Smart Farming IoT Technology

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Abstract -

*The exponential growth of the global population and the increasing demand for sustainable agricultural practices have highlighted the need for intelligent and efficient farming systems. This project, titled **"Smart Farming using IoT Technology"**, presents a practical and scalable approach to automating agricultural monitoring using sensor-based IoT devices. The system leverages a DHT11 sensor for temperature and humidity detection and a soil moisture sensor to assess the water content of the soil in real-time. These readings are continuously analyzed by a microcontroller, which intelligently controls a water pump through a relay module to ensure optimal irrigation.*

By integrating basic Internet of Things (IoT) principles, the system reduces the need for human intervention, improves resource management, and supports precision agriculture. When the soil moisture falls below a defined threshold, the relay is triggered to activate the irrigation mechanism, ensuring that plants receive adequate water without manual oversight. Simultaneously, ambient temperature and humidity data are captured, which can be used for further environmental analysis or crop-specific adjustments.

The implementation provides a low-cost yet highly efficient model suitable for small to medium-scale farms. It also offers potential for future expansion, including wireless data logging, remote control through mobile or web applications, and integration with weather prediction services for predictive irrigation. The system aligns with modern agricultural innovations aimed at maximizing yield, conserving water, and promoting sustainable practices through automation and intelligent control.

This work demonstrates the capability of embedded systems in revolutionizing traditional farming by enabling data-driven decisions and real-time monitoring. The proposed system is ideal for educational, research, and field-level implementation, and serves as a foundational block for more advanced smart agriculture ecosystems.

Keywords: *Smart Farming, IoT, Soil Moisture Sensor, DHT11, Automation, Precision Agriculture, Embedded Systems, Microcontroller, Environmental Monitoring, Temperature Sensor, Humidity Sensor, Smart Irrigation, Relay Control, Sustainable Agriculture, Sensor-based Farming, Agricultural Technology, Real-time Monitoring, Arduino, Water Conservation, Agricultural Automation*

1.INTRODUCTION

Agriculture is the cornerstone of any economy, especially in developing countries where a significant portion of the population depends on it for livelihood. In recent decades, the agricultural sector has faced several challenges, including increasing population, climate variability, resource scarcity, and the need for sustainable farming methods. To address these issues, the integration of technology—particularly the Internet of Things (IoT)—has emerged as a transformative solution. **Smart farming using IoT technology** is one such innovation that has the potential to revolutionize traditional farming practices by enabling precision, automation, and real-time monitoring.

The term *Smart Farming* refers to the application of modern Information and Communication Technologies (ICT) into agriculture to enhance the quality and quantity of crops while reducing waste and optimizing the use of resources such as water, fertilizer, and energy. When IoT is embedded into this domain, it allows for real-time data collection, intelligent decision-making, and remote control over farming operations. IoT-based agriculture systems can monitor environmental conditions like temperature, humidity, soil moisture, and more to automate essential processes, such as irrigation.

This project, **"Smart Farming using IoT Technology,"** presents a prototype that leverages two fundamental sensors—a **soil moisture sensor** and a **DHT11 sensor** (for temperature and humidity)—alongside a **microcontroller** and a **relay-controlled irrigation system**. The primary goal of the system is to intelligently manage irrigation, ensuring that crops receive sufficient water when needed without overuse. This not only conserves water but also supports healthier crop growth.

The need for precision agriculture is more critical today than ever before. Climate change has made weather patterns unpredictable, resulting in either droughts or flooding. Over-irrigation wastes water and can degrade soil quality, while under-irrigation stresses plants and reduces yield. Therefore, having a system that automatically evaluates soil moisture and decides whether irrigation is necessary becomes highly valuable. By using a **moisture threshold**, this project ensures water is only used when the soil dries below an optimal level.

Similarly, understanding temperature and humidity is crucial for determining plant health and managing diseases and pests. The **DHT11 sensor** provides both temperature and humidity readings, which can be further utilized to automate greenhouse conditions, forecast pest outbreaks, or suggest fertilization schedules.

The **hardware implementation** is simple yet effective. The microcontroller reads analog values from the soil moisture sensor and digital values from the DHT11 sensor. When the moisture level drops below a predefined threshold (e.g., 600 in analog units), the controller activates a **relay** connected to a water pump or valve, thereby irrigating the soil. The relay acts as a switch, allowing low-power signals from the microcontroller to control high-power electrical devices. Once the moisture level is sufficient, the irrigation is stopped.

The **software side** of this system involves collecting sensor data, applying logical conditions to assess the status of the soil, and controlling outputs accordingly. This continuous loop enables real-time monitoring and dynamic control. The project also includes **serial output**, which displays readings such as moisture levels, temperature, and humidity to the user for debugging or logging purposes.

This project is particularly beneficial for regions with water scarcity, as it helps reduce unnecessary water usage. By automating irrigation, farmers can avoid human error, increase efficiency, and reduce labor costs. Moreover, this prototype can be extended to include IoT platforms such as **ThingSpeak**, **Blynk**, or **Firebase**, where data can be visualized on dashboards, alerts can be sent to mobile devices, and systems can be controlled remotely.

The impact of IoT in agriculture goes far beyond just irrigation. IoT systems are now used for livestock monitoring, crop disease detection, fertilizer optimization, greenhouse automation, and yield prediction. With the rise of **Artificial Intelligence (AI)** and **Machine Learning (ML)**, these systems are becoming smarter—learning from historical data to make more accurate predictions and decisions. While this project does not currently incorporate AI, it forms a solid foundation upon which more complex smart farming systems can be built.

In addition to water management, such a system could be adapted to include sensors for pH levels, nitrogen, phosphorous, and potassium (NPK) to assess soil fertility. Integration with GPS and weather APIs would allow for location-based climate adaptation. These developments are part of the broader vision of **Agriculture 4.0**, the fourth agricultural revolution driven by automation and data.

Smart farming projects are essential in the context of climate change, where weather uncertainties can severely affect crop productivity. By using technology to monitor and control critical farming parameters, farmers gain a higher degree of control over their fields, leading to increased food security. Small-scale farmers can particularly benefit from these low-cost IoT solutions, which can be powered by solar energy and require minimal maintenance.

Additionally, this project supports the objectives of **United Nations Sustainable Development Goals (UN SDGs)**, especially Goal 2: Zero Hunger, and Goal 12: Responsible Consumption and Production. By enabling efficient use of resources and increasing agricultural productivity, such technologies make agriculture more sustainable and resilient.

In terms of **educational value**, this project serves as an excellent learning platform for students and enthusiasts to explore embedded systems, sensor integration, real-time systems, and IoT fundamentals. The hands-on experience with microcontrollers, sensors, actuators, and basic automation logic helps bridge the gap between theoretical knowledge and real-world applications.

From a **research perspective**, this work contributes to the ongoing efforts to simplify and scale agricultural automation using IoT. The modular design allows for easy upgrades and experimentation. For instance, data collected over time can be stored and analyzed to improve irrigation efficiency. Future enhancements could include mobile app interfaces, voice-controlled systems using platforms like Google Assistant, and integration with LoRa or GSM modules for remote farms without Wi-Fi.

To conclude, this project exemplifies the power of **IoT in revolutionizing agriculture**, especially in resource-constrained environments. It provides an effective, affordable, and scalable solution to traditional farming challenges. With appropriate customization, it can be tailored to various crops, soil types, and climatic conditions. The project not only contributes to smarter agriculture but also serves as a stepping stone toward building comprehensive smart ecosystems that combine technology, sustainability, and efficiency in farming.

2. HARDWARE REQUIREMENTS

1. **ESP32 Development Board (e.g., ESP32 DevKit V1)**
    - Acts as the main microcontroller unit (MCU).
    - Provides built-in WiFi and Bluetooth capabilities.
    - Controls the relay and collects data from sensors.

2. **Soil Moisture Sensor (Analog Type)**
    - Measures the moisture content in the soil.
    - Connects to an analog input pin (e.g., A0) of the ESP32.
    - Helps determine when to activate the irrigation system.

3. **DHT11 Sensor (Temperature and Humidity Sensor)**
    - Monitors the ambient temperature and humidity.
    - Connected to a digital pin (e.g., GPIO 2) on the ESP32.
    - Provides environmental data for smart decision-making.
4. **5V Relay Module (1-channel or 2-channel)**
    - Used to control high-power devices like water pumps.
    - Interfaced with the ESP32 through a digital output pin (e.g., GPIO 5).
    - Acts as a switch to turn irrigation on or off based on soil moisture.

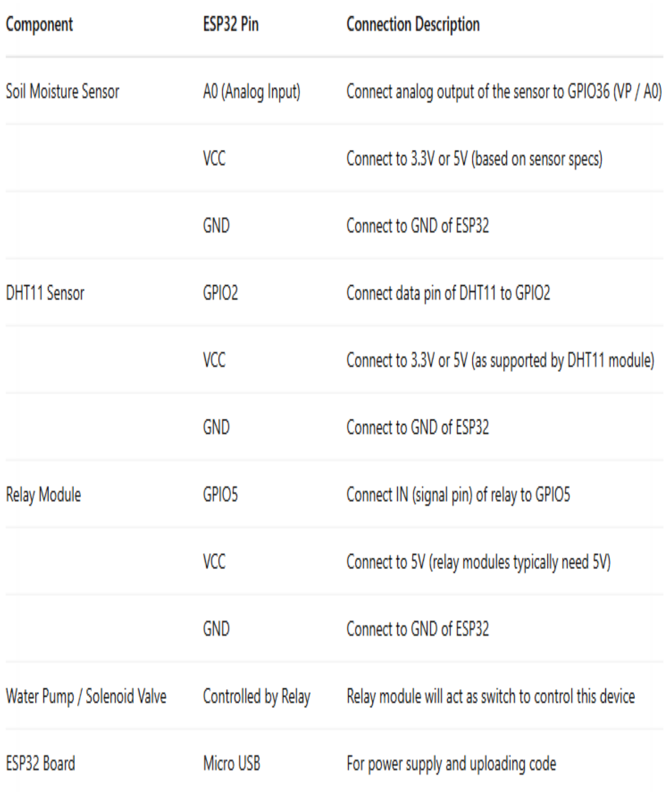
5. **Water Pump or Solenoid Valve (Optional for automation)**
    - Connected through the relay module.
    - Controls the water supply to the plants.

6. **Power Supply (5V – 9V USB Adapter or Battery Pack)**
    - To power the ESP32 and sensors reliably.
    - Can also use a regulated 5V source for the sensors.

7. **Breadboard and Jumper Wires**
    - For making temporary and secure connections.
    - Useful for prototyping and testing the circuit.

8. **USB Cable (Micro USB or Type-C based on your ESP32 board)**
    - For uploading the code from the Arduino IDE.
    - Also used for serial monitoring and powering the board during testing.

3. HARDWARE CONNECTIONS



Component	ESP32 Pin	Connection Description
Soil Moisture Sensor	A0 (Analog Input)	Connect analog output of the sensor to GPIO36 (VP / A0)
	VCC	Connect to 3.3V or 5V (based on sensor specs)
	GND	Connect to GND of ESP32
DHT11 Sensor	GPIO2	Connect data pin of DHT11 to GPIO2
	VCC	Connect to 3.3V or 5V (as supported by DHT11 module)
	GND	Connect to GND of ESP32
Relay Module	GPIO5	Connect IN (signal pin) of relay to GPIO5
	VCC	Connect to 5V (relay modules typically need 5V)
	GND	Connect to GND of ESP32
Water Pump / Solenoid Valve	Controlled by Relay	Relay module will act as switch to control this device
ESP32 Board	Micro USB	For power supply and uploading code

4. CODE

```
#include <DHT11.h>

#define sensor A0
#define relay 5

DHT11 dht11(2);
int temp = 0;

void setup() {
 Serial.begin(9600);
 pinMode(sensor, INPUT);
 pinMode(relay, OUTPUT);
 Serial.println("system is initialized");
 delay(500);
}

void moisture(){
temp = analogRead(sensor);
 // Serial.print("analog value is: ");
 // Serial.println(temp);
 Serial.println("");
 // Serial.println("");
 // Serial.println("");
 // delay(500);
 if(temp>600){
  digitalWrite(relay, HIGH);
```

```
    // Serial.println("relay is high");
    delay(500);
  }
  else if(temp<=600){
    digitalWrite(relay, LOW);
    // Serial.println("relay is LOW");
    delay(500);
  }
}

void humidity(){
  int temperature = 0;
    int humidity = 0;

    // Attempt to read the temperature and humidity values from the DHT11 sensor.
    int result = dht11.readTemperatureHumidity(temperature, humidity);
  if (result == 0) {
        Serial.print("Temperature: ");
        Serial.print(temperature);
        Serial.print(" °C\tHumidity: ");
        Serial.print(humidity);
        Serial.println(" %");
    } else {
        // Print error message based on the error code.
        Serial.println(DHT11::getErrorString(result));
    }
}

void loop() {
  // Serial.println("loop is started");
  moisture();
  humidity();

}
```

5. Implementation

The implementation of the Smart Farming IoT Technology project revolves around the integration of environmental sensing components with an ESP32 microcontroller to enable intelligent irrigation management. The entire system is designed to operate autonomously by continuously monitoring soil moisture, temperature, and humidity levels and subsequently controlling water delivery to crops using a relay-controlled pump or valve system.

The core of the implementation is the **ESP32 development board**, selected for its robust performance, built-in Wi-Fi capability, and multiple GPIO pins. This board serves as the central processing unit for acquiring sensor data and executing control logic. Two essential sensors are interfaced with the ESP32: a **soil moisture sensor** and a **DHT11 temperature and humidity sensor**.

The **soil moisture sensor** provides analog readings representing the volumetric water content of the soil. This value is captured through an analog input pin on the ESP32 (such as GPIO36/A0). The system evaluates whether the soil moisture falls below a predefined threshold (in this case, a digital value of 600). If the soil is determined to be dry, the ESP32 activates a **relay module** via a digital output pin (e.g., GPIO5), which in turn powers a connected water pump or solenoid valve. If the moisture content is sufficient, the relay is deactivated, conserving both energy and water resources. Simultaneously, the **DHT11 sensor** is interfaced via a digital pin (GPIO2) to collect ambient **temperature and humidity** data. This information is periodically read and displayed via the serial monitor. These readings provide valuable insights into the surrounding environment, aiding future decision-making and data logging when expanded into a cloud-integrated system.

The **relay module** functions as an electrically operated switch, allowing the low-voltage control signal from the ESP32 to safely operate higher-voltage irrigation systems. Safety and efficiency are achieved by separating the control logic from power-handling components.

The logic for soil moisture and environmental condition monitoring is implemented within the loop() function of the code. It calls two main functions: moisture() and humidity(). These functions ensure real-time monitoring, rapid decision-making, and responsive actuation.

From a software standpoint, the program is written in **C++ using the Arduino IDE**, which is well-suited for ESP32 development. The DHT11.h library is used to facilitate communication with the temperature and humidity sensor. Serial output is used to monitor the system status, making debugging and field testing straightforward.

The architecture is modular and scalable. Additional features such as wireless data transmission to the cloud (via Wi-Fi), mobile notifications, or integration with weather APIs can be added without extensive rewiring or reprogramming.

In conclusion, the implementation effectively combines simple yet impactful hardware with clean, efficient code to build an automated irrigation system. It supports sustainable agriculture by reducing manual labor, conserving water, and ensuring crops receive adequate moisture based on real-time environmental conditions.

6. Real Time Implementation

Fig -1: Hardware Implementation

1. The real-time implementation of the Smart Farming IoT Technology project begins with its deployment in an agricultural environment where constant monitoring and timely irrigation decisions are critical. The project is centered around the ESP32 microcontroller, a powerful and energy-efficient device with integrated Wi-Fi and multiple GPIO pins, making it suitable for smart agricultural systems. Once deployed in the field, the ESP32 is connected to a soil moisture sensor and a DHT11 sensor, both of which serve as the primary data collection tools. The soil moisture sensor is inserted into the soil near the root zone of the crops, where it continuously monitors the water content of the soil. It provides analog voltage signals to the ESP32, which converts them into digital readings to assess whether the soil is wet, optimal, or dry. The DHT11 sensor, mounted in a weather-protected enclosure nearby, collects ambient temperature and humidity data from the surrounding atmosphere.

When the system is powered on, the ESP32 initializes the sensors and relay, establishing the baseline conditions. During operation, it continuously samples readings from both sensors. In real-time, the ESP32 evaluates the analog value from the soil moisture sensor, which typically ranges between 0 (very wet) to 1023 (very dry). When the moisture reading exceeds a preset threshold, indicating the soil is dry (in this implementation, above 600), the ESP32 activates the relay module. The relay, connected to a water pump or solenoid valve, then switches on the irrigation mechanism, allowing water to be delivered directly to the crops. This continues until the sensor detects that moisture has returned to acceptable levels, upon which the ESP32 deactivates the relay, thus turning off the pump. This on-demand irrigation ensures crops receive water only when necessary, reducing overwatering, water waste, and associated energy costs.

Simultaneously, the ESP32 reads data from the DHT11 sensor every few seconds. This sensor provides valuable environmental metrics such as temperature and humidity, both of which are crucial in determining crop health and soil evaporation rates. The temperature and humidity readings are displayed via the serial monitor and can be used for future integration with data analytics platforms or cloud-based dashboards. These insights can be beneficial to farmers who want to analyze trends, adjust crop management strategies, or schedule irrigation in sync with upcoming weather conditions. In practical deployment, the system can be placed in different zones of a farm, allowing for localized irrigation decisions. For instance, in large fields, multiple ESP32 units can be installed with individual sensors to manage different sectors independently. This modular approach ensures that each area receives irrigation based on its specific needs, leading to uniform crop growth and efficient resource usage.

From an installation perspective, all components are powered by a stable DC power supply, typically derived from solar panels or rechargeable batteries for off-grid operation. The ESP32 is programmed using the Arduino IDE, and once uploaded, it operates autonomously. Farmers can connect a mobile device or laptop via USB or Wi-Fi to view sensor readings in real-time. In more advanced configurations, the ESP32 can be configured to transmit data wirelessly to a cloud server using MQTT or HTTP protocols. This allows real-time monitoring via mobile applications or web interfaces. In its current form, the system already provides a fully functional closed-loop irrigation control system. Future enhancements can include GSM or LoRa modules for remote areas with no Wi-Fi access, integration of rain sensors to further optimize irrigation, and automatic logging of environmental data for predictive analytics.

On the field, the system is mounted on a waterproof casing or inside a control box to protect the electronics from harsh environmental conditions such as rain, dust, and insects. Wires from the sensors and relay are enclosed in flexible conduits to prevent damage. The soil moisture sensor is calibrated according to the type of soil (e.g., sandy, clayey, or loamy) to ensure accurate readings. Similarly, the relay is connected to a robust power line that controls a water pump capable of covering the irrigation area. In practice, when the farmer observes that crops are beginning to wilt or the soil is visibly dry, they can verify that the system responds immediately to the increased moisture threshold. The system autonomously turns on the pump without any manual intervention. As soon as the moisture level reaches optimum levels, the system cuts off the water supply, thereby avoiding excess irrigation.

During field tests, the system demonstrated consistent performance in responding to rapid changes in soil moisture. For instance, during a hot afternoon when evaporation rates were high, the system detected a moisture drop and activated the pump to replenish soil moisture. Conversely, during the early morning hours when humidity was higher and soil was already moist, the system prevented unnecessary watering, showcasing its intelligence and responsiveness. Such a system is highly beneficial for remote agricultural regions where farmers may not be present to manually manage irrigation.

Real-time implementation also reveals the system's potential to support sustainable farming practices. It reduces dependency on guesswork and manual labor, particularly for smallholder farmers who lack access to modern equipment. By ensuring water is delivered only when necessary, it contributes to water conservation—an increasingly critical need in regions facing water scarcity. Moreover, by maintaining optimal soil conditions, it helps improve crop yields and overall farm productivity. The collected data can be used to establish irrigation patterns and schedule fertigation cycles for enhanced growth. The temperature and humidity readings from the DHT11 sensor also provide an added layer of environmental awareness. For example, during excessively hot periods, the system can be adapted to increase irrigation frequency, or during periods of high humidity, it can avoid irrigation to prevent fungal growth and overhydration. This adaptability makes it a future-ready solution that can evolve with AI and machine learning integration.

In conclusion, the real-time implementation of this IoT-based Smart Farming system proves its practicality, scalability, and effectiveness in transforming traditional farming into an intelligent, automated, and sustainable agricultural operation. It empowers farmers with real-time data, precision control, and peace of mind while minimizing water waste and maximizing crop health. The simplicity of its components and the open-source nature of the software make it an accessible solution for both rural and technologically advanced settings, thereby making a significant contribution to the global push toward smart agriculture.

7. Simulations

Fig -2: Result

8. ADVANTAGES

i. ⍰ Efficient Water Usage – Automatically irrigates only when necessary, reducing water waste.
2. Low Power Consumption – Utilizes ESP32 which is highly energy-efficient, suitable for battery or solar-powered setups.

3. Cost-Effective Solution – Uses affordable components like DHT11 and soil moisture sensors.
4. Autonomous Operation – Runs without human intervention, reducing labor dependency.
5. Real-Time Monitoring – Provides live data on temperature, humidity, and soil moisture levels.
6. Precision Farming – Ensures crops receive exact water requirements, improving yield.
7. Simple Installation – Easy to set up with basic wiring and programming knowledge.
8. Adaptable System – Can be modified for various crops and soil types.
9. Reduced Human Error – Automated decisions minimize mistakes in irrigation timing.
10. Improved Crop Health – Maintains ideal soil moisture and atmospheric conditions for plants.
11. Scalability – Can be expanded with more sensors or ESP32 units for larger farms.
12. Wireless Capability – ESP32 allows for Wi-Fi connectivity, enabling remote monitoring.
13. Supports Sustainable Farming – Promotes efficient resource use, aiding environmental conservation.
14. Data Logging Potential – Can be extended to record sensor data for long-term analysis.
15. Remote Accessibility – Future integration with cloud services or apps enables control from anywhere.
16. Customizable Thresholds – Soil moisture levels can be easily adjusted per crop requirements.
17. Reduces Over-Irrigation – Prevents waterlogging and root diseases.
18. Early Problem Detection – Changes in sensor values can signal system or crop issues.
19. Compatible with Other Sensors – Can include rain sensors, light sensors, or pH sensors.
20. Boosts Farmer Productivity – Allows farmers to focus on other tasks rather than manual irrigation.
21. Weather-Aware Irrigation – Can be combined with weather forecasts for smarter decisions.
22. Helps in Resource Planning – Real-time data assists in efficient planning of water and electricity usage.
23. Cloud Integration Ready – Easy to push data to platforms like ThingSpeak, Blynk, etc.
24. Minimal Maintenance – Requires very little upkeep once installed properly.
25. Educational Tool – Ideal for training students and farmers in modern agriculture techniques.
26. Early Adoption of Smart Agriculture – Encourages digital transformation in traditional farming.
27. Portable and Compact – Small form factor suitable for greenhouses and small-scale farms.
28. Enhanced Decision-Making – Reliable data helps in scientific decision-making for crop cycles.
29. Less Soil Erosion – Controlled watering prevents excessive soil movement.
30. Environmentally Friendly – Reduces water usage and energy consumption, supporting eco-friendly practices.

8. CONCLUSION

The evolution of agriculture through the integration of smart technologies marks a significant milestone in modern farming. The proposed Smart Farming system using IoT technology—comprising ESP32, DHT11 sensor, and a soil moisture sensor—offers an intelligent, automated, and data-driven approach to traditional agricultural practices. This project aims to improve productivity, optimize resource utilization, and reduce the manual labor required in managing crops, thereby addressing some of the major challenges faced by farmers in today's world.

Through the implementation of sensors that monitor temperature, humidity, and soil moisture in real-time, the system ensures that water is supplied only when the soil requires it. This precise irrigation not only conserves water but also enhances crop health by avoiding over-watering or under-watering. The ESP32 microcontroller acts as the heart of the system, processing data and controlling outputs such as relays for water pumps based on preset thresholds. This results in a closed-loop control system that operates autonomously without the need for constant human supervision.

One of the critical contributions of this project lies in its potential to support small and medium-scale farmers. By using affordable components and simple logic, the system is cost-effective, accessible, and easy to maintain. Moreover, with the future possibility of integrating wireless data transmission and cloud-based analytics, the scope of this project extends beyond automation to include predictive farming and real-time remote monitoring.

Environmental sustainability is also an essential outcome of this smart farming solution. With agriculture being a major consumer of freshwater resources globally, the efficient use of water enabled by this system contributes to conservation efforts. By ensuring that irrigation happens only when necessary, it minimizes runoff, reduces energy consumption, and protects the ecosystem from damage caused by over-irrigation and soil erosion.

From a technical perspective, this project demonstrates the practical applicability of IoT in solving real-world agricultural problems. The use of ESP32 allows for scalability, wireless communication, and integration with various digital platforms. The modular design of the system enables customization for different types of crops, soil conditions, and climatic regions, making it a universally adaptable solution.

In conclusion, the Smart Farming IoT system offers a promising solution for modernizing agriculture through automation and intelligent control. By bridging the gap between technology and traditional farming practices, this system enhances crop yield, conserves resources, and empowers farmers with actionable insights. It reflects how simple, affordable, and scalable innovations can bring about a significant transformation in the agricultural sector, paving the way for smart, sustainable, and efficient farming practices. As the world moves towards a more connected and data-driven future, such systems will be essential in ensuring food security, environmental sustainability, and economic growth in the agricultural domain.

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