NAAN MUDHALVAN PROJECT

IoT Based - Soil Nutrients Moniting and Management

College Code -3114

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TABLE OF CONTENT

Executive Summary

Our IoT project, "Soil Nutrition Monitoring and Management", is designed to help farmers monitor and manage their fields more effectively. Connected with the Farm-PA mobile app, the system uses smart sensors to measure real-time soil temperature, moisture, and key nutrients like Nitrogen, Phosphorus, and Potassium (NPK).

Farm-PA allows users to control irrigation remotely, ensuring optimal water usage based on current soil conditions. By tracking NPK levels, it also helps in applying the right nutrients at the right time, improving crop health and yield. This project brings smart, efficient, and sustainable farming to the fingertips of users.

Project Objective:

The primary objective of our IoT project, "Soil Nutrition Monitoring and Management", is to create a smart farming solution that enhances crop productivity and resource efficiency through real-time soil analysis. The system is designed to continuously monitor vital soil parameters such as temperature, moisture, and essential nutrient levels—specifically Nitrogen (N), Phosphorus (P), and Potassium (K)—using integrated IoT sensors. These live readings are transmitted to our mobile application, Farm-PA, which serves as the central control interface for farmers.

Through Farm-PA, users can remotely manage irrigation systems, ensuring precise water delivery based on the real-time needs of the soil, thus reducing water waste and preventing over-irrigation. Additionally, the system supports efficient nutrient management by identifying deficiencies early and enabling timely, targeted fertilizer application. This results in improved crop health, better yields, and reduced input costs

Another key objective is to facilitate data-driven decision making by presenting real-time field data in a clear and accessible format through the Farm-PA app. This empowers farmers to make informed choices quickly, increasing the overall effectiveness of their agricultural practices. Ultimately, the project aims to promote sustainable agriculture by optimizing the use of water and fertilizers, lowering environmental impact, and advancing the adoption of smart technology in farming

Scope

The Soil Nutrition Monitoring and Management project aims to improve farming through real-time monitoring of soil temperature, moisture, and nutrients (Nitrogen, Phosphorus, Potassium) using IoT sensors. Connected to the Farm-PA app, it allows farmers to remotely control irrigation and receive live soil data. The project helps in making timely decisions for efficient water use and accurate fertilizer application, leading to better crop yield, reduced waste, and sustainable farming practices.

Hardware Development : The Arduino UNO serves as the main hardware platform in this project, collecting real-time soil data and transmitting it to the Farm-PA app. Its reliability and ease of use make it ideal for IoT-based agricultural monitoring and control.

Simulation and testing : Tinkercad was utilized for simulation and initial testing of the circuit design in this project. It enabled accurate verification of sensor connections and Arduino UNO functionality in a virtual environment. This approach ensured efficient prototyping and reduced errors prior to hardware implementation.

User Interface : The Farm-PA application was developed using HTML, CSS, and JavaScript to provide a responsive user interface. It efficiently displays real-time soil data received from the Arduino UNO, enabling remote monitoring and control.

Methodology :

1. Requirement Analysis

The project began with identifying the core needs of modern agriculture—real-time monitoring of soil temperature, moisture, and NPK nutrient levels, along with the ability to remotely control irrigation. Key requirements included low-cost deployment, mobile accessibility, and reliable data transmission to improve farm productivity and sustainability.

2. Hardware Selection

Based on these requirements, components such as soil moisture sensors, temperature sensors, and NPK sensors were selected for accurate field data collection. The Arduino UNO was chosen as the main microcontroller for its ease of integration, reliability, and strong community support, making it ideal for IoT-based solutions.

3. Microcontroller Programming

The Arduino UNO was programmed using the Arduino IDE to interface with sensors, read data, and transmit it to the Farm-PA web application. The code also handled logic for automated irrigation based on moisture thresholds, ensuring responsive control based on sensor inputs.

4. Simulation and Testing

Before hardware implementation, Tinkercad was used to simulate the circuit design and test the microcontroller logic. This step helped verify sensor connections, troubleshoot errors, and optimize the code in a virtual environment, reducing the risk of hardware fail

5. Prototype Deployment

After successful simulation, the hardware prototype was deployed in a controlled environment. Sensors were connected to the Arduino UNO and placed in soil to monitor real-time conditions. The data was transmitted to the Farm-PA interface built using HTML, CSS, and JavaScript, allowing remote access and control.

6. Data Collection and Analysis

Real-time data from the field was collected via the Farm-PA interface, enabling continuous monitoring of soil health. This data was analyzed to make informed decisions on irrigation and fertilizer application, demonstrating improvements in resource efficiency, crop health, and field management.

Artifacts used:

1.ARDUNIO UNO :The Arduino UNO is a reliable, open-source microcontroller board based on the ATmega328P. It is widely used for prototyping due to its ease of programming, versatile I/O pins, and strong community support. In this project, it serves as the central unit for sensor integration and real-time data processing.

2.Bluetooth sensor (nRF51822) : The nRF51822 module enables efficient Bluetooth Low Energy (BLE) communication between the Arduino system and the Farm-PA application. Its low power consumption and custom firmware support make it ideal for transmitting real-time soil data, ensuring reliable and energy-efficient operation in field conditions.

3.N P K -sensor : The NPK sensor module measures the real-time levels of Nitrogen, Phosphorus, and Potassium in soil, which are vital for crop health. In our IoT project, it connects to the Arduino UNO to collect nutrient data and sends it to the Farm-PA app. This helps farmers optimize fertilizer use and improve crop productivity through precision farming.

4.Temperature Sensor: The DS18B20 is a precise digital temperature sensor with waterproof options, ideal for soil temperature monitoring in our IoT project. It uses a 1-Wire interface, allowing multiple sensors on one line, and integrates easily with Arduino for reliable real-time data collection.

4.Soil sensor : A soil moisture sensor measures soil water content and provides real-time data for IoT-based irrigation systems. By detecting moisture levels, it enables precise water management, improving crop health and conserving resources in automated farming applications.

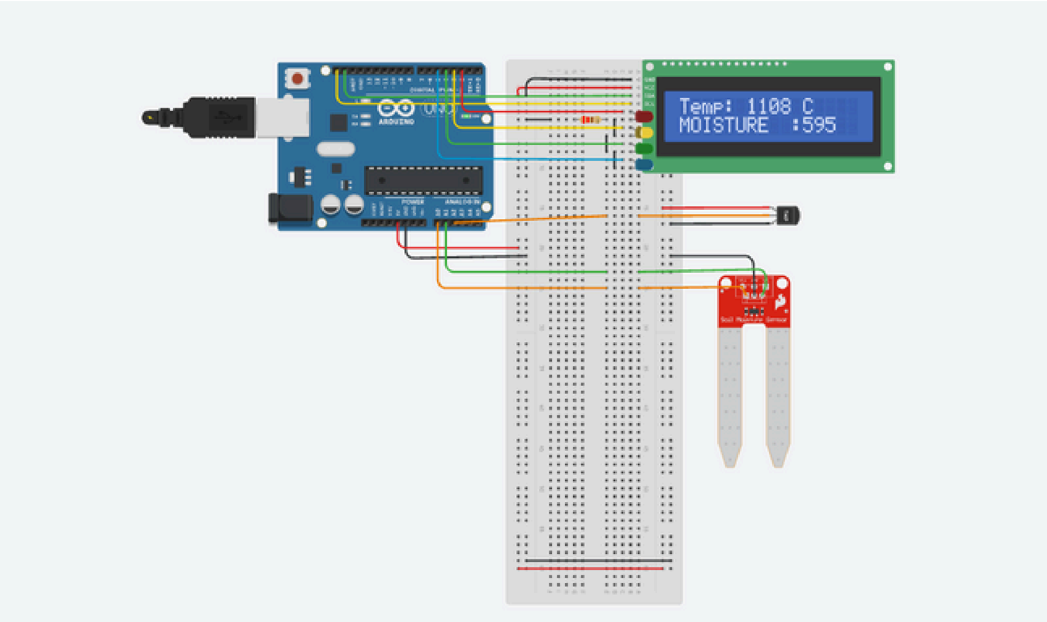
5.Web Bluetooth : Web Bluetooth in Chrome allows our Farm-PA application to connect directly with the IoT device via Bluetooth Low Energy (BLE). It enables real-time data transfer from sensors like soil moisture and temperature, ensuring seamless monitoring and control without needing additional software .

6.Spck Editor : Spck Editor is a mobile web development tool that supports HTML, CSS, and JavaScript. In our IoT project, it enables efficient development and testing of the Farm-PA application interface, helping manage real-time data from Bluetooth-connected sensors on the go .

7.Arduino IDE : The Arduino IDE software was used in the project to write and test the code for the hardware components. It facilitated verification and uploading of the program to the Arduino board. Prior to implementation on the physical device, Tinkercad Simulation was employed to test and visualize the circuit and code virtually. This approach streamlined debugging and ensured the code functioned as intended.

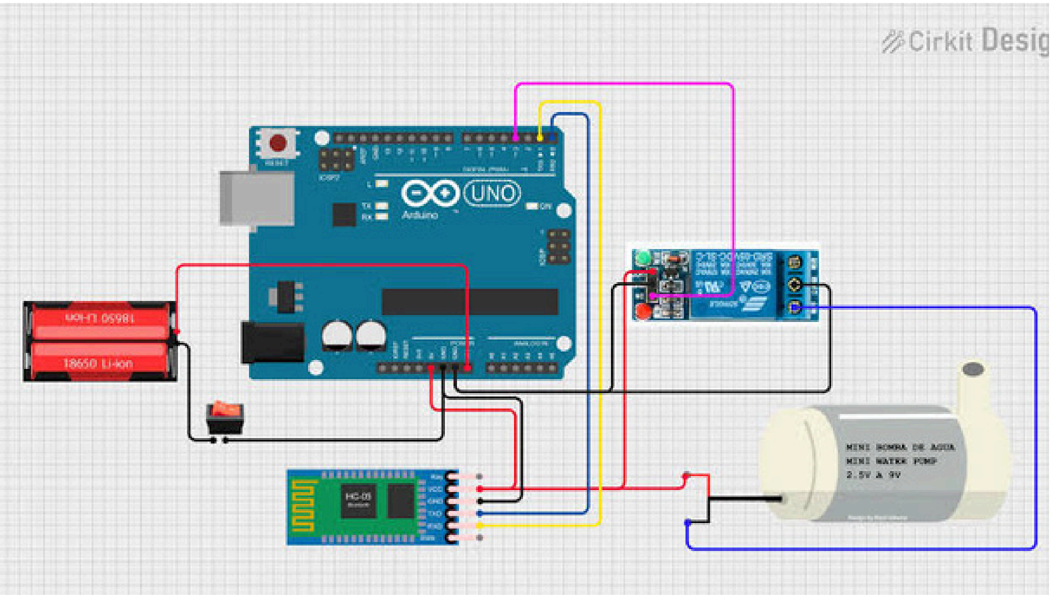
MODULES

1.Module one



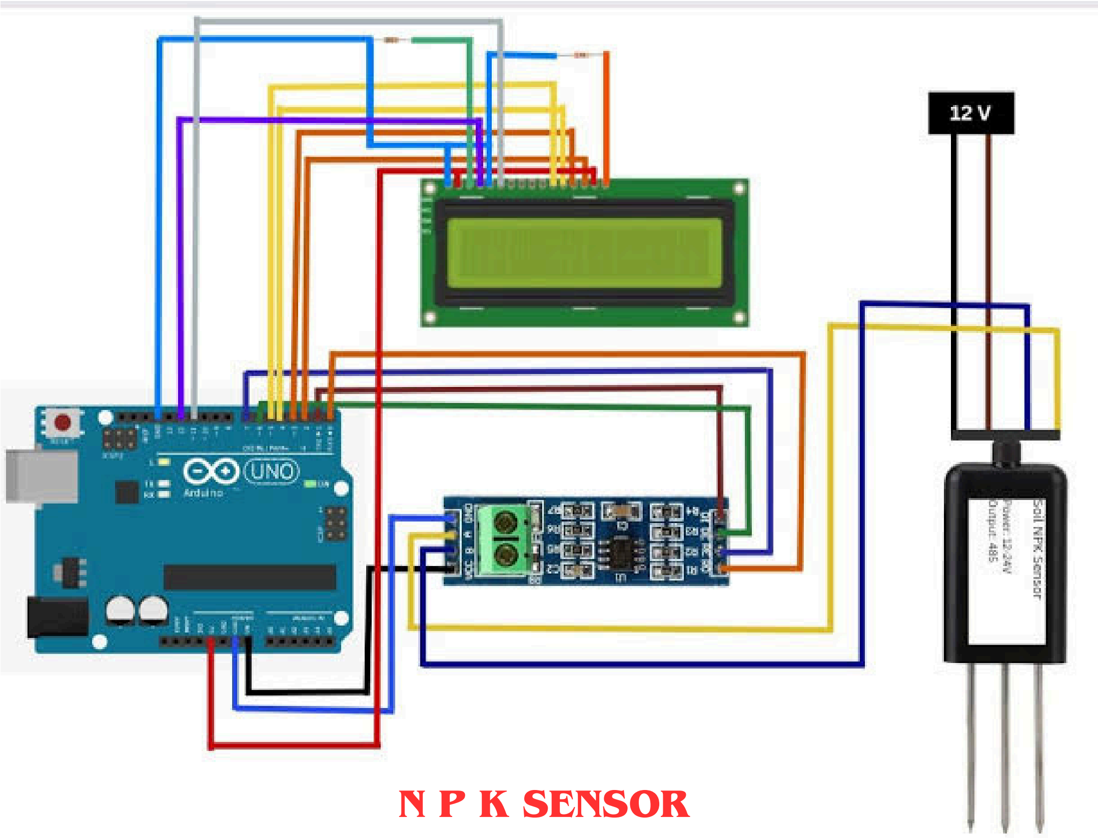
Temperature and Moisture module

2.Module Two



Water pump module

3.Module Three



N P K SENSOR

Key features of the module

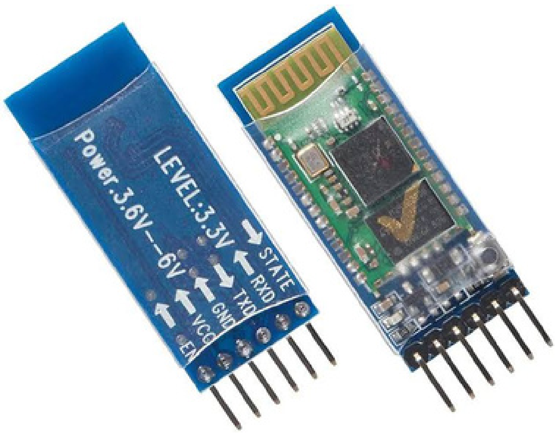
The integrated system comprises three core modules: soil temperature and moisture sensing, water pump control, and NPK nutrient sensing. These modules collaboratively provide comprehensive monitoring and management of critical agricultural parameters. The soil temperature and moisture sensors continuously assess environmental conditions that influence crop health, while the NPK sensor accurately quantifies essential nutrient levels to guide fertilization strategies. The water pump control module dynamically regulates irrigation based on real-time soil moisture data, optimizing water usage and promoting sustainable crop growth.

A Bluetooth communication module facilitates seamless wireless connectivity among these modules and the Farm-PA application. This interface enables real-time transmission of sensor data to the application, allowing users to remotely monitor soil conditions and nutrient status. Concurrently, the system receives control commands via Bluetooth, such as activating or deactivating the water pump, thereby supporting automated irrigation management and reducing the need for manual intervention. This bidirectional communication enhances operational efficiency and responsiveness

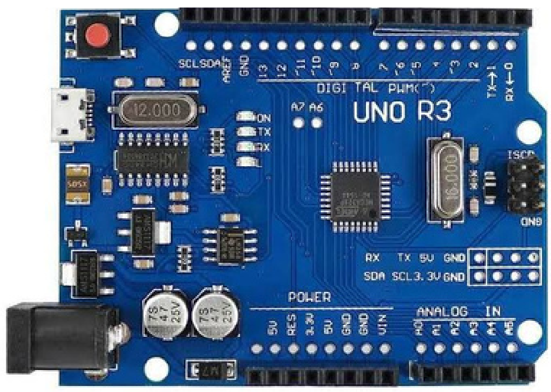
Key features of the module

Utilizing Bluetooth technology offers distinct advantages, including reliable low-power wireless communication well-suited for agricultural environments. Its compatibility with standard mobile devices ensures broad accessibility, empowering users to interact effortlessly with the system through the Farm-PA application. Collectively, this communication architecture significantly enhances precision, efficiency, and user convenience in modern agricultural management.

The system uses smart sensors and Bluetooth connectivity to monitor soil conditions, control irrigation, and track nutrient levels. Data is sent in real time to the Farm-PA app, allowing users to monitor and manage the farm remotely. This setup improves efficiency, reduces manual work, and supports smarter, data-driven farming.



HC-05
Bluetooth sensor



Arduino UNO R3 Sensors

Code Snippets :

1.Source code for Module-1

```
// Enhanced Arduino code to control water pump via Bluetooth commands from any device

const int pumpPin = 8;  // Digital pin connected to the relay or transistor controlling the water pump
String inputCommand = ""; // String to accumulate received characters

void setup() {
 Serial.begin(9600);       // Initialize serial communication (match HC-05/HC-06 baud rate)
 pinMode(pumpPin, OUTPUT);  // Set pump pin as output
 digitalWrite(pumpPin, LOW); // Ensure pump is initially OFF
 Serial.println("Ready to receive commands: 'ON' or 'OFF'");
}

void loop() {
 // Read and accumulate characters from serial until newline
 while (Serial.available()) {
  char receivedChar = Serial.read();

  // End of command (line break or carriage return)
  if (receivedChar == '\n' || receivedChar == '\r') {
   processCommand(inputCommand);  // Process the full command
   inputCommand = "";          // Clear for next command
  }
  else {
   inputCommand += receivedChar;  // Append character to the command string
  }
 }
}

// Function to process full command
void processCommand(String cmd) {
 cmd.trim(); // Remove any leading/trailing spaces

 if (cmd.equalsIgnoreCase("ON")) {
  digitalWrite(pumpPin, HIGH);
  Serial.println("Pump turned ON");
 }
 else if (cmd.equalsIgnoreCase("OFF")) {
  digitalWrite(pumpPin, LOW);
  Serial.println("Pump turned OFF");
 }
 else {
  Serial.println("Invalid command. Send 'ON' or 'OFF'");
 }
}
```

2.Source Code for Module-2

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <DHT.h>

// Sensor and module pins
#define DHTPIN 2
#define DHTTYPE DHT11        // Or DHT22
#define SOIL_PIN A0          // Soil moisture analog pin

// Initialize DHT and LCD
DHT dht(DHTPIN, DHTTYPE);
LiquidCrystal_I2C lcd(0x27, 16, 2); // Change to 0x3F if LCD doesn't
show

void setup() {
  Serial.begin(9600);       // Serial for Bluetooth (HC-05 uses Serial at
9600)
  dht.begin();

  lcd.init();             // Start LCD
  lcd.backlight();
  lcd.setCursor(0, 0);
  lcd.print("System Starting");
  delay(2000);
  lcd.clear();
}

void loop() {
  // Read temperature & humidity
  float temperature = dht.readTemperature();
  float humidity = dht.readHumidity();
```

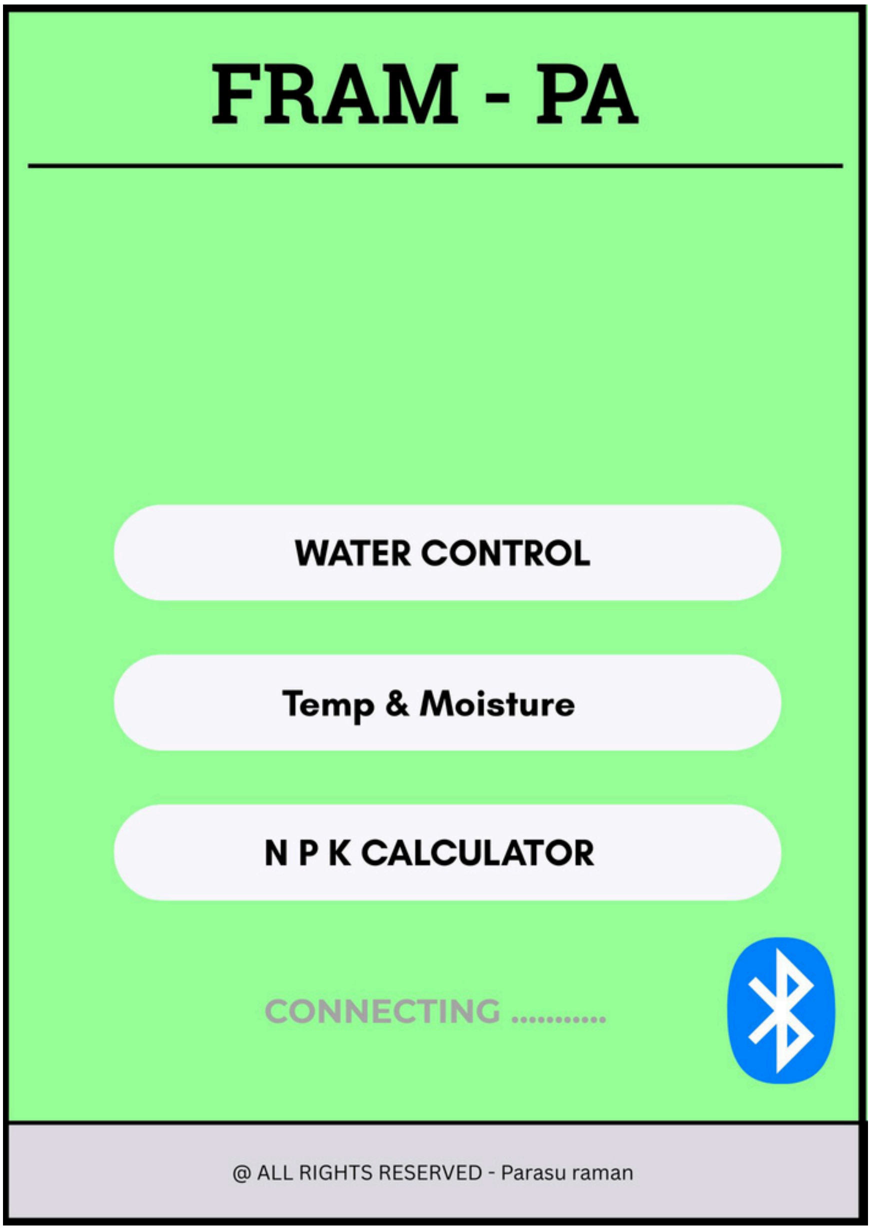
```
// Read soil moisture and convert to % (inverted scale)
  int soilAnalog = analogRead(SOIL_PIN);
  int soilMoisturePercent = map(soilAnalog, 1023, 0, 0, 100);

  // Display on LCD
  lcd.setCursor(0, 0);
  lcd.print("Temp:");
  lcd.print(temperature, 1);
  lcd.print("C");

  lcd.setCursor(0, 1);
  lcd.print("Soil:");
  lcd.print(soilMoisturePercent);
  lcd.print("%");

  // Send via Bluetooth Serial
  Serial.print("Temp: ");
  Serial.print(temperature, 1);
  Serial.print(" C, Humidity: ");
  Serial.print(humidity, 1);
  Serial.print(" %, Soil: ");
  Serial.print(soilMoisturePercent);
  Serial.println(" %");

  delay(2000); //
Update every 2 seconds
}
```

3.Source Code for Module-3

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <SoftwareSerial.h>

// LCD I2C
LiquidCrystal_I2C lcd(0x27, 16, 2);

// NPK sensor connected via SoftwareSerial
SoftwareSerial npkSerial(10, 11);  // RX, TX

void setup() {
  lcd.init();
  lcd.backlight();
  lcd.setCursor(0, 0);
  lcd.print("NPK Sensor Init");

  delay(2000);
  lcd.clear();

  Serial.begin(9600);        // Main Serial for Bluetooth (HC-05)
  npkSerial.begin(9600);     // NPK sensor serial communication
}

void loop() {
  // MODBUS command to request NPK data
  uint8_t command[] = {0x01, 0x03, 0x00, 0x1C, 0x00, 0x03,
0x84, 0x0F};
  npkSerial.write(command, sizeof(command));
  delay(1000); // Give sensor time to respond
```

```
if (npkSerial.available() >= 11) {
  uint8_t response[11];
  for (int i = 0; i < 11; i++) {
   response[i] = npkSerial.read();
  }

  // Extract NPK values
  int nitrogen   = response[3] << 8 | response[4];
  int phosphorus = response[5] << 8 | response[6];
  int potassium  = response[7] << 8 | response[8];

  // Display on LCD
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("N:");
  lcd.print(nitrogen);
  lcd.print(" P:");
  lcd.print(phosphorus);

  lcd.setCursor(0, 1);
  lcd.print("K:");
  lcd.print(potassium);

  // Send values via Bluetooth (Serial)
  Serial.print("Nitrogen: ");
  Serial.print(nitrogen);
  Serial.print(" mg/kg, Phosphorus: ");
  Serial.print(phosphorus);
  Serial.print(" mg/kg, Potassium: ");
  Serial.print(potassium);
  Serial.println(" mg/kg");
 }

 delay(5000); // Read every 5 seconds
}
```

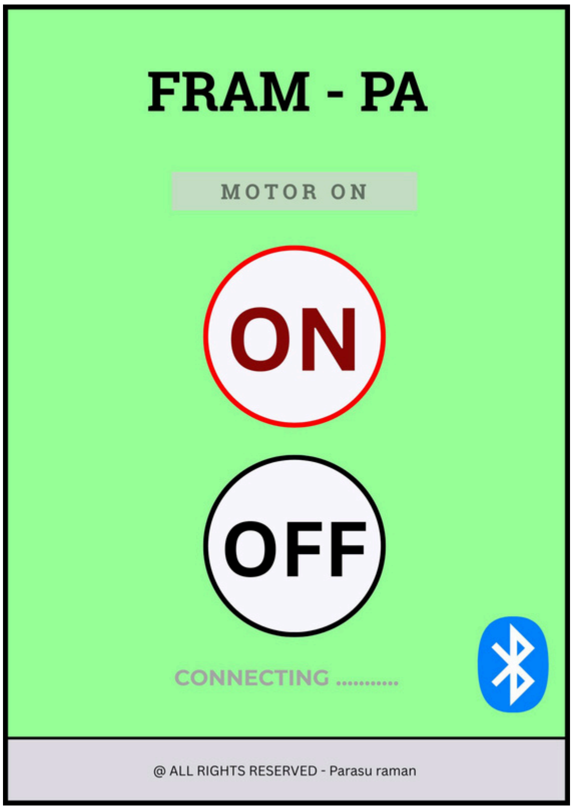
Interface of Farm-PA



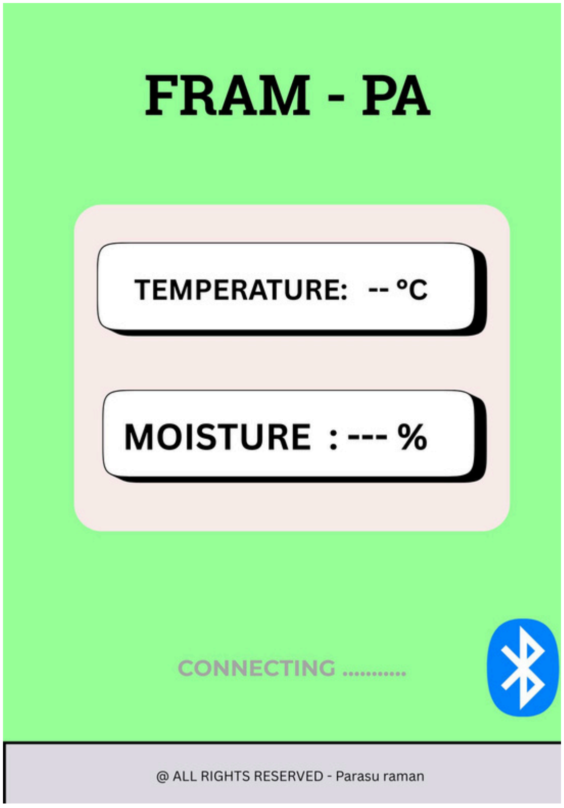
(1.1)

The user interface of our Farm-PA application serves as the central control and monitoring hub of the system. It is designed with integrated Web Bluetooth functionality, enabling seamless connection with the three Bluetooth-enabled modules— Water pump control soil temperature & moisture and NPK sensors. This connectivity allows real-time data exchange and system control directly through the web interface, enhancing user interaction, accessibility, and efficiency in managing field conditions.

This **(1.2)** interface serves as the control panel for managing the water irrigation system within our Farm-PA application. It allows users to remotely turn the water pump on or off through Bluetooth connectivity, enabling efficient and timely irrigation based on real-time soil data. This feature ensures precise water management, reduces manual effort, and supports sustainable agricultural practices.



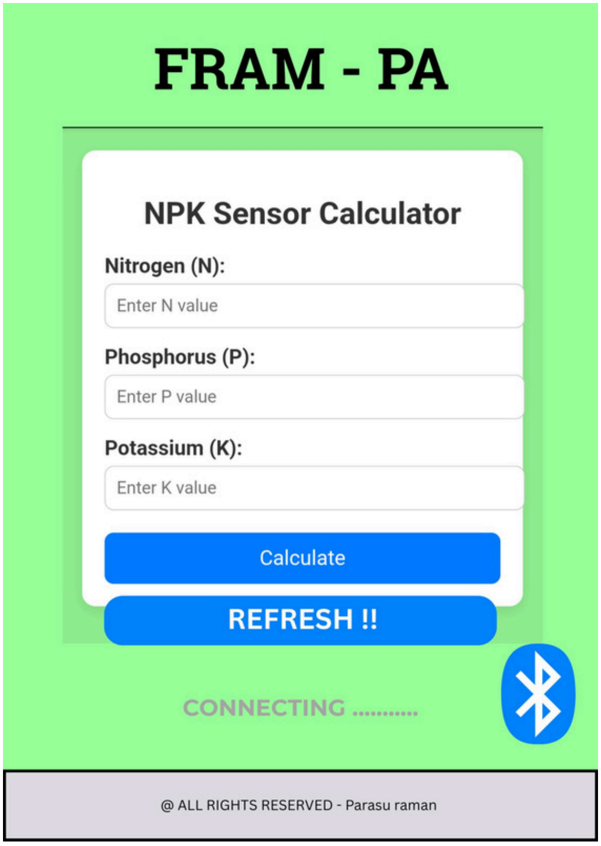
(1.2)



(1.3)

This **(1.3)** interface is developed to receive real-time soil temperature and moisture data from the crop field through Bluetooth connectivity. It enables continuous monitoring of field conditions, allowing the Farm-PA application to provide accurate insights for timely irrigation and crop management decisions. This seamless data flow enhances the overall efficiency and effectiveness of the IoT-based farming system.

This **(1.4)** interface is designed to receive real-time NPK (Nitrogen, Phosphorus, and Potassium) values from the field using Bluetooth connectivity. It enables accurate monitoring of soil nutrient levels, which helps in evaluating the nutritional status of the soil. Based on this data, the system can recommend suitable crops and the appropriate type and quantity of fertilizers required for optimal growth. Additionally, the interface provides an option for users to manually input NPK values, ensuring flexibility and accuracy in crop and soil management.



(1.4)

(1.5)

This **(1.5)** interface is developed to provide recommended crops based on the real-time NPK (Nitrogen, Phosphorus, and Potassium) values detected from the soil. By analyzing the nutrient composition, the system suggests the most suitable crops that align with the current soil conditions, enabling farmers to make data-driven decisions for improved yield, resource efficiency, and sustainable farming practices.

Results

1.Real time Moniting : The real-time monitoring feature in the Soil Nutrition Monitoring and Management IoT project enables continuous tracking of critical soil parameters such as nitrogen, phosphorus, potassium (NPK), and moisture levels. Integrated sensors collect live data, which is processed by a microcontroller and displayed on an I2C LCD for immediate on-site visibility. Simultaneously, the data is transmitted wirelessly via Bluetooth to external devices, allowing remote access and monitoring. This real-time capability supports timely, data-driven decisions, enhances resource efficiency, and promotes optimal soil and crop management practices.

2.Remote Management : The Soil Nutrition Monitoring and Management project incorporates remote management capabilities that allow users to access and oversee soil health data from a distance. Through the integration of wireless communication modules such as Bluetooth, sensor data—including NPK levels and soil moisture—is transmitted to connected devices in real time. This enables users to monitor field conditions without being physically present, facilitating timely interventions and efficient resource allocation. The remote management feature enhances convenience, reduces labor, and supports precision agriculture by enabling proactive decision-making based on live soil data.

3.Data Analysis & Optimization : The Soil Nutrition Monitoring and Management IoT project features accurate data analysis and optimization capabilities for efficient soil management. By monitoring real-time NPK and moisture levels, the system enables precise, data-driven decisions on fertilizer and water usage. This ensures optimal crop growth, reduces resource waste, and supports sustainable farming practices.

4.Production Increase : The system enhances agricultural productivity by delivering precise insights into soil conditions through real-time monitoring and data-driven analysis. By optimizing nutrient and water application, it ensures crops receive the necessary inputs at the right time, promoting healthier growth. This targeted approach improves yield, reduces resource wastage, and supports efficient farm management.

5.Fertilizer Management : The system optimizes fertilizer usage by accurately assessing soil nutrient levels and providing data-driven recommendations. This targeted application minimizes overuse and wastage, reduces environmental impact, and ensures crops receive the appropriate nutrients for healthy growth. Efficient fertilizer management ultimately lowers costs and supports sustainable agricultural practices.

Data Flow Diagram :

```
+-------------------+      Sensor Data      +-------------------+
|            |------------------------->|            |
| Soil Sensors  |                  |  Microcontroller|
| (NPK, Moisture, |                  | (e.g., Arduino) |
|  Temperature)  |<-------------------------|            |
+-------------------+    Control Signal    +---------+--------+
                          |
                          |
                  Processed Sensor Data
                          |
                          v
                 +-------------+-------------+
                 |               |
                 |    Bluetooth Module    |
                 |    (e.g., HC-05)      |
                 +-------------+-------------+
                          |
              Transmit/Receive via Bluetooth
                          |
                          v
                +---------------+---------------+
                |                 |
                |    Farm-PA Mobile App     |
                | (Display data & send control) |
                +-------------------------------+
```

The data flow diagram illustrates how sensor data is collected, processed, and transmitted within the system. Soil sensors (NPK, moisture, temperature) send data to the Arduino microcontroller. The microcontroller processes this data and forwards it to the Bluetooth module (e.g., HC-05), which transmits the information to the Farm-PA mobile app. The app also sends control signals (like pump commands) back through Bluetooth, enabling remote and real-time farm management.

Challenges

1. Sensor Accuracy and Calibration: Ensuring reliable and accurate readings from NPK, moisture, and temperature sensors requires proper calibration and maintenance, which can be time-consuming.

2. Power Supply Limitations: In remote agricultural areas, providing a stable power source for continuous sensor and communication operation can be difficult.

3. Bluetooth Range Constraints: Bluetooth modules have limited range, which may restrict real-time communication if the mobile device is far from the field.

4. Environmental Interference : Harsh weather conditions, soil composition, or electromagnetic interference may affect sensor performance and data transmission.

5. **Data Integration and Interpretation**: Collecting data is not enough; analyzing it meaningfully for actionable decisions requires proper algorithms and interpretation tools.

6. Hardware Durability : Sensors and microcontrollers exposed to the outdoor environment must be protected from water, dust, and physical damage.

7. Cost and Scalability: Expanding the system across large farms may increase costs and complexity, limiting affordability for small-scale farmers.

8. Integration Challenges : Compatibility Issues: Integrating different types of sensors, microcontrollers (like Arduino, ESP32), and software platforms (cloud/database) can be technically challenging.Interfacing Errors: Miscommunication between hardware and software (e.g., incorrect sensor readings due to wrong code logic or driver issues).

9. Localization and Customization : Soil Type Variation: Different regions have different soil types, so a one-size-fits-all solution may not work.
Crop-Specific Needs: Different crops require different nutrient levels, so the system must be adaptable and configurable.

10. User Interface (UI/UX) Issues : Complex Interfaces: If the dashboard or mobile app is not user-friendly, farmers may find it difficult to use.Language Barriers: Lack of regional language support can limit usage among local farmers.

Use Cases

1. Real-time Soil Nutrient Monitoring :

- Measure NPK (Nitrogen, Phosphorus, Potassium) levels in soil in real time.
- Help farmers understand nutrient deficiencies instantly.

2. Soil Moisture Monitoring :

- Continuously check moisture levels to optimize irrigation.
- Prevent overwatering or underwatering.

3. Soil Health Monitoring for Research :

- Used in agricultural research institutions to collect data over time.Helps in analyzing soil degradation trends and testing new soil treatments.

4. Greenhouse Management :

- Monitors nutrient and moisture levels in controlled environments.
- Ensures optimal soil conditions for high-value crops grown in greenhouses.

5.Crop Recommendation Systems :

- Recommends the best crops to grow based on current nutrient and moisture levels.
- Improves crop planning and soil usage efficincy.

6. Alert and Notification System :

- Sends alerts to farmers when any nutrient level or moisture level falls below or exceeds the optimum range.
- Allows quick corrective actions to protect crops.

7. Fertilizer Efficiency Optimization :

- Tracks nutrient depletion after crop cycles.
- Helps determine the exact amount and timing of fertilizer application, minimizing cost and environmental impact.

8. Support for Organic Farming :

- Monitors natural nutrient cycles without synthetic inputs.
- Helps organic farmers ensure soil remains fertile using composts and natural fertilizers.

9.Remote Farm Management :

- Allows farmers or agronomists to monitor multiple fields remotely through a mobile or web app.
- Saves time and reduces the need for physical field visits.

10.Educational Demonstrations :

- Used in agricultural colleges and schools to teach students about real-time soil science and smart farming.
- Demonstrates hands-on IoT integration with agriculture.

11. Support for Organic Farming :

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- Helps organic farmers ensure soil remains fertile using composts and natural fertilizers.

12. Remote Farm Management :

- Allows farmers or agronomists to monitor multiple fields remotely through a mobile or web app.
- Saves time and reduces the need for physical field visits.

Conclusion

The Soil Nutrients Monitoring and Management IoT project represents a significant advancement in the field of precision agriculture. By integrating sensors that monitor key parameters such as soil moisture, temperature, and nutrient levels (NPK), the system enables real-time assessment of soil health and crop conditions. The inclusion of automated water control ensures efficient irrigation based on live soil moisture data, thereby conserving water and optimizing plant growth

In essence, this project bridges the gap between traditional farming methods and smart agricultural practices. It not only aids in improving yield and reducing input waste but also promotes sustainable resource usage. The system's adaptability and ease of use make it a valuable tool for farmers, researchers, and agri-tech innovators aiming to build a more resilient and productive farming future.

Overall, this project delivers a scalable, cost-effective, and sustainable solution for modern farming. It empowers users to make informed, data-driven decisions, improves crop yield and resource efficiency, and supports environmentally responsible farming practices. By bridging the gap between traditional agriculture and modern IoT technology, the system offers a practical and innovative approach to enhancing agricultural productivity and sustainability.

App link

1.FARM-PA - www.frampa/pa_tech.com

2.Full Documentation of the project:
https://parasuraman005.github.io/NN_project/

References

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2.Ardunio Documentation -https://www.arduino.com
3.Content writing -https://openai.com
4.Github -https://github.com