Sensor Based Smart Agriculture Monitoring System Using Web & IOT Based

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Abstract

Agriculture played an important role in maintaining human life, and technological advances contributed significantly to improving agricultural productivity. The project was a sensor-based smart agricultural monitoring system using Web and IoT, which integrated web-based surveillance and nanotechnology (IoT), optimized farming efficiency, optimized resource use, and improved harvest revenue. These sensors sent real-time data to cloud-based servers via IoT-enabled devices such as microcontrollers ESP32. The collected data was displayed on a web-based dashboard, allowing farmers to monitor and control a variety of agricultural parameters from afar. The most important features of the system included automatic irrigation control. In this irrigation control, the level of soil moisture determined the actual warnings of water needs and important conditions such as drought, excessive moisture, and temperature fluctuations. Additionally, the system provided data analysis and visualization that enabled farmers to make well-informed decisions to improve plant health and productivity. The proposed solution was aimed at creating a sustainable, inexpensive, and user-friendly approach for modern precision breeding.

Keywords: IoT, smart agriculture, precision agriculture

1. Introduction

One of the most significant industries is agriculture. This is due to the substantial presence provided by the Indian sector. This portion of the populace supports the strong financial condition of the country. However, many challenges exist in this sector, such as water shortages. There are systems that attempt to solve this problem through real-time irrigation and monitoring, though there remains a lack of control. The necessity of innovative and economically effective solutions can optimize and increase resource usage and productivity. There is a growing need to improve farm performance due to factors such as expanding global population—projected to increase by 70% by 2050 (according to the United Nations Food and Agricultural Organization)—as well as the reduction in arable land, exhaustion of traditional systems, and the need to increase the profitability of resources and participation. Another interfering factor in agriculture is the change in the organizational structure of work. Agricultural Labor has decreased in most countries. As a result, physical Labor has been replaced by contractual work, which has reduced the availability of agricultural workers. Conventional farming practices are no longer productive, and the growing demand for food production cannot be met through traditional means. Modernizing the agriculture industry through technological adoption is necessary to address this issue.

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Precision agriculture is a novel method. So far, the use of plant production optimization has minimized resource use. IoT-based smart agricultural systems have the potential to bring a revolution by providing real-time data for plants and the environment in the agricultural sector. These systems can help farmers make appropriate decisions for irrigation, fertilizer application, and other important aspects [3][4]. One of the most significant problems for farmers is the lack of timely and accurate information about plants and their habitats. IoT-based intelligent agricultural systems can provide reliable data regarding soil temperature, humidity, and moisture. Such data can support informed decision-making about irrigation scheduling and correction timing. Another problem is inefficient resource usage. Farmers often overuse water, fertilizers, and pesticides, which causes environmental damage and high production costs. The IoT-based smart agricultural system helps farmers optimize their resources by providing data on plant environmental conditions and needs. Plagues and diseases are also serious threats to agricultural crops. Traditional methods of pest and disease control, such as insecticides, can harm the environment and human health [3]. Smart agriculture helps farmers analyze and prevent the development of pests and diseases, thereby supporting environmental and human health.

The aim of the proposed system is to supply landowners with a dependable and cost-effective option for precision farming. The IoT technology used in the system gives farmers access to real-time agricultural data in their immediate surroundings, which can help prevent pest-related crop losses and promote efficient resource use. The proposed system provides real-time data to farmers, allowing better cultural control. As a result, the risk of resource waste and plant loss is reduced, enhancing profitability and minimizing environmental damage.

1.1 Design of the prototype system

A. Proposed block diagram:

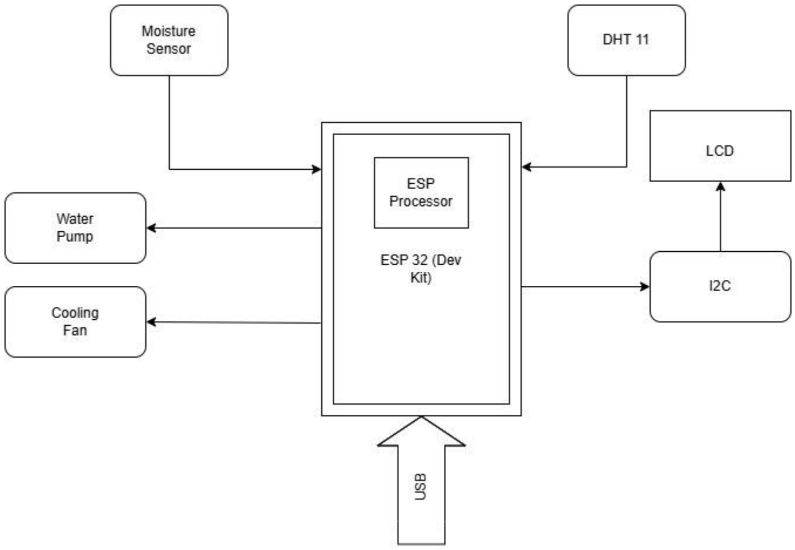


Figure 1. Detailed Block Diagram of Working Proposed Model

B. Block diagram described:

This block diagram represents an intelligent agricultural monitoring system built using the ESP32 microcontroller. The system integrates several sensors and actuators to automate and monitor agricultural conditions. It functions as the central processing unit of the ESP32 development kit system, where it collects and processes data from sensors and manages output devices based on defined requirements. Peripherals are used to enable communication and programming via a USB interface. The soil moisture sensors measure the soil level and send this data to the ESP32. This input is used to activate the water pump when the soil moisture falls below a set threshold. The DHT11 sensor measures the temperature and humidity of the surrounding environment and provides the data to the ESP32 for further analysis. The water pump is controlled by the ESP32, toggling on or off based on the soil moisture sensor's readings, which supports automated irrigation. When the temperature exceeds the defined threshold, the cooling fan is activated to help maintain optimal temperatures for plant growth.

The LCD display shows real-time environmental data, including temperature, air humidity, and soil moisture levels. It is connected via an I2C module for efficient data transmission, which also simplifies the wiring by reducing the number of connections required. The USB connection is used for both programming the ESP32 and supplying power to the microcontroller. The task operates on the principle that sensors such as humidity and DHT11 continuously monitor ambient conditions. The ESP32 processes this sensor data and displays it on the LCD. If the measured values fall below pre-set thresholds, the system automatically activates the water pump or cooling fan. This real-time feedback and automation contribute significantly to improving farming efficiency.

C. Hardware details:

The following components make up the hardware of the suggested system:

The microcontroller ESP32 is a strong module that can be used as an application of the Wi-Fi module. This article uses ESP32 to provide a system that feels the temperature and humidity connected to the moisture level of the data sensor through the cloud through the Internet. ESP32 is a compact choice for this application. Interize operates with Wi-Fi and strong processing options. There is a dual-core processor, and it works at 240 MHz with an SRAM of 520 KB or more. Up to 16 MB of electronically erasable programmable read-only memory (EEPROM) flash memory. The ESP32 has a feature to support Wi-Fi 802.11 B/G/N in a wide Wi-Fi network area. I feel that the temperature and moisture levels of the DHT11 sensor and module are attached to the ESP32 moisture sensor. This sensor provides accurate readings. You can control the increment and real-time conditions. ESP32 is used with Wi-Fi-integrated WLANs that can send this data to the cloud. Send access and analyze in real time. This is what happened on a cloud-IoT platform within the cloud. Uses powerful processing that handles Wi-Fi ESP32 integrated with processing. You can feel the temperature, humidity, and moisture level and know how to transmit such data to the cloud dynamically in real time. Effective monitoring and detailed analysis provide real environmental status [6][7].

A servomotor is driven with control of angle, speed, and direction. It operates on pulse modulated signals (PWM) and is typically used for control valves or gates in automatic irrigation systems. The ESP32 creates a PWM signal that controls the rotation of the servo drive. With precise settings, it works from 0° to 90°. The servo motor delivers 5 V and is controlled via the GPIO pin.

The cooling fan for the ESP32 cooling fan is used to adapt the temperature of a greenhouse, storage device, or automatic farming system. The ESP32 can control the fan with a module relay or a transistor system. When the temperature sensor (DHT11 or DHT22) detects a high temperature, the ESP32 turns on the fan. The fan will be direct current for 12 days, and you will need to switch between the relay or MOSFET circuit. This provides adequate air circulation to prevent heat voltages in agricultural plants.

A servo motor pump with ESP32 is a system that controls water valves for correct irrigation of servo drives. Instead of using existing DC pumps, the servo drive controls moisture flow according to the moisture sensor; it reads data from the sensor. When the soil moisture sensor records and detects low moisture, then the ESP32 commands the servo drive to open the water valve. After the servo reaches optimal moisture, it stores water and drives valves. This system provides a controlled amount of water distribution to reduce water waste. DHT11 is used in various applications, such as frequently used, inexpensive digital temperature and moisture sensor modules; home station automation; and weather and agricultural monitoring. It has a small module, and it’s easy to use. It’s a perfect choice. Applications with limited space. He has put the capacity, moisture, and temperature sensors into accurate and reliable temperatures and moisture. DHT11 is compatible with an extensive spectrum. Microcontrollers and simple communication protocols promote integration in the project [6].

The 9V battery is a popular portable device for high energy density and long-term service life. This battery is compact for a water pump. Suitable for several other electronic components. With a power engine and a complete circuit, the system works for expansion. It does not require frequent charging. Under any circumstances there is a 9-volt power supply and a valuable battery, with the other electrons being sufficient. This means you can calculate it at a reasonable price. Plan. Accumulated batteries. Use this system. This system provides reliable and efficient performance. Soil-moisture sensors are the devices designed for measuring soil moisture content. This is usually used in agriculture and horticultural application systems to obtain the right amount of water. The higher the value of moisture content of the soil, the lower the resistance, and the same applies. Soil moisture sensors prevent excessive handling or touching of systems that can achieve lower growth and production. Simply use it to provide an accurate soil measurement by a gardener or farmer.

The I2C display is a 16x2 display, and these sensors are displayed in real time using the I2C communication protocol. It is commonly used to indicate the temperature, humidity, air humidity, and system conditions of an intellectual farming system. Communication I2C: The display is connected to the ESP32 by using only two contacts (SDA & SCL) to reduce cable complexity. Electrical requirements: Operates at 3.3 V or 5 V, so compatible with ESP32. Features: Displays real-time sensors, system notifications, and working status. Buzzers are used in agricultural systems for sensor-based warning messages. Acoustic alarms are generated when important conditions such as low soil moisture, high temperatures, or water pumps are generated. Type: Active (continuous) or manual (programming). Performance requirements: Operates at 3.3 V or 5 V and is controlled via the GPIO pin. Use: Warn if the moisture is too low (water required). Extreme temperature (high or low) warning. A full-body error or failure will be displayed. The Adapter 5V provides stable performance for ESP32 and connected components and stable operation with an intelligent agricultural IoT system. Input: Normal 240 V. 110. Conclusion: DC, 2A, or 3A 5 is sufficient to provide ESP32, sensors, and AD. Features: Convert to convert current performance to achieve constant system performance.

D. IDE (Integrated Development Environment)

Arduino IDE is a software platform that is used to program the microcontroller ESP32 in the proposed system described in this article. The Arduino IDE offers a convenient graphical interface simplified in C/C++. This allows developers to write and upload code to microcontroller boards using a C/C++-based programming language. The IDE features a code editor with functions like predefined syntax, automatic code suggestion, error isolation, code completion, testing, debugging, and more. It is also equipped with a serial debug monitor that displays real-time data. Examples can be used with various libraries, allowing developers to easily activate project features such as reading sensors, communicating with motors, and interacting with other devices. Developers can program the ESP32 using the Arduino IDE by selecting the appropriate board and port, then uploading the code via the board's USB data cable. Arduino IDE is a popular, universal platform for programming microcontrollers and is ideal for both beginners and experienced developers in various projects. This is shown in Figure 2.

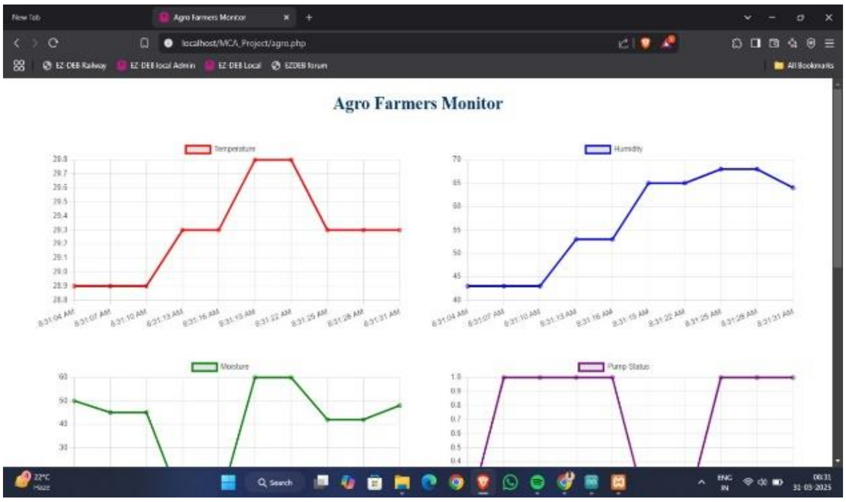


Figure 2. Web application for proposed system

XAMPP is a local web server environment where PHP scripts and MySQL databases are published, allowing HTTP processes using ESP32 to interact. This provides a connection between the ESP32 for IoT applications and the web system. Key features and usage in projects based on ESP32 include the Apache server, which hosts a PHP script that processes data from ESP32; and a MySQL database, which stores ESP32 sensor data such as temperature, air humidity, and moisture. PHP integration is used for processing ESP32 requests (data registration, command management, etc.). PhpMyAdmin serves as the web interface for recording database entries related to ESP32. ESP32 sends sensor data to PHP scripts published in XAMPP using HTTP POST requests. PHP handles MySQL queries and stores the data accordingly. ESP32 can also retrieve data from the database using PHP and HTTP requests. A web panel built with HTML and PHP is used to display sensor data and send commands back to the ESP32.

Visual Studio Code (VS Code) is a powerful editor used to create PHP scripts that interact with the ESP32. It supports the creation of web control interfaces and data management systems for IoT projects based on ESP32. Key features and usage in ESP32 projects include PHP

IntelliSense, which provides syntax suggestions, error isolation, and automatic code completion for PHP scripts. The integrated terminal allows developers to run PHP scripts directly in the XAMPP environment. Additional support for PHP servers, interfaces, and REST clients enhances development. For web development with ESP32, VS Code is used to create PHP-based APIs that can communicate with the microcontroller. It also assists in debugging and processing errors in PHP scripts before deployment. Developers create PHP scripts in VS Code to handle ESP32 HTTP requests and then deploy them in a XAMPP (localhost) environment. The ESP32 is configured to communicate with these PHP scripts to send or retrieve data. Web panels created using HTML, PHP, and JavaScript in VS Code enable remote monitoring and management of the ESP32.

1.2. Literature Review

Agriculture was revolutionized through automated irrigation and remote control of agricultural companies, carried out in real time using monitoring based on data collection sensors. Various studies have examined intellectual farming systems based on ESP32, increasing the integration of sensors, cloud platforms, weaving tax panels, and improving the efficiency of stored water and productivity. Several researchers have proposed sensor-based agricultural surveillance systems. Sharma et al. demonstrated an intelligent irrigation system based on ESP32, which reduced water consumption by 30% through automatic soil moisture monitoring and pump control [10]. Gondchawar and Kawitkar highlighted the role of temperature and humidity sensors, along with soil moisture sensors, in optimizing irrigation patterns and improving agricultural plant health [10]. Patil and Kale demonstrated increased productivity by optimizing environmental conditions through the introduction of an intellectual greenhouse with IoT support, incorporating DHT11, soil moisture sensors, and pH sensors [11]. To monitor internet-based IoT systems and web panels, one study proposed a web panel for remote monitoring and control of farm irrigation systems, communicating with PHP web servers using Wi-Fi and HTTP protocols [12]. Shinde et al. focused on storing MySQL data using XAMPP, allowing farmers to access data in real time via web applications on mobile devices [13]. The TeamSpeak and Firebase Cloud platforms have also been tested to ensure data availability and remote access by registering sensors in real time [14]. In the domain of intellectual agriculture, cloud systems and big data integration have also been explored. Kumar et al. applied machine learning (ML) to help farmers analyze weather conditions and soil moisture trends, allowing them to predict optimal irrigation patterns [15]. AI-controlled IoT solutions have been tested to identify plants based on sensors and image processing data [16]. The integration of AWS IoT and Google Firebase allowed for automated data storage and analytics to reduce manual intervention in agricultural monitoring [17]. Automation and control mechanisms using relay modules and servo drives are often employed to control water pumps, ventilation systems, and smart irrigation setups [18]. Long-range communication technologies such as LoRa and Zigbee sensors have been examined to support sustainable wireless communication in agricultural farms [19]. Solar-powered IoT devices have emerged as a solution to power ESP32 microcontrollers and sensor nodes in remote agricultural areas, enabling continuous monitoring even without electricity [20]. Despite these advances, several research gaps persist. Connectivity remains a problem, especially in distant areas where Wi-Fi or mobile networks are not stable. LoRa-based technologies have been considered a long-term solution to this challenge. Another concern is energy consumption: continuous data transmission affects the autonomous operation time of ESP32 devices, necessitating solar energy-based solutions. Additionally, most existing IoT-based smart farming systems are designed for small-scale farms, and expansion to commercial agriculture is still limited. Lastly, the security and confidentiality of data remain a challenge; strong encryption and blockchain-based solutions are necessary to protect agricultural data in cloud-based farming systems.

2. Methodology

The methodology begins with hardware setup and sensor integration. In the first step, the selected components are installed and connected. The moisture sensor is responsible for recognizing soil moisture content, while the DHT11 or DHT22 sensor measures temperature and humidity. The ESP32 microcontroller is used for data collection from these sensors. The operation and control mechanism recovery module is employed to control the water pump and cooling fan based on sensor readings. In the second step, data communication is established using the ESP32 microcontroller. It connects to a Wi-Fi network and sends the collected data to a web application. Data transmission uses IoT communication protocols, specifically HTTP (via REST API) or MQTT (when integrated with cloud systems). Sensor data is processed and stored in a MySQL database through a PHP script running on a XAMPP server. The third step involves the development of a web panel and interface for remote monitoring. A PHP-based web application extracts and displays real-time data from the sensors. The interface includes graphical elements and visualization features, such as notifications. Farmers can interact with the interface and manage settings, including manually turning the water pump or fan on or off using a web-based control button. Additionally, the system is capable of automatic decision-making. If the soil moisture level drops below the defined threshold, the system automatically activates the pump without requiring user intervention. The final step focuses on system automation and notification thresholds. When soil moisture drops below the set value, the pump is activated automatically. If the temperature exceeds the predefined limit, the cooling fan is turned on. The system also includes a notification feature to inform the user about environmental conditions.

To validate the system, a module-level test was conducted. Individual components such as the ESP32, sensors, and drives were tested independently. During integration testing, data transmission between the ESP32 and the web server was confirmed. The complete system was also deployed in a real-world environment for performance monitoring by farmers.

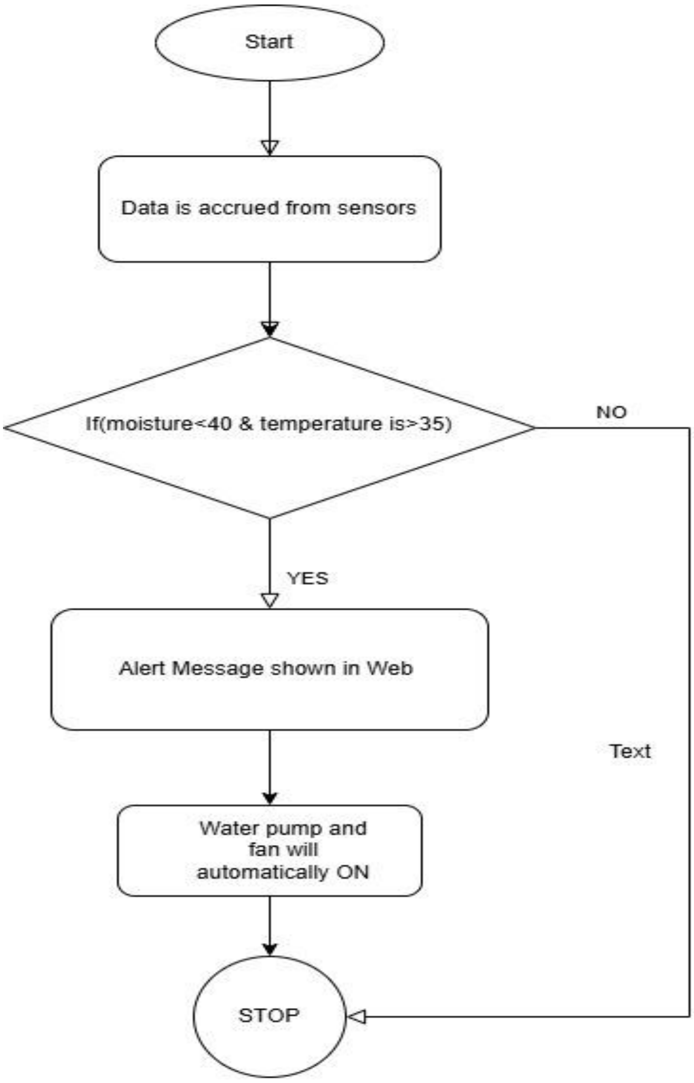


Figure 3. Flow Chart for Sensor Based Smart Agriculture Monitoring System Using

2.1 CONNECTION DIAGRAM

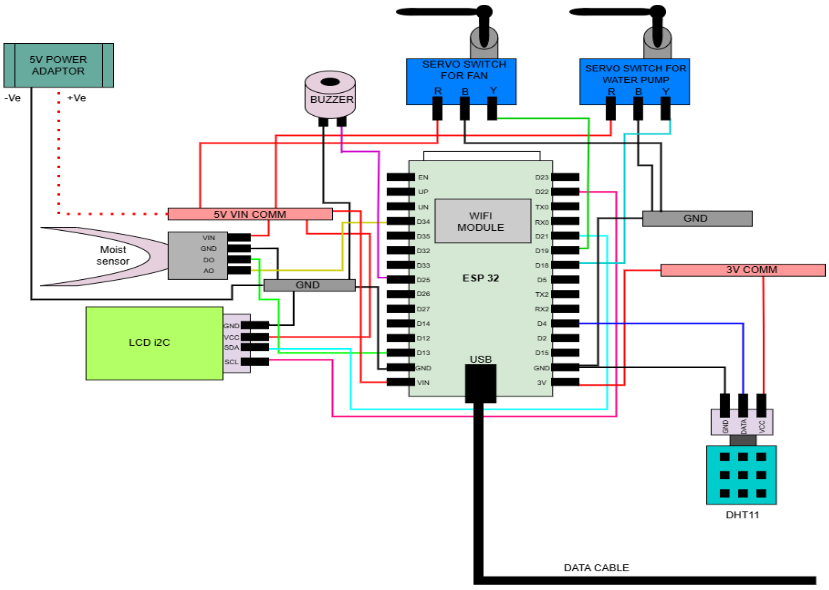


Figure 4. Connection Diagram of Sensor Based Smart Agriculture Monitoring System

3. Results and Analysis

After the real-time system was deployed, various environmental parameters were successfully monitored and controlled in real time. For instance, floor moisture levels were detected as low, prompting the system to automatically activate the water pump. Temperature and humidity data were also monitored and responded to by the system, as shown in Figure 5.


Agro Farmers Monitor

Click here to see data

Click above for Smart Agricultural Data 👈

WARNING! Make sure there is proper air for crops. The temperature is increasing.

Sensor Data & Status

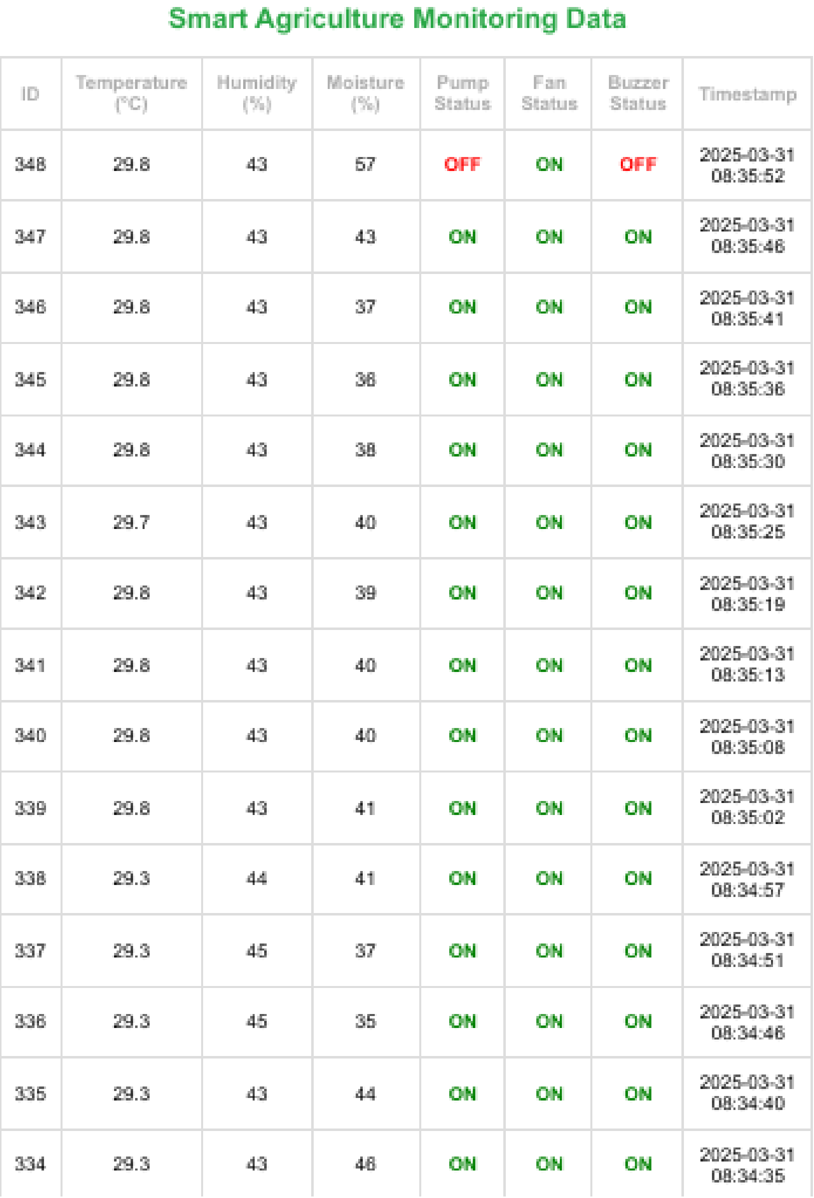
Temperature	Humidity	Moisture	Pump Status	Fan Status
29.8°C	57%	38%	OFF	ON

Click here to navigate to Agro History Analysis

Figure 5. image of graphical representation sensor data in our website

When the DHT11 sensor recorded a temperature exceeding 30°C, the cooling fan was automatically activated. Light conditions were also monitored to support accurate agricultural decision-making. The automation feature allowed for effective water pump control based on real-time soil moisture data. When the temperature surpassed a specified threshold, the cooling system was triggered to turn on the fan, thereby improving greenhouse conditions and mitigating heat-related effects.

In cases of extreme environmental conditions, summer warnings were activated by the system, enabling immediate intervention by farmers. The system also supported remote access through web panels, ensuring successful data transmission. Sensor data was sent to the PHP-MySQL server, allowing for centralized monitoring. These functionalities and sensor outputs are demonstrated in Figure 6.



Smart Agriculture Monitoring Data

ID	Temperature (°C)	Humidity (%)	Moisture (%)	Pump Status	Fan Status	Buzzer Status	Timestamp
348	29.8	43	57	OFF	ON	OFF	2025-03-31 08:35:52
347	29.8	43	43	ON	ON	ON	2025-03-31 08:35:46
346	29.8	43	37	ON	ON	ON	2025-03-31 08:35:41
345	29.8	43	36	ON	ON	ON	2025-03-31 08:35:36
344	29.8	43	38	ON	ON	ON	2025-03-31 08:35:30
343	29.7	43	40	ON	ON	ON	2025-03-31 08:35:25
342	29.8	43	39	ON	ON	ON	2025-03-31 08:35:19
341	29.8	43	40	ON	ON	ON	2025-03-31 08:35:13
340	29.8	43	40	ON	ON	ON	2025-03-31 08:35:08
339	29.8	43	41	ON	ON	ON	2025-03-31 08:35:02
338	29.3	44	41	ON	ON	ON	2025-03-31 08:34:57
337	29.3	45	37	ON	ON	ON	2025-03-31 08:34:51
336	29.3	45	35	ON	ON	ON	2025-03-31 08:34:46
335	29.3	43	44	ON	ON	ON	2025-03-31 08:34:40
334	29.3	43	46	ON	ON	ON	2025-03-31 08:34:35

Figure 6. Image of a prototype website with server data recorded in table

allowing farmers to follow the remote conditions. Automation to Control Users: Farmers were able to manually control irrigation and ventilation via web panels. Graphic Data Visualization: The system provides diagrams and magazines to easily analyze agricultural conditions over time. Here are the mentions of all components that are using this monitoring figure 7.

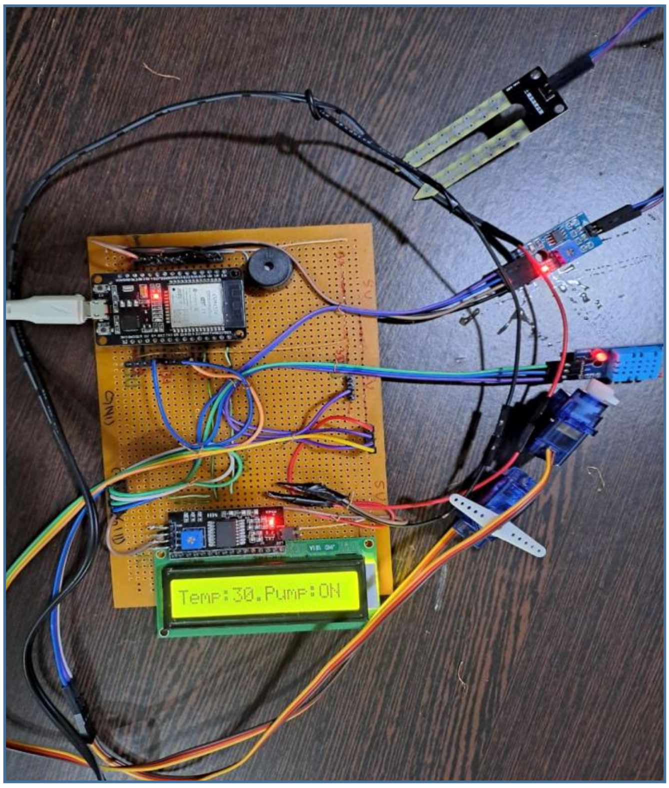


Figure 7. Image of prototype

4. Discussion

The IoT-based monitoring efficiency system provided real-time information on humidity and temperature, enabling farmers to make informed decisions based on actual environmental data. The automation of irrigation and ventilation significantly reduced water and electricity consumption. In terms of system performance, the ESP32 microcontroller demonstrated accuracy and quick response in processing sensor data and executing control commands. Table 1 presents a comparison between traditional farming practices and the IoT-based smart farming system. Parameters such as water usage, labor requirements, data availability, and system efficiency illustrate the advantages of the proposed approach.

Table 1 Comparison with Traditional Farming

Parameter	Traditional Farming	IoT-Based Smart Farming
Water Usage	High (Manual Irrigation)	Optimized (Automated Control)
Labor Requirement	High (Manual Monitoring)	Reduced (Remote Access)
Data Monitoring	No Real-Time Data	Continuous Sensor Data
System Efficiency	Low	High (Data-Driven)
Response Time	Delayed Actions	Instant Alerts & Control

4.1 Future of Sensor-Based Smart Agriculture Monitoring System

The future of IoT-based intellectual agriculture includes advancements in automation, artificial intelligence (AI), communication technology, and stable energy solutions. Some key areas of development include AI-controlled agricultural predictive analytics, where historical data is used to predict crop diseases, irrigation patterns, and weather conditions. Machine learning models will optimize responses based on soil health data. Image processing and intelligent chambers may be used for the automatic detection of pests. The integration of 5G technology in IoT communication aims to overcome the limitations of Wi-Fi, enabling broader farm surveillance. Edge computing (extreme calculation) will allow local processing of sensor data before it is sent to the cloud, improving response speed. Blockchain technology will enhance data security for farm records, weather logs, market analytics, and harvest protection. Automation will further advance through smart irrigation systems based on real-time moisture data, enabling precise nutrient delivery. AI-controlled systems can dynamically adjust inputs according to plant requirements. Robotics and drones will assist in monitoring plant health using thermal imaging, enabling weed detection and reducing the use of chemical insecticides. IoT-based automated harvesting systems like Evengrad will support seamless harvesting. Renewable energy sources such as wind and hybrid systems will power ESP32-based IoT devices and sensors for large-scale automated farms. Mobile application integration with voice assistants (like Alexa or Google Assistant) will provide real-time irrigation updates, temperature alerts, and weather forecasts. AI-based supply chain forecasting will assist in market price optimization, enabling farmers to make informed selling decisions. Blockchain-based smart contracts will support secure and direct farm-to-market transactions, while IoT-enabled logistics will facilitate real-time tracking in storage and distribution.

4.2 Challenges and Limitations

Several challenges hinder the adoption of smart agriculture. One major issue is the high initial cost of deploying IoT sensors, cloud services, and web infrastructure. Rural areas often face poor internet connectivity, which affects real-time monitoring and data transmission. IoT sensors require regular calibration and maintenance to ensure accurate data collection. Cybersecurity remains a concern, as these devices are vulnerable to hacking and data breaches. The complexity of handling large sensor datasets demands substantial memory, processing power, and analytics infrastructure. Limited technical expertise among farmers can also hinder effective deployment and troubleshooting of IoT systems. In remote regions, inconsistent power availability may affect continuous operation. Environmental factors such as extreme weather can degrade sensor accuracy and lifespan. There are additional limitations. The system's reliance on continuous internet connectivity and cloud services can result in data loss or delayed responses during outages. IoT devices powered by batteries require frequent recharging or replacement, reducing autonomy. Expanding the system for commercial-scale farming can be costly and technically challenging. Compatibility issues between diverse IoT platforms complicate integration efforts. Sensor accuracy may also be influenced by environmental variables like dust, humidity, and temperature fluctuations. Lastly, concerns over data confidentiality and ownership may prevent farmers from sharing valuable agricultural data, and dependence on external service providers introduces further vulnerability.

5. Conclusion

A system that monitors intellectual agricultural infrastructure using Web and IoT successfully integrates the ESP32 microcontroller, sensors, and web panels to optimize agricultural operations. Automation in irrigation, environmental monitoring, and remote control improves operational efficiency, reduces water loss, and enhances cultural management. The main performance indicators of the system include moisture, temperature, humidity, soil moisture, air humidity, and light resistance. The system enables automatic irrigation and ventilation, which reduces manual labor and improves water resource utilization. A web panel for remote control allows farmers to make informed decisions based on real-time data. Immediate alerts and notifications ensure timely actions under critical environmental conditions. Despite limitations related to Wi-Fi connectivity and energy consumption, the system demonstrated high efficiency and accuracy. Future enhancements, such as the integration of LoRa communication, AI-controlled forecasting, and mobile application interfaces, could further expand the system's capabilities. Overall, the solution supports sustainable agriculture, precision farming, and the development of intelligent agricultural practices through the application of Internet of Things technologies.

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