Agro Gurad : Soil And Crop Management System By Intelligent Robot For Enhanced Plant Health

[1]A.Vidyullatha [2]N.Pavan Rakesh [3]U.Madhan

[4] M .Geetha Krishna [5]R.Banu Sujith

[1]Assistant Professor ,ECE Department, N.E.C.N., Nellore
[2345]UG scholor, ECE Department, N.E.C.N., Nellore

Abstract: *This paper describes the design, construction, and working of AgroGuard, a pioneering advancement in agricultural technology. AgroGuard optimizes plant growth and ensures soil health through integrated sensor-based analysis and machine learning. This innovative robot leverages a suite of sensors, including soil moisture and NPK (Nitrogen, Phosphorus, Potassium) sensors, to meticulously analyze soil fertility and tailor fertilizer applications for optimal plant protection and growth. By employing advanced machine learning algorithms, AgroGuard identifies the most suitable fertilizers and evaluates weather conditions to recommend ideal crops for specific climates. The system incorporates real-time weather analysis to predict and mitigate the risks of natural disasters such as droughts and floods, offering proactive measures to safeguard crops. The ESP32 controller orchestrates the robot's seed and fertilizer dispensing mechanisms, ensuring precise and efficient application. Agro Guard's comprehensive approach addresses both immediate and long-term agricultural challenges, promising enhanced crop yields, reduced plant epidemics, and effective disaster prevention. This research highlights the role of AI-driven robotics in revolutionizing modern farming practices with cutting-edge technology.*

Keywords*: Precision Agriculture, AI in Farming, Crop Monitoring, Soil Analysis, IoT, Smart Farming, Agricultural Robotics*

I.INTRODUCTION

Agriculture is the backbone of the global economy, yet it faces numerous challenges such as soil degradation, unpredictable weather patterns, inefficient resource utilization, and increasing demand for higher crop yields. **AgroGuard** is an intelligent robotic system designed to address these challenges by integrating cutting-edge technology into modern farming. The system combines **sensor-based analysis, machine learning, and automation** to monitor soil conditions, predict weather changes, and optimize fertilizer and seed application. Equipped with **soil moisture and NPK sensors**, AgroGuard provides precise data on soil fertility, enabling farmers to make informed decisions regarding fertilizer use. The inclusion of **real-time weather analysis** helps in forecasting potential natural disasters like droughts and floods, allowing for proactive measures to safeguard crops. The **ESP32 controller** efficiently manages seed and fertilizer dispensing, ensuring accurate and automated distribution. By leveraging AI-driven insights and robotics, AgroGuard significantly improves **crop health, resource efficiency, and disaster preparedness**. This project represents a step forward in **precision agriculture**, offering a scalable and sustainable solution to enhance productivity while minimizing environmental impact.

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II.FUNCTIONAL OVERVIEW

On startup, after providing power to **Agro Guard**, the **ESP32 microcontroller** initializes and begins executing the core functionalities. The system first **calibrates its sensors**, including **soil moisture, temperature, and NPK sensors**, to ensure accurate data collection. It may take a few moments to establish connections with **external data sources**, such as real-time weather updates, depending on the speed of the network connection. The onboard **AI-based processing unit** then begins analyzing soil conditions and climate data to recommend suitable crops and fertilizers. This data is essential for optimizing soil fertility and ensuring that crops receive the right nutrients at the right time, reducing wastage and maximizing yield potential.

A **power-saving mode** is incorporated using an **ultrasonic range sensor** mounted on the robotic unit. This sensor detects nearby motion and activates the system when a user approaches, thereby enhancing power efficiency. The ability to intelligently power down during inactivity ensures that Agro Guard operates with minimal energy consumption, making it highly suitable for long-term deployment in agricultural fields. Additionally, this feature ensures that the system remains functional even in remote locations with limited power supply.

Once fully operational, Agro Guard starts performing **automated soil analysis, crop health monitoring, and precision fertilizer application** based on its collected data. The AI-driven algorithms analyze environmental factors and suggest the most effective course of action to improve crop health. The system autonomously navigates across the field using motorized wheels and **terrain-adaptive sensors**, ensuring **uniform coverage** and **real-time monitoring**. By continuously scanning and assessing the soil conditions, Agro Guard can identify early signs of **nutrient deficiencies, pest infestations, and water stress**, allowing farmers to take proactive measures before significant damage occurs.

The system is equipped with an **interactive display** where users can **view real-time agricultural insights**, including **soil fertility reports, pest detection alerts, and climate conditions**. This data is presented in an easy-to-understand format, allowing farmers to make quick and informed decisions. Agro Guard also features a **remote monitoring option**, enabling users to access system reports via a mobile or web interface. This ensures that even when away from the field, farmers can still oversee operations and receive important alerts regarding their crops. Furthermore, the system supports **customization and scalability**, allowing advanced users to integrate additional functionalities such as **automated irrigation control, drone-assisted surveillance, and AI-driven yield forecasting**. The open-source nature of Agro Guard allows for modifications and improvements, making it a flexible and future-ready solution for modern agricultural needs.

Components Required

The development of **AgroGuard** requires a combination of hardware and software components that work together seamlessly to provide real-time agricultural intelligence. The key components include:

- **ESP32 Microcontroller** – The central unit responsible for processing data and controlling various sensors and mechanisms.
- **Soil Moisture Sensor –** Measures the water content in the soil, ensuring optimal irrigation management.

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- **NPK Sensor** – Determines the levels of essential nutrients (Nitrogen, Phosphorus, and Potassium) to analyze soil fertility.
- **DHT Sensor** – Measures temperature and humidity for real-time climate monitoring.
- **LDR Sensor** – Detects light intensity, aiding in optimizing crop growth cycles.
- **Motorized Wheels** – Enables autonomous movement and coverage of large agricultural fields.
- **Wi-Fi Module –** Facilitates cloud-based data synchronization for remote access and control.
- **Battery Pack –** Provides sufficient power for uninterrupted operation in the field.
- **Fertilizer & Seed Dispenser Mechanism** – Ensures precise and automated application of fertilizers and seeds, minimizing waste.
- **5V Water Pump** – Helps in automated irrigation by supplying water to plants based on soil moisture levels.
- **Relay Module** – Controls electrical components such as pumps and dispensers, facilitating automation in farming operations.
- **DC-DC Converter Board** – Regulates power supply efficiently, ensuring the smooth functioning of all components.
- **Laptop Interface** – Displays real-time weather, soil conditions, and other system insights for better decision-making.

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III.BLOCK DIAGRM OF PROJECT.

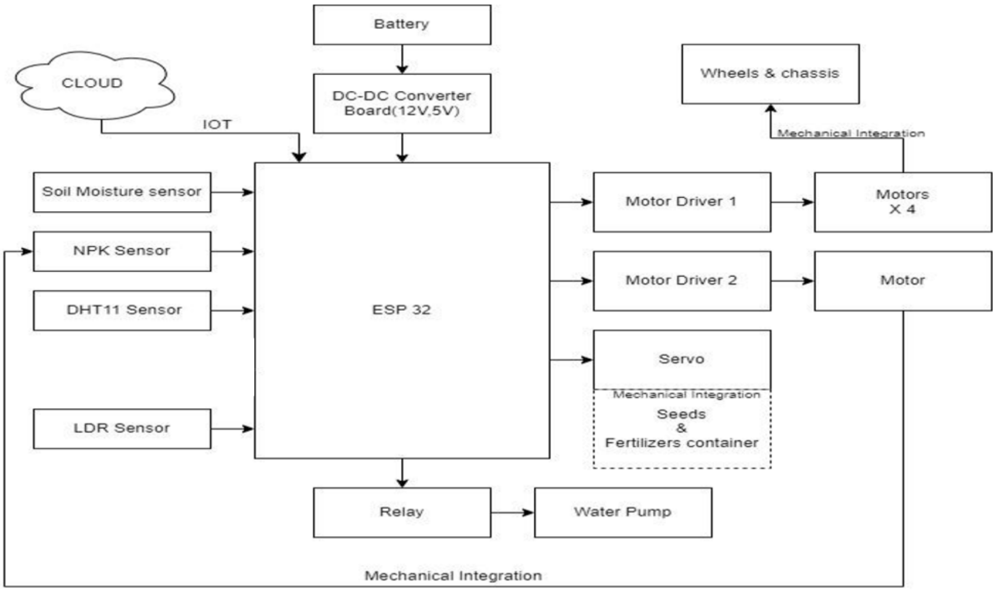

Fig 1:Block diagram Of Project

This block diagram represents a **smart agriculture system** designed for automated tasks and remote monitoring using IoT (Internet of Things) technology. Let's break down each component and its role:

Core Processing Unit:

- **ESP32:** This is the heart of the system. It's a microcontroller with built-in Wi-Fi and Bluetooth capabilities, making it ideal for IoT applications. It receives data from various sensors, processes it, and controls the actuators based on the programmed logic. It also transmits data to the cloud for remote monitoring and analysis.

Power Supply:

- **Battery:** Provides the main power source for the entire system.
- **DC-DC Converter Board (12V, 5V):** Converts the battery's voltage to the required levels for different components. The ESP32 and most sensors typically operate at 5V, while motors might require 12V.

Sensors:

- **Soil Moisture Sensor:** Measures the moisture content of the soil.
- **NPK Sensor:** Measures the levels of Nitrogen (N), Phosphorus (P), and Potassium (K) in the soil, which are essential nutrients for plant growth.
- **DHT11 Sensor:** Measures temperature and humidity of the surrounding environment.

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- **LDR Sensor (Light Dependent Resistor):** Measures the ambient light intensity.

Actuators:

- **Motor Driver 1 & 2:** These modules control the speed and direction of the motors.
- **Motors (X4):** These are likely used for driving the **Wheels & Chassis** of the system, enabling it to move autonomously.
- **Motor (Single):** This could be used for a specific task like operating a gate or a mechanism for seed/fertilizer distribution.
- **Servo:** A servo motor is used for precise angular control, likely for operating the **Seeds & Fertilizers container**. This allows for controlled dispensing of seeds or fertilizers.
- **Relay:** An electrically operated switch that controls the **Water Pump**.

Water System:

- **Water Pump:** Pumps water for irrigation, controlled by the relay based on the soil moisture sensor readings.

Mechanical Integration:

- **Wheels & Chassis:** Provides mobility to the system.
- **Seeds & Fertilizers Container:** Stores and dispenses seeds and fertilizers using the servo motor.
- **Mechanical Integration (Lines):** These lines indicate the physical connections and mechanical linkages between the components, ensuring proper operation and movement.

Connectivity:

- **IOT (Internet of Things):** Enables remote monitoring and control of the system.
- **CLOUD:** Stores and processes the data collected by the sensors, allowing for analysis, visualization, and remote control

Category	Components	Purpose
Microcontroller	ESP32	Central processing and control unit
Sensors	Soil Moisture Sensor	Measures soil water content
	NPK Sensor	Analyzes soil fertility (Nitrogen, Phosphorus, Potassium)
	DHT Sensor	Monitors temperature and humidity
	LDR Sensor	Detects light intensity for crop growth cycles
Actuators & Motors	Stepper Motors	Controls movement and precise positioning
	Servo Motors	Operates seed and fertilizer dispensers
Power System	Rechargeable Battery Pack	Provides power for field operations
	DC-DC Converter Board	Regulates power distribution
Connectivity	Wi-Fi Module	Enables remote access and cloud synchronization
Dispensing Mechanism	Seed Dropping/Fertilizer Dropping Mechanism	Ensures accurate application of fertilizers/seeds
Mobility	Motorized Wheels	Allows autonomous movement across the field
User Interface	Laptop	Displays real-time weather, soil conditions, and insights

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Table 1: basic requirements

IV.FLOW CHART

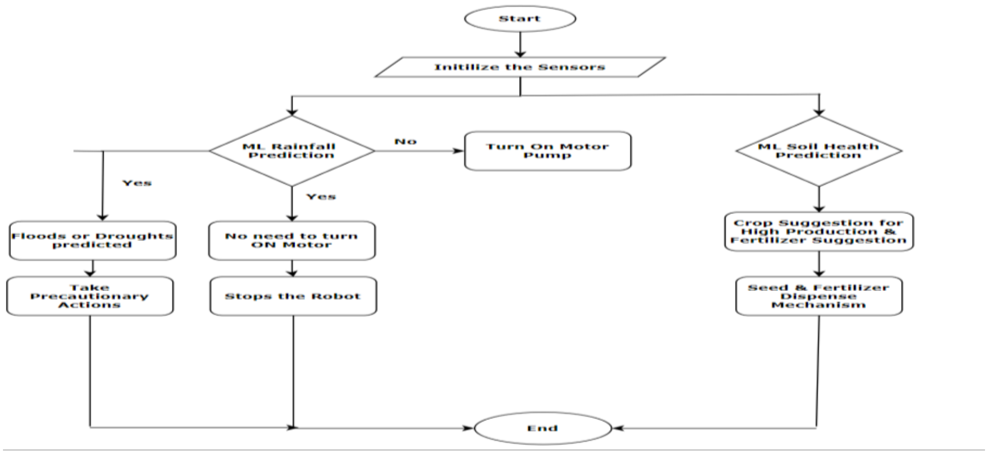

Fig 2 : Flow Chart of Project

This flowchart represents the operational logic of an automated agricultural system, likely an extension of the block diagram we discussed earlier, incorporating Machine Learning (ML) for predictive analysis. Let's breakdown each step:

- **Start:** The process begins.
- **Initialize the Sensors:** The system starts by initializing all the sensors (soil moisture, NPK, temperature, light, etc.) to gather initial data.
- **ML Rainfall Prediction:** The system uses a Machine Learning model to predict rainfall.
- **Yes (Rain Predicted):**
  - **No need to turn ON Motor:** The system recognizes that irrigation is not needed due to the predicted rainfall.
  - **Stops the Robot:** The robot, if operational, is stopped or remains idle to prevent unnecessary movement during potential rainfall.
  - **Floods or Droughts Predicted:** The system analyzes the rainfall prediction further to determine if it indicates potential floods or droughts.
  - **Take Precautionary Actions:** Based on the prediction, the system may trigger alerts or take specific actions. For example, it might send notifications to farmers about potential flooding or adjust water management strategies in case of drought.
- **No (Rain Not Predicted):**
  - **Turn On Motor Pump:** If no rain is predicted, the system activates the motor pump to irrigate the field.
  - **ML Soil Health Prediction:** Independently, the system uses another Machine Learning model to analyze soil health based on the sensor data (NPK, moisture, etc.).
- **Crop Suggestion for High Production & Fertilizer Suggestion:** Based on the soil analysis, the system suggests suitable crops for optimal yield and recommends appropriate fertilizers.

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- **Seed & Fertilizer Dispense Mechanism:** The system activates the seed and fertilizer dispensing mechanism (likely using the servo motor mentioned in the block diagram) to plant seeds and apply fertilizers according to the recommendations.
- **End:** The process concludes

V .WORKING

HARDWARE WORKING

1. ESP32 Controller (Microcontroller)

Acts as the brain of the system.Reads data from sensors and controls motors, pump, and other actuators.Supports Wi-Fi and Bluetooth for remote data monitoring and control.

Fig 3 : ESP32 Controller

2. Sensors for Soil & Crop Monitoring

a) Soil Moisture Sensor Measures moisture levels in the soil. Helps decide whether irrigation is needed.Data is sent to ESP32 for analysis.

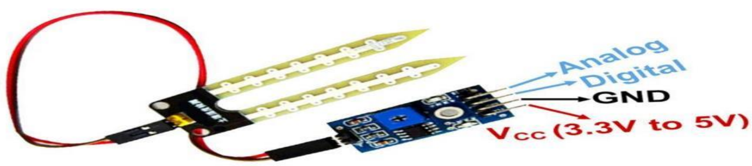

Fig4 : Soil Moisture Sensor

b) NPK Sensor

Detects Nitrogen (N), Phosphorus (P), and Potassium (K) levels in the soil.Helps in assessing soil fertility.Provides data for fertilizer recommendations.

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Fig 5: NPK Sensor

c) DHT-11 Sensor (Temperature & Humidity)

Measures ambient temperature and humidity.Helps understand environmental conditions affecting crop growth.

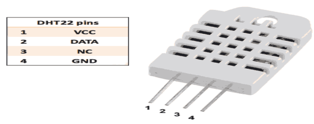

Fig 6: DHT-11 Sensor

d) LDR Sensor (Light Intensity)

Measures sunlight intensity in the field.Useful for optimizing planting schedules and shading mechanisms.

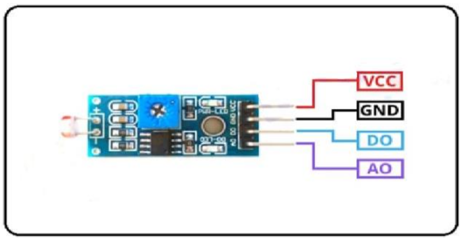

Fig 7: LDR Sensor

3. Actuators & Mechanisms

a) 5V Water Pump (Irrigation System)Controlled via a relay module.

Activated based on soil moisture sensor data.Pumps water to the soil when needed.

Fig 8 :5V Water Pump

b) Relay Module

Controls high-power devices like the water pump.Acts as an electrical switch based on ESP32 signals.

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Fig 9 : Relay Module

c) Stepper Motors

Used for robot movement and precise positioning.Helps navigate the robot across the field.

Fig 10: Stepper Motor

d) Servo Motors

Fig 11: Servo Motor

Used for seed dropping and fertilizer dispensing mechanisms.Moves specific parts of the robot for precise actions.

e) Seed Dropping / Fertilizer Dropping MechanismDispenses seeds or fertilizers at the correct location.Controlled by servo motors to ensure precision.

4. Power & Energy Management

a) Rechargeable Batteries

Powers the ESP32, sensors, and actuators.Ensures long-term autonomous operation.

b) DC-DC Converter Board

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Converts battery voltage to required levels (e.g., 12V to 5V for ESP32).Ensures stable power supply to all components.

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SOFWARE WORKING

1. Arduino (ESP32/Uno) - Microcontroller

- Acts as the **central controller** for the robot.
- Reads data from sensors (**Soil Moisture, NPK, DHT-11, LDR**).
- Controls **motors, servo for seed/fertilizer dropping, and water pump** via relay.
- Sends collected data to **Ubidots for real-time monitoring**.

Fig 12 : Arduino ide

2 Jupyter IDE (Data Processing & AI Analysis)

- Retrieves data from **Ubidots API** for analysis.
- Uses **Python for data visualization & trend prediction**.
- Can integrate **Machine Learning models** to:
    - Predict optimal irrigation & fertilization schedules.
- Generates **automated reports** for farmers.

Fig 13 : Jupyter ide

3. Ubidots (IoT-Based Monitoring & Control)

- **Receives real-time sensor data** from Arduino via Wi-Fi.
- Displays data on a **dashboard (web/mobile app)** for remote monitoring.
- Enables **automated control** (e.g., triggering irrigation based on soil moisture levels).
- Sends **alerts/notifications** for abnormal conditions (e.g., high temperature, dry soil).

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Fig 14 : Ubidots Interface

VI .RESULT

EXPERIMENTAL SETUP

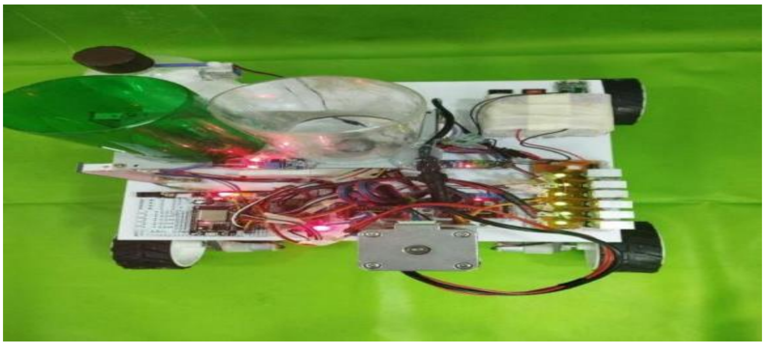

Fig 15 : Top View Of Project

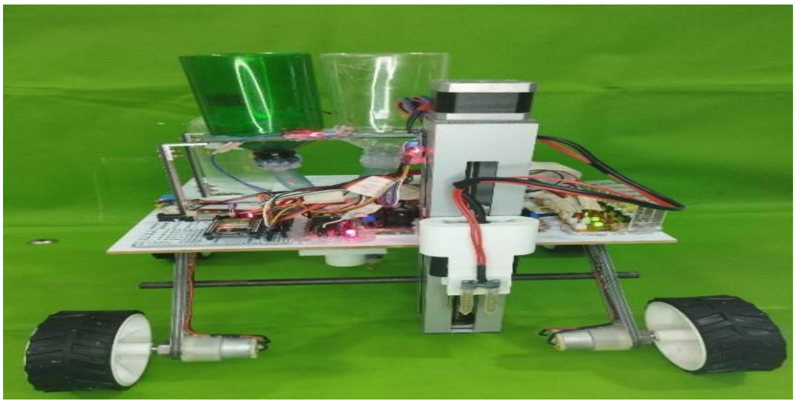

Fig 16 : Front View Of Project

OUTPUT

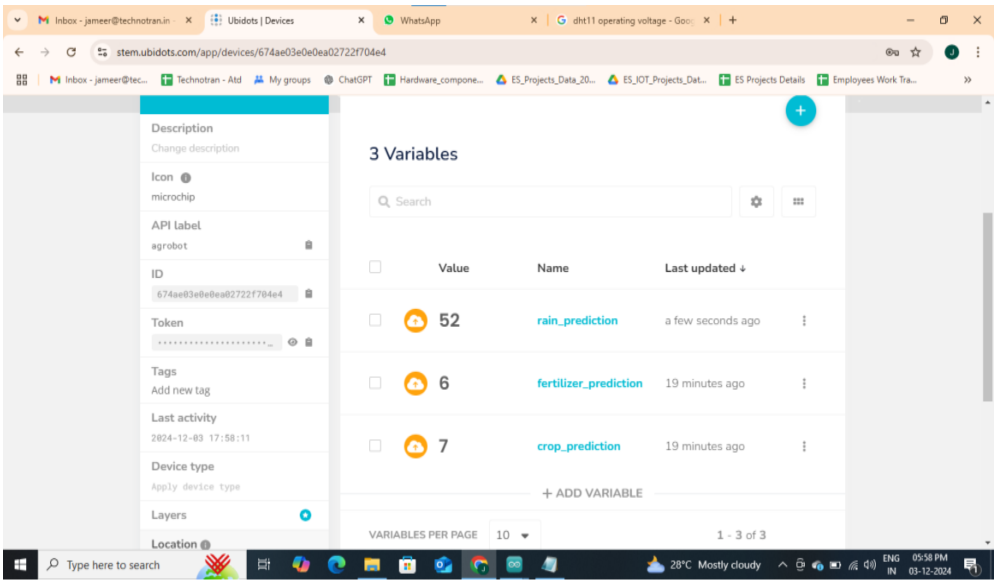

Fig 17:Ouput Of Project

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OUTPUT PREDICTION INSTRUCTIONS:

Crop Prediction

0: Barley

1: Cotton

2: Groundnuts

3: Maize

4: Millets

5: Oil Seeds

6: Paddy

7: Pulses

8: Sugar Cane

9: Tobacco

10: Wheat

Fertilizer Prediction

0: 14-35-14

1: 17-17-17

2: 20-20

3: 28-28

4: DAP

5: 10-26-26

6: Urea

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VII. CONCLUSION

Agro Guard system successfully integrates Arduino (ESP32), IoT (Ubidots), and AI-based data analysis (Jupyter IDE) to automate and optimize soil and crop monitoring. The robotic system efficiently collects real-time data on soil moisture, NPK levels, temperature, humidity, and light intensity, enabling precise irrigation and fertilization.By using Ubidots IoT integration, farmers can remotely monitor field conditions and receive real-time alerts, making data-driven decisions to enhance crop health. Additionally, Jupyter-based analysis allows for predictive insights, optimizing irrigation schedules and improving overall farm productivity.The system reduces manual labor, minimizes resource wastage, and increases agricultural efficiency, making it a cost-effective and scalable solution for modern smart farming. Future enhancements could include AI-based disease detection, GPS navigation, and solar power integration to further improve automation and sustainability.This project demonstrates a practical and innovative approach to precision agriculture, promoting smart, sustainable, and efficient farming.

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