IoT - Driven Wireless Sensor Network for Precision Agriculture Monitoring

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ABSTRACT

Agriculture, a foundational element of human civilization, is increasingly challenged by climate variability, resource constraints, and the demand for higher efficiency. Traditional farming practices often lack the real-time data necessary for optimal resource management, leading to inefficiencies and lower yields. This paper presents the design and development of an intelligent agricultural environment monitoring system that leverages Wireless Sensor Networks (WSNs) and the Internet of Things (IoT). The proposed system deploys low-cost, energy-efficient sensor nodes across agricultural fields to enable continuous monitoring of critical environmental parameters. By delivering real-time, actionable insights, the system supports data-driven decision-making in key areas such as irrigation scheduling, nutrient application, and pest control. The ultimate goal is to enhance crop productivity, reduce input wastage, minimize environmental impact, and pave the way toward more sustainable and resilient farming practices.

Keywords: IoT, Wireless Sensor Network, Optimal Resource Management.

1. INTRODUCTION

Agriculture continues to be a vital component of many national economies and plays a crucial role in ensuring global food security. Despite its importance, conventional farming methods often struggle with challenges such as erratic weather patterns, suboptimal irrigation, and inefficient resource utilization. These limitations can result in decreased crop productivity and unnecessary consumption of essential inputs like water and energy. To address these issues, technological advancements—particularly the integration of Wireless Sensor Networks (WSNs) and the Internet of Things (IoT)—have paved the way for more intelligent and efficient farming solutions.

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Agriculture Environment Monitoring System using Wireless Sensor Network and IoT aims to deliver continuous, real-time environmental data critical to crop health management. The system employs various sensors and components, including the DHT11 for monitoring temperature and humidity, the MQ-135 for assessing air quality, the RTC 2321 for precise timekeeping, and the ESP8266 Wi-Fi module for wireless data transmission. These inputs enable responsive actions through actuators such as a DC fan, a 9V water pump with a sprinkler mechanism, and a 60W bulb, creating a semi-automated system that helps maintain ideal growing conditions.

An Arduino Uno serves as the core controller, coordinating the operation and interfacing with LCD and I2C modules for real-time data visualization. This setup reduces manual effort and allows remote monitoring, thereby increasing efficiency and promoting sustainable farming. The project showcases how affordable and widely available components can be effectively combined to develop a smart, scalable agricultural monitoring system capable of addressing key challenges in modern farming.

BLOCK DIAGRAM OF PROPOSED SYSTEM

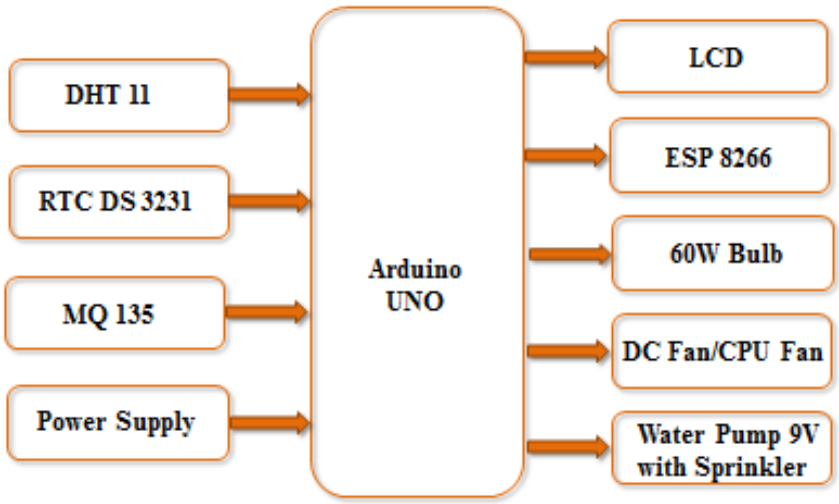

Figure 1: Block Diagram

2. INTERNET OF THINGS

The Internet of Things (IoT) is instrumental in modernizing traditional agriculture by enabling smart and automated farming solutions. In this project, IoT technology facilitates continuous environmental monitoring, remote system control, and data-informed decision-

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making to maintain ideal conditions for plant growth. The integration of sensors with a microcontroller, paired with internet connectivity via the ESP8266 Wi-Fi module, allows for constant collection and transmission of environmental parameters such as temperature, humidity, and air quality to an online platform.

This connected infrastructure offers numerous benefits. Farmers can access real-time data through mobile applications or web-based interfaces from any location, making it easier to identify and respond quickly to adverse conditions like extreme heat or deteriorating air quality. In addition, the system supports automatic activation of devices—such as fans or water pumps—based on sensor readings or remote user inputs.

IoT connectivity also enables data storage and historical analysis, which are crucial for recognizing long-term patterns and improving farm management strategies. For example, analysing trends in temperature and humidity over time can guide irrigation scheduling or help predict pest outbreaks. Overall, the use of IoT elevates the system from a basic monitoring tool to a smart agricultural platform that enhances operational efficiency, conserves essential resources, and supports healthier crop development through intelligent automation.

3. DHT11

The DHT11 sensor plays a vital role in this agricultural monitoring system by measuring two essential environmental variables: temperature and humidity. These elements have a direct impact on plant development, soil moisture retention, and overall crop vitality. Known for its digital output and sufficient accuracy, the DHT11 is an ideal choice for cost-effective and energy-efficient embedded applications like this one.

Within the setup, the DHT11 is connected to the Arduino Uno microcontroller, which reads the sensor data at regular intervals. Temperature readings help determine if the environment is outside the optimal range for plant growth, prompting automated responses such as turning on a cooling fan or activating a heat source like a 60W bulb when necessary. Humidity data is used to monitor atmospheric moisture; if levels drop too low, the system can automatically activate the water pump and sprinkler to restore appropriate conditions, which is particularly useful in indoor or controlled farming environments.

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The sensor uses a single-wire digital communication interface, simplifying its connection with the microcontroller. Its low energy usage makes it well-suited for long-duration operation, even in remote or solar-powered installations. In addition to immediate control of actuators, the sensor data is transmitted online through the IoT module, allowing for remote access and long-term data logging. This enables farmers to observe environmental trends over time, leading to more informed decisions about irrigation planning, crop management, and pest prevention strategies.

4. EXISTING SYSTEM

Conventional farming methods largely depend on manual observation to monitor environmental factors like temperature, humidity, and soil moisture. Farmers often rely on experience and occasional field checks to make decisions related to irrigation, pest control, and ventilation. Although this approach has been used for generations, it is labor-intensive, susceptible to errors, and lacks the accuracy required to meet the needs of modern agriculture. The absence of real-time insights can result in suboptimal resource utilization, lower crop productivity, and delayed responses to changing environmental conditions.

In recent times, basic sensor-based systems have been introduced to aid monitoring efforts. These typically involve standalone instruments that measure individual variables such as temperature or soil moisture. However, many of these systems still depend on manual data retrieval and lack connectivity features. Without automation or remote access, these setups continue to require considerable manual effort to interpret the data and implement corrective actions, which reduces their suitability for extensive or remote agricultural operations.

Although advanced commercial smart farming solutions are available, they often come with high costs and require specialized technical knowledge, making them impractical for small and medium-sized farmers. These systems may support IoT integration and cloud-based monitoring, but their affordability and adaptability remain a barrier in rural or low-resource settings. Recognizing this gap, the present project proposes a cost-effective, user-friendly, and automated agricultural monitoring system. Utilizing accessible components like the Arduino Uno, ESP8266 Wi-Fi module, and various sensors and actuators, this solution offers a scalable and practical approach for improving farming efficiency and sustainability.

5. PROPOSED SYSTEM

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Agriculture Environment Monitoring System using Wireless Sensor Network and IoT is designed to offer a fully automated and real-time monitoring solution for agricultural environments. The system incorporates sensors such as the DHT11 for measuring temperature and humidity, and the MQ-135 for assessing air quality, enabling continuous and accurate data collection. This sensor data is managed by an Arduino Uno microcontroller, which processes inputs and triggers responses based on predefined environmental thresholds. A local LCD display, interfaced through an I2C module, provides real-time updates to the farmer on-site.

Beyond data acquisition, the system integrates automated control functionalities to improve agricultural efficiency. When environmental conditions exceed acceptable limits, actuators—including a DC fan, a 9V water pump equipped with a sprinkler, and a 60W heating bulb—are automatically activated to restore favorable conditions. An RTC 2321 module is incorporated to facilitate time-based operations such as scheduled irrigation and ventilation. For remote accessibility, the ESP8266 Wi-Fi module enables farmers to monitor and control field conditions via smartphones or computers.

The emphasis of this system is on affordability, scalability, and ease of use, making it a practical solution for small and medium-sized farming operations. By reducing dependency on manual labor, optimizing input usage, and maintaining optimal crop conditions, this project supports a more sustainable approach to agriculture. It exemplifies how wireless communication, automation, and real-time monitoring can converge to deliver an intelligent farming solution that is both accessible and effective.

6. RESULT & DISCUSSIONS

The developed Agriculture Environment Monitoring System, incorporating Wireless Sensor Network and IoT technologies, effectively automates climate regulation and irrigation activities by relying on real-time environmental data. The system employs the DHT11 sensor to detect temperature and humidity conditions, which are then transmitted to the cloud through the ESP8266 Wi-Fi module. This live data is uploaded to the ThingSpeak platform for continuous monitoring.

A notable benefit of the system is its ability to provide remote access to environmental data. Farmers can conveniently track temperature and humidity levels using a mobile device through a specific ThingSpeak link, enabling constant supervision and analysis

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without the need for on-site presence.

The system operates based on well-defined control logic:

- When the temperature rises above 40°C or humidity surpasses 90%, the DC fan is automatically activated to enhance airflow and alleviate heat or excessive moisture, thereby protecting plant health.
- If the temperature falls below 28°C, a 60W bulb is switched on to generate additional heat, creating a more suitable growing environment.
- In situations where neither condition is met, the system continues to monitor sensor data at two-minute intervals. Once a predefined condition is satisfied, the 9V water pump with sprinkler is triggered to provide timely irrigation.

This intelligent control mechanism ensures optimal growing conditions are maintained with minimal human intervention. By activating components only when necessary, the system promotes energy conservation and efficient resource use. Furthermore, with real-time data updates and remote access through the IoT cloud, the setup offers enhanced convenience and reliability, aligning well with the requirements of modern, technology-driven agriculture.

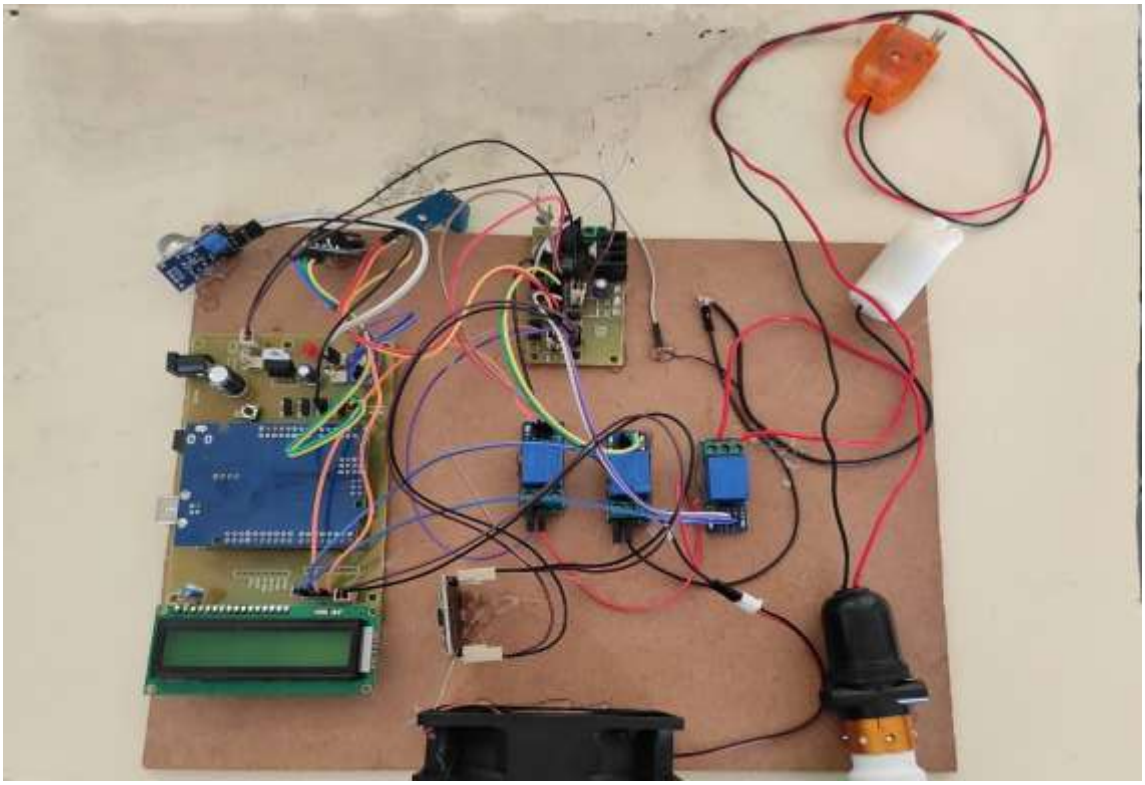

Figure 2: Experimental Setup

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7. CONCLUSION

The Agriculture Environment Monitoring System, powered by Wireless Sensor Network and IoT technologies, demonstrates the potential of integrating modern innovations into conventional farming practices. It incorporates sensors such as the DHT11, MQ-135, and RTC DS3231 to monitor critical environmental parameters in real time. Automated functions—including irrigation, climate regulation through a fan and heating bulb, and real-time data display via an LCD—contribute to improved operational efficiency. The ESP8266 Wi-Fi module facilitates remote monitoring and control, while the Arduino Uno serves as the central controller for the entire system. Designed to be scalable and budget-friendly, this solution minimizes manual effort, promotes resource efficiency, and encourages sustainable agricultural practices, particularly in rural or hard-to-reach areas.

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