Soil Analyser with AI-Based Crop and Fertiliser Recommendation System

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ABSTRACT

By offering real-time soil data analysis and intelligent crop selection and fertilizer usage suggestions, this research study introduces a novel AI-integrated soil analyser that aims to increase agricultural output. To identify vital soil factors like nitrogen (N), phosphorous (P), potassium (K), pH, moisture, and micronutrients, the suggested system makes use of a collection of Internet of Things (IoT)-based sensors. A cloud-based artificial intelligence program processes sensor data and produces customized recommendations based on both history and current data. To readily obtain this vital information, farmers might use an intuitive smartphone application as the user interface. By increasing yield results and optimizing fertilizer use, this approach seeks to advance sustainable agriculture.

Keywords: Soil analysis, IoT, AI, NPK detection, precision agriculture, crop recommendation, fertilizer recommendation.

I. INTRODUCTION

Agriculture has long been the foundation of human civilization, giving societies all over the world economic stability and nutrition. A sizable section of the populace in many developing nations makes their living from farming. However, there are many issues facing modern agriculture, such as soil erosion, climate change, and ineffective farming methods. Among these difficulties, inadequate soil management continues to have a significant impact on agricultural output. Inadequate crop yields, excessive or insufficient fertilizer use, and long-term harm to soil fertility result from many farmers' lack of access to timely and accurate soil health data. These inefficiencies show how urgently a more intelligent, data-driven method of managing and monitoring soil is needed.

We suggest a soil analyser with an AI-based crop and fertilizer recommendation system to address these issues. This technology uses artificial intelligence (AI) and the Internet of Things (IoT) to deliver real-time soil analysis, empowering farmers to choose crops and apply fertilizer with knowledge. The system is able to evaluate soil attributes like moisture content, nutrient levels, and colour features by combining cutting-edge sensor technology with cloud-based data processing. AI algorithms are then used to process these parameters and produce exact suggestions for the best farming methods, guaranteeing long-term soil management and higher agricultural output.

This smart soil analyser's primary function is to collect and evaluate soil data in real time. Farms must gather samples and ship them to labs in order to use traditional soil testing methods, which is an expensive, time-consuming, and frequently impracticable process for small-scale farms. On the other hand, our system uses sophisticated sensors, such as moisture detection and nutrient analysis based on spectroscopy, to deliver real-time information about soil health. This minimizes delays in agricultural planning and lessens reliance on outside soil testing facilities by enabling farmers to take prompt corrective action. By continuously enhancing recommendations based on real-world data, an AI-driven model is added to the system, increasing its potential and guaranteeing more precise and adaptable answers over time.

The AS7265X Triad Spectroscopy Sensor, one of the main parts of the suggested system, is essential for determining the colour and nutrient content of the soil. An important determinant of the amount of organic matter, mineral makeup, and general health of the soil is its hue. The system can identify different types of soil and connect them with known fertility levels by utilizing spectral data from the AS7265X sensor to analyse soil colour. A moisture sensor is also integrated into the device to measure soil hydration levels, which is crucial for crop growth and irrigation scheduling. Together, these sensors serve as the cornerstone of the data collection procedure, supplying the input required for analysis and suggestions powered by AI.

The gathered information is sent to a cloud-based platform, where artificial intelligence (AI) algorithms analyse it to produce suggestions for crops and fertilizer. The AI model can make accurate and context-aware decisions since it has been trained on a large dataset that includes soil properties, crop appropriateness, and fertilizer efficacy. Scalability is ensured by using cloud computing, which allows the system to manage massive data volumes while preserving high processing efficiency. Additionally, the AI model keeps learning from fresh data, which enhances its precision and flexibility in response to various farming circumstances. To ensure simplicity of use and real-time decision-making help, farmers can get the advice via a mobile application.

This system's scalability and modularity are other important advantages. Sensors and processing units are among the hardware elements that can be readily enlarged and integrated in accordance with particular agricultural needs. The system can be tailored to satisfy a variety of farming demands, whether it is implemented on small farms or major agricultural operations. The system is extremely effective and user-friendly thanks to the IoT-based connectivity, which guarantees smooth communication between sensors, cloud servers, and user interfaces. Furthermore, local computing is made possible by the integration of a Raspberry Pi-based processing unit, which lessens reliance on constant internet connectivity and guarantees functionality even in isolated agricultural areas.

Given the long-term environmental effects of excessive fertilizer use and inadequate soil management, sustainability is a key component of this project. Excessive fertilizer use causes contaminated water, degraded soil, and higher greenhouse gas emissions. Our solution reduces waste and encourages sustainable farming methods by offering precise fertilizer recommendations based on current soil conditions. This lowers expenses for individual farmers while also supporting international initiatives for environmental preservation and sustainable agriculture. Such a system has long-term effects that go beyond short-term increases in output; it promotes soil preservation and prudent resource management for coming generations.

This system could be improved further in addition to monitoring soil health, such as by adding more sensors for electrical conductivity, pH testing, and the gathering of real-time weather data. The system's capacity to accommodate a greater variety of crops and soil types would be increased with these changes, which would also increase the suggestions' accuracy. To further improve agricultural resilience, future versions of this technology might also include machine learning algorithms that forecast crop illnesses and give farmers early warnings.

The use of this intelligent soil analyser is a big step in the direction of technologically modernizing agriculture. This approach equips farmers with the information and resources they need to maximize their agricultural operations by bridging the gap between conventional farming methods and data-driven decision-making. Real-time soil condition monitoring and AI-powered suggestions have the potential to completely transform farming and make it more productive, profitable, and ecologically friendly.

In conclusion, ineffective soil management is a major issue in contemporary agriculture that is addressed by the Soil Analyser with an AI-based crop and fertilizer recommendation system. The technology gives farmers useful insights to increase crop yields, cut down on fertilizer waste, and preserve soil health by fusing real-time data collecting enabled by IoT with analysis driven by AI. It is a useful tool for both small-scale farmers and major agribusiness companies because of its modular and scalable design, which guarantees flexibility to various farming settings. Future developments in intelligent and sustainable agriculture will be greatly influenced by technological advancements, guaranteeing future generations' access to food and preservation of the environment.

II. LITERATURE REVIEW

Monitoring soil pH and nutrients is crucial for maximizing agricultural output, and numerous studies have looked into ways to increase the precision and effectiveness of soil analysis. By combining sensors and cloud computing, Shohag et al. created an Internet of Things-based soil nutrient and pH monitoring system that allows for real-time data collecting and fertilizer recommendations. By continuously evaluating soil conditions, this method improves precision agriculture; yet, its reliance on internet access and restriction to particular nutrients limit its use in remote locations. Similarly, Khairnar and Kulkarni used colourimetry and an embedded microcontroller to introduce an automated soil macro-nutrient analyser. Their technology provides accurate

NPK analysis while reducing measuring time and human error. Although it is accurate, it ignores shortages in micronutrients, which are just as important for soil health.

A robotics-based soil nutrient detection and fertilizer dispensary system that automates soil analysis and fertilizer distribution was proposed by Amrutha et al. Robotics integration reduces manual involvement by ensuring accurate and efficient nutrient detection. However, small-scale farmers find the system less practical due to its high cost, which is caused by the numerous sensors and robotic components. In order to improve measurement accuracy, Regalado and Dela Cruz combined colour and pH sensors to create a colourimetry-based soil pH and nutrient analyser. Although this method increases the reliability of soil evaluation, the use of many sensors complicates the system and may necessitate more calibration and maintenance.

An on-the-go soil pH mapping device was created by Kheiralla and El-Fatih to offer real-time pH data while conducting fieldwork. Because it allows for tailored soil treatment based on regional changes, this method is extremely advantageous for large-scale precision agriculture. However, it ignores other vital nutrients like potassium, phosphate, and nitrogen in favor of concentrating only on pH measurement. A sensor-based real-time NPK measurement system was also established by Adhikary et al., enabling farmers to keep an eye on macronutrient levels right in the field. Although this method works well for quick nutritional evaluation, it only considers macronutrients and ignores important micronutrients that affect crop growth.

These studies show how soil analysis methods have advanced, each with unique benefits and drawbacks. Real-time monitoring is made possible by IoT-based and sensor-based methods, however they frequently concentrate on particular nutrients and call for consistent connectivity. While colourimetry-based techniques and robotics improve accuracy, they also raise issues with cost and complexity. All things considered, combining several methods could result in a soil analysis system that is more thorough and effective.

Table: Literature Review

S. No	Author's Names	Title	Technique Used	Key Findings	Drawbacks
1.	K. M. Shohag, M. A. Mottalib, M. M. Rahman, M. M. Islam, Md. R. U. Khan	IoT-based Soil Nutrient and pH Level Monitoring System for Fertilizer Recommendation.	IoT-based system with pH and nutrient sensors, microcontroller, and cloud-based data analysis.	Provides real-time soil monitoring for nutrient and pH levels, allowing accurate fertilizer recommendations to improve crop yield.	Limited to specific nutrients, requires internet connectivity for cloud-based data processing.
2.	Harshal M. Khairnar, Sangeeta S. Kulkarni.	Automated Soil Macro-Nutrient Analyser using Embedded Systems.	Colourimetry with microcontroller for soil analysis.	Reduced human errors and time in NPK measurement.	Limited to macro-nutrient analysis; does not handle micro-nutrients.

3.	Amrutha A., Lekha R., A. Sreedevi.	Automatic Soil Nutrient Detection and Fertilizer Dispensary System.	Robotics-based nutrient detection system.	Automated nutrient analysis with dispensing capabilities.	High system cost due to multiple sensors and robotic components.
4.	Rigor G. Regalado, Jennifer C. Dela Cruz.	Soil pH and Nutrient (N, P, K) Analyser using Colourimetry.	Colourimetry with sensor integration.	Accurate pH and nutrient analysis through colour sensor and pH sensor.	Increased system complexity with multiple sensors.
5.	A. F. Kheiralla, Waddah Tilal El-Fatih.	Design and Development of On-the-Go Soil pH Mapping System for Precision Agriculture.	Field pH mapping system integrated with sensors.	Provides real-time soil pH data for precision agriculture.	Focuses only on pH and ignores other essential nutrients.
6.	Tamal Adhikary, Amit Kumar Das, Md. Abdur Razzaque.	Test Implementation of a Sensor Device for Measuring Soil Macronutrients.	Sensor-based real-time NPK measurement.	Effective for on-field, real-time nutrient monitoring.	Limited to specific macro-nutrient types.

III. METHODOLOGY

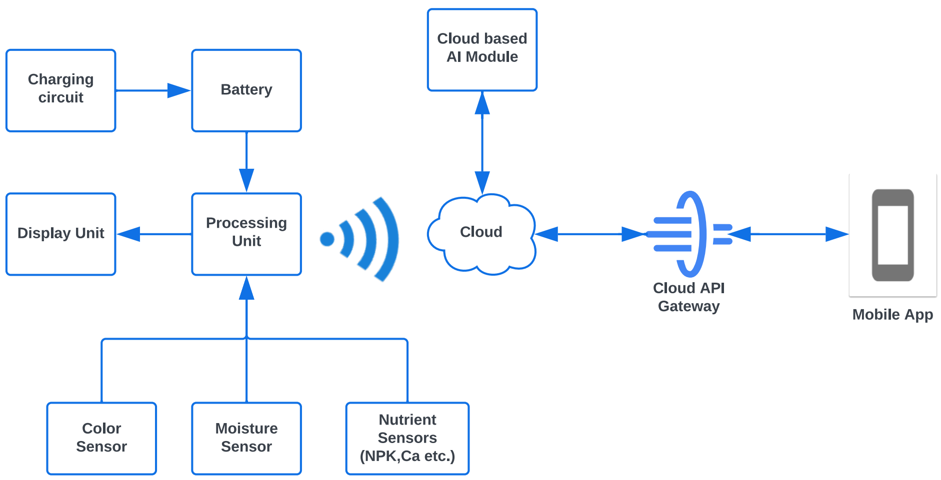

Fig. 1: Schematic diagram of Soil Analyser

1. The battery that powers the system gets its energy from a charging circuit. Even in isolated agricultural areas where direct power sources might not be accessible, this guarantees uninterrupted functioning.
2. Soil health metrics are gathered using a variety of sensors, such as a colour sensor, moisture sensor, and nutrient sensors (NPK, Ca, etc.). These sensors are in charge of collecting data in real time so that soil conditions may be precisely evaluated.

3. After receiving the data from the sensors, the Raspberry Pi Zero W processor unit processes it for additional analysis. Additionally, it manages the display unit, which gives consumers real-time information about the condition of the soil.
4. The processing unit wirelessly sends the processed sensor data to the cloud. This guarantees scalability for various agricultural situations and permits remote access to the data.
5. Machine learning methods are used by a cloud-based AI module to assess the gathered soil data. In order to maximize agricultural productivity, it makes recommendations for crops and fertilizer based on soil conditions.
6. A Cloud API Gateway, which serves as a link between the AI module and the end-user interface, communicates with the cloud. This guarantees seamless data transfer between the user's mobile application and the cloud.
7. The smartphone app gives customers insights for improved farm management, AI-driven suggestions, and real-time soil analysis data. This enhances production and sustainability by enabling farmers to make well-informed choices about crop selection and fertilizer application.

IV. WORKING PRINCIPLE

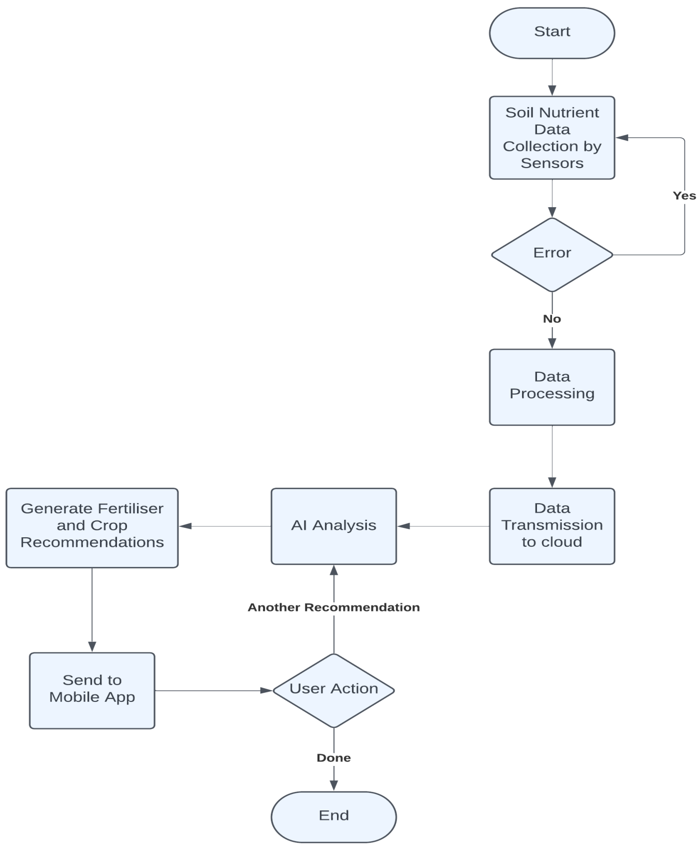

Fig. 2: Flowchart

1. Using a variety of sensors, including as colour, moisture, and nutrient sensors, the process begins with the gathering of soil nutrient data. These sensors record data on the state of the soil in real time.

2. The gathered data is examined for mistakes. To guarantee accuracy and dependability, the system loops back to collect the data if an error is found. The procedure moves on to the following stage if no mistakes are discovered.
3. In the processing unit, the soil data is formatted and made ready for additional examination. This stage guarantees that the data is appropriately formatted for both transmission and AI analysis.
4. After processing, the data is sent to the cloud, where it is safely kept and made accessible for analysis using artificial intelligence. This allows for scalability and remote accessible for many users.
5. The received soil data is processed by the cloud-based AI module, which then uses machine learning techniques to analyse it. On the basis of the identified soil parameters, it makes a preliminary proposal.
6. Based on the particular soil conditions, the AI model recommends crops and fertilizer. The goal of these suggestions is to maximize agricultural sustainability and output.
7. The recommendations are shown to the consumer via a mobile application. The AI module reprocesses the data to produce a different recommendation if the user asks for one. The procedure is over if the user agrees with the suggestion.

V. CONCLUSION

By combining IoT, AI, and cloud computing, the Soil Analyser with AI-based crop and fertiliser recommendation system offers a revolutionary approach to contemporary agriculture. The system improves precision farming by automating soil analysis and offering real-time advice, guaranteeing sustainable agricultural practices and ideal nutrient management. AI-driven analysis and the use of various sensors for soil health monitoring enable farmers to make well-informed choices about crop choice and fertilizer application, which eventually increases output and lessens environmental impact.

The solution provides farmers in various agricultural situations with accessibility and comfort thanks to its scalable architecture and mobile app integration. Cloud-based AI's remote data processing capabilities guarantee efficiency, and users can dynamically improve their agricultural methods with real-time feedback. Solutions like these are essential for encouraging intelligent farming methods as climate change and soil degradation present more and more difficulties for the agricultural sector. This system is a great tool for the agriculture industry, and future developments might include deeper AI training with more varied datasets and increased sensor capabilities to further improve recommendations.

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