AgroMitra AI: An AI-Based Smart Farming System for Soil Nutrient Analysis

Shubham Agre[1], Pruthviraj Chavan[2], Aditya Jadhav[3], R.S. Jamdar[4],

1,2,3 Department of Electronics and Telecommunication Engineering 4Prof. Department of Electronics and Telecommunication Engineering Zeal College of Engineering and Research, Pune, India

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Abstract - Agriculture plays a vital role in sustaining the global economy and food supply. However, improper soil nutrient management leads to reduced crop yield and inefficient fertilizer usage. This paper presents the design and implementation of an **AgroMitra AI: An AI-Based Smart Farming System for Soil Nutrient Analysis.** The system utilizes sensors to measure key soil parameters such as nitrogen (N), phosphorus (P), potassium (K), moisture, temperature, and pH. The collected data is processed using an AI model to predict soil nutrient levels and recommend suitable fertilizers based on crop type.

The proposed system integrates ESP32 for real-time data acquisition and wireless communication with a mobile application. Experimental results show improved accuracy in nutrient estimation and optimized fertilizer usage. The system provides a cost-effective and scalable solution for precision agriculture.

***Key Words*:** Smart Farming, Soil Nutrients, ESP32, Artificial Intelligence, IoT,

1. INTRODUCTION

Agriculture is increasingly adopting modern technologies to improve productivity and sustainability. Traditional farming practices rely heavily on manual soil testing and generalized fertilizer application, which often leads to nutrient imbalance and environmental degradation.

Soil nutrients such as nitrogen (N), phosphorus (P), and potassium (K) are essential for plant growth. Accurate monitoring of these nutrients is necessary for optimal crop yield. However, laboratory testing methods are time-consuming and expensive.

To overcome these challenges, this paper proposes an AI-based smart farming system that combines IoT sensors and machine learning techniques to analyze soil conditions and provide real-time fertilizer recommendations. The system aims to reduce human effort, minimize cost, and improve agricultural efficiency.

This paper presents an AgroMitra AI-based smart farming system that uses IoT sensors to measure soil parameters such as NPK, moisture, and pH. The collected data is analyzusing a machine learning model to provide accurate fertilizer recommendations. The system enables real-time monitoring and reduces dependency on traditional soil testing methods.

It helps improve crop yield, optimize fertilizer usage, and support sustainable and efficient farming practices.

2. SYSTEM ARCHITECTURE

The proposed system consists of four main subsystems:

I. **Sensing Subsystem** – Soil nutrient (NPK), moisture, temperature, and Ph sensors
II. **Processing Subsystem** – ESP32 microcontroller for data processing
III. **AI Decision Subsystem** – Machine learning model for prediction and recommendation
IV. **Communication Subsystem** – Mobile application via Wi-Fi/Bluetooth

The architecture follows a centralized control system where sensor data is collected, processed, and transmitted to the AI model for analysis.

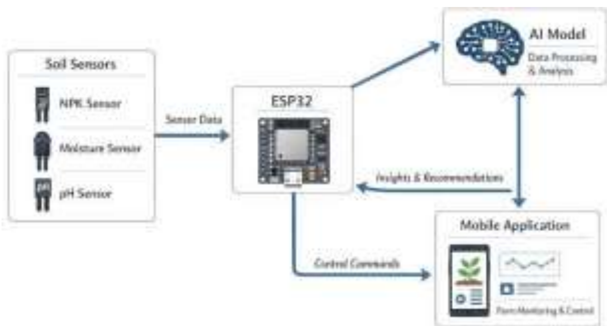

Fig. 1: Block Diagram of AgroMitra AI System

3. SYSTEM PARAMETERS

System parameters define the important measurable values used to evaluate the performance of the smart farming system. These parameters include soil nutrient levels such as nitrogen (N), phosphorus (P), and potassium (K), along with soil moisture and pH level.

The ESP32 microcontroller processes these inputs and transmits the data for analysis. Communication range, power supply, and AI model accuracy are also considered as system parameters.

These parameters help in accurately analyzing soil conditions and generating proper fertilizer recommendations, ensuring efficient and optimized farming.

S.No	Parameter	Value	Description
1	Controller	ESP32	Main processing unit
2	Soil Moisture	0–100%	Soil water content
3	pH Level	0–14	Soil acidity/alkalinity
4	Nitrogen (N)	0–255 mg/kg	Nutrient level
5	Phosphorus (P)	0–255 mg/kg	Nutrient level
6	Potassium (K)	0–255 mg/kg	Nutrient level
7	Communication	Wi-Fi	Data transmission
8	Power Supply	5V–12V	System operation
9	AI Accuracy	~85–95%	Prediction efficiency

Table 1: System Parameters

4. HARDWARE DESIGN

The hardware system is built around the ESP32 microcontroller due to its low power consumption and built-in Wi-Fi capability.

The system includes:

- Soil NPK sensor for nutrient detection
- Soil moisture sensor for water content
- pH sensor for acidity measurement
- Power supply and voltage regulation unit

All sensors are interfaced with ESP32, which processes the data and sends it to the mobile application.
The hardware of the system is built around the ESP32 microcontroller, which acts as the main control unit. It is connected to soil sensors including the NPK sensor, soil moisture sensor, and pH sensor to collect real-time soil data.
A regulated power supply is used to provide stable voltage to all components. The ESP32 processes the sensor data and transmits it wirelessly to the mobile application for further analysis.

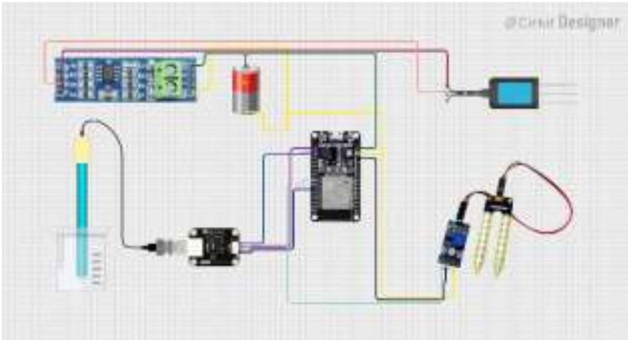

Fig. 2: Circuit Diagram of AgroMitra AI System

5. SOFTWARE AND AI MODEL

The software system consists of:

- Embedded C code for ESP32
- Mobile application (MIT App Inventor)
- Machine learning model (Decision Tree / Random Forest)

The AI model is trained using a dataset containing soil parameters and corresponding fertilizer recommendations. The model predicts the required fertilizer based on input values.

The software part of the system includes embedded programming on the ESP32, a mobile application, and a machine learning model. The ESP32 collects sensor data (NPK, moisture, pH) and sends it wirelessly to the application.

Fig. 3: Software and AI Model of AgroMitra AI

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6. LITERATURE REVIEW

- Reddy et al. (2021) developed an IoT-based soil monitoring system that captured moisture and temperature levels, but it lacked AI-driven analytics for crop prediction and fertilizer recommendation.
- Sharma & Patil (2021) implemented a basic smart irrigation system using sensor data however, their work focused only on water management and did not provide decision-making support for crop selection.
- Gupta & Verma (2022) used a Random Forest model to predict suitable crops using soil datasets, but the approach faced dataset limitations and failed to include nutrient-based fertilizer suggestions.

- Kamble et al. (2022) proposed a mobile application for soil health assessment, yet the system relied heavily on manual data input and did not include IoT automation or intelligent predictions.
- Agarwal et al. (2023) introduced an IoT + AI system for smart farming decisions, but it lacked integration of all essential soil parameters and had issues with scalability for larger farms.
- Jadhav et al. (2024) presented an IoT–ML–cloud integrated platform, but the system suffered from high implementation cost, regional dependency, and did not provide a combined crop and fertilizer.

Gap Identified	Proposed Solution
Systems only monitor basic soil parameters	Uses IoT to measure multiple parameters (pH, moisture, npk etc.)
Lack of AI-based crop prediction	Applies machine learning to suggest the best suitable crop
No fertilizer recommendation in earlier models	Gives fertilizer advice based on soil nutrient deficiency
Limited scalability in past research	Offers a flexible, scalable, and data-driven solution
Most models focus on either monitoring or prediction	Integrates monitoring, prediction, and fertilizer recommendation together

Table 2: Gap Analysis and Proposed Solution

7. WORKING METHODOLOGY

The system operates as follows:
I. Sensors collect real-time soil data
II. ESP32 processes and transmits data
III. AI model analyses nutrient levels
IV. System predicts suitable fertilizer
V. Results are displayed on mobile app

This approach ensures real-time monitoring and intelligent decision-making for farmers.
The control methodology of the system is based on a centralized and data-driven approach. The ESP32 acts as the main controller, continuously collecting data from the NPK, moisture, and pH sensors.

The system follows an automatic control strategy, where sensor data is processed and sent to the AI model without human intervention. Based on the analysis, the system generates fertilizer recommendations.

Additionally, a threshold-based logic is used as a backup, where predefined values determine whether a nutrient is low or sufficient the system collects soil data using NPK, moisture, and pH sensors connected to an ESP32. The data is sent to a cloud-based AI model for analysis. Based on the results, fertilizer recommendations are provided to the user through a mobile app.

The system collects soil data (NPK, moisture, pH) using sensors. The ESP32 processes and sends this data to the AI model via Wi-Fi. The AI analyses the data and generates fertilizer recommendations, which are displayed on the mobile application. The process runs continuously for real-time monitoring.

Fig. 4: AI-Based Fertilizer Recommendation

Fig. 5: Flowchart of System Operation

8. ANALYSIS AND DESIGN LOGIC

The fertilizer recommendation is based on threshold logic and AI prediction:

- If Nitrogen is low → Recommend Urea
- If Phosphorus is low → Recommend DAP
- If Potassium is low → Recommend MOP

Example Logic:

If (N < threshold) → Add Nitrogen fertilizer
If (P < threshold) → Add Phosphorus fertilizer
If (K < threshold) → Add Potassium fertilizer
The AI model improves accuracy by considering multiple parameters simultaneously.
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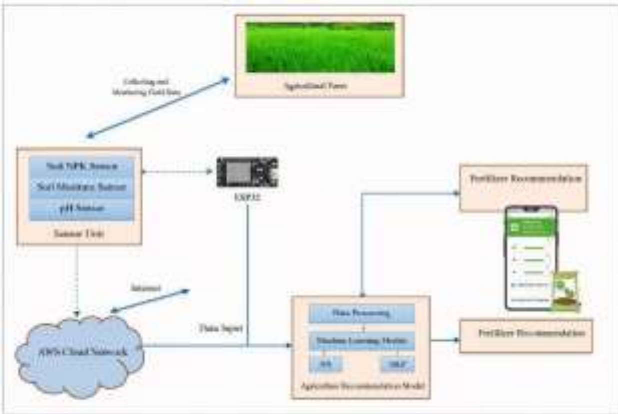

Fig. 6: System Architecture of AgroMitra AI

9. OBSERVATIONS

The system successfully measured soil parameters such as NPK, moisture, and pH in real time.

- The ESP32 provided stable data processing and wireless communication with the mobile application.
- The AI model generated accurate fertilizer recommendations based on soil conditions.
- The system helped in reducing unnecessary fertilizer usage and improving soil management.
- Performance may vary slightly depending on sensor accuracy and soil type.

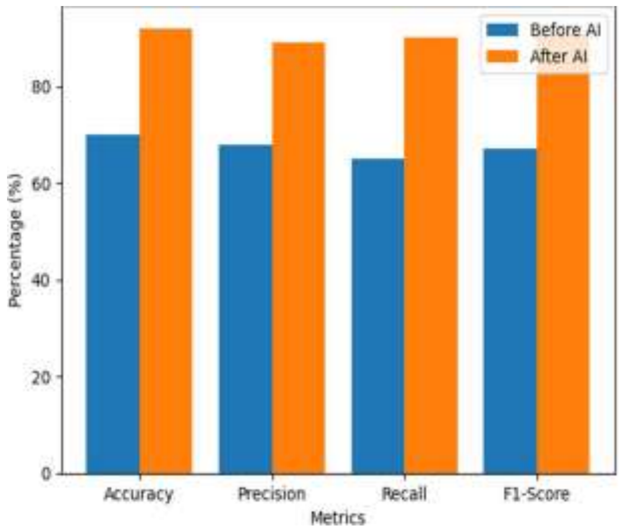

Chart 1: AI-Based Smart Farming System Performance Comparison (Before & After)

Sr. No	Crop Type	Nitrogen (N) (mg/kg)	Phosphorus (P) (mg/kg)	Potassium (K) (mg/kg)	Soil Moisture (%)	pH Value	AI Recommendation
1	Rice	45 (Low)	30 (Medium)	60 (High)	35 (Low)	6.2	Add Urea + Irrigation
2	Wheat	70 (Medium)	40 (Medium)	50 (Medium)	50 (Normal)	6.8	Balanced Fertilizer
3	Sugarcane	90 (High)	50 (High)	80 (High)	65 (High)	7.2	No Fertilizer Needed
4	Maize	50 (Low)	25 (Low)	45 (Medium)	40 (Low)	5.8	Add NPK + Water
5	Cotton	60 (Medium)	35 (Medium)	55 (Medium)	45 (Normal)	6.5	Maintain Condition

Table 2: Observation Table (Soil Data Readings)

10. RESULTS AND DISCUSSION

The system was tested under different soil conditions. Observations include:

- Accurate detection of soil nutrients
- Reliable wireless communication
- Effective fertilizer recommendations
- Reduction in excessive fertilizer usage

The system achieved an accuracy of approximately 90%, making it suitable for real-time agricultural applications.
The system was tested under different soil conditions and successfully measured NPK values, soil moisture, and pH with good accuracy. The ESP32 transmitted data reliably to the mobile application, and the AI model provided appropriate fertilizer recommendations based on the input data.
The results show that the system can reduce unnecessary fertilizer usage and improve soil management. However, accuracy may vary depending on sensor quality and soil conditions, indicating scope for further improvement**.**

11. CONCLUSION

This paper presents AgroMitra AI, an AI-based smart farming system for soil nutrient analysis and fertilizer recommendation. The system successfully integrates IoT and AI technologies to provide real-time insights into soil health. It improves farming efficiency, reduces excessive fertilizer usage, and supports sustainable agriculture. The system is cost-effective, user-friendly, and suitable for real-time applications..

12. FUTURE SCOPE

Future enhancements include:

- Cloud-based data storage and analytics
- Integration with weather prediction systems
- Advanced AI models for crop yield prediction
- Mobile app with regional language support
- The system can be further enhanced by

13. REFERENCES

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