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Smart Crop Recommendation Using IoT Sensor for Precision Agriculture

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Abstract

This study addresses precision agriculture, which leverages modern technologies to enhance farming efficiency and sustainability. This study proposes a Smart Crop Recommendation System using IoT sensors to optimize crop selection based on real-time environmental conditions. The system integrates multiple sensors, including a temperature sensor, flame sensor, soil sensor, moisture sensor, and LDR sensor, to monitor crucial parameters such as temperature, soil moisture, light intensity, and fire hazards. An Arduino microcontroller processes sensor data, while an LCD display (16×2 lines) provides real-time feedback. The NodeMCU module enables wireless data transmission to an IoT-based cloud platform, allowing remote monitoring and analysis. A buzzer alerts farmers to critical environmental changes, ensuring timely intervention. The collected data is analyzed to recommend suitable crops, promoting optimal resource utilization, increased productivity, and sustainable farming. This IoT-powered system provides data-driven insights for precision agriculture, reducing manual effort and enhancing decision-making for improved crop yield and farm management.

Keywords: IoT, smart farming, precision agriculture, crop recommendation, sensors, Arduino, NodeMCU, real-time monitoring

INTRODUCTION

Agriculture is a fundamental sector that ensures global food security and economic stability. However, with the growing population and climate change effects, conventional farming methods are becoming less effective in maintaining sustainable agricultural productivity [1]. Precision agriculture (PA) is an innovative approach that integrates modern technologies such as the Internet of Things (IoT), machine learning (ML), and big data analytics to optimize agricultural processes [2].

The adoption of IoT-based precision agriculture enables real-time monitoring of soil conditions, weather parameters, and crop health, thereby facilitating data-driven decision-making for farmers [3]. Various IoT sensors, including temperature, moisture, soil pH, and light sensors, provide continuous environmental data, which helps in selecting the most suitable crop for cultivation [4].

Several studies have focused on implementing IoT in agriculture. Islam *et al.* developed an IoT-based crop recommendation system that uses machine learning (ML) algorithms for crop selection based on soil parameters [1]. Similarly, Kankara *et al.* proposed an Arduino and NodeMCU-based system that monitors soil conditions and recommends crops through a cloud-based data processing framework [2]. Despite significant advancements, existing methods face multiple challenges**,** which hinder their practical implementation on a large scale.

To address the challenges, this work aims to develop an advanced IoT-based crop recommendation system with improved sensor

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integration, cost-effective components, and a real-time alert mechanism. Unlike existing solutions, this system will incorporate power-efficient microcontrollers, multiple sensors (temperature, moisture, soil pH, LDR, flame, and gas sensors), and a real-time monitoring dashboard.

By leveraging NodeMCU, Arduino, and cloud-based IoT platforms, farmers will have remote access to real-time farm data, ensuring better decision-making for crop selection and resource optimization. Additionally, a buzzer alert mechanism will notify farmers about potential fire hazards and extreme weather conditions, preventing crop damage.

OBJECTIVES

The main objectives of this research are:

1. To develop a smart IoT-based crop recommendation system integrating multiple sensors (temperature, soil moisture, pH, LDR, flame, etc.).
2. To implement a real-time monitoring dashboard that provides remote access to soil and environmental conditions.
3. To enhance data accuracy using machine learning algorithms for better crop recommendations.
4. To reduce operational costs by using low-power IoT components (Arduino, NodeMCU).
5. To incorporate a buzzer alert system for real-time notifications on extreme weather conditions or fire hazards.

The key contributions of this study are:

- An IoT-based system integrating six different sensors (temperature, moisture, pH, flame, LDR, and gas sensors) for comprehensive farm monitoring.
- A cloud-connected crop recommendation model using machine learning algorithms for enhanced decision-making.
- A cost-effective microcontroller-based implementation utilizing Arduino and NodeMCU, making the system suitable for small-scale farmers.
- A real-time monitoring and alert system, which includes buzzer-based notifications for emergency alerts.
- A comparative analysis of various IoT communication protocols to select the most efficient and reliable option for rural deployment.

The study is organized as follows: The following Sections review related literature on IoT-based precision agriculture and crop recommendation systems; information about existing system; describe the proposed system architecture, including hardware components and IoT communication methods; show the implementation of the circuit; discuss the simulation setup and results; and the last Section concludes the study, providing insights into the future directions of research.

RELATED WORKS

Islam *et al*. developed an IoT-based system integrating soil moisture, temperature, and pH sensors to recommend suitable crops. They used machine learning (ML) algorithms for analysis and achieved a higher accuracy in crop selection [1].

Kankara *et al*. implemented an Arduino and NodeMCU-based crop suggestion system. The study emphasized real-time soil parameter monitoring and cloud-based data processing for remote access [2].

Atalla *et al*. proposed an IoT-enabled precision agriculture model that utilizes wireless sensor networks (WSN) to transmit soil condition data. Their approach optimized water and fertilizer usage [3].

Niranjan *et al.* designed a smart agriculture framework using temperature, humidity, and moisture sensors. They integrated decision support systems (DSS) and AI-based analytics for enhanced crop yield prediction [4].

Saleem *et al*. focused on an automated crop selection system using deep learning models. IoT sensors captured real-time field conditions, and ML classified crops based on historical climate data [5].

Fauziah *et al.* explored the role of soil nutrient analysis in smart farming. They used Arduino Uno and an ESP8266 Wi-Fi module for data logging and remote monitoring via a mobile application [6].

Kannan introduced an AI-based crop recommendation approach that merged IoT sensor data with big data analytics. The study highlighted data processing challenges and sensor calibration issues [7].

Xing *et al*. developed a GIS-integrated IoT framework for region-specific crop recommendations. They combined satellite imagery, IoT data, and ML models for improved accuracy [8].

Manimegalai *et al.* investigated LDR and moisture sensor-based precision irrigation for sustainable farming. Their study reduced water wastage by 30% while maintaining optimal crop health [9].

Almalki *et al*. proposed a low-cost smart farming solution using Arduino, LCD displays, and NodeMCU. They focused on fire detection and soil health monitoring with real-time alerts [10].

García *et al*. designed a smart greenhouse system with automated irrigation and climate control. Their approach used DHT11 sensors for temperature regulation and improved crop growth [11].

Kalyani and Collier integrated IoT and edge computing to process real-time crop data at the field level. Their method reduced latency and dependency on cloud services [12].

Wagner implemented deep reinforcement learning for smart crop rotation and selection. They achieved 15% higher crop yield compared to traditional ML approaches [13].

Akhigbe *et al.* focused on IoT-based pest and disease detection for early intervention. They used image processing techniques on leaf samples to prevent major losses [14].

Sajib *et al*. demonstrated a solar-powered IoT sensor network for sustainable farming. They ensured continuous monitoring without reliance on grid power [15].

Ibrahim *et al*. emphasized wireless data transmission using LoRaWAN for large farms. They enhanced data accuracy and reduced energy consumption in remote agricultural areas [16].

Senoo *et al.* developed a real-time IoT dashboard for farmers to access crop suggestions. They provided personalized recommendations based on soil and weather conditions [17].

Kalyani *et al*. proposed an IoT-cloud hybrid system for smart agriculture. They integrated AWS IoT Core for scalability and security in agricultural data transmission [18].

Zhang *et al*. used multi-sensor fusion techniques to improve crop suitability analysis. Their hybrid model combined ML and expert knowledge for better decision-making [19].

Dhanya and Geethalakshmi designed a buzzer-alert system for extreme climate conditions. Farmers received early warnings for frost, heatwaves, and soil degradation via IoT notifications [20].

EXISTING SYSTEM

- Crop selection and field management in traditional farming methods are based on manual observation and traditional agricultural practices.
- Frequently without real-time soil and environmental condition monitoring, farmers base their judgments on past data, seasonal patterns, and experience.

- Simple soil testing kits or recurring weather forecasts are used by some sophisticated systems, although these methods lack automation, real-time data processing, and remote accessibility.

PROPOSED METHOD

In this study, ‘The Smart Crop Recommendation System using IoT Sensors for Precision Agriculture’ is an advanced solution designed to optimize farming by integrating real-time environmental monitoring and automated decision-making. The system utilizes a power supply to ensure stable operation of various sensors, including a temperature sensor (DHT11 or LM35) for measuring ambient temperature, a flame sensor to detect fire hazards, a soil sensor to analyze soil pH and nutrient levels, a moisture sensor (YL69 or FC-28) to monitor soil water content, and an LDR sensor to measure sunlight intensity. These sensors continuously collect data, which is processed by an Arduino microcontroller, acting as the central unit to analyze field conditions and determine the most suitable crops for cultivation. A buzzer provides alerts for critical conditions like fire detection or extreme dryness, while an LCD display (16×2) shows real-time sensor values and recommended actions. Additionally, the system integrates NodeMCU (ESP8266) to enable IoT connectivity, transmitting data to cloud platforms such as Blynk or ThingSpeak, allowing farmers to remotely monitor field conditions via a mobile app or web interface. The smart system not only recommends optimal crops based on soil and climate conditions but also ensures efficient water management, hazard detection, and farm safety, ultimately enhancing crop yield and sustainability. By leveraging IoT and automation, this system provides a cost-effective, scalable, and data-driven approach to modern precision farming. The proposed method is shown in Figure 1.

Power Supply

- Provides the necessary voltage and current to the sensors, Arduino, NodeMCU, and display units. Typically, a 5 or 12 V DC power supply is used for stable operation.

Temperature Sensor

- Measures the ambient temperature to determine suitable crop-growing conditions. Example: DHT11 or LM35 sensor.
- Helps in selecting crops that thrive at specific temperature ranges (Figure 2).

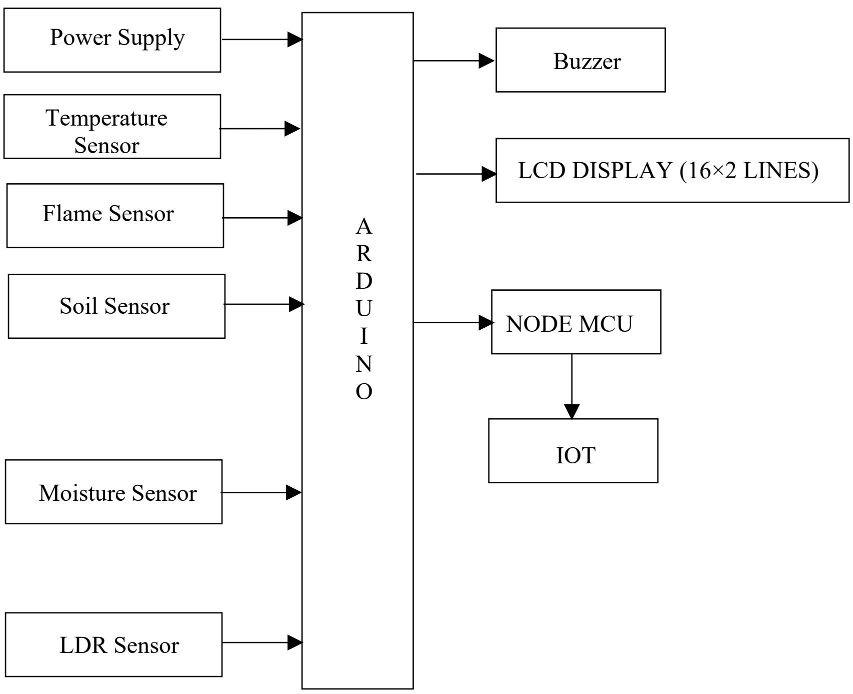

Figure 1. Proposed method.

Flame Sensor
- Detects fire hazards in the field.
- Helps in preventing crop damage due to unexpected fires.
- Sends an alert if fire is detected, activating the buzzer for warnings (Figure 3).

Soil Sensor
- Measures soil pH and nutrient levels (Nitrogen, Phosphorus, Potassium (NPK)).
- Helps in recommending fertilizers for soil improvement. Example: NPK soil sensor.

Moisture Sensor
- Measures the water content in the soil.
- Helps in automated irrigation control and crop selection. Example: YL69 or FC-28 soil moisture sensor (Figure 4).

LDR Sensor (Light Dependent Resistor)
- Detects the amount of **s**unlight available.
- Determines if the field receives enough sunlight for optimal plant growth.
- Helps in selecting crops based on light requirements (Figure 5).

Arduino (Microcontroller)
- Acts as the central processing unit (CPU).
- Collects data from all sensors and processes it.
- Controls buzzer, LCD display, and transmits data to NodeMCU (Figure 6).

Buzzer
- Provides alerts for conditions like fire detection, extreme temperature, or low moisture.
- Helps in preventing damage to crops.

LCD Display (16×2)
- Displays real-time sensor data such as temperature, soil moisture, and recommended crops.
- Provides local monitoring for farmers without internet access.

NodeMCU (ESP8266)
- Enables IoT connectivity by sending sensor data to cloud platforms.
- Allows farmers to remotely monitor field conditions via a smartphone or computer (Figure 7).

IoT Integration
- Uses cloud storage and mobile applications to provide real-time data access. Platforms like Blynk, ThingSpeak, or Ubidots can be used for visualization.
- Enables automated decision-making and crop recommendations based on sensor data (Figure 8).

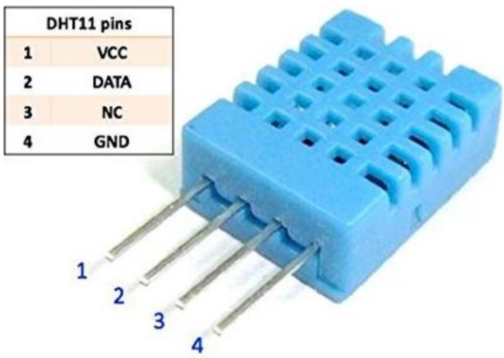

Figure 2. Temperature sensor.

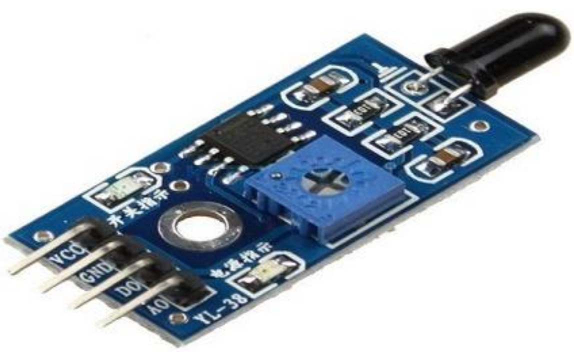

Figure 3. Flame sensor.

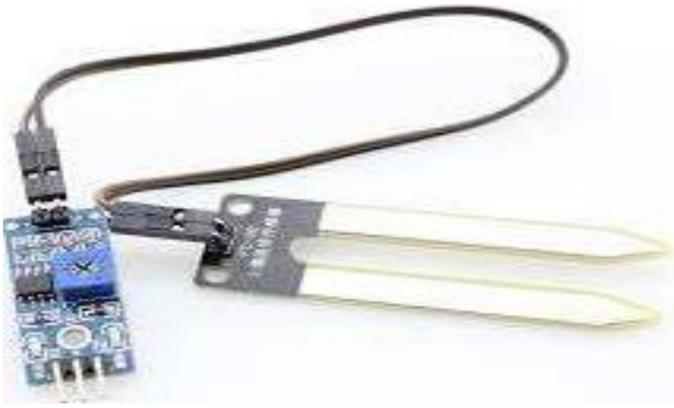

Figure 4. Soil moisture sensor.

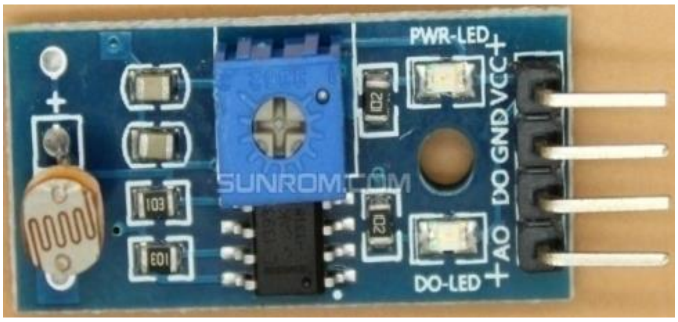

Figure 5. LDR sensor.

Figure 6. Arduino microcontroller.

Figure 7. Node MCU.

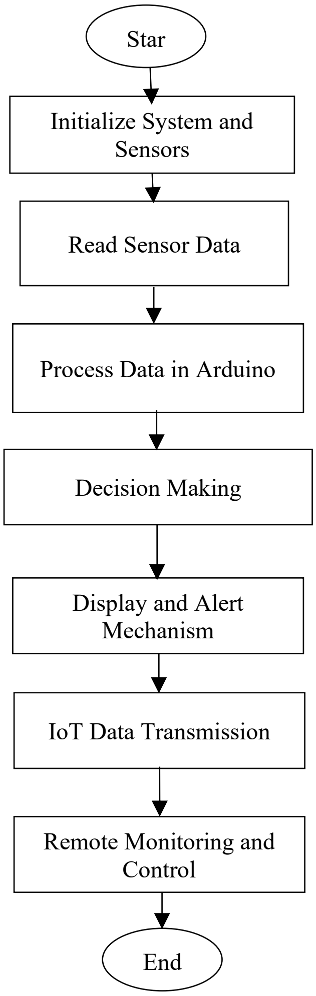

Figure 8. Implementation flow chart of proposed method.

IMPLEMENTATION

The flowchart in Figure 8 outlines the step-by-step process of how the Smart Crop Recommendation System works, integrating IoT sensors, data processing, and remote monitoring for precision agriculture.

Start

The system begins by initializing all components; ensuring power is supplied to the microcontroller, sensors, LCD display, buzzer, and IoT module (NodeMCU).

Initialize System and Sensors

The power supply activates the system and ensures all sensors are operational. Sensors like temperature, moisture, pH, light, and fire detection are initialized and start collecting data.

Read Sensor Data

The system continuously monitors environmental and soil parameters by gathering data from: Temperature sensor (measures ambient temperature); Moisture sensor (checks soil water content); Soil sensor (measures pH and nutrient levels); LDR sensor (analyzes sunlight intensity); and Flame sensor (detects fire hazards).

Process Data in Arduino

The Arduino microcontroller collects sensor values and compares them against predefined thresholds. It processes the data to determine the suitability of the soil and environment for different crops.

Decision Making

Based on the analyzed data, the system makes decisions:

- If conditions match optimal ranges, the system recommends suitable crops. If conditions are unfavorable (e.g., low moisture, extreme heat, or fire detection), alerts are triggered.

Display and Alert Mechanism

- *LCD Display (16×2):* Shows real-time sensor values and recommended crops.
- *Buzzer:* Activated if hazards like fire or drought are detected.

IoT Data Transmission

The NodeMCU (ESP8266) module sends real-time sensor data to the cloud. Data is stored and visualized using IoT platforms like Blynk or ThingSpeak.

Remote Monitoring and Control

Farmers can access sensor readings and alerts through a mobile app or web dashboard. They can make informed decisions about irrigation, fertilization, or crop selection based on the data.

End

The process repeats indefinitely unless manually stopped. The system operates autonomously, requiring minimal human intervention while optimizing agricultural productivity.

SIMULATION RESULTS

To Program the Atmega328 Microcontroller we used this IDE. Arduino microcontrollers are pre-programmed with a boot loader that simplifies uploading of programs to the on-chip flash memory. The default bootloader of the Arduino UNO is the Optiboot bootloader. Boards are loaded with program code via a serial connection to another computer.

Ubidots is an open source Internet of Things (IoT) application and API to store and retrieve data from things using the HTTP protocol over the Internet or via a Local Area Network. Ubidots is a cloud service that allows data storage, visualization, and analysis. The NodeMCU sends data to the cloud platform, facilitating remote monitoring and control of the solar plant.

Figure 9 presents the data sending to IoT and hardware connectivity kit. Figure 10 shows reading the temperature value with the help of temperature sensor and send this information through IoT. Figure 11 displays the measured value of temperature.

Figure 9. Display information data to IoT.

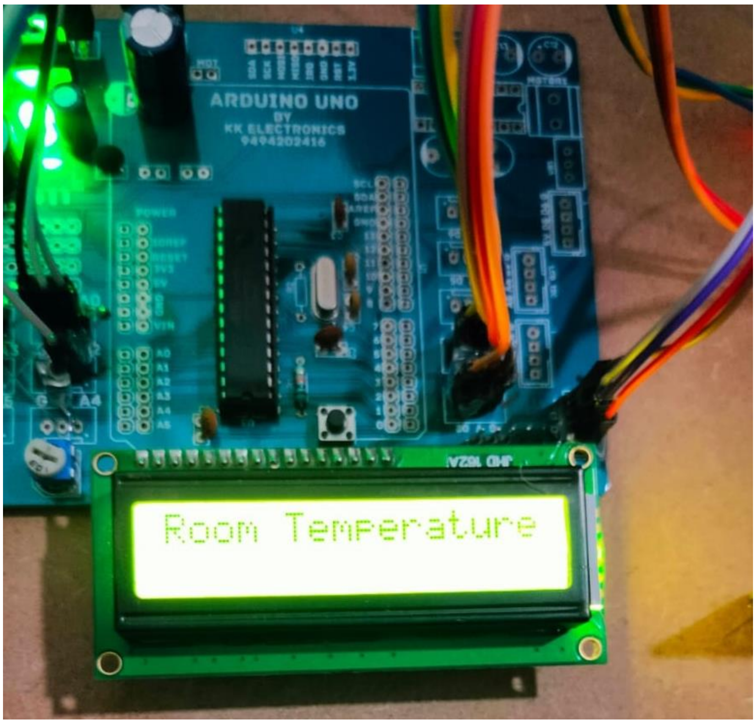

Figure 10. Indication of room temperature.

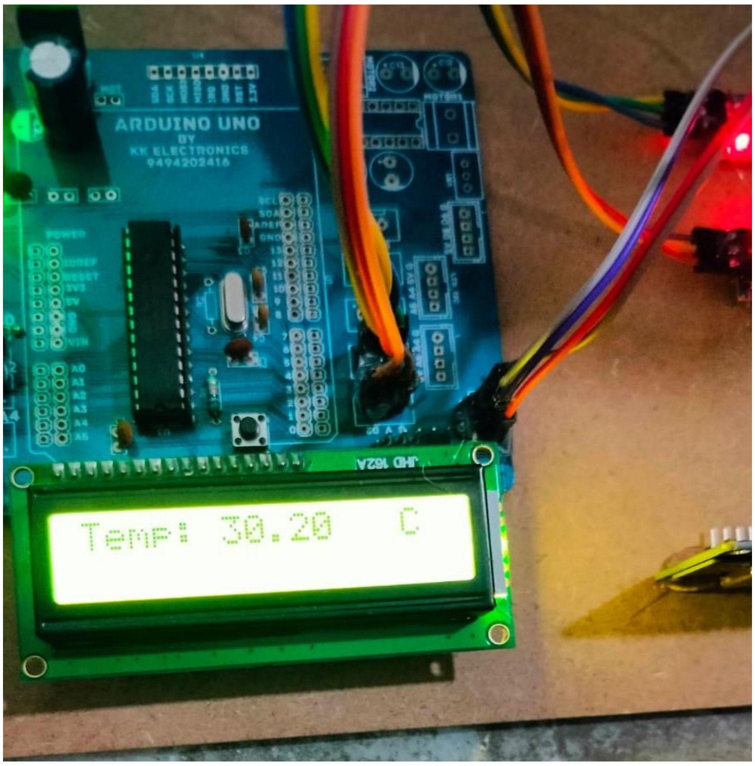

Figure 11. Display temperature.

Figure 12 measures the soil moisture and displays it through Ubidots platform. Figure 13 indicates the measured soil moisture.

Figure 14 detects the fire with the help of flame sensor and also measures the humidity; the values of humidity and fire status are shown in Figures 15 and 16 respectively.

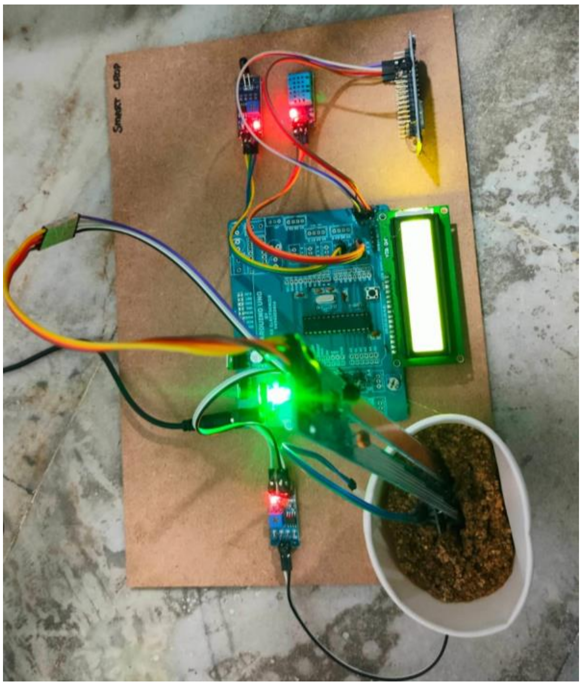

Figure 12. Display temperature.

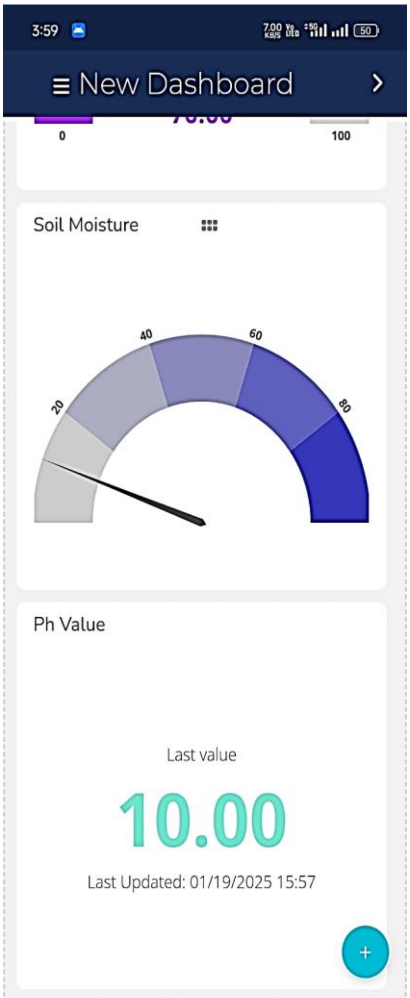

Figure 13. Indication of soil moisture.

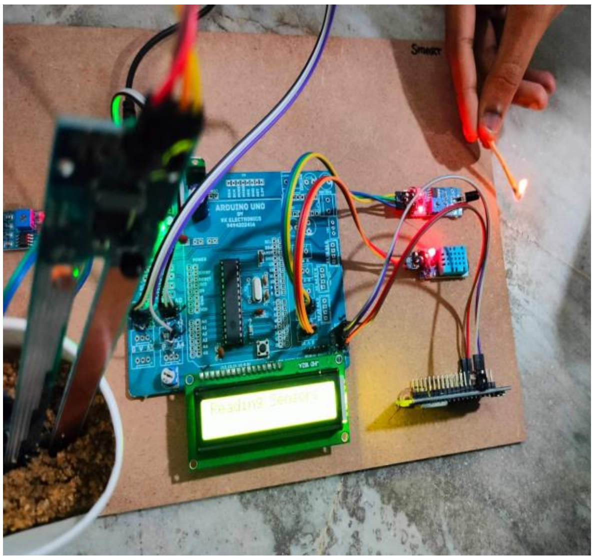

Figure 14. Detection of fire.

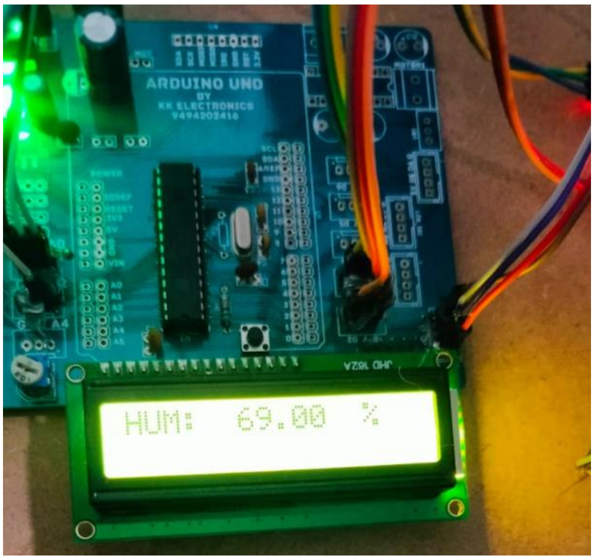

Figure 15. Measured humidity.

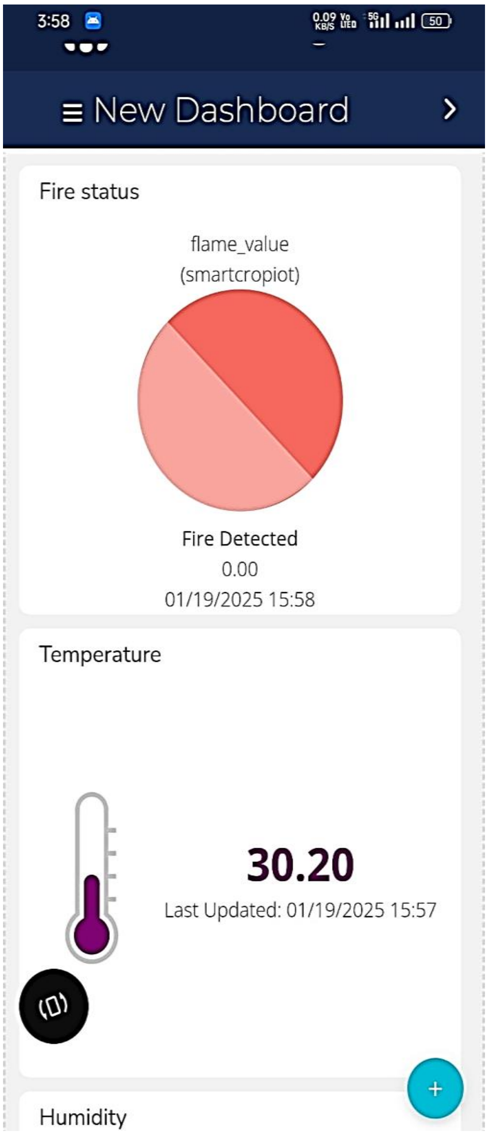

Figure 16. Fire status.

CONCLUSION AND FUTURE SCOPE

In this study, using Internet of Things sensors, the Smart Crop Recommendation System provides a creative way to improve agricultural output and farming methods. Real-time monitoring, automatic crop recommendations, and resource management are made possible by the system's integration of temperature, soil moisture, PIR, and LDR sensors with Arduino and ESP8266 (NodeMCU). Farmers may access vital data remotely with the Ubidots IoT technology, which enhances decision-making and minimizes manual labor. This method guarantees data-driven, sustainable farming, which improves crop yields, resource efficiency, and farmers' ability to make well-informed decisions.

Future work can focus on incorporating machine learning algorithms to provide predictive analytics for crop growth, disease detection, and yield forecasting.

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