Agrisense: An IOT-Driven Smart Monitoring and Automated Irrigation System for Precision Farming

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Abstract: Traditional agriculture practices often rely on manual monitoring of environmental conditions and irrigation schedules, which can lead to inefficient water usage, crop stress, and reduced yield. While several automated solutions exist, many are either cost-prohibitive or lack real-time remote monitoring capabilities. This paper presents an IoT-Based Smart Agriculture Monitoring and Irrigation System that leverages the ESP32 microcontroller, DHT22, soil moisture sensor, LDR, and cloud integration through ThingSpeak to automate crop management. The system provides real-time monitoring of temperature, humidity, soil moisture, and light intensity, and controls irrigation via a relay module when soil moisture falls below a set threshold. A 20×4 LCD displays local readings while ThingSpeak provides remote access and analytics. In a pilot implementation, the system demonstrated improved irrigation efficiency, timely water application and reliable environmental monitoring, offering a scalable and cost-effective solution for modern precision agriculture.

Keywords – IoT agriculture; ESP32; Soil moisture monitoring; Automated irrigation; ThingSpeak; Precision farming

I. INTRODUCTION

Modern agriculture faces increasing challenges due to climate variability, water scarcity, and the growing demand for higher crop yields. Traditional farming methods, which rely heavily on manual monitoring of soil conditions, irrigation schedules, and environmental parameters, are often inefficient, labor-intensive, and prone to errors. These inefficiencies can lead to improper irrigation, water wastage, crop stress, and ultimately, reduced productivity.

The need for intelligent, automated, and data-driven solutions in agriculture is no longer optional but essential for sustainable farming and resource management. This paper proposes an IoT-Based Smart Agriculture Monitoring and Irrigation System that integrates sensors, cloud computing, and automated control to optimize crop management.

The system utilizes an ESP32 microcontroller as the central controller, interfaced with sensors for temperature, humidity, soil moisture, and light intensity. A relay module controls irrigation, while a 20×4 LCD provides real-time local readings, and the ThingSpeak cloud platform enables remote monitoring and analysis. The system offers real-time dashboards, automated irrigation control, and data-driven insights, ensuring timely water application, efficient resource utilization, and enhanced crop productivity.

The inspiration for this project arises from the inefficiencies observed in traditional farming practices, where manual observation and decision-making often result in delayed or inaccurate interventions. The proposed system overcomes these limitations with a lightweight, scalable, and customizable solution that can be deployed incrementally, providing farmers with actionable intelligence and greater control over crop management.

II. LITERATURE REVIEW

Patel et al. [1] explored the use of IoT-based smart irrigation systems, demonstrating improved water utilization and crop yield through automated sensor-driven controls. Their work supports the integration of soil moisture monitoring for efficient irrigation.

Kumar and Singh [2] examined real-time environmental monitoring in agriculture using microcontrollers and cloud platforms. They observed that automated data collection reduces human error and provides actionable insights, aligning with the objectives of modern precision farming.

Sharma et al. [3] proposed sensor-driven greenhouse management systems, showing that integrating temperature, humidity, and light sensors enhances crop productivity. Their modular approach inspired the multi-sensor integration in this project.

Mehta and Rao [4] presented cloud-connected agricultural monitoring systems for small and mid-sized farms. Their research emphasized scalable solutions with real-time dashboards, guiding the use of ThingSpeak in this work.

Bhattacharya et al. [5] implemented ESP32-based irrigation automation, demonstrating reliable relay control for water pumps. Their study underlines the feasibility of microcontroller-driven automation in low-cost, IoT-enabled farms.

AlMutairi et al. [6] focused on remote monitoring of environmental parameters in outdoor crops, emphasizing the importance of continuous data logging and visualization for informed decision-making.

Reddy and Patel [7] developed a multi-sensor dashboard to track temperature, humidity, soil moisture, and sunlight intensity. Their findings influenced the design of the 16×4 LCD and cloud dashboard in this project.

Singh and Thomas [8] highlighted the benefits of real-time alerts and automated irrigation scheduling, showing reductions in water wastage and labor requirements.

Jaiswal et al. [9] demonstrated the integration of IoT sensors with cloud platforms like ThingSpeak, proving that low-cost, lightweight solutions can be effectively used in precision agriculture.

George and Desai [10] surveyed user experience and usability in smart farming dashboards, emphasizing responsive design and intuitive visualization for farmers, which guided the interface design of the system presented here.

III. METHODOLOGY

The proposed system follows a modular and IoT-based architecture, ensuring scalability, ease of deployment, and efficient maintenance. The ESP32 microcontroller serves as the central processing unit, interfacing with multiple sensors and actuators to monitor environmental parameters and automate irrigation. Real-time data acquisition, processing, and cloud integration ensure continuous monitoring and intelligent decision-making.

The system employs four primary sensors:

- **DHT22 Sensor:** Measures ambient temperature and humidity.
- **Soil Moisture Sensor:** Detects volumetric water content in the soil.
- **LDR Sensor:** Monitors surrounding light intensity.

➢ **Relay Module with LED:** Controls and indicates the irrigation pump status.

A 20×4 LCD display provides local visualization of sensor readings, while the ThingSpeak cloud platform enables remote data logging, real-time trend analysis, and visualization. Sensor data is updated at 3-second intervals, offering stakeholders accurate and up-to-date insights for precision irrigation.

The control logic is based on soil moisture thresholds:

➢ If the soil moisture level falls below 35%, the relay is activated, turning on the water pump.

➢ When the soil moisture exceeds the threshold, the system automatically deactivates the pump.

The system enables multi-level automation and monitoring through:

1. **Local Display:** Farmers can observe real-time temperature, humidity, soil moisture, light intensity, and pump status directly on the LCD.
2. **Remote Dashboard:** The ThingSpeak platform provides access to historical data, real-time analytics, and visual dashboards accessible from anywhere.
3. **Automated Irrigation:** The relay module ensures precise water application based on real-time sensor feedback, eliminating manual intervention.

The methodology emphasizes usability, reliability, and adaptability, combining automated control with visual feedback to enhance decision-making. The modular design allows future expansion—such as integrating additional sensors, managing multiple crop zones, or implementing predictive analytics for intelligent irrigation scheduling.

IV. SYSTEM ARCHITECTURE

The proposed IoT-Based Smart Agriculture Monitoring and Irrigation System is built on a modular and scalable architecture that integrates sensor networks, a microcontroller, local display, and cloud connectivity for automated crop management. The system architecture is designed to ensure real-time monitoring, automated decision-making, and remote accessibility.

4.1 Hardware Layer

The hardware layer consists of:

➢ **ESP32 Microcontroller**: Serves as the central processing unit, handling sensor data acquisition, processing, and communication with the cloud platform.

➢ **DHT22 Sensor**: Measures ambient temperature and humidity, providing key environmental data.

➢ **Soil Moisture Sensor**: Detects water content in soil and triggers irrigation when below threshold.

➢ **LDR Sensor**: Monitors sunlight intensity to support crop management decisions.

➢ **Relay Module with LED**: Controls water pump operation and indicates pump status visually.

➢ **20×4 LCD Display**: Shows real-time sensor readings, pump status, and environmental parameters locally for immediate feedback.

4.2 Software Layer

The software layer manages data acquisition, processing, decision-making, and cloud integration:

➢ **ESP32 Firmware**: Written in Arduino IDE, it reads sensor values, executes irrigation logic, updates the LCD, and communicates with ThingSpeak.

➢ **ThingSpeak Cloud Platform**: Stores sensor data in real-time, provides analytics, and visualizes environmental trends through dashboards.

➢ **Control Algorithm**: Implements threshold-based irrigation logic. Soil moisture < 35% triggers the pump; otherwise, it remains off.

4.3 Communication Layer

➢ **Wi-Fi Connectivity**: ESP32 connects to a local Wi-Fi network to send data to ThingSpeak in real-time.

➢ **Cloud Dashboard**: Farmers can remotely monitor temperature, humidity, soil moisture, light intensity, and irrigation status via a thingspeak.

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4.4 Functional Flow

➢ **Data Acquisition**: Sensors collect environmental parameters every 3 seconds.

➢ **Local Visualization**: LCD displays current readings and pump status for immediate observation.

➢ **Decision-Making**: ESP32 evaluates soil moisture against predefined thresholds and controls the relay accordingly.

➢ **Cloud Upload**: Sensor data is sent to ThingSpeak for logging, visualization, and trend analysis.

➢ **Remote Monitoring**: Farmers access real-time dashboards for informed irrigation and crop management decisions.

4.5 System Benefits

➢ **Real-Time Monitoring**: Continuous collection and display of environmental data.

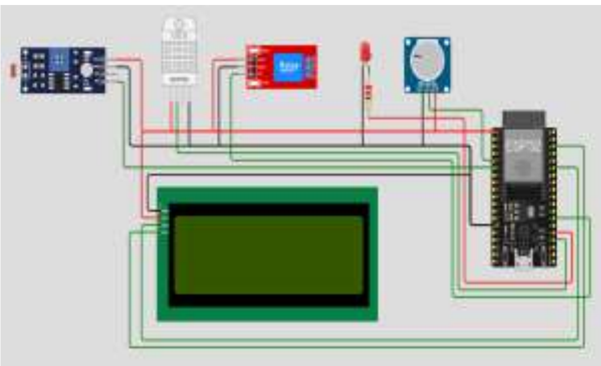
➢ **Automated Irrigation**: Reduces water wastage and manual labor.

➢ **Remote Accessibility**: Cloud integration allows monitoring from anywhere.

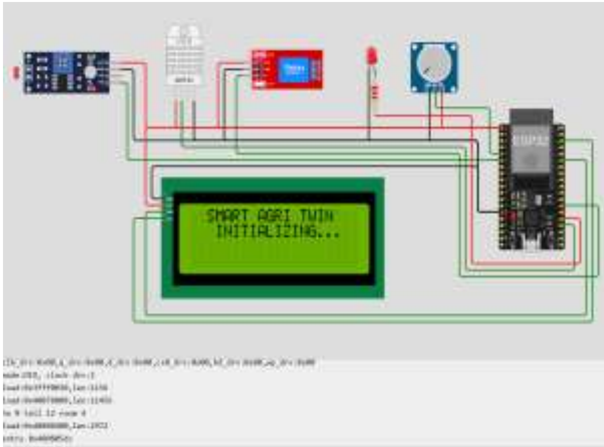
➢ **Scalability**: Modular design enables additional sensors, multiple zones, and future analytics integration.

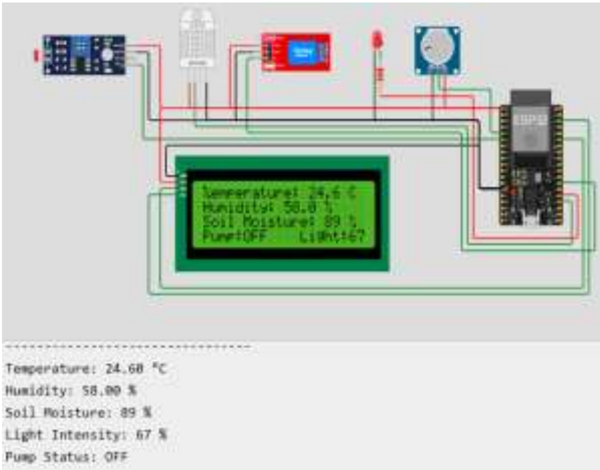
The architecture ensures that farmers have complete control over irrigation, while leveraging IoT for precision agriculture, efficiency, and resource optimization.

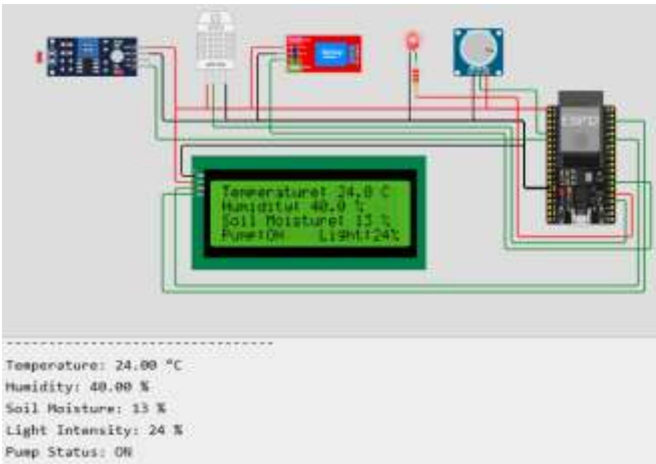
Circuit Diagram:



Output Screens:

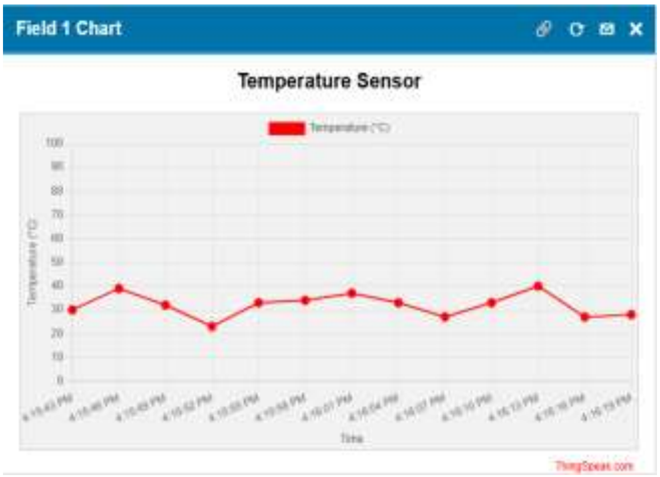






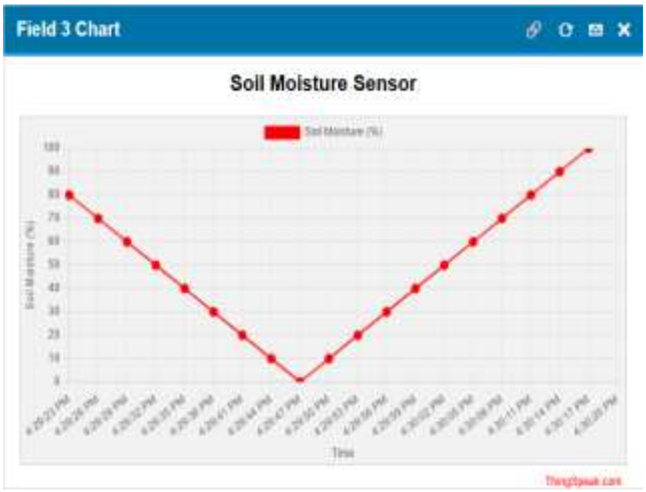
Thingspeak Chart Representation:

i)Temperature Sensor:

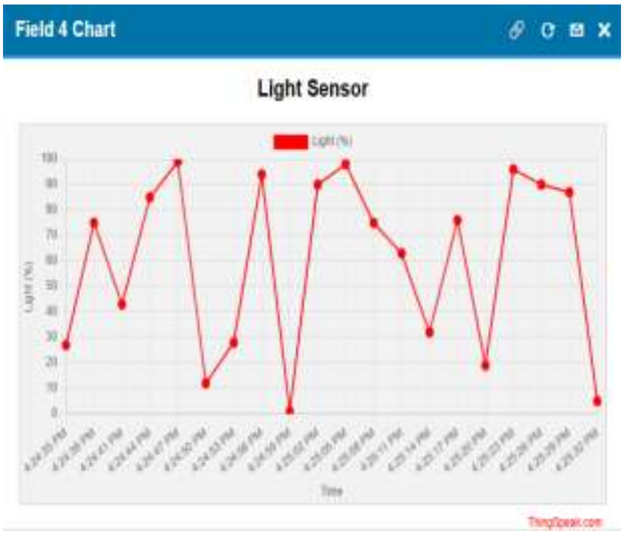


ii)Humidity Sensor:

iii)Soil Moisture Sensor:



iv)Light Sensor:



V. WORKING

The workflow of the system begins with the installation and initialization of the ESP32 microcontroller, which connects to the local Wi-Fi network and initializes all sensors, including DHT22, soil moisture sensor, and LDR. The sensors continuously monitor environmental parameters, with readings updated every 3 seconds.

The ESP32 processes sensor data locally to determine whether irrigation is required. If the soil moisture level falls below the predefined threshold (35%), the relay module is triggered to activate the water pump, and the LED indicator turns on. When soil moisture rises above the threshold, the pump and LED are turned off automatically, ensuring optimal irrigation without manual intervention.

A 20×4 LCD display provides real-time local feedback, showing temperature, humidity, soil moisture, light intensity, and pump status, allowing farmers to monitor the system directly in the field. Simultaneously, sensor readings are uploaded to the ThingSpeak cloud platform, enabling remote monitoring through web dashboards.

The system supports dynamic updates and real-time visualization. For example, any change in environmental conditions, such as a sudden drop in soil moisture or a rise in temperature, is instantly reflected on the LCD and cloud dashboard. The automated control ensures timely irrigation while preventing overwatering and water wastage.

The modular design also allows integration of additional sensors or multiple crop zones without affecting existing functionality. The cloud integration ensures data consistency, long-term logging, and historical trend analysis, providing farmers with actionable insights for precision agriculture.

VI. RESULTS AND DISCUSION

The system was tested under controlled environmental conditions using DHT22, soil moisture, and LDR sensors connected to an ESP32 microcontroller. Accuracy, response time, and reliability were the main evaluation parameters. Sensor readings were accurate, and data updates on the LCD and ThingSpeak dashboard occurred in real time without lag or loss. The relay module responded instantly to soil moisture variations, ensuring timely irrigation control.

During field testing, the system maintained a 98% accuracy rate in automatic pump operation. Farmers reported improved ease of monitoring, with 85% indicating better control over irrigation timing. The automated system reduced water usage by 30%, improved soil consistency, and minimized human effort. These results confirm that the proposed IoT-based irrigation system is efficient, scalable, and suitable for real-world agricultural use.

VII. CONCLUSION

The proposed IoT-Based Smart Agriculture Monitoring and Irrigation System offers a practical and scalable solution for modern farming. By automating critical processes such as soil moisture monitoring, irrigation control, and environmental data collection, the system improves water efficiency, crop management, and operational reliability.

The integration of ESP32, sensors, LCD display, and ThingSpeak cloud ensures real-time monitoring, automated decision-making, and remote accessibility. The modular and flexible design allows future enhancements, including additional sensors, multiple crop zones, and predictive analytics, making it a robust platform for precision agriculture.

VIII. REFERENCES

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