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Sustainable Farming in Rural India: An IoT-Based Approach for Optimized Irrigation and Crop Health Management

Anirudha B G Somayaji, **Dr. Jothimani K**

II MCA, Department of Master of Computer Applications, Vivekananda College of Engineering and Technology Puttur, India

Professor, Department of Master of Computer Applications, Vivekananda College of Engineering and Technology Puttur, India

ABSTRACT: In recent years, the increasing pressures on agriculture and growing concerns about water scarcity have highlighted the urgent need for sustainable water management practices in India. Agriculture consumes a substantial share of the country's water resources, yet inefficiencies in water management result in significant waste. This study introduces an innovative IoT-based crop monitoring system aimed at optimizing water usage in agriculture. By leveraging real-time data, this system seeks to improve water efficiency and minimize waste. The proposed solution holds the potential to foster more sustainable agricultural practices, ensuring that water resources are managed effectively to meet the rising demands for food production.

KEYWORDS: Agricultural sector, Crop monitoring system, Internet of Things, Microcontroller, Sensors.

I. INTRODUCTION

Water is essential for agriculture, especially in India, where the sector is a cornerstone of the economy. Agriculture consumes 80-90% of the country's freshwater resources, yet around 60% of this water is wasted due to inefficient irrigation and poor water management. This inefficiency contributes to India's significant water stress, as the country holds only 4% of the world's freshwater to support 18% of the global population. The overuse of groundwater, particularly in Punjab and Haryana, exacerbates the crisis, threatening agricultural sustainability.

To combat these challenges, innovative solutions are needed. This paper presents an IoT-based crop monitoring system designed to improve water efficiency and reduce waste. By delivering real-time data on soil moisture, weather, and crop water needs, the system empowers farmers to make better irrigation decisions, thereby conserving water and boosting crop yields. This technology not only supports water conservation but also promotes sustainable agricultural practices across India.

A. Objectives

The proposed work aims to achieve three key objectives. Firstly, it focuses on accurately assessing water quality, particularly pH levels, to ensure optimal conditions for crop irrigation, thereby promoting enhanced agricultural yields and sustainable water resource management. Secondly, the research leverages the Blynk platform to provide real-time monitoring and alerts on critical factors such as soil moisture, temperature, humidity, and water quality, enabling farmers to make data-driven decisions. Lastly, the project seeks to implement cost-effective IoT-based solutions for continuous monitoring of crop health and fertility, with the goal of improving productivity while minimizing resource use.

II. RELATED WORKS

The related works section discusses several significant studies that focus on the challenges encountered by farmers in Karnataka, as well as the strategies proposed to overcome these obstacles and promote agricultural sustainability.

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Vijay Kumar Hemappa Manegar and his team explore the myriad challenges faced by farmers in Karnataka, stressing the critical need for solutions to enhance agricultural conditions. Their comprehensive analysis examines initiatives such as the establishment of regulated marketplaces and the development of remote storage facilities as potential remedies. The authors offer valuable insights into both the difficulties confronting farmers and the measures being implemented to address them, providing fresh perspectives on the intricate agricultural landscape in Karnataka [1].

A notable advancement in precision irrigation is the development of an IoT-based smart water management platform. This platform is designed to create efficient business models and architectural layers that optimize water usage in agriculture. By utilizing sensor data, conducting analysis, and enabling real-time decision-making, the platform seeks to improve water distribution management and boost the overall efficiency of agricultural systems [2].

The implementation of sensor networks and IoT technology in precision agriculture is thoroughly examined in research focusing on wireless sensor networks. This study investigates the monitoring of environmental factors such as temperature, humidity, and soil moisture on small-scale farms, while also addressing the challenges associated with deploying such networks in agricultural contexts [3].

Anupama and colleagues discuss a proposed IoT-based system for smart farming that emphasizes water management. This system integrates various components connected to an Arduino UNO board and a Wi-Fi module, offering intelligent irrigation and farming solutions, particularly in regions with scarce water resources [4].

Another study delves into the integration of IoT and machine learning for soil monitoring and fertility testing, aimed at improving crop prediction and yield. The proposed system utilizes sensors to measure soil nutrients, stores the data in a database, and employs ML algorithms to analyze soil types and suggest suitable crops, thus promoting smart farming practices [5].

Research by Mohammed Ameenul Hasan and colleagues emphasizes the importance of soil testing in agriculture and the role of IoT and sensors in creating a cost-effective Site-Specific Nutrient Management system. This system is designed to enhance productivity, protect the environment, and reduce costs and energy consumption in farming [6].

Muthumanickam Dhanaraju and his team emphasize the advantages of smart farming, particularly in the conservation of water resources in agriculture. Their study highlights the application of IoT technologies in implementing controlled and efficient irrigation systems, enabling farmers to optimize water usage and achieve significant environmental and economic benefits [7].

III. PROPOSED SYSTEM

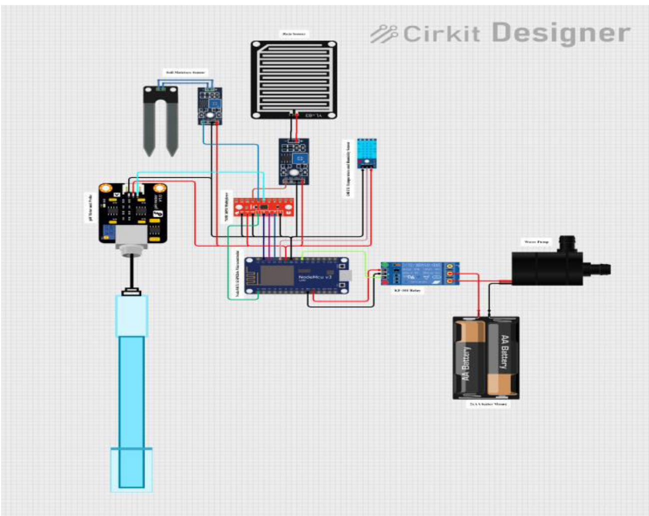

Fig1. Circuit Diagram of the Experiment

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The proposed IoT-based crop monitoring system is designed to collect crucial data including soil moisture levels, rainfall occurrence, water pH value, temperature, and humidity. The system integrates various components with a NodeMCU ESP8266 microcontroller to achieve this:

- **Soil Moisture Sensor:** Monitors the moisture content in the soil.
- **Rain Sensor:** Detects and records the occurrence of rainfall.
- **pH Meter:** Measures the pH levels of the water used for irrigation to ensure suitability for crops.
- **DHT11 Temperature and Humidity Sensor:** Captures real-time data on the ambient temperature and humidity levels.
- **NodeMCU ESP8266 Microcontroller:** Serves as the core processing unit, coordinating data collection and processing from all connected sensors.

A. System Setup

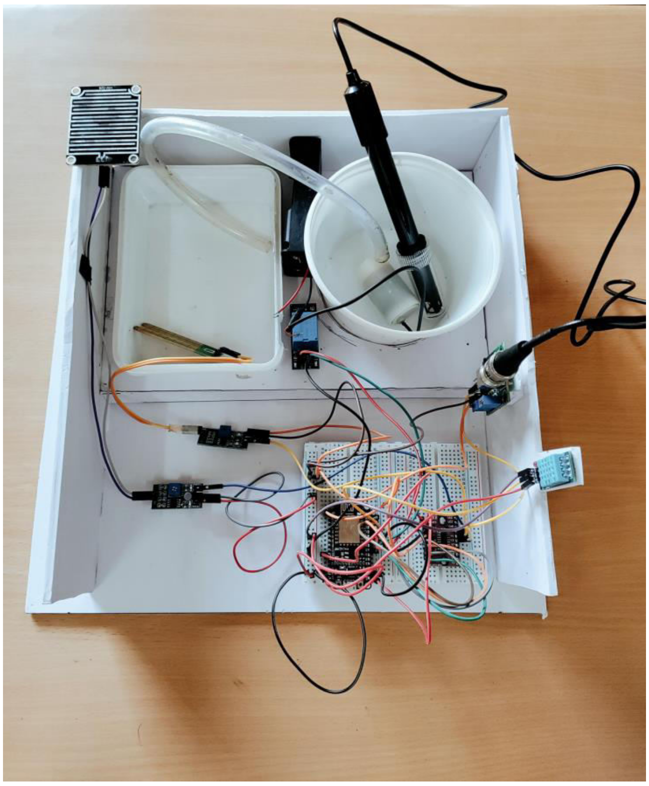

Fig2. Diagrammatic View of the Experiment

The system setup is divided into two primary components: an agricultural field represented by a tray and a water storage system represented by a small tank.

- **Water Storage (Tank):**
- **pH Sensor:** Installed within the water tank to continuously monitor the pH levels of the water.
- **Water Pump:** Situated inside the tank, it is responsible for pumping water to the field as required.
- **Agricultural Field (Tray):**
- **Soil Moisture Sensor:** Embedded in the soil within the tray to track moisture levels.
- **Rain Sensor:** Positioned adjacent to the field to detect the occurrence of rain.
- **Temperature and Humidity Sensor (DHT11):** Placed near the field to measure and record temperature and humidity.
- **NodeMCU ESP8266 Microcontroller:** Located nearby to collect and process data from all the sensors.

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IV. METHODOLOGY

The implementation of the proposed IoT-based crop monitoring system was carried out through several methodical stages to ensure optimal performance. The process began with an in-depth analysis of the system requirements to identify the essential hardware components. The necessary components, including soil moisture sensors, a rain sensor, the DHT11 temperature and humidity sensor, a pH sensor, the NodeMCU ESP8266 microcontroller, a CJMCU-4051 8 Channel Analog Multiplexer/De-multiplexer Breakout Board, a mini water pump with a relay module, a breadboard, and jumper wires, were then assembled and connected according to the system design.

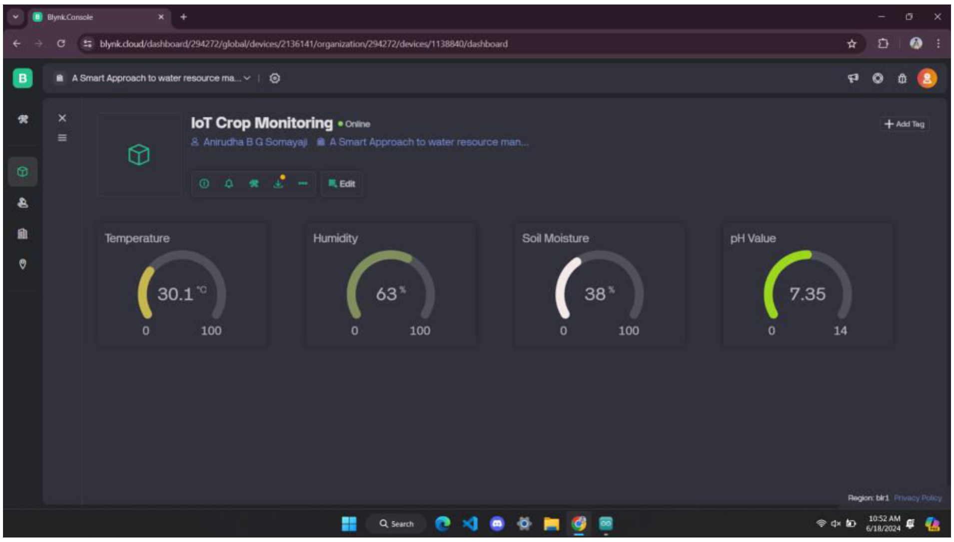

Fig3. Blynk Web Application

Subsequently, the system was integrated with the Blynk platform to facilitate real-time data transmission and notifications, as shown in Figure 3. The system's operation begins with the rain sensor detecting rainfall. If rain is detected, the system promptly alerts the user; if not, it proceeds to assess the soil moisture levels. When the moisture content falls below a user-defined threshold, the system notifies the user and then evaluates the water's pH content. If the soil moisture is adequate, no further action is taken.

The system then measures the water's pH level. If the pH falls within the ideal range of 6.0 to 8.0, the water pump is activated to irrigate the crops. Should the pH value deviate from this range, the system alerts the user about the pH levels. This sequence of operations empowers farmers with real-time data, enabling informed decisions that can significantly enhance crop yield and productivity.

V. RESULTS AND DISCUSSION

The IoT-based crop monitoring system successfully integrated sensors, microcontrollers, and the Blynk platform, resulting in significant improvements in agricultural management and productivity. The system offered continuous rain intensity monitoring to enhance irrigation practices, aiding in water conservation and preventing overwatering. Soil moisture levels were closely monitored, with alerts triggered when thresholds were exceeded, enabling proactive soil management. Real-time pH monitoring of water quality ensured optimal conditions for irrigation, with immediate notifications facilitating timely corrective actions. Table I provides a summary of the system's comprehensive outcomes.

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Important Parameters	Results		
	Criteria	**Expected Result**	**Outcome**
Rain Intensity	Below Threshold	Soil Moisture Content Analysis	Soil Moisture Content Analysis
	Above Threshold	Pump is off	Pump is off
Soil Moisture Content	Below Threshold	Alert the user, pH Content Analysis	Alert the user, pH Content Analysis
	Above Threshold	Pump is off	Pump is off
pH Content in Water	Above 8.0	Alert the user about alkalinity, pump stays off	Alert the user about alkalinity, pump stays off
	Below 6.0	Alert the user about acidity, pump stays off	Alert the user about acidity, pump stays off
	Between 6.0 - 8.0	Watering the plants	Watering the plants

Apart from overseeing temperature and humidity, the system furnished crucial information for well-informed crop planning and resource distribution. The Blynk platform improved remote monitoring capabilities and overall system usability by enabling real-time notifications on ambient conditions, soil moisture, and water quality.

The IoT technology demonstrated dependable functionality by providing precise sensor measurements and smooth data transfer. It successfully solved the main issues that farmers in rural India faced, such as controlling soil health, adjusting to climate unpredictability, and maximising irrigation. The study emphasised how IoT technologies might help promote resource management, economic resilience, and sustainable agriculture practices. The hands-on training in sensor integration and data management highlighted the revolutionary influence of IoT in advancing environmental sustainability and modernising farming techniques.

VI. CONCLUSION

The implementation of the IoT-based crop monitoring system has demonstrated significant advancements in agricultural management and productivity. By integrating sensors, microcontrollers, and the Blynk platform, the system has effectively addressed key challenges in irrigation and soil management. Continuous monitoring of rain intensity, soil moisture, and water pH levels has allowed for optimized irrigation practices, improved soil health, and better water quality management.

The system's ability to provide real-time alerts and notifications has empowered farmers to make informed decisions and take timely corrective actions. The data-driven approach facilitated by this IoT system has proven to be a valuable tool in adapting to climate variability and promoting sustainable agricultural practices.

Overall, the research underscores the transformative potential of IoT technologies in modernizing agriculture. By enhancing resource management and supporting sustainable practices, the system contributes to improved productivity and economic resilience for farmers. The practical experience gained through sensor integration and data management further highlights the role of IoT in advancing agricultural practices and fostering environmental sustainability. Future work may explore additional features and technologies to further enhance the capabilities of such systems and address emerging agricultural challenges.

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