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AgriPulse: Smart Agriculture & Ecological Data Collection and Decision Support System

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Abstract : AgriPulse is a smart agricultural and ecological data collection and decision support system developed to enhance farming efficiency through Internet of Things (IoT)–based monitoring and automation. The system serves as a practical testbed to evaluate the effectiveness of modern technologies in sustainable agriculture while demonstrating real-world implementation of information technology in farming practices. Using a NodeMCU ESP8266 microcontroller, the system integrates multiple environmental and soil sensors to enable real-time data acquisition and wireless data transmission. The collected data supports automated decision-making aimed at optimizing resource utilization and reducing water and energy wastage. AgriPulse demonstrates how IoT-driven automation can improve agricultural productivity and promote sustainable living for both rural and urban farmers.

IndexTerms - **Smart Agriculture, Internet of Things (IoT), Precision Farming, Automated Irrigation, Soil Moisture Monitoring, NodeMCU (ESP8266), Environmental Sensing, Sustainable Farming, Water Resource Optimization, Real Time Monitoring, Relay Based Pump Control, Agricultural Decision Support System, Multi Sensor Integration, Low Cost Farming Technology, Rural Smart Farming Solutions.**

I. INTRODUCTION

Agriculture has long been the foundation of India’s economy, providing food security and a livelihood to nearly 50% of the population. Even today, a major portion of rural communities relies directly or indirectly on farming for survival. Despite its immense importance, the agricultural sector is under continuous stress due to declining productivity, environmental degradation, and low income for farmers. Rapid climate change, unpredictable rainfall, poor soil health, excessive dependence on chemical fertilizers, and slow adoption of modern technologies have weakened the reliability of conventional farming practices. Among the numerous issues faced by farmers, water scarcity is one of the most pressing concerns. Over-extraction of groundwater and inefficient irrigation practices—particularly flood irrigation—have caused water levels to fall sharply across many regions. Inadequate monitoring and lack of timely irrigation result in massive water wastage, higher farming costs, crop stress, reduced yields, and long-term environmental damage. Since many farmers depend on intuition or traditional experience to decide irrigation timing, improper watering—either too much or too little—is common. To address these challenges, technology-driven farming methods have become crucial. Smart farming combines the use of IoT devices, automation, and analytical tools to transform traditional practices. By deploying sensors and microcontrollers, farmers can continuously track soil moisture, temperature, humidity, and water levels. This ensures accurate, data-based decisions instead of guesswork, improving productivity while minimizing the misuse of resources. With this need in mind, AgriPulse: Smart Agricultural & Ecological Data Collection and Decision Support System is designed as a cost-efficient, IoT-enabled smart farming system aimed at improving irrigation efficiency and promoting sustainable agricultural practices. The project utilizes low-cost components such as the YL-59 soil moisture sensor, DHT11 temperature and humidity sensor, and water-level sensors, all controlled via NodeMCU . These components help automate irrigation based on real-time field data, ensuring water is supplied precisely when required. This minimizes manual intervention, conserves water, and protects crops from inconsistent irrigation. A key advantage of AgriPulse: Smart Agricultural & Ecological Data Collection and Decision Support System is its affordability and accessibility. Unlike many expensive smart farming solutions, AgriPulse: Smart Agricultural & Ecological Data Collection and Decision Support System specifically targets small and medium-scale farmers who cannot invest in advanced technologies. The system delivers the benefits of precision agriculture without requiring heavy expenditure. It helps farmers reduce operational costs, enhance yield, and adopt sustainable farming practices. AgriPulse: Smart Agricultural & Ecological Data Collection and Decision Support System also aligns with global sustainability goals, particularly the United Nations Sustainable Development Goals—SDG 2 (Zero Hunger) and SDG 12 (Responsible Consumption and Production). By reducing water wastage and promoting efficient irrigation, AgriPulse: Smart Agricultural & Ecological Data Collection and Decision Support System contributes to both agricultural development and environmental conservation. This background highlights the necessity and relevance of AgriPulse: Smart Agricultural & Ecological Data Collection and Decision Support System in today’s agricultural landscape. Through the integration of affordable IoT technologies, it offers a practical and scalable solution for better water management and improved crop productivity.

II. LITERATURE SURVEY

Over the last decade, agriculture has witnessed significant technological advancements aimed at increasing productivity and ensuring sustainable use of natural resources. With rising concerns about climate change, declining water availability, and increasing population pressure, research in precision agriculture has gained momentum. Precision farming relies on real-time data collected from sensors to help farmers manage crops more accurately and efficiently. Several research studies show that IoT-based agricultural systems can greatly reduce water usage and enhance crop yields. Evidence suggests that irrigation systems based on soilmoisture data can cut water consumption by 20–40% while improving plant health and productivity. Compared with fixed-schedule irrigation, soil-moisture-based systems ensure that plants receive water only when needed, preventing over-irrigation and under-irrigation. Recent studies also emphasize the use of low-cost sensors for continuous monitoring of environmental conditions. Devices like the YL-59 soil moisture sensor, DHT11 temperaturehumidity sensor, and basic water-level sensors are frequently recommended for small-scale agricultural systems because of their affordability and satisfactory accuracy. When integrated with microcontrollers like NodeMCU or Raspberry Pi, these sensors enable automated, efficient, and economically viable irrigation systems. Many researchers have also highlighted the importance of mobile or web dashboards that display sensor data remotely. Such interfaces reduce the need for farmers to be physically present in their fields and allow them to make quick decisions based on real-time conditions. This reduces labor effort and helps farmers respond promptly to environmental changes. Government-supported initiatives, such as NAIN 2.0, and various student innovation programs have further encouraged the development of scalable and farmer-friendly IoT solutions. These initiatives prioritize small and marginal farmers who lack access to expensive agricultural technologies. Despite promising results, existing research also points out several challenges—sensor inaccuracy in harsh conditions, poor hardware durability, inconsistent power supply, unreliable connectivity, and user interfaces that may be too complex for non-technical users. These limitations hinder the effective long-term implementation of IoT-based systems. The reviewed literature clearly shows a need for integrated, low-cost, reliable smart farming solutions that are easy for farmers to adopt. Many existing systems either monitor only one environmental parameter or are too expensive for practical use in rural areas. Addressing these gaps, AgriPulse: Smart Agricultural & Ecological Data Collection and Decision Support System is developed as an economical and comprehensive solution that integrates multiple sensors on a single platform for automated irrigation, real-time monitoring, and efficient water usage. By overcoming the cost and technical challenges found in previous systems, AgriPulse: Smart Agricultural & Ecological Data Collection and Decision Support System provides a practical and sustainable approach to modern agriculture.

III. EXISTING SYSTEM

In many regions of India, farming still relies heavily on manual observation of soil conditions, water needs, and crop health. Farmers typically decide irrigation schedules based on visual cues, routine patterns, or traditional experience. While such practices work under stable weather conditions, they become unreliable during climate fluctuations such as heat waves, irregular monsoons, or prolonged dry periods.

This conventional approach often results in two major problems:

1. **Over-Irrigation**

- Excessive water use
- Loss of essential soil nutrients due to leaching
- Higher electricity bills from continuous pump usage
- Reduced soil fertility over time

2. **Under-Irrigation**

- Water stress in plants
- Poor growth rate
- Low crop yield
- Risk of crop failure during prolonged dry spells

Some technologically advanced farms use automated watering systems based on timers or basic soil-moisture detection. However, these systems also have limitations:

- They usually monitor only one parameter and ignore others such as temperature, humidity, and water availability.
- Many operate based on fixed thresholds and cannot adapt dynamically to changing environmental conditions.
- High installation costs make them unsuitable for small rural farms.
- They lack remote monitoring features such as mobile or cloud dashboards.
- Most require technical understanding that many farmers do not possess.

Most existing IoT-based farming setups are designed for large commercial farms with good infrastructure and financial resources. As a result, small and marginal farmers—who make up a large portion of India's agricultural sector—are unable to access these technologies.

This highlights a clear gap between available agricultural technology and the actual needs of rural farmers. To bridge this gap, there is a need for a low-cost, multi-sensor, easy-to-use, and automated smart-farming system—which forms the foundation for AgriPulse: Smart Agricultural & Ecological Data Collection and Decision Support System.

IV. PROPOSED SYSTEM

The proposed-system, The proposed AgriPulse: Smart Agricultural & Ecological Data Collection and Decision Support System model provides a complete IoT-enabled smart-farming solution that addresses the shortcomings of existing systems. It integrates multiple sensors with an NodeMCU -based controller for continuous monitoring and automated irrigation.

Key Components of the AgriPulse: Smart Agricultural & Ecological Data Collection and Decision Support System System

- **YL-59 Soil Moisture Sensor** – Measures soil moisture levels
- **DHT11 Sensor** – Records temperature and humidity
- **Water Level Sensor** – Detects available water in the tank
- **NodeMCU Microcontroller** – Processes sensor data and controls irrigation
- **Relay Module + Water Pump** – Enables pump automation
- **Mobile Dashboard / Display Interface** – Shows live data and alerts

Working Mechanism

Sensors continuously monitor environmental conditions in the field. The NodeMCU processes the incoming data and makes decisions based on predefined thresholds:

- When soil moisture drops below the required value → Pump automatically turns ON
- When soil moisture becomes adequate → Pump turns OFF to prevent over-watering
- Temperature and humidity readings provide additional climatic information
- The water-level sensor prevents irrigation when the tank is empty

A mobile dashboard displays live readings, alerts, and irrigation activity, enabling farmers to:

- Remotely check field conditions
- Receive notifications
- Track system performance in real time

Advantages of the Proposed System

- Fully automated irrigation
- Low cost and affordable for rural communities
- Multi-parameter environmental monitoring
- Very little manual involvement
- Simple to install and maintain
- Easily expandable to larger farms
- Supports sustainable agricultural practices

Future Enhancements

- Machine-learning-based irrigation prediction
- Cloud data storage for long-term analysis
- Integration with weather APIs for climate-smart irrigation

AgriPulse: Smart Agricultural & Ecological Data Collection and Decision Support System is specifically designed to provide small farmers with an economical and technologically efficient alternative to expensive commercial solutions.

V. SYSTEM DESIGN

System design is one of the most important phases of the AgriPulse: Smart Agricultural & Ecological Data Collection and Decision Support System project because it explains how the system is structured and how all components work together. This chapter describes the logical flow of data, the interaction between different users and modules, and the step by step working of the system using a Data Flow Diagram and the algorithmic process.

The main purpose of the design is to ensure that the system is:

• Simple and clear to understand
• Reliable for real time farming use
• Easy for farmers to operate
• Safe by keeping irrigation decision under manual control without automatic pump switching

Data Flow Diagram

The Data Flow Diagram represents how data moves through the AgriPulse system. It shows:

• Where the data comes from
• How it is processed
• Where it is stored
• Who receives the final information

External Entities

1. Farmer User

The farmer is the main user of the system. The farmer:

• Views soil moisture, temperature, humidity and water level on the mobile app or dashboard
• Receives alerts and notifications
• Manually decides whether to irrigate or not based on system suggestions

2. Sensors (Input Devices)

• YL 59 Soil Moisture Sensor measures soil water content
• DHT11 or DHT22 Sensor measures temperature and humidity
• Water Level Sensor checks water availability in the tank or source

System Processes

1. Sensor Data Collection

This process runs on the NodeMCU ESP8266 and collects live data from:
• Soil moisture sensor
• Temperature and humidity sensor
• Water level sensor

2. Data Processing and Analysis

The ESP8266:
• Reads raw sensor values
• Formats them into structured data
• Sends data to Firebase Realtime Database via WiFi
The system then:
• Compares sensor values with predefined crop specific threshold values
• Identifies whether conditions are normal or critical
• Decides which alerts and suggestions to send to the farmer
Important:
• The system does not automatically switch the pump ON or OFF
• It only sends recommendations and alerts
• The final decision always remains with the farmer

3. Notification and Display Process

The mobile application reads the latest data from Firebase and displays:
• Soil is Dry – Irrigation Recommended
• Soil Moisture Optimal – No Irrigation Needed
• Low Water in Tank
• Temperature and humidity alerts
This information is displayed on:
• React Native mobile application
• Optional web dashboard
• SMS, WhatsApp, or push notifications if enabled

4. Manual Decision by Farmer

After receiving the notification:
• The farmer decides whether to irrigate or wait
• The farmer uses manual pump control which is outside the scope of automatic control in this project
This ensures:
• Human control is always present
• There is no risk of unwanted automatic irrigation

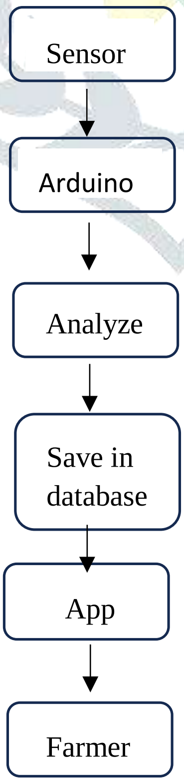


Fig 5.1: System Flow Chart.

VI. METHODOLOGY

This chapter presents the structured and systematic methodology adopted for the design, development, and deployment of the AgriPulse: Smart Agricultural & Ecological Data Collection and Decision Support System. The methodology defines the step by step procedure followed to transform the agricultural problem into a practical, cost effective, and scalable IoT based solution.
The approach ensures that the system satisfies both functional requirements such as real time monitoring and automated irrigation, and non functional requirements including reliability, affordability, scalability, and user friendliness. The methodology is specifically designed considering the needs of small and marginal farmers and emphasizes simplicity, sustainability, and precision agriculture.

6.1 Methodological Framework

The development of AgriPulse follows a structured engineering lifecycle consisting of the following phases:

1. Problem Identification and Requirement Analysis
2. Conceptual Model Development
3. System Architecture Design
4. Hardware Selection and Integration
5. Software Development and Communication Setup
6. Algorithm Design for Irrigation Control
7. Testing, Validation, and Performance Evaluation

Each phase is explained below.

6.2 Problem Identification and Requirement Analysis

The first stage involved identifying key challenges faced by farmers in irrigation management. Field level observations and literature review indicated issues such as irregular watering, water wastage, lack of environmental monitoring, and absence of affordable smart farming tools.
Based on this analysis, the following system requirements were defined:

- Real time soil moisture monitoring
- Temperature and humidity tracking
- Water level detection
- Automated irrigation control
- Remote monitoring capability
- Low cost implementation
- Ease of installation and maintenance

These requirements formed the foundation for system development.

6.3 Conceptual Model Development

After defining system requirements, a conceptual IoT based smart farming model was developed. The model integrates environmental sensors, a microcontroller, irrigation hardware, and a user interface.
The conceptual workflow is as follows:

1. Sensors continuously monitor field conditions
2. The microcontroller processes sensor readings
3. Predefined threshold logic evaluates irrigation need
4. The system controls pump operation automatically
5. Data is displayed on a dashboard for monitoring

This model ensures intelligent decision making based on real time environmental data.

6.4 System Architecture Design

The system architecture consists of three primary layers:

1. Sensing Layer
   This layer includes soil moisture, temperature, humidity, and water level sensors. These sensors collect environmental data from the field.
2. Processing and Control Layer
   The NodeMCU microcontroller processes sensor data, compares it with threshold values, and controls the relay module connected to the water pump.
3. Application Layer
   This layer includes the mobile dashboard interface that displays live sensor readings, irrigation status, and alerts to the farmer.

The architecture is modular, scalable, and suitable for rural deployment.

6.5 Hardware Integration

The hardware components were selected based on affordability, availability, and energy efficiency. The integration process involved:

- Connecting soil moisture sensor to the analog input of NodeMCU
- Interfacing DHT11 sensor for temperature and humidity monitoring
- Connecting water level sensor for tank monitoring
- Integrating relay module for pump control
- Ensuring stable power supply for field operation

Proper calibration of sensors was performed to ensure accurate data acquisition.

6.6 Software Development and Communication

The system software was developed using Arduino IDE for programming the NodeMCU microcontroller. The software performs the following tasks:

- Reading sensor values at fixed intervals
- Converting raw data into meaningful units
- Comparing values with predefined irrigation thresholds
- Activating or deactivating the relay module
- Sending data to the mobile dashboard

WiFi communication enables real time monitoring and remote accessibility.

6.7 Smart Suggestion

The system fetches numerical sensor readings such as soil moisture (%), temperature (°C), humidity (%), and water level from Firebase.

Each crop has stored numeric threshold ranges (e.g., Soil Moisture: 40–60%, Temperature: 20–30°C).

The algorithm performs numerical comparison operations:

If value < minimum threshold → Low condition detected

If value > maximum threshold → High condition detected

* Example: Soil Moisture = 32% and minimum = 40% → condition = Soil Dry.
* Multiple parameters are checked sequentially using conditional statements (if–else logic).
* The system assigns a condition score or status (Normal / Warning / Critical) based on deviation size.
* A rule table links each numeric condition to a predefined suggestion (e.g., moisture deficit → irrigate for specific duration).
* The generated suggestion and calculated comparison result are then displayed in the dashboard with the numeric reason.

6.8 Testing and Validation

The system was tested under different soil and environmental conditions to evaluate:

- Accuracy of sensor readings
- Response time of pump activation
- Stability of WiFi communication
- Reliability of continuous monitoring
- Power consumption efficiency

Multiple test cycles were conducted to ensure consistent performance. The results confirmed that the system operates reliably under real field conditions.

VII. IMPLEMENTATION

The implementation of the AgriPulse: Smart Agricultural & Ecological Data Collection and Decision Support System system integrates hardware components, cloud services, and a mobile application into a unified smart agriculture monitoring and advisory platform. The system has been designed to provide real-time environmental data, crop-specific recommendations, alerts, and AI-based insights to farmers. The implementation process comprises the hardware layer, firmware development, backend configuration, mobile application development, and integration of AI-driven decision support.

7.1 Hardware Implementation

The hardware layer is built using the NodeMCU ESP8266 microcontroller, chosen due to its affordability, Wi-Fi capability, and lightweight power consumption suitable for agricultural field deployment. The following sensors form the core of the data acquisition system:

- **Soil Moisture Sensor** – measures soil humidity to determine irrigation needs.
- **Temperature & Humidity Sensor (DHT11/DHT22)** – provides environmental climatic data.
- **Water Level Sensor** – monitors available water in the storage tank.

All sensors are interfaced with the NodeMCU using appropriate digital and analog GPIO pins.

Before deployment, each sensor's range and behavior were validated using the NodeMCU Serial Monitor. The microcontroller is powered using 5V supply or solar power, depending on field conditions. All components were enclosed in a waterproof casing to prevent damage due to moisture or dust.

The firmware for the ESP8266 was written using the NodeMCU IDE. Libraries such as **Firebase ESP8266 Client**, **DHT sensor library**, and **ESP8266WiFi** were integrated to enable both sensing and cloud connectivity. The firmware follows a continuous cycle of reading sensor data, formatting it into JSON, and pushing the values into Firebase Realtime Database under the authenticated user node. This ensures each user receives personalized and isolated data feeds.

7.2 Backend Implementation (Firebase)

The backend is powered by **Google Firebase**, chosen for its real-time synchronization, lightweight API, secure authentication system, and free-tier suitability for student and smallscale agricultural projects.

The following Firebase modules were configured:

1. **Authentication Module**
   The login and registration system uses Firebase Email/Password Authentication. Additional fields such as phone number, selected crop, and family structure (if multi-user setup is required) are stored under user profile nodes.
2. **Realtime Database**
   Sensor values and system alerts are stored under structured paths such as:

- /users/{uid}/sensorData/
- /users/{uid}/alerts/
- /users/{uid}/customCrops/

These nodes maintain real-time updates, enabling the mobile app to fetch new data instantly without manual refresh.

3. **Database Rules**
   Secure read/write rules were implemented to ensure that each user can only access their own sensor data and crop profiles. Authentication-based access prevents unauthorized manipulation of sensor values or user data.
4. **Cloud Messaging (Optional for Notifications)**
   Firebase Cloud Messaging (FCM) is enabled to deliver real-time alerts, SMS or WhatsApp notifications, and warning messages whenever environmental conditions become unfavorable.

7.3 Mobile Application Implementation (React Native)

The mobile application was developed using **React Native**, ensuring cross-platform support for Android devices commonly used by farmers. The application follows a modular structure with separate screens for authentication, dashboard, crop selection, alerts, analytics, and settings.

Key Features Implemented

- **User Authentication Screen**
  Provides secure sign-in and registration with Firebase integration. User profile data is stored for personalized dashboards and crop preferences.
- **Real-Time Dashboard**
  Displays live values of soil moisture, temperature, humidity, and water level retrieved from the Realtime Database. Critical values are highlighted with color-coded indicators, and threshold breaches trigger alert banners.
- **Crop Selection and Management**
  Users can select predefined crops or add custom crops along with their environmental thresholds. These values are stored under /customCrops and dynamically loaded into the dashboard and alert logic.
- **Alerts and Notifications**
  The app displays alerts whenever sensor values exceed safe limits. These alerts include reasoning such as “Low Soil Moisture” or “High Temperature,” enabling farmers to take immediate action.
- **Analytics Screen**
  Provides visual charts and trend analysis for historical sensor values. This helps users understand environmental patterns and plan irrigation or maintenance activities.
- **Settings and Customizations**
  Users can edit thresholds, add new crops, or update their phone number for SMS/WhatsApp alerts.

All screens were implemented using React Native hooks, Firebase SDK, and state management through React Context or useState/useEffect hooks.

7.4 AI/ML Implementation

To enhance the advisory capability of AgriPulse: Smart Agricultural & Ecological Data Collection and Decision Support System, a lightweight AI module was integrated using TensorFlow.js**.** The AI component analyzes current sensor values alongside crop thresholds to generate:

- **Crop Suitability Suggestions**
- **Explanation for Alerts (Reasoning Engine)**
- **Recommended Corrective Actions (e.g., irrigation, shading, ventilation)**

The AI model operates entirely on the device without requiring a cloud connection, which ensures immediate response and works even with intermittent internet connectivity. This module is integrated into the **InsightsCard** displayed on the dashboard.

7.5 System Integration

After individual subsystem implementation, complete integration was performed:

1. The ESP8266 began sending live sensor values to Firebase.
2. The mobile app retrieved updated values in real time.
3. Alerts, notifications, and AI suggestions responded correctly to threshold changes.
4. Multiple test cycles were conducted for both field conditions and simulated values via Firebase Console.

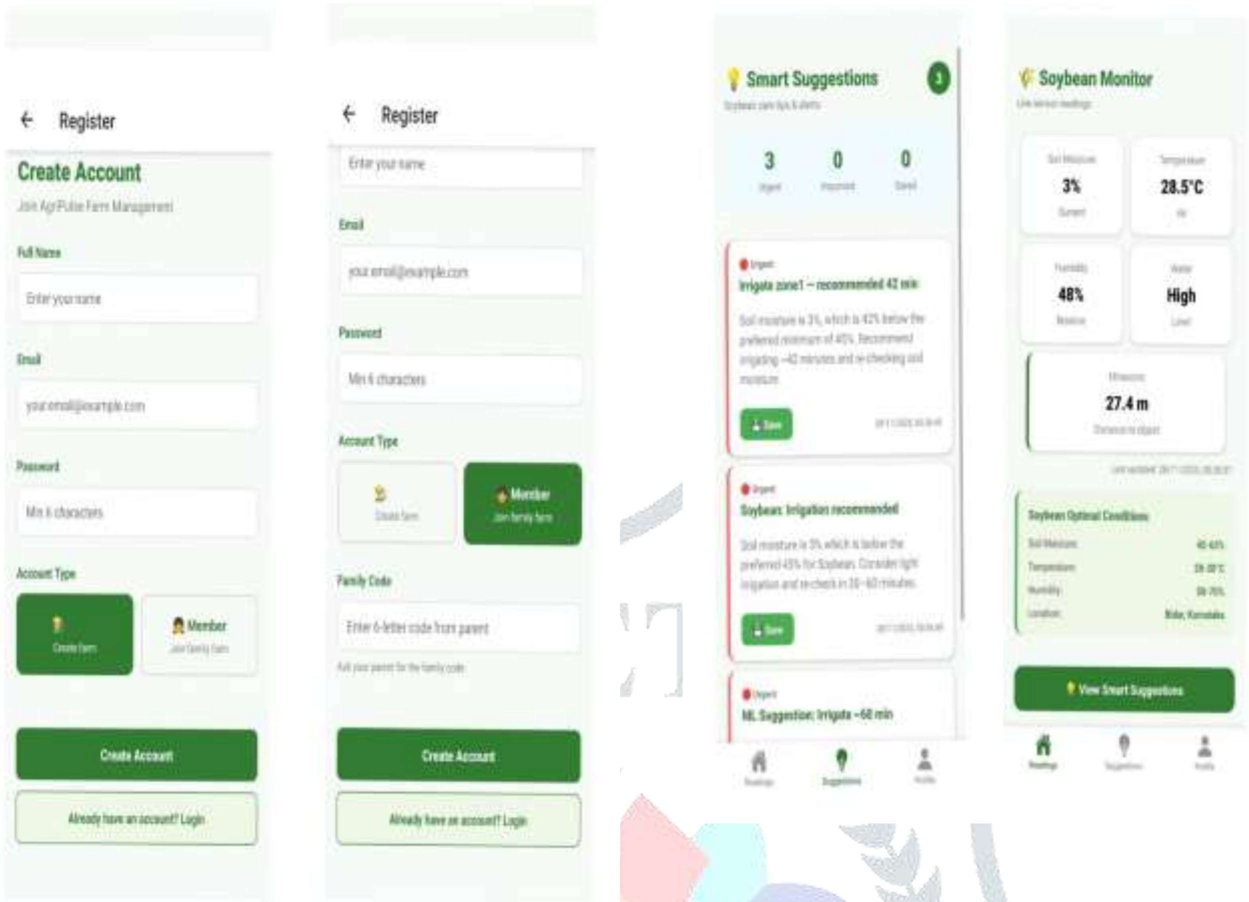
The integrated system successfully demonstrated seamless interaction between hardware, cloud, and mobile app layers, enabling robust monitoring and advisory features for agricultural use.

7.6 Field Deployment and Testing

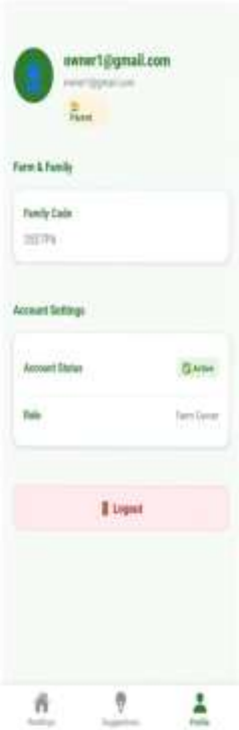
The system was deployed in real-time agricultural conditions. Sensors were installed at optimal soil depth and the NodeMCU enclosure protected from environmental factors. Continuous testing validated:

- Stable sensor readings
- Real-time synchronization with Firebase
- Immediate alert generation during unfavorable conditions
- Accurate AI-based recommendations The system proved reliable for practical farm use, supporting the project's objective of providing real-time smart agricultural assistance.

VIII. USER INTERFACE




Register
Create Account
Full Name
Owner1
Registration Successful!
Welcome Owner1!
Your Family Code: 35E7P6
Share this code with family members to let them join your farm management.
OK
Parent
Member
Create Account
Already have an account? Login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Login
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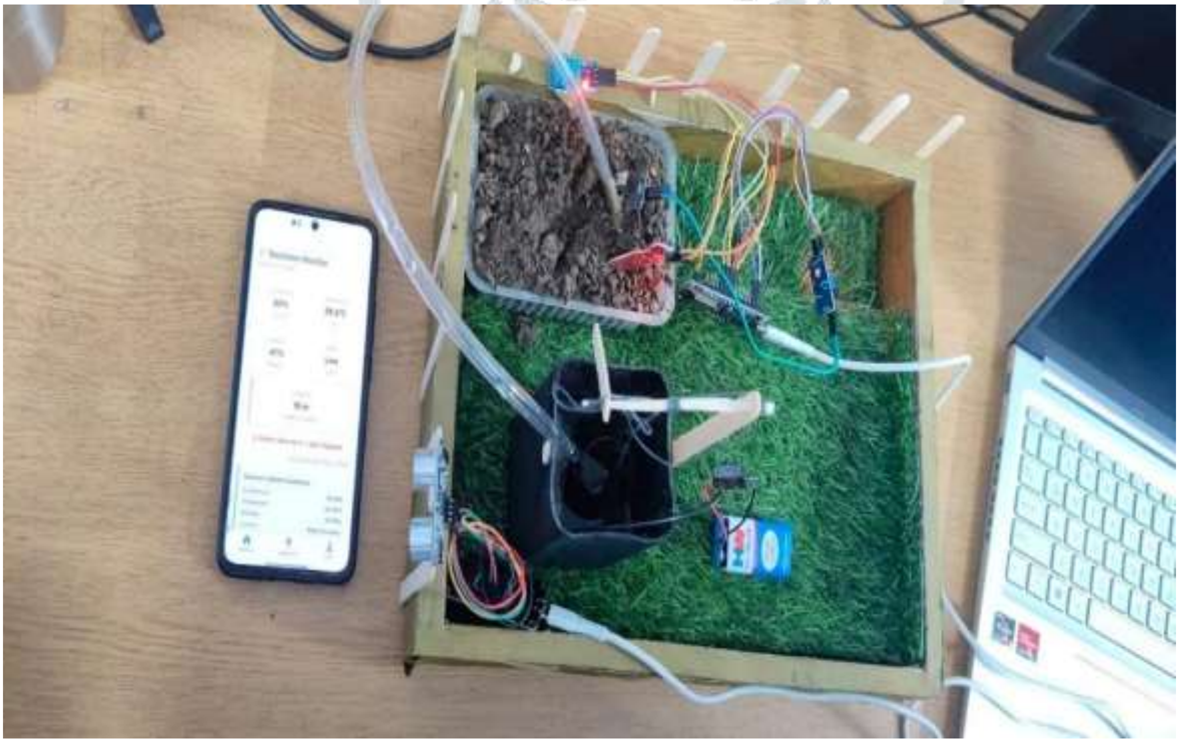

IX. FUTURE SCOPE

The AgriPulse: Smart Agricultural & Ecological Data Collection and Decision Support System provides a strong foundation for intelligent and sustainable farming. Although the current system successfully implements automated irrigation and real time environmental monitoring, several advanced enhancements can further improve its efficiency, intelligence, and scalability.
The future scope of the project includes the following developments:

1. Machine Learning Based Irrigation Prediction
Future versions of the system can integrate machine learning models to predict irrigation requirements based on historical sensor data, crop type, seasonal trends, and climatic patterns. This will enable predictive irrigation rather than simple threshold based control.

2. Cloud Based Data Storage and Analytics
Integration with cloud platforms can allow long term data storage and advanced analytics. Farmers will be able to analyze crop performance trends, water usage statistics, and seasonal productivity comparisons.

3. Weather API Integration
Connecting the system with real time weather forecasting APIs can improve irrigation decisions by considering rainfall predictions, humidity forecasts, and temperature trends. This will support climate smart agriculture.

4. Mobile Application Enhancement
A fully developed Android and iOS application with graphical dashboards, multilingual support, voice alerts, and data visualization features can enhance accessibility for rural farmers.

5. Solar Powered System
To improve sustainability, the system can be powered using solar panels. This will reduce electricity dependency and make it suitable for remote agricultural areas.

6. Expansion to Large Scale Farms
The system can be expanded using multiple sensor nodes connected through wireless communication protocols such as LoRa or ZigBee for large agricultural fields.

7. Crop Specific Customization
Future versions can include crop selection modules where irrigation thresholds automatically adjust according to selected crop type and growth stage.

8. Integration with Fertigation Systems
The system can be upgraded to control fertilizer injection systems along with irrigation, enabling precise nutrient management.

9. AI Based Crop Health Monitoring
Integration of camera modules and computer vision models can help detect plant diseases, pest attacks, and nutrient deficiencies.

10. Government and Smart Village Integration
The platform can be integrated with agricultural advisory services, government schemes, and smart village initiatives to provide centralized agricultural monitoring.
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X. CONCLUSION

AgriPulse: Smart Agricultural & Ecological Data Collection and Decision Support System has shown that it can handle irrigation on its own, meaning farmers no longer need to constantly check their fields. The system looks at the soil moisture and decides when the plants actually need water and when they don't. This smart, automated way of watering has really changed how irrigation can work, whether it's for a small garden or a large farm.

But it's not just about automation. AgriPulse: Smart Agricultural & Ecological Data Collection and Decision Support System also helps save water, which is one of the most important resources in farming. By giving water only when it's needed and in the right amounts, it cuts down on waste while still keeping the crops healthy. This shows that smart farming isn't just convenient—it actually has real benefits for both the environment and the farm.

On top of that, AgriPulse: Smart Agricultural & Ecological Data Collection and Decision Support System keeps farmers in the loop all the time. No matter where they are—at home, in town, or somewhere else—they can check how their irrigation system is doing, what the soil conditions are, and other environmental details. This constant connection makes it easy to manage the farm and gives farmers peace of mind knowing everything is under control.

XI. REFERENCES

[1] M. Shabeer *et al.*, "Network technologies for smart agriculture: A comparative study of LPWAN, 5G, and hybrid models," *IEEE Access*, vol. 13, pp. 11245–11260, 2025.

[2] X. Li *et al.*, "Robotic harvesting using vision-based automation for precision agriculture," *IEEE Transactions on Automation Science and Engineering*, vol. 21, no. 2, pp. 890–902, 2024.

[3] T. Li *et al.*, "IoT and computer vision-based pest detection system for smart farming," *IEEE Sensors Journal*, vol. 24, no. 5, pp. 4567–4576, 2024.

[4] N. R. Gatkal *et al.*, "Low-power smart sensors for affordable precision agriculture," *IEEE Internet of Things Journal*, vol. 11, no. 3, pp. 3341–3352, 2024.

[5] T. V. *et al.*, "IoT-based eco-conscious irrigation system for sustainable agriculture," *IEEE Access*, vol. 12, pp. 77410–77422, 2024.

[6] P. Khedekar *et al.*, "Real-time environmental monitoring using IoT for smart farming," in *Proc. IEEE Int. Conf. Smart Computing*, 2023, pp. 210–215.

[7] H. Pal and S. Tripathi, “Machine learning and computer vision for reducing post-harvest losses,” in *Proc. IEEE Int. Conf. Artificial Intelligence in Agriculture*, 2023, pp. 98–104.

[8] N. S. and M. Priya T., “Predictive storage management using AI for agricultural produce,” in *Proc. IEEE Int. Conf. Intelligent Systems*, 2023, pp. 345–350.

[9] P. Ghutke and R. Agrawal, “Integrated sustainable farming using IoT, drones, and data analytics,” in *Proc. IEEE Int. Conf. Sustainable Technologies*, 2022, pp. 150–156.

[10] A. Kamilaris and F. X. Prenafeta-Boldú, “Deep learning in agriculture: A survey,” *Computers and Electronics in Agriculture*, vol. 147, pp. 70–90, 2018.

[11] S. Wolfert, L. Ge, C. Verdouw, and M.-J. Bogaardt, “Big data in smart farming—A review,” *Agricultural Systems*, vol. 153, pp. 69–80, 2017.

[12] J. Gubbi *et al.*, “Internet of Things (IoT): A vision, architectural elements, and future directions,” *Future Generation Computer Systems*, vol. 29, no. 7, pp. 1645–1660, 2013.

[13] L. Ruiz-Garcia, L. Lunadei, P. Barreiro, and J. I. Robla, “A review of wireless sensor technologies and applications in agriculture and food industry,” *Sensors*, vol. 9, no. 6, pp. 4728– 4750, 2009.

[14] R. Ray, D. Jain, and P. Kumar, “Precision agriculture using IoT and machine learning techniques,” *IEEE Access*, vol. 10, pp. 84562–84575, 2022.

[15] M. Ayaz *et al.*, “Internet-of-Things-based smart agriculture: Toward making the fields talk,” *IEEE Access*, vol. 7, pp. 129551–129583, 2019.