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Automated Irrigation System for Plantation Crops

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Abstract
This project presents a cost-effective, energy-efficient smart irrigation system tailored for plantation crops such as lemon trees. Built on the ESP32 microcontroller, the system integrates soil moisture and temperature sensors, along with weather data, to enable real-time, automated irrigation based on environmental conditions. Sensor data is processed and transmitted via Wi-Fi to a cloud platform, with monitoring and control available through a Blynk-based mobile application. To ensure wider accessibility, SMS alerts are also incorporated for users with basic mobile phones. The system reduces water consumption and manual labor while promoting healthier crop growth. Designed for scalability and ease of use, it supports sustainable agriculture and empowers farmers through accessible smart farming technology.
Keywords: *Smart Irrigation, ESP32, IoT in Agriculture, Soil Moisture Monitoring, Blynk App, Precision Farming, Sustainable Agriculture, Automated Water Management, SMS Alerts, Lemon Tree Cultivation*

1. Introduction

Water management has become an increasingly critical challenge in modern agriculture, where over-irrigation and inefficient practices often lead to resource waste and reduced crop productivity. In response, smart irrigation systems are emerging as a sustainable solution that leverages technology to optimize water usage and promote healthier plant growth. By using real-time data from environmental sensors, these systems ensure that crops receive the right amount of water no more, no less improving yield while conserving vital resources. This paper presents the design and development of a smart irrigation system powered by the ESP32 microcontroller. Known for its low cost, energy efficiency, and built-in Wi-Fi capabilities, the ESP32 serves as the core controller, interfacing with soil moisture, temperature, and humidity sensors to make intelligent, automated irrigation decisions. What sets this system apart is the integration of an automated fertilization module, which delivers nutrients to crops at optimal times based on environmental data or preset schedules. This dual-functionality combining smart watering and nutrient delivery enhances crop health while minimizing manual labor. With wireless connectivity to cloud platforms and mobile apps, users can remotely monitor conditions, receive alerts, and adjust parameters as needed. Designed for scalability and ease of use, this system can be applied in diverse settings, from home gardens to large-scale agricultural operations. Ultimately, the proposed solution demonstrates how smart farming technologies can contribute meaningfully to sustainable agriculture, resource conservation, and data-driven decision- making for farmers of all backgrounds [1].

1.1 Methodology of the Smart Irrigation System

To address the challenges of efficient water and nutrient management in plantation agriculture, we developed a smart irrigation system tailored for lemon tree cultivation. The methodology combines real-time environmental sensing, automated control

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logic, and wireless communication to ensure timely and precise irrigation and fertilization. Sensor Deployment: Soil moisture and temperature sensors were strategically placed near the root zones of the lemon trees to ensure accurate and responsive data collection. Sensors were securely embedded at consistent depths to avoid displacement from wind or manual activity [2]. ESP32 Microcontroller Setup: The ESP32, selected for its built-in Wi-Fi and low power consumption, served as the central controller. Programmed via the Arduino IDE, it collects sensor data, processes irrigation logic, and triggers actuation through a relay module. System Thresholds and Calibration: Initial field testing helped establish optimal soil moisture thresholds. Irrigation was configured to activate below 30% soil moisture and deactivate above 60%. Temperature readings were used to fine-tune irrigation durations during warmer periods. Wireless Communication and Alerts: The ESP32 transmits live sensor data to the Blynk cloud platform over Wi-Fi, enabling remote monitoring through a smartphone dashboard. In areas without reliable internet access, a GSM module was integrated to deliver SMS alerts to basic mobile phones, ensuring broader accessibility. Flow Monitoring and Fertilizer Automation: A flow sensor tracks the volume of water dispensed, and a solenoid-based fertilization module automates nutrient delivery based on either timed intervals or detected soil conditions. This ensures consistent and efficient fertilization without manual input. Remote Interface via Mobile App: Users can access live and historical data, receive notifications, and manually override settings through the Blynk mobile application. The interface displays parameters such as temperature, moisture level, water flow rate, and pump status. Safety and Error Handling: The system includes safety logic to shut off irrigation in the event of hardware malfunction, excessive flow rate, or sensor failure. Farmers are notified via the mobile app or SMS in such cases, allowing quick intervention. Table 1 shows Experimental Parameters Used in System Testing.

1.2 Plan of Experiments

To validate system performance, the smart irrigation solution was deployed and tested in a small-scale lemon plantation. The goal was to evaluate the system's ability to autonomously manage irrigation and nutrient delivery based on live environmental data. The experimental setup included fixed thresholds for moisture and temperature, with the ESP32 programmed to operate autonomously under varying field conditions. Parameters such as water consumption, plant health, and labour involvement were monitored to assess effectiveness. Figure 1 shows Workflow of Esp32 And Gsm Module.

Table 1 Experimental Parameters Used in System Testing

Crop Type	Soil Moisture Threshold (%)	Temperature Range (°C)	Irrigation Trigger	Fertilizer Schedule
Lemon Tree	30 (low), 60 (high)	25–35	Automated via ESP32	Once every 5 days

Figure 1 Workflow of Esp32 And GSM Module

2. Proposed System

The proactive monitoring capabilities of the proposed smart irrigation system enable early detection of operational anomalies, allowing for timely maintenance and minimizing disruption to crop irrigation [3]. By identifying faults such as sensor malfunctions, unexpected flow variations, or communication failures in real time, the system ensures reliable and continuous support for healthy crop growth. At the heart of the system is the ESP32 microcontroller, which serves as the central processing and control unit. It continuously gathers environmental data from soil moisture and temperature sensors, processes this information locally and transmits relevant insights to a cloud-based Firebase database via Wi-Fi. This centralized data architecture enables real-time analytics, remote system monitoring and the ability to make informed, data-driven decisions regarding irrigation cycles and system maintenance [4]. To further enhance usability and accessibility, a user- friendly mobile application developed using the Blynk platform serves as a comprehensive dashboard for farmers and system administrators. The application displays live sensor data, pump status, historical trends, and system alerts. Users can remotely adjust irrigation parameters, review past performance, and receive instant notifications regarding any faults or abnormal conditions [10]. This intuitive interface simplifies farm management and empowers users to take timely actions without physical presence in the field. The proposed system represents a forward-thinking approach to agricultural automation by integrating smart technologies that reduce water waste, improve operational reliability, and lower manual labor demands. Through automation, remote accessibility, and real-time intelligence, the solution supports sustainable farming practices while increasing crop yield and resource efficiency [11]. Ultimately, it contributes to the development of more resilient and technologically enabled agricultural environments. Figure 2 shows Proposed Prototype.

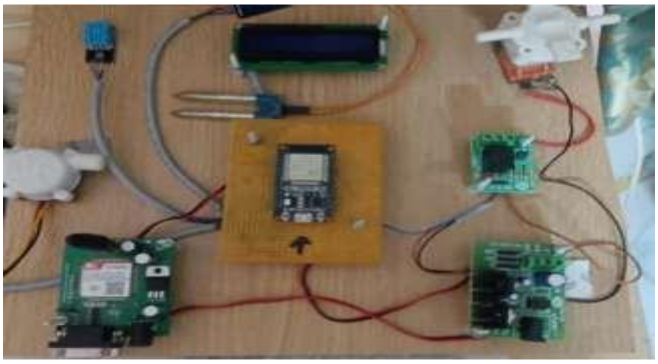

Figure 2 Proposed Prototype

3. Results and Discussion

3.1 Results

To evaluate the performance of our smart irrigation system, we conducted field trials in a lemon tree plantation over a two-week period. The system was designed to monitor soil moisture and temperature in real time, automate irrigation when needed, and provide remote access and alerts through both a mobile app and SMS notifications. Throughout the testing phase, the system consistently maintained soil moisture within the ideal range for lemon trees by automatically triggering irrigation when moisture levels fell below 30% and stopping once it reached 60%. The water flow sensor accurately tracked the volume of water used, and the data was successfully sent to a cloud dashboard via Wi-Fi using the ESP32 microcontroller. In areas where internet connectivity was unreliable, SMS alerts provided backup notifications to the farmer’s mobile phone. A comparison with traditional irrigation methods showed promising results. The automated system reduced average water usage by about 32%, maintained stable soil conditions, and significantly reduced the time required for manual supervision and watering [5].

Table 2 Comparison Between the Irrigation

Parameter	Traditional Irrigation	Smart Irrigation System
Average Water Used per Cycle (L)	50	34
Soil Moisture Maintained (%)	58	55
Daily Labor Time (minutes)	60	10
Response Time to Issues (hours)	>12	<1

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Overall, the system performed as expected, with reliable data collection, timely irrigation, and responsive user notifications. Figure 3 shows Hardware Working Model.

Figure 3 Hardware Working Model

Figure 4 Hardware Working Model

3.2 Discussion

The field results clearly show the value of smart irrigation in improving both water efficiency and ease of farm management [8]. By automating watering based on live sensor data, the system ensures that plants are neither over- nor under-watered something that's often difficult to manage with manual methods. One of the key advantages was the system's ability to quickly detect and respond to potential faults. For example, if the pump ran longer than expected or if a sensor reading was out of range, the system sent an alert within minutes, helping avoid unnecessary water waste or crop stress [6]. This proactive approach to maintenance is especially useful for farmers who can't always be present in the field. Figure 4 shows Hardware Working Model. Another important aspect is accessibility. While the mobile app offers real-time dashboards and manual control for tech-savvy users, the built-in GSM module ensures that farmers with basic phones are not left behind. This dual communication method bridges the gap between traditional farming and modern technology. Labour savings were also significant. By reducing the need for daily checks and manual watering, the system gave farmers more time to focus on other tasks, contributing to better overall productivity. Figure 5 shows Use case Diagram.

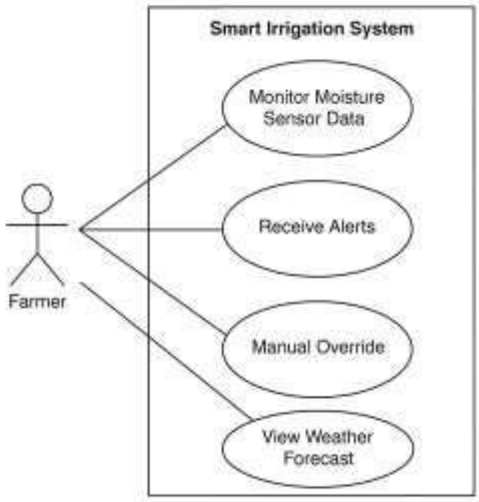

Figure 5 Use case Diagram

Conclusion

This project set out to solve a common yet critical problem faced by many farmers: how to efficiently manage irrigation without constant manual effort or wasting precious water resources. Through the development of a smart irrigation system using the ESP32 microcontroller, soil moisture and temperature sensors, and both app-based and SMS communication, we achieved a reliable and accessible solution tailored for lemon tree plantations [9]. The system proved effective during testing, showing a noticeable reduction in water usage, better consistency in maintaining soil moisture, and quicker response times to system faults. By allowing farmers to remotely monitor and control irrigation, the solution reduces the need for daily field visits and ensures that water is used only when truly necessary

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[7]. Importantly, it offers both modern app integration and basic SMS alerts making the technology usable for a wide range of farmers, regardless of their access to smartphones or internet.

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