ECOPROBE – IOT DRIVEN SMART FARMING SOLUTIONS

PROJECT REPORT

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BONAFIDE

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1. INTRODUCTION

In the dynamic landscape of modern agriculture, the Ecoprobe project stands as a beacon of innovation, poised to revolutionize smart farming practices. By harnessing the transformative power of Internet of Things (IoT) technology, Ecoprobe integrates a sophisticated array of sensors with an Arduino board and a GSM module. This fusion of cutting-edge hardware and connectivity creates a robust and versatile solution tailored for monitoring and managing a diverse range of agricultural parameters. The core philosophy driving Ecoprobe is the seamless integration of advanced technology into traditional farming practices, empowering farmers with actionable insights and real-time data. This integration not only streamlines agricultural operations but also fosters sustainable practices by optimizing resource utilization and enhancing productivity.

1.1 Motivation

The motivation behind Ecoprobe is to enhance agricultural practices through data-driven insights. By collecting real-time data from sensors, farmers can make informed decisions about irrigation, fertilization, and crop health. This leads to improved efficiency, higher crop yields, and reduced resource wastage. It contributes to environmental sustainability and the conservation of natural resources by promoting precision agriculture. This project makes sure all farmers irrespective of their technological background can access user-friendly interfaces. In the final analysis, the goal of Ecoprobe initiative is empowerment of farmers, enhancing agricultural productivity, and creation of a more robust food production culture that can stand on its own environmentally.

1.2 Objective

The main objective of Ecoprobe is to develop a scalable, cost-effective, and comprehensive smart farming solution. This involves designing a system capable of accurately measuring and transmitting data on soil moisture, weather conditions, gas levels, water depth, temperature, pressure, and flame detection for enhanced farm safety. The system is designed to be user-friendly and capable of remote monitoring, catering to the diverse needs of farmers while promoting sustainable agricultural practices.

1.3 Problem Statement

Traditional farming methods often rely on manual observations and guesswork, leading to suboptimal results and resource misuse. Farmers face challenges in monitoring diverse environmental factors simultaneously and lack timely insights for decision-making. Ecoprobe addresses these issues by automating data collection and providing actionable information to farmers.

1.4 Challenges

- **Sensor Integration:** Integrating multiple sensors into a cohesive system while ensuring accuracy and reliability.

- **Communication Stability:** Ensuring stable communication between the sensors, Arduino board, GSM module, and cloud platform for data transmission.

- **Power Management:** Optimizing power consumption to prolong the system's battery life, especially in remote agricultural areas.

- **Data Interpretation:** Developing algorithms to analyze sensor data and generate meaningful insights for farmers.

- **Scalability:** Designing Ecoprobe to scale effectively for different farm sizes and types, accommodating varying sensor requirements.

- **Cost Efficiency:** Balancing the cost of components and infrastructure to make Ecoprobe affordable for small-scale farmers.

By addressing these formidable challenges, Ecoprobe not only aims to empower farmers with actionable data but also strives to revolutionize agricultural practices. Through the seamless integration of advanced sensor technologies, robust communication protocols, and efficient power management strategies, Ecoprobe sets a new standard for smart farming solutions. Its scalable design ensures adaptability to diverse farm sizes and types, fostering inclusivity and accessibility for farmers worldwide. Moreover, by optimizing cost efficiency and leveraging data interpretation algorithms, Ecoprobe paves the way for sustainable agriculture, contributing significantly to food security and environmental conservation efforts on a global scale.

2. LITERATURE SURVEY

1. This paper likely discusses the development of an Internet of Things (IoT) based data logger system for weather monitoring. It likely involves the use of Arduino-based wireless sensor networks to gather weather data, such as temperature, humidity, and possibly other parameters. The system may include a remote graphical application for visualizing the collected data and generating alerts based on predefined thresholds or conditions. Overall, it focuses on leveraging IoT technology to create a comprehensive weather monitoring solution with real-time data visualization and alerting capabilities.

2. The paper titled "Renewable Energy Integration Into Cloud & IoT-Based Smart Agriculture" explores the integration of renewable energy sources with cloud computing and Internet of Things (IoT) technologies in the context of smart agriculture. It discusses how renewable energy, such as solar or wind power, can be harnessed to power IoT devices and cloud infrastructure used in smart farming applications. The focus includes on optimizing energy usage, improving sustainability, and enhancing the efficiency of agricultural processes through the synergy of renewable energy, cloud computing, and IoT.

3. The paper "Recent Trends in Internet-of-Things-Enabled Sensor Technologies for Smart Agriculture" covers the latest advancements and developments in IoT-enabled sensor technologies specifically designed for smart agriculture applications. It discusses various sensors used in agriculture, such as soil sensors, weather sensors, crop monitoring sensors, and livestock tracking sensors, among others. The paper delves into topics like data collection, analysis, and utilization of IoT data to optimize agricultural practices, increase crop yields, and improve overall farm management efficiency.

4. The paper "A Survey on LoRa for Smart Agriculture: Current Trends and Future Perspectives" explores LoRa technology's role in smart agriculture. It covers its benefits for long-range communication, low-power IoT devices, data monitoring, and challenges like interference and security. The survey discusses current trends, potential future uses, and research directions for LoRa in agriculture.

5. The paper discusses a remote monitoring system for measuring tributary water depth and velocity. It likely uses Arduino and LoRa technology for data collection and transmission. This system enables real-time monitoring of water parameters in tributaries, which is valuable for various applications such as flood monitoring, water resource management, and environmental monitoring.

6. The paper explores the integration of artificial intelligence (AI) and the Internet of Things (IoT) in sustainable farming and smart agriculture. It likely discusses how AI techniques, such as machine learning and data analytics, are used with IoT devices to optimize farming practices, improve crop yields, reduce resource wastage, and promote environmental sustainability in agriculture.

7. The paper “Fabrication and Characterization of Soil Moisture Sensors on a Biodegradable, Cellulose-Based Substrate” focuses on the development and evaluation of soil moisture sensors fabricated on a biodegradable substrate made from cellulose. The study involves the design and manufacturing process of these sensors, including the selection of materials suitable for biodegradability and sensor functionality. The characterization part probably includes testing the sensors' performance in measuring soil moisture levels,

durability over time, and environmental impact due to their biodegradable nature.

8. This paper “Evaluation of Suitability of Low-Cost Gas Sensors for Monitoring Indoor and Outdoor Urban Areas”, assesses the feasibility and effectiveness of low-cost gas sensors for monitoring air quality in both indoor and outdoor urban environments. It involves testing various low-cost gas sensors to determine their accuracy, reliability, and suitability for detecting pollutants such as carbon monoxide, nitrogen dioxide, and particulate matter. The evaluation include comparison with standard reference sensors and analysis of the sensors' performance under different environmental conditions.

9. This survey paper “Internet of Things and Wireless Sensor Networks for Smart Agriculture Applications: A Survey”, explores the utilization of Internet of Things (IoT) technology and wireless sensor networks (WSNs) in smart agriculture applications. It likely covers various aspects such as sensor deployment, data collection and analysis, communication protocols, and applications of IoT and WSNs in enhancing agricultural productivity, optimizing resource usage, and improving decision-making processes in farming practices.

10. This study “Effects of IoT Communication Protocols for Precision Agriculture in Outdoor Environments” investigates the impact of IoT communication protocols on precision agriculture in outdoor settings. It likely compares different communication protocols, such as LoRa, NB-IoT, and Wi-Fi, in terms of their reliability, range, energy efficiency, and data transfer rates for collecting and transmitting agricultural data. The focus is on identifying the most suitable communication protocol that enhances the performance and effectiveness of precision agriculture systems in outdoor

environments.

11. This “IoT-Equipped and AI-Enabled Next Generation Smart Agriculture: A Critical Review, Current Challenges and Future Trends” review paper assesses the integration of IoT and AI technologies in next-generation smart agriculture. It discusses the current state of IoT-equipped and AI-enabled agricultural systems, including their benefits and challenges. The review covers the topics such as data analytics, automation, precision farming, and sustainability in agriculture.

12. This paper focuses on how IoT technology can be leveraged to improve crop yields through precision agriculture practices. It likely discusses the implementation of IoT devices such as sensors, drones, and automated equipment to monitor and manage crop conditions more precisely. The emphasis is on using real-time data analytics, remote sensing, and automated decision-making processes to optimize resource usage, detect crop stress factors early, and enhance overall agricultural productivity.

13. This project involves developing and implementing an IoT-based automated irrigation system for precision agriculture. It likely includes designing sensor networks to monitor soil moisture levels, weather conditions, and plant health parameters. The system uses IoT technology to collect data, analyze it in real time, and automate irrigation processes based on precise requirements, thereby optimizing water usage, enhancing crop growth, and improving overall farm efficiency.

14. This project focuses on developing an energy-efficient IoT network using LoRa technology for smart sensor agriculture systems. It likely involves integrating multiple sensors such as soil moisture, temperature, humidity, and

crop health sensors into a LoRa-based network. The emphasis is on optimizing energy consumption, extending sensor battery life, and ensuring reliable long-range communication for real-time data monitoring and decision-making in precision agriculture.

15. This study focuses on the integration of IoT-based environmental monitoring and data analytics for crop-specific smart agriculture management. It likely involves deploying sensors to monitor environmental factors like soil moisture, temperature, humidity, and weather conditions. The data collected is then analyzed using multivariate analysis techniques to optimize crop-specific management practices. The emphasis is on leveraging IoT technology and data analytics to enhance agricultural productivity, resource efficiency, and decision-making in smart farming.

LIMITATIONS OF THE EXISTING SYSYTEMS:

The limitations faced until now of the existing systems will be that the models are focused on single sensing technology as follows:

1. **Limited Sensor Integration**: Existing systems often monitor only a few parameters, lacking a comprehensive view.

2. **Delayed Data Access**: Manual data collection or periodic uploads lead to delays in accessing real-time information.

3. **Restricted Remote Monitoring**: Lack robust remote monitoring features, requiring frequent on-site visits.

4. **Limited Scalability**: Difficult to expand or integrate additional sensors without major system disruptions.

5. **Inefficient Resource Management**: Less data-driven, leading to suboptimal resource allocation.

6. **Higher Operational Costs**: Separate devices and data plans increase overall operational expenses.

3. REQUIREMENTS

3.1 Requirement Analysis

Requirement analysis is a critical step in developing "Smart Farming Solutions with Ecoprobe," integrating sensors, Arduino boards, and Microsoft Azure. It involves identifying stakeholders' needs, defining system scope, and specifying hardware, software, functional, and non-functional requirements. This analysis ensures alignment with stakeholders' expectations and guides implementation for an effective and user-centric smart farming solution. The goal of requirement analysis for Ecoprobe is to define the scope of the project, outline the hardware and software components required, specify the functional and non-functional aspects of the system, and establish clear guidelines for implementation and testing. By conducting a thorough requirement analysis, we can align our efforts with the expectations of farmers, agricultural experts, and other stakeholders, ultimately delivering a robust and user-centric smart farming solution.

3.2 Hardware Requirements

- **Arduino Board:** The system should support Arduino boards for sensor integration and data processing.
- **Gas Sensor:** An accurate gas sensor is required to monitor gas levels in the farm environment for safety and health monitoring.
- **Water Depth Sensor:** To measure the water level in irrigation systems or water bodies for efficient water management.
- **Rain Sensor:** For detecting rainfall and adjusting irrigation schedules accordingly.
- **Temperature and Humidity Sensor:** To monitor ambient temperature and humidity levels for crop health and climate control.
- **Soil Moisture Sensor:** Essential for measuring soil moisture content to

optimize irrigation and prevent overwatering or underwatering.

- **Pressure Sensor:** Required for measuring atmospheric pressure, which can impact weather forecasting and crop growth.
- **Flame Detection Sensor:** To detect fires or overheating in farm equipment or areas, ensuring timely response and safety measures.
- **GSM Module:** Enables communication and data transmission to a cloud platform for remote monitoring and control.

3.3 Software requirements

- **Blynk IoT Integration:** Seamless integration with Blynk IoT as the cloud platform for data storage, analytics, and remote access.
- **Sensor Data Processing:** Development of software algorithms to process sensor data, perform analytics, and generate actionable insights for farmers.
- **Arduino IDE:** Utilization of Arduino IDE for programming and interfacing with Arduino boards, facilitating sensor integration and control within the Ecoprobe system.
- **User Interface:** Creation of a user-friendly interface for farmers to access data, receive alerts, and control farm systems remotely.

3.4 Functional Requirements

- **Real-time Data Monitoring:** Continuous monitoring of sensor data such as gas levels, water depth, rainfall, temperature, humidity, soil moisture, pressure, and flame detection.
- **Data Analytics:** Analyzing sensor data to provide insights on crop health, irrigation needs, weather patterns, and potential hazards.
- **Remote Control:** Allowing farmers to remotely control irrigation systems, climate control devices, and receive alerts for critical events.

- **Cloud Integration:** Seamless integration with Blynk IoT Cloud for data storage, processing, and access from anywhere with internet connectivity.
- **Scalability:** The system should be scalable to accommodate additional sensors or functionalities in the future**.**

4. PROPOSED SYSTEM & ARCHITECTURE AND DESIGN

Proposed System:

The proposed system combines Ecoprobe IoT devices with GSM modules to create an advanced agricultural monitoring system. It includes seven key sensors (Water Depth, Soil Health, Temperature/Humidity, Pressure, Gas Levels, flame detection and Rainfall) in one device, giving farmers a complete picture of their field's conditions. The GSM module sends real-time data and alerts to farmers' phones or central monitoring systems, allowing quick decisions and proactive farm management. Farmers can remotely check their fields' status, reducing the need for on-site inspections and helping them use resources efficiently. The system also provides data analytics to process sensor data, generate insights, and suggest ways to optimize irrigation, fertilization, and pest control strategies.

Architecture Overview:

Ecoprobe follows a layered architecture, integrating hardware components, software modules, cloud services, and user interfaces to create a comprehensive smart farming system.

Hardware Layer:

- **Arduino Board:** Interface with sensors and act as data acquisition units.
- **Sensors:** Including gas sensors, water depth sensors, rain sensors, temperature and humidity sensors, soil moisture sensors, pressure sensors, and flame detection sensors.
- **GSM Module:** Facilitates communication between the system and the cloud platform.

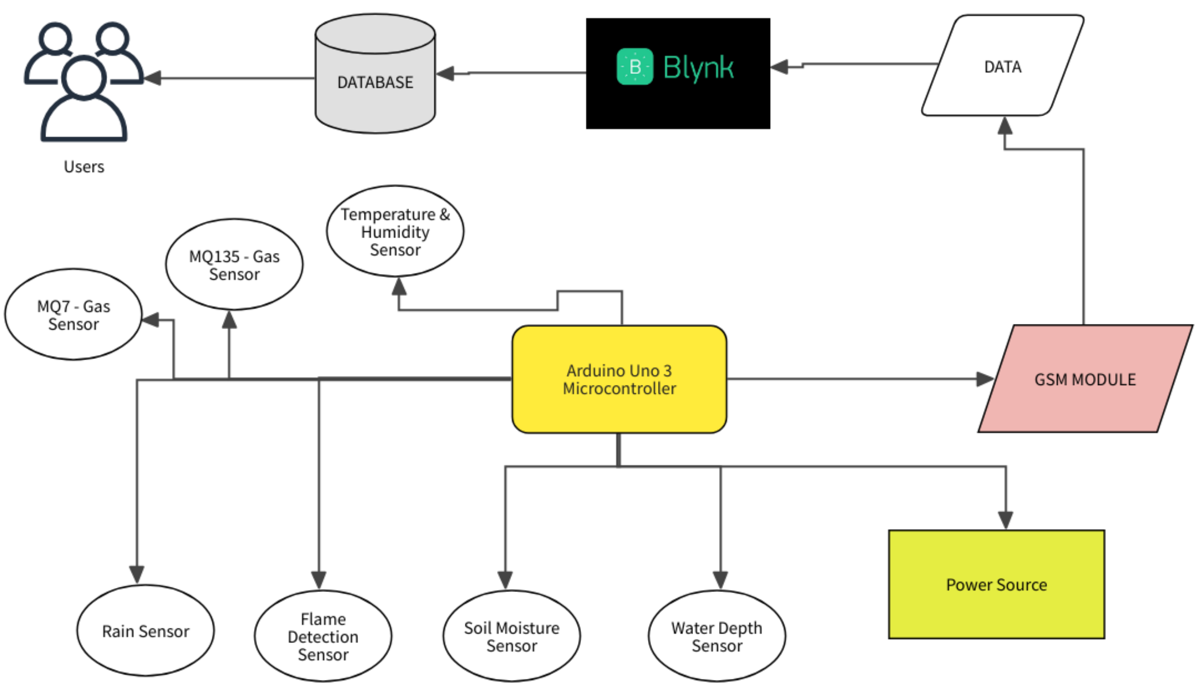
Software Layer:

- **Arduino IDE:** Used for programming Arduino boards and interfacing with sensors.

- **Sensor Data Processing Algorithms:** Process sensor data, perform analytics, and generate insights.
- **User Interface:** Developed using web technologies or a dedicated application for farmers to interact with the system.

Cloud Layer:

- **Blynk IoT Cloud:** Cloud platform for data storage, analytics, and remote access.
- **Data Storage:** Stores sensor data and analytical results for historical analysis and real-time monitoring.
- **Analytics Services:** Perform complex analytics on sensor data to generate actionable insights.
- **Remote Access:** Enables farmers to access data, receive alerts, and control farm systems remotely.



Design Considerations:

i) Modularity and Scalability:

- The system is designed with modularity to easily add or replace sensors based on farm requirements.
- Scalable architecture allows for expansion to accommodate additional sensors or functionalities in the future.

ii) Data Processing and Analytics:

- Efficient algorithms for processing sensor data and performing analytics to generate meaningful insights for farmers.
- Real-time analytics for immediate decision-making and historical data analysis for trend identification.

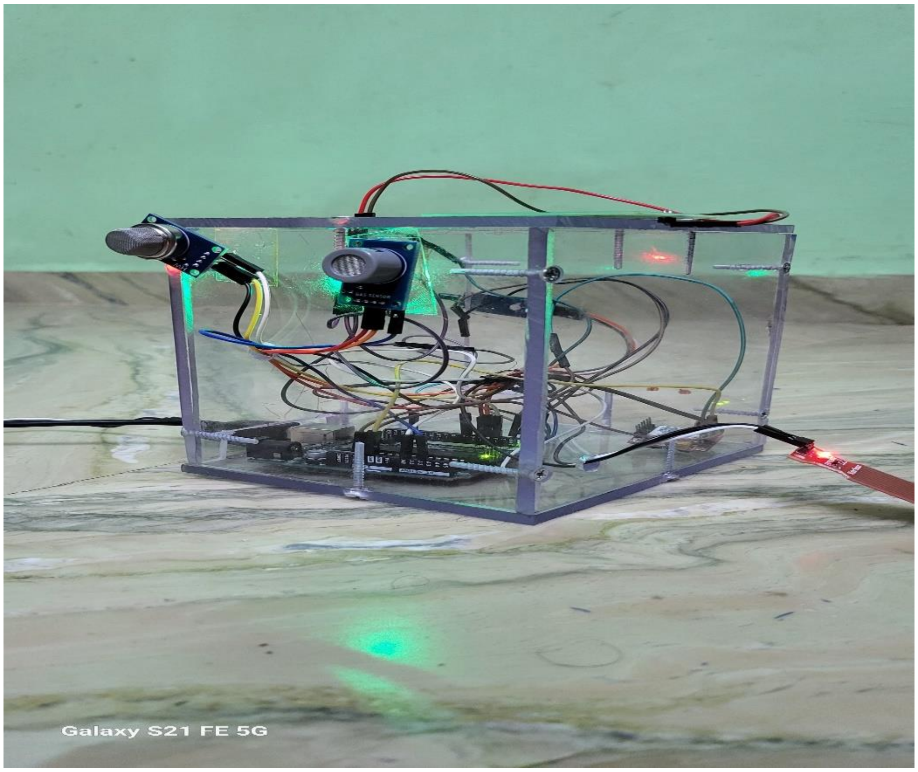
iii) User Experience:

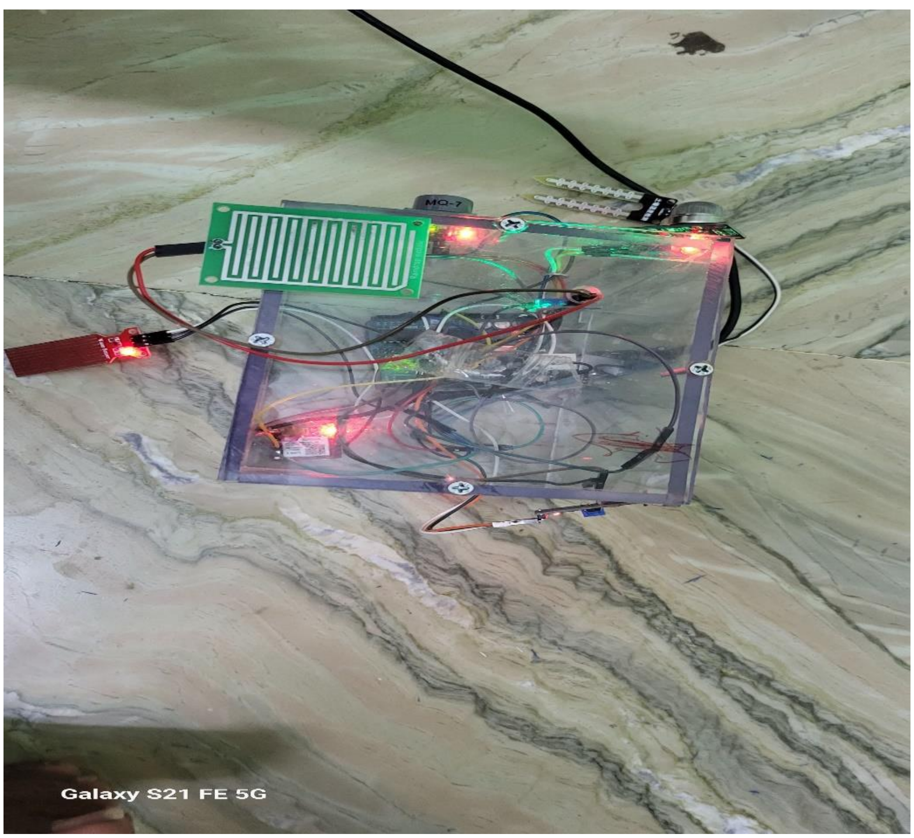
- User-friendly interfaces with intuitive design for easy navigation and understanding of farm data.
- Alerts and notifications system to inform farmers about critical events or anomalies.

iv) Security and Reliability:

- Implement security measures such as encryption for data transmission and access control for secure remote management.
- Ensure system reliability with backup mechanisms and failover strategies to handle unexpected disruptions.

PROTOTYPE DESIGN:





5. IMPLEMENTATION

```
#include <SoftwareSerial.h>
#include <BlynkSimpleSIM800.h>

// Define sensor pins
#define FLAME_SENSOR_PIN 4
#define MQ135_SENSOR_PIN A0
#define MQ7_SENSOR_PIN A2
#define WATER_SENSOR_PIN 3
#define RAINDROP_SENSOR_PIN 7
#define SOIL_SENSOR_PIN 5

// Define thresholds for MQ135 and MQ7 sensors
#define MQ135_THRESHOLD 500 // Adjust this value according to your needs
#define MQ7_THRESHOLD 300   // Adjust this value according to your needs

// Define software serial pins for SIM800L module
#define SIM800_RX_PIN 2
#define SIM800_TX_PIN 3

char auth[] = " sLq7NO6xbslKtEA5HyB1mjhnxGiAMIjQ "; // Blynk authentication
token

SoftwareSerial sim800(SIM800_RX_PIN, SIM800_TX_PIN); // RX, TX

void setup() {
  Serial.begin(9600);
  sim800.begin(9600); // SIM800L baud rate
```

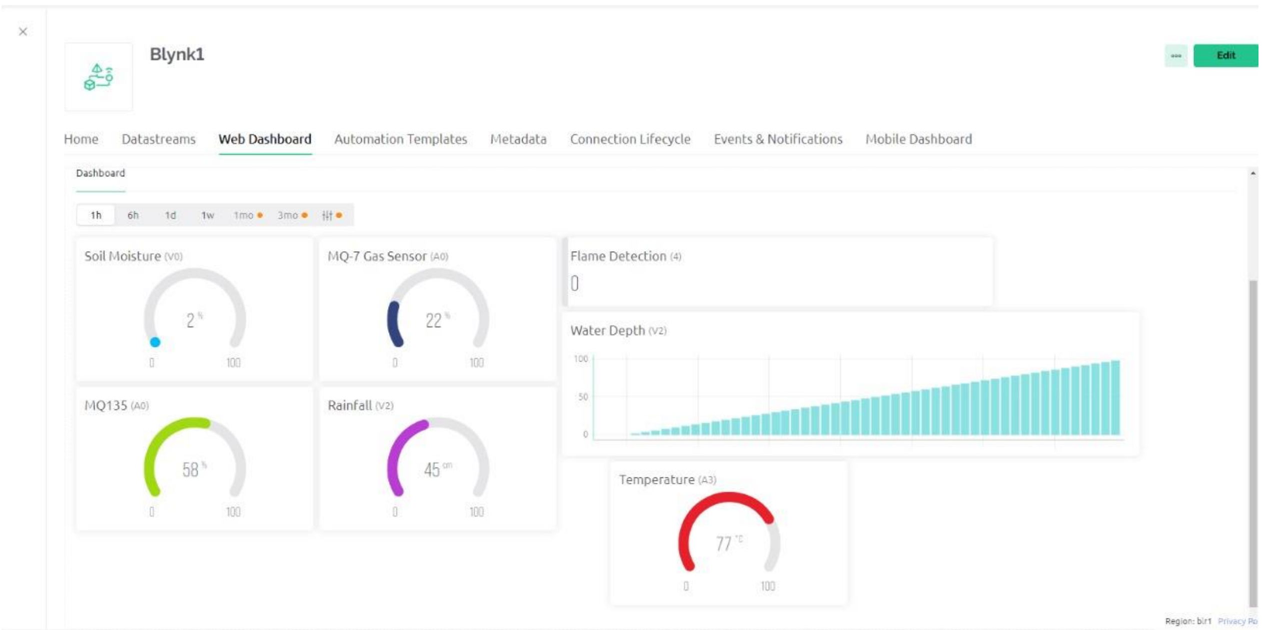
```
  delay(10000); // Wait for SIM800L to initialize

  Blynk.begin(auth, sim800, " airtelgprs.com ", "", ""); // Your mobile network APN

  // Set sensor pins as inputs
  pinMode(FLAME_SENSOR_PIN, INPUT);
  pinMode(MQ135_SENSOR_PIN, INPUT);
  pinMode(MQ7_SENSOR_PIN, INPUT);
  pinMode(WATER_SENSOR_PIN, INPUT);
  pinMode(RAINDROP_SENSOR_PIN, INPUT);
  pinMode(SOIL_SENSOR_PIN, INPUT);
}

void loop() {
  Blynk.run();

  // Read sensor values
  int flameValue = digitalRead(FLAME_SENSOR_PIN);
  int mq135Value = analogRead(MQ135_SENSOR_PIN);
  int mq7Value = analogRead(MQ7_SENSOR_PIN);
  int waterValue = digitalRead(WATER_SENSOR_PIN);
  int raindropValue = digitalRead(RAINDROP_SENSOR_PIN);
  int soilValue = digitalRead(SOIL_SENSOR_PIN);

  // Send sensor data to Blynk cloud
  Blynk.virtualWrite(V4, flameValue);
  Blynk.virtualWrite(A0, mq135Value);
  Blynk.virtualWrite(A1, mq7Value);
  Blynk.virtualWrite(V2, waterValue);
  Blynk.virtualWrite(V5, raindropValue);
  Blynk.virtualWrite(V0, soilValue);
```

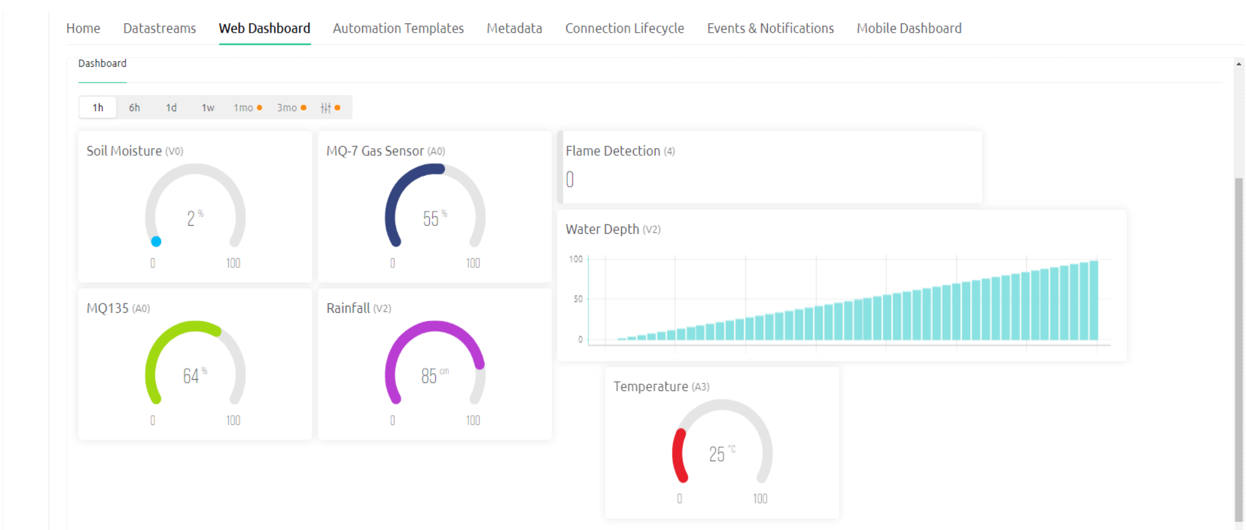
```
Blynk.virtualWrite(A3, temperatureValue);


  delay(1000); // Adjust delay as needed
}
```

6. RESULTS AND DISCUSSION

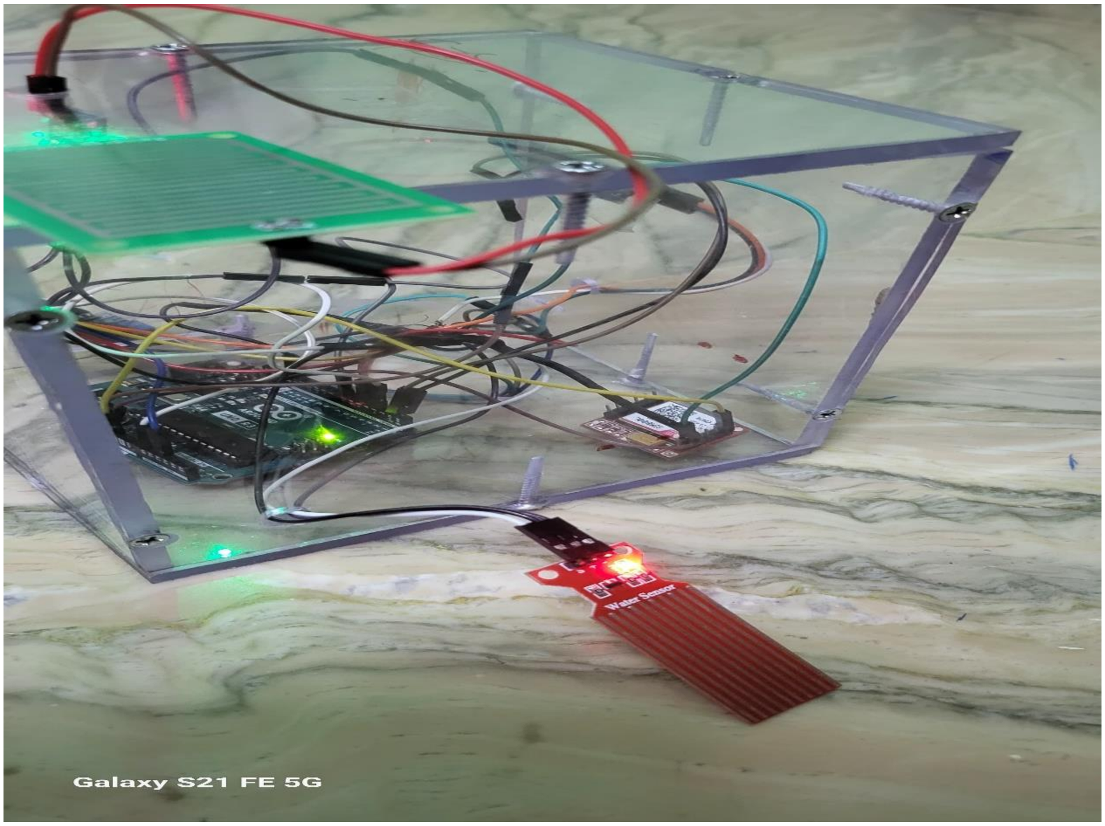
6.1 OUTPUT

WEB DASHBOARD:





Working of the Model



The Ecoprobe Smart Farming Solutions project demonstrates successful data collection from seven key sensors essential for monitoring agricultural conditions: rain, gas levels, soil moisture, temperature, humidity, flame detection and water depth. This data is efficiently transmitted to the cloud through a GSM module and Arduino board setup, enabling remote access and analysis. The selection of these sensors reflects a comprehensive approach to gathering vital information for farmers, empowering them to make informed decisions about irrigation, pest control, and overall crop management.

One of the project's critical discussions revolves around ensuring the accuracy and reliability of sensor data, emphasizing the need for calibration protocols and ongoing maintenance to uphold data integrity. Additionally, the integration with cloud services enables real-time monitoring and analysis, enhancing the scalability and adaptability of the system to future sensor additions or expanded functionalities. User-friendly interfaces and robust security measures are also highlighted, ensuring ease of use for farmers while safeguarding sensitive agricultural data. Overall, Ecoprobe's implementation presents a promising solution for modernizing farming practices, optimizing resource utilization, and promoting sustainable agricultural growth.

Moreover, Ecoprobe's user-centric design extends to the visualization and interpretation of collected data. Through intuitive dashboards and analytics tools, farmers can gain valuable insights into trends, anomalies, and correlations within their agricultural environment. This actionable information empowers them to implement targeted strategies for crop optimization, resource allocation, and risk mitigation. The seamless integration of data visualization not only enhances decision-making capabilities but also fosters a deeper understanding of the interconnected factors influencing crop health and yield.

7. CONCLUSION

The Ecoprobe Smart Farming Solutions project stands as a beacon of innovation in the realm of agricultural technology, particularly in its adept utilization of IoT advancements. By seamlessly amalgamating sensor data acquisition, cloud-driven analysis, and user-centric interfaces, Ecoprobe delivers a robust toolkit to farmers, empowering them to monitor their fields' conditions with unprecedented precision. This capability translates into tangible benefits, enabling farmers to make data-driven decisions regarding irrigation, pest control, and overall crop management.

Moreover, Ecoprobe's success is not merely confined to data collection and analysis but extends to its seamless data transmission mechanisms. The project's ability to efficiently transmit crucial agricultural data from remote locations to centralized cloud servers ensures real-time insights and proactive responses to emerging challenges. This real-time data access equips farmers with the agility needed to address environmental fluctuations promptly, thereby mitigating risks and optimizing resource allocation for enhanced productivity.

The project's holistic approach, encompassing sensor functionality, cloud integration, and user accessibility, positions Ecoprobe as a catalyst for transforming traditional farming practices into data-informed, sustainable operations. As sensor technologies continue to evolve and data analytics capabilities expand, Ecoprobe sets a solid foundation for ongoing advancements in smart farming solutions, promising a future where agriculture is not only efficient but also environmentally conscious and economically viable.

8. REFERENCES

1. Mabrouki, J., Azrour, M., Dhiba, D., Farhaoui, Y., & El Hajjaji, S. (2021). IoT-based data logger for weather monitoring using arduino-based wireless sensor networks with remote graphical application and alerts. *Big Data Mining and Analytics*, *4*(1), 25-32.
2. Bouali, E. T., Abid, M. R., Boufounas, E. M., Hamed, T. A., & Benhaddou, D. (2021). Renewable energy integration into cloud & IoT-based smart agriculture. *IEEE Access*, *10*, 1175-1191.
3. Shaikh, F. K., Karim, S., Zeadally, S., & Nebhen, J. (2022). Recent trends in internet-of-things-enabled sensor technologies for smart agriculture. *IEEE Internet of Things Journal*, *9*(23), 23583-23598.
4. Pagano, A., Croce, D., Tinnirello, I., & Vitale, G. (2022). A survey on LoRa for smart agriculture: Current trends and future perspectives. *IEEE Internet of Things Journal*, *10*(4), 3664-3679.
5. Jasni, A. A., Ahmad, Y. A., Gunawan, T. S., Yaacob, M., Ismail, N., & Wasik, A. (2022, July). Tributary water depth and velocity remote monitoring system using Arduino and LoRa. In *2022 IEEE 8th International Conference on Computing, Engineering and Design (ICCED)* (pp. 1-6). IEEE.
6. AlZubi, A. A., & Galyna, K. (2023). Artificial intelligence and internet of things for sustainable farming and smart agriculture. *IEEE Access*.
7. Zaccarin, A. M., Iyer, G. M., Olsson, R. H., & Turner, K. T. (2023). Fabrication and Characterization of Soil Moisture Sensors on a Biodegradable, Cellulose-Based Substrate. *IEEE Sensors Journal*.
8. Wang, J., Viciano-Tudela, S., Parra, L., Lacuesta, R., & Lloret, J. (2023). Evaluation of Suitability of Low-Cost Gas Sensors for Monitoring Indoor and Outdoor Urban Areas. *IEEE Sensors Journal*.

9. Mowla, M. N., Mowla, N., Shah, A. S., Rabie, K., & Shongwe, T. (2023). Internet of Things and Wireless Sensor Networks for Smart Agriculture Applications-A Survey. *IEEE Access*.
10. Hashmi, A. U. H., Mir, G. U., Sattar, K., Ullah, S. S., Alroobaea, R., Iqbal, J., & Hussain, S. (2024). Effects of IoT Communication Protocols for Precision Agriculture in Outdoor Environments. *IEEE Access*.
11. Qazi, S., Khawaja, B. A., & Farooq, Q. U. (2022). IoT-equipped and AI-enabled next generation smart agriculture: A critical review, current challenges and future trends. *Ieee Access*, *10*, 21219-21235.
12. Sharma, R., Mishra, V., & Srivastava, S. (2023, May). Enhancing Crop Yields through IoT-Enabled Precision Agriculture. In *2023 International Conference on Disruptive Technologies (ICDT)* (pp. 279-283). IEEE.
13. Kumar, A., Tiwari, R. G., & Trivedi, N. K. (2023, September). Smart Farming: Design and Implementation of an IoT-Based Automated Irrigation System for Precision Agriculture. In *2023 3rd International Conference on Innovative Sustainable Computational Technologies (CISCT)* (pp. 1-6). IEEE.
14. Mishra, S., Nayak, S., & Yadav, R. (2023, January). An energy efficient LoRa-based multi-sensor IoT network for smart sensor agriculture system. In *2023 IEEE Topical Conference on Wireless Sensors and Sensor Networks* (pp. 28-31). IEEE.
15. Vimal, V. (2023, November). Integrating IoT-Based Environmental Monitoring and Data Analytics for Crop-Specific Smart Agriculture Management: A Multivariate Analysis. In *2023 3rd International Conference on Technological Advancements in Computational Sciences (ICTACS)* (pp. 368-373). IEEE.