenges related to inefficient water distribution, excessive consumption, and the limitations of manual monitoring practices. Thote et al. developed an IoT-assisted irrigation model that integrated machine learning-based analysis with field data interpretation to determine appropriate watering strategies under different agricultural conditions. Reddy et al. proposed an ESP32-supported irrigation mechanism that evaluated soil moisture variations and controlled the activation of water supply based on real-time field observations. Sharma et al. designed an IoT-enabled platform that allowed remote supervision and operation of irrigation activities using internet-based communication. Similarly, Rahman et al. presented a sensor-based irrigation solution using ESP32 and soil moisture monitoring, which delivered water according to the detected requirement of the soil. The outcomes of these studies highlight the capability of interconnected IoT frameworks to improve agricultural water handling by supporting automated operation, reducing unnecessary usage, and enhancing the efficiency of irrigation practices.

2.3. Intelligent Moisture-Sensing Approaches for Automated Irrigation

The use of soil moisture monitoring technology has become an important element in developing automated irrigation solutions. They continuously check soil

moisture levels and help deliver water when necessary. These sensors work with IoT and microcontrollers to automate irrigation and cut down on water waste. Studies by Sahoo and Patnaik, Kumar et al., and Patel and Joshi showed that sensor-based irrigation systems improve water management, support remote monitoring, and boost irrigation efficiency in modern agriculture.

2.4. Cloud and Mobile-Based Monitoring Systems

The adoption of cloud-enabled solutions with smartphone applications has provided a convenient way to supervise and regulate irrigation operations without being physically present at the field location. These technologies allow users to access real-time soil and irrigation data from anywhere. Prakash et al., Rao and Ramesh, Rao et al., and Pereira et al. developed IoT-based irrigation systems that enhanced water management, lowered energy usage, and allowed for remote monitoring through cloud connectivity. Their studies indicate that cloud-integrated irrigation systems make farming more efficient, flexible, and user-friendly.

2.5. Advanced Smart Irrigation Technologies

Recent advancements in smart irrigation systems have focused on technologies like artificial intelligence, IoT, fuzzy logic, renewable energy, and TinyML to improve automation and water management. Researchers such as Thote et al., Suresh et al., Velela et al., and Aisyah et al. proposed IoT-enabled irrigation approaches that supported continuous field observation, automated regulation of water supply, and improved utilization of available water resources. Dong et al. and Zheng et al. enhanced irrigation accuracy with precision monitoring and fuzzy control techniques. Newer studies by Kunt, Hasib and Akib, and Taueatsoala et al. explored AI, cloud analytics, and TinyML-based irrigation systems for more intelligent and energy-efficient farming. These studies show that modern irrigation systems are becoming smarter, more automated, and sustainable for future agriculture.

2.6. Research Gap

While several smart irrigation systems exist, many are expensive, complicated to set up, or mainly focus on monitoring rather than full automation. These issues make them less suitable for small farms and home gardening. Therefore, a simple, affordable, and efficient irrigation system is needed. This system should monitor soil moisture in real time, automatically control water supply, support remote monitoring through IoT technology, reduce water waste, and lessen manual effort. The designed system incorporates an ESP32 controller along with moisture detection technology to provide an economical and accessible solution for automated agricultural monitoring

and intelligent plant maintenance.

3. Methodology and Design

The proposed IoT-enabled Smart Plant Irrigation System follows a systematic approach for developing an automated watering mechanism that evaluates soil conditions continuously and activates water supply based on the actual requirements of plants. The system combines a soil moisture sensor, ESP32 microcontroller, and IoT technology to enable effective irrigation control. The entire development process includes hardware setup, software development, internet-based monitoring, and system testing to ensure reliable performance.

3.1. Proposed System Architecture

The overall system architecture consists of four major units:

- Sensing Unit
- Control Unit
- Irrigation Unit
- IoT Monitoring Unit

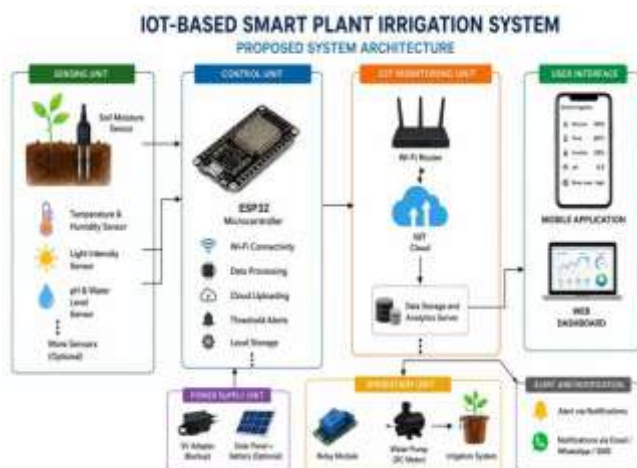


Fig. 1 Proposed System Architecture

3.2. Hardware Components and Setup

The hardware implementation involves connecting all physical components required for smart irrigation.

ESP32 Microcontroller: ESP32 is the main processing unit of the system that controls the overall irrigation operation and supports IoT connectivity through Wi-Fi.

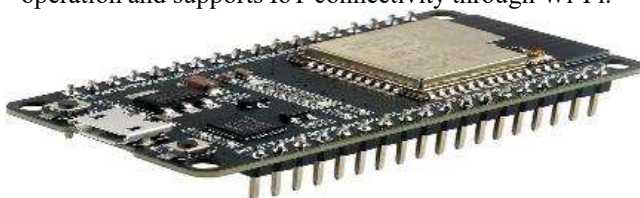


Fig. 2 ESP32 Microcontroller

Soil Moisture Sensor: Soil Moisture Sensor: This sensing device measures the moisture level present in the soil and provides the necessary information to determine the appropriate time for irrigation.



Fig. 3 ESP32 Soil Moisture Sensor

Relay Modul: The relay module acts as an automatic electronic switch that controls the operation of the water pump safely.

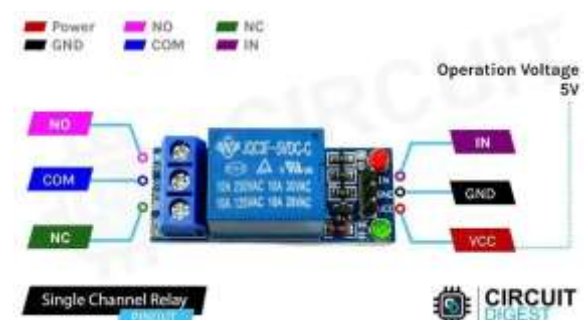


Fig. 4 Relay Module

DC Water Pump: The DC water pump supplies water to the plants automatically whenever the soil becomes dry.



Fig. 5 DC Water Pump

Power Supply: The power supply ensures stable and continuous power delivery to all system components for proper functioning.

Connecting Wires and Breadboard: Jumper wires and breadboards are used for circuit connections and prototype development.

3.3. Working Principle of the System

The system operates in a continuous cycle of sensing, decision-making, and irrigation control.

- The moisture sensing unit periodically measures the water level present in the soil environment.
- The collected analog signals are transmitted to the ESP32 controller for further processing and

analysis.

- The ESP32 evaluates the sensor readings against the configured moisture limit stored in the system.
- When the detected moisture value falls below the set level, the controller triggers the relay circuit, which starts the pump operation to provide water to the plants
- When sufficient moisture is deactivated the relay module is deactivated and pump turns OFF automatically.
- The current moisture level and pump status are uploaded to the cloud platform for remote monitoring.

This automated process reduces manual effort and ensures efficient water management.

3.4. IoT Integration and Remote Monitoring

IoT connectivity provides a link between the irrigation setup and the user, allowing continuous data exchange and remote supervision of system activities. The ESP32 connects to the internet using built-in Wi-Fi functionality and sends data to cloud platforms such as Blynk or ThingSpeak. Users can monitor the following information remotely:

- Soil moisture percentage
- Pump ON/OFF status
- Irrigation activity
- Real-time sensor readings

The mobile application also allows users to manually control the pump remotely whenever necessary. This feature improves flexibility, convenience, and smart farm management.

The program performs the following operations:

- Reads moisture sensor values
- Processes sensor data
- Compares values with threshold limits
- Controls relay and pump operation
- Uploads data to cloud platforms
- Enables remote monitoring and control

The irrigation logic used in the system is simple and efficient:

- If soil is dry → Pump ON
- If soil is wet → Pump OFF

This automated operation helps deliver water according to the actual requirements of the plants, avoiding unnecessary irrigation.

4. System Implementation and Testing

The developed IoT-enabled irrigation model was implemented and evaluated through experimental testing. The required hardware units, including the ESP32 controller, moisture sensing device, relay circuit, and water pump, were integrated and programmed to achieve automated plant watering operations. The system programming is carried out through the Arduino IDE, enabling sensor data analysis and automatic operation of the water pump based on soil conditions. The system is tested under different soil conditions to verify proper sensing, automatic pump operation, and IoT-based remote monitoring. The testing results show that the system efficiently supplies water only when required, helping to reduce water wastage and improve irrigation management.

5. Result Analysis

Configuration	Water Usage	Automation	Remote Monitoring	Overall Efficiency
Manual Irrigation	High Water Wastage	Manual Operation	Not available	Low
Timer-Based Irrigation	Moderate water control	Partial automation	Not available	Moderate
Proposed IoT Smart Irrigation System	Water supplied only when required	Fully automatic	Available through mobile/cloud	High

Performance and Feature Comparison of Irrigation Systems:

Table 1. Feature Comparison of Irrigation Systems

The results summarized in Table 1 highlight the potential of the developed system to achieve improved irrigation control and efficient resource utilization in comparison with conventional watering practices. Unlike manual and timer-based systems, the proposed system supplies water only when the soil becomes dry, which helps reduce water wastage and improves irrigation efficiency. In addition, the system supports remote monitoring through mobile or cloud platforms, making irrigation management more convenient and intelligent.

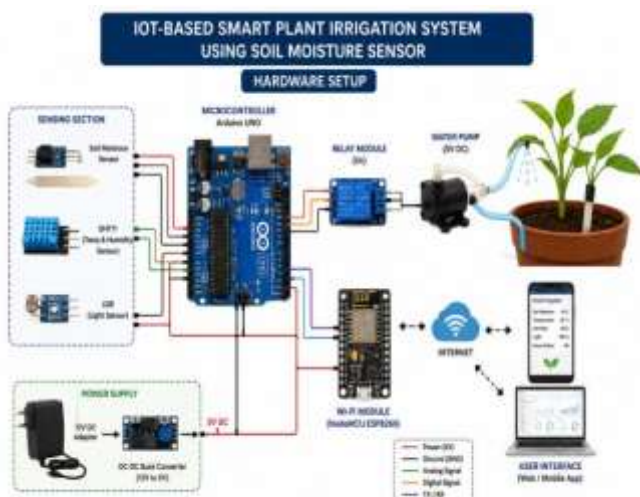


Fig. 5. Hardware Setup

Fig. 6 Hardware Setup

3.5. Software Implementation

The software for the proposed system is developed using Arduino IDE. Embedded C/C++ programming is used to control the ESP32 and implement irrigation logic.

6. Conclusion

The proposed plant care model utilizes connected sensing and control technologies to automate the watering process with minimal user intervention. The moisture condition of the soil is evaluated by the system, and the pumping mechanism operates according to the detected requirement of the plants. The soil moisture detection, relay-based switching, water delivery hardware, and IoT communication enables the system to conserve water, simplify maintenance activities, and enhance the reliability of irrigation operations. The ability to remotely monitor and control the system through mobile applications makes it more convenient and suitable for modern agriculture, gardens, and greenhouse settings. Overall, the proposed system provides an affordable, reliable, and eco-friendly method for smart irrigation and effective water management.

7. Future Work

The proposed smart irrigation system can be further

improved by integrating advanced technologies and additional smart features. Future enhancements can help increase system efficiency, reduce power consumption, and support better water management for modern agriculture and gardening applications. The following improvements can be considered for future development:

- Adding weather prediction to improve irrigation decisions during rainfall conditions.
- Integrating solar power for energy-efficient and eco-friendly operation.
- Incorporating additional monitoring units to track environmental factors, parameters such as temperature and atmospheric moisture levels to obtain more detailed field information.
- Improving the mobile application by integrating features such as warning messages, user notifications, and historical data visualization.
- Adapting the developed system for wider agricultural areas and advanced smart farming environments

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