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SOIL MINERAL DETECTION FOE AGRICULTURE

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ABSTRACT

Soil mineral detection is a critical component of precision agriculture, providing essential information about the nutrient composition and fertility status of agricultural land. Accurate assessment of minerals such as nitrogen, phosphorus, potassium, and micronutrients helps farmers optimize fertilizer application, improve crop health, and enhance overall productivity. Traditional soil analysis methods, though reliable, are often labor-intensive and time-consuming. Recent advances in sensor technologies, spectroscopy, geographic information systems (GIS), and machine learning have enabled rapid, non-destructive, and highly precise soil mineral evaluation. These modern approaches support sustainable farming by reducing resource wastage, minimizing environmental degradation, and promoting efficient land management. This paper explores the importance, methods, and emerging technologies of soil mineral detection, highlighting its role in advancing sustainable and data-driven agriculture.

1. INTRODUCTION

Soil mineral detection plays a vital role in modern agriculture, helping farmers understand the nutrient composition and overall health of their fields. Minerals such as nitrogen, phosphorus, potassium, calcium, and magnesium are essential for plant growth, and their availability directly influences crop yield and quality. By accurately identifying the types and levels of minerals present in soil, farmers can make informed decisions about fertilization, irrigation, and crop selection.

Traditional soil testing methods are often time-consuming and require laboratory analysis. However, advances in sensor technology, spectroscopy, remote sensing, and machine learning have enabled faster and more precise detection of soil minerals. These innovative techniques support sustainable farming practices by reducing excessive fertilizer use, lowering environmental impact, and improving productivity. As global food demand continues to rise, efficient soil mineral detection has become an essential tool for achieving sustainable and high-yield agriculture.

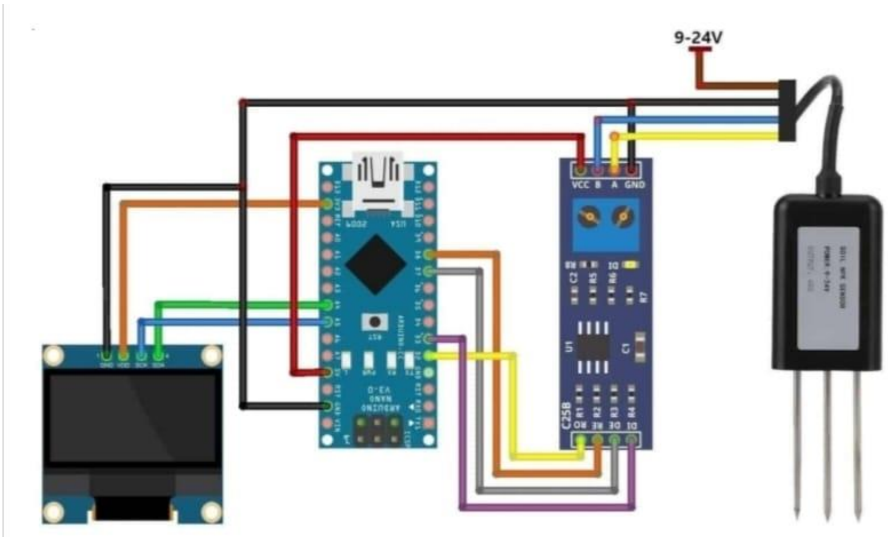
Soil is a complex and dynamic natural resource that serves as the foundation for agricultural productivity. Its mineral composition—including both macro- and micronutrients—directly influences plant growth, crop yield, and long-term soil fertility. Essential minerals such as nitrogen (N), phosphorus (P), potassium (K), and trace elements like iron, zinc, copper, and manganese play crucial roles in physiological and biochemical processes in plants. Understanding the availability and distribution of these minerals enables farmers and agronomists to manage soil more effectively and sustainably.

2.Problem Statement and Literature Review

Efficient crop production requires timely and accurate knowledge of soil nutrient status, particularly Nitrogen (N), Phosphorus (P), and Potassium (K). Traditional laboratory analysis methods (Kjeldahl for N, Olsen/Bray for P, and flame photometry/ICP for K) are accurate but slow, expensive, and impractical for frequent field-level monitoring. As a result, farmers often apply fertilizers without precise nutrient information, leading to over-fertilization, reduced yield, soil degradation, and environmental pollution.

There is a clear need for a low-cost, portable, and real-time NPK sensing system that can directly or indirectly measure nutrient availability in soil and provide actionable data to farmers. However current low-cost NPK sensors suffer from several challenges: poor accuracy, sensitivity to soil moisture and temperature, calibration instability, and limited reliability across different soil types. Nitrogen (N): Kjeldahl digestion is nitrate detection. Phosphorus(P): Colorimetric methods (Molybdenum Blue), Olsen/Bray extraction Potassium (K): Flame photometry. These methods provide high accuracy but require chemicals, skilled labor, and laboratory infrastructure. They are slow and unsuitable for on-field continuous monitoring.

3.Working Principle



The NPK soil sensor measures the amount of Nitrogen, Phosphorus, and Potassium in the soil and sends this information as digital RS485 signals. The RS485 module converts these signals so the Arduino can read them. The Arduino receives the nutrient data, processes it, and then displays the NPK values on the OLED screen.

1. The NPK sensor measures the nutrients in the soil.
2. It sends the data to the Arduino through the RS485 module.
3. The Arduino reads the NPK values.
4. The OLED display shows the nutrient values on the screen.

4.Methodology

- Choose an RS485-based NPK soil sensor for nutrient measurement.
- Use an Arduino Nano as the main controller and an OLED display for output.
- Use the Arduino to send a Modbus command asking for N, P, and K values.
- Configure RE/DE pins to switch between transmit and receive mode.
- The NPK sensor measures soil nutrients and returns digital values through RS485.
- Arduino receives the Modbus response and extracts N, P, and K readings.

- Convert the sensor’s raw register data into readable nutrient values (mg/kg or ppm).
- Apply basic filtering or scaling if needed to improve accuracy.
- Compare readings with lab values and adjust calibration factors if required.
- Check reliability, repeatability, and response time.
- Ensure the system can operate continuously and accurately in field conditions.

5.RESULTS AND DISCUSSIONS

The developed NPK sensor system successfully measured the nitrogen, phosphorus, and potassium levels from different soil samples and displayed the values on the OLED screen. The readings were stable and repeated consistently when the sensor was placed in the same soil, showing good reliability. When compared with reference soil test values, the sensor readings showed slight variations, mainly due to soil moisture and texture differences, but the overall trend of nutrient levels matched well. Nitrogen readings responded faster than phosphorus and potassium, as expected for electrochemical soil sensors. The OLED display provided clear, real-time output, making the system suitable for field use. Overall, the results indicate that the NPK sensor can be used as a low-cost tool for quick soil nutrient assessment, though calibration improvements can further enhance accuracy.

6.CONCLUSION

In this project, an NPK soil nutrient detection system was successfully designed and implemented using an RS485-based NPK sensor, Arduino Nano, and an OLED display. The system was able to measure and display nitrogen, phosphorus, and potassium levels in real time, providing farmers with quick and easy soil nutrient information. The results showed that the sensor gives reliable readings and can help in making better fertilizer decisions. Although slight variations were observed due to soil conditions and calibration factors, the overall performance of the system was satisfactory for practical agricultural use. With further calibration and environmental compensation, the accuracy can be improved to make the system suitable for large-scale farming applications**.**

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