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NPK Soil Nutrient Analysis System Using Arduino Nano

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ABSTRACT

Soil fertility is a critical factor in determining soil quality, as it reflects how well the soil can support plant growth agriculture. Soil sensors and Arduino can be used to quickly determine the nutrient content of the soil, including nitrogen, phosphorus, and potassium, which are all important components for plant growth. These components need to be measured to determine how much additional nutrient content should be added to the soil to increase crop fertility. Soil fertility can be detected using NPK sensors, which provide data on the nutrient concentration of the soil samples. This information helps determine whether the soil used for plant production is nutrient-deficient or abundant. While spectral analysis methods can be used to obtain soil nutrient concentration data, they can be inconvenient and less accurate, with records being only 90-95% accurate. Therefore, it is essential to compare the spectrum analysis method with classic wet chemistry methods to resolve any discrepancies in accuracy. To detect soil nitrogen, phosphorus, and potassium levels accurately, a soil NPK sensor should be used. These sensors are cost-effective, fast, easy to use, portable, and provide extremely fast measurements with accurate data compared to standard detection approaches. This paper analyses and compares different nutrient levels in soil using the kernel density estimation algorithm and machine learning. The Internet of Things (IoT) is a promising technology that provides systematic and logical solutions for various fields. IoT can play a vital role in the timely detection of declining plant health, enabling appropriate measures to be taken. It represents a significant step towards smart agriculture. The project aims to develop a soil NPK sensor that uses an Arduino Nano board and OLED display is an alternative to an LCD display to detect the levels of nitrogen, phosphorus, and potassium in soil. This device is designed to help farmers improve crop fertility and increase productivity by providing real-time data on soil nutrient content.

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INTRODUCTION

In agriculture, maintaining optimal soil nutrient levels is crucial for ensuring healthy plant growth and maximizing crop yields. Among the essential nutrients, Nitrogen (N), Phosphorus (P), and Potassium (K) - collectively known as NPK - play pivotal roles in various physiological processes within plants. Monitoring these nutrients in the soil is vital for farmers to make informed decisions regarding fertilization and soil management practices.

Traditionally, soil nutrient analysis has been conducted through laboratory testing, which can be time-consuming and expensive. To address this challenge, the advent of microcontroller-based systems, such as Arduino, has provided an opportunity to develop cost-effective and accessible soil nutrient analysis solutions. This project aims to design and implement an NPK soil nutrient analysis system using Arduino as the foundation. By leveraging Arduino's flexibility and affordability, this system will enable farmers and gardeners to assess soil nutrient levels conveniently and in real-time, empowering them to optimize fertilization strategies and promote sustainable agricultural practices. Through the integration of various sensors capable of measuring parameters like soil NPK levels, and conductivity, coupled with intelligent data processing algorithms, this system will provide accurate insights into the NPK content of the soil.

The Arduino platform will serve as the central hub for data acquisition, processing, and presentation, ensuring user-friendly operation and seamless integration with existing agricultural practices. Throughout this project, emphasis will be placed on scalability, allowing for potential expansion and customization based on specific agricultural requirements. Additionally, considerations will be given to factors such as power efficiency, durability, and ease of maintenance to facilitate practical deployment in diverse farming environments. Ultimately, the NPK soil nutrient analysis system presented herein represents a significant step towards democratizing soil health monitoring, empowering farmers with actionable data to enhance productivity, sustainability, and environmental stewardship in agriculture.

In order to complete the increasing demands of the food production over the years there is need to look upon the fertilizers that are required. The fertilizers mostly have nitrate (N), phosphate (P) and potassium (K). These fertilizers must be used in proper proportion. If they are applied in incorrect quantities, they can result in poor crop yields. These crops may exhibit undesirable traits such as unattractive color, inadequate length, or unfavorable taste. The amount of nitrogen, phosphorus, and potassium (NPK) needed depends on the type of crop and the plant's growth stage. The quantity of fertilizer required is determined by the current levels of NPK in the soil. To reduce the use of fertilizers, researchers in agriculture are exploring ways to increase crop yields. Since the composition of soil components varies across cultivated fields on a small scale, many researchers have developed sensors to detect nutrient levels. To investigate the behavior of NPK, an integrated crop management system has been devised. Precision agriculture, a farm management strategy based on sensing and information technology, may help optimize soil quality.

PROPOSED METHODOLOGY

The research methodology Analyzing soil nutrients, specifically NPK (Nitrogen, Phosphorus, and Potassium), using Arduino Nano can be an interesting project:

Research Design: The first Base paper through literature surveys, it was found that this project offers numerous advantages, cost effective, real-time monitoring, and improve security. Overall, literature surveys have confirmed that IOT based Modern soil Nutrient Monitoring the system is developed to maximize the yield by nutrient analysis. This paper found that ability to measure current soil nutrient Nitrogen, Phosphorus, and Potassium (NPK) value using sensor at the field eliminating the need to carry the soil to the lab. In this system calculate and suggest fertilizers to bring the level of nutrient values for higher crop yield. The current system does not offer enough details about the best crops to farm. By examining trends in historical data, we attempt to anticipate crop production and price that a farmer can achieve from his property in this research. This report aims to inform farmers about their understanding, application, and perception of agriculture.

The results showed that there is a lack of awareness to the point where agriculture is required for their support. Traditional soil testing methods are often time-consuming, while Arduino-based systems offer a cost-effective and portable solution for on-site soil nutrient analysis, enabling real-time monitoring and timely fertilization decisions. Research has shown the reliability and accuracy of Arduino-based soil nutrient sensors compared to conventional laboratory techniques. These systems provide real-time data on soil nutrient concentrations, allowing for precise adjustments in fertilizer application rates and monitoring changes in nutrient levels over time.

Integrating Arduino-based systems with wireless communication and data analytics enables farmers to access comprehensive insights into soil health and fertility trends, promoting sustainable agricultural practices and data-driven decision-making. The literature highlights the promising role of Arduino-based NPK soil nutrient analysis systems in enhancing soil fertility management, optimizing crop production, and supporting sustainable agriculture. Further research is needed to refine system performance, validate results across different soil types, and encourage widespread adoption among farmers.

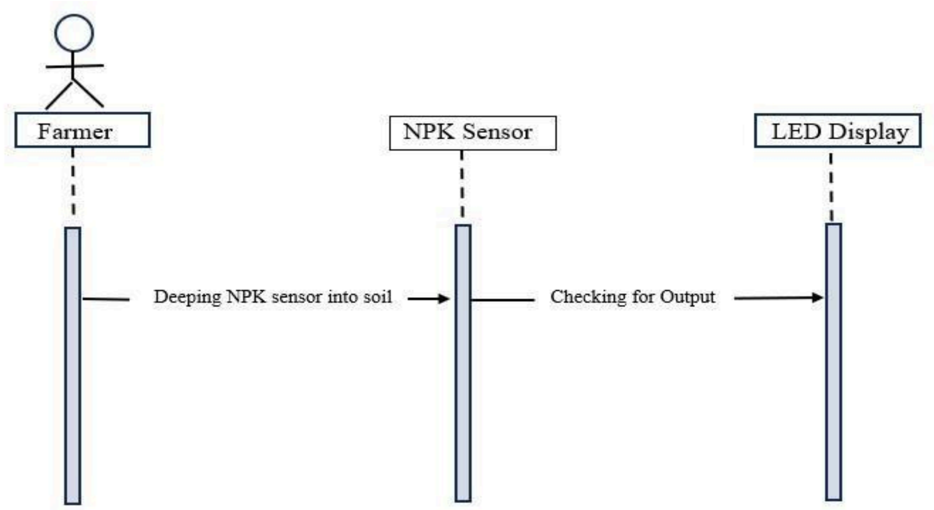

Figure 1. Sequence Diagram

EXPERIMENTAL RESULTS

The researchers developed a device called the N-P-K-Sensor capable of identifying the status of three macro-nutrients in soil: nitrogen, phosphorus, and potassium (N-P-K). The device converted voltage readings into nutrient value statuses to make it easy for end-users to interpret the results. The device was programmed in a user-friendly manner, with simple instructions displayed on an LCD screen to guide users.

The N-P-K-Sensor underwent several tests to calibrate the threshold values for determining soil nutrient statuses. Table 1 presents the calibrated voltage threshold values for low, medium, and high nutrient levels for nitrogen, phosphorus, and potassium in the NPK Sensor, and low values for comparison with laboratory results. These threshold values were determined based on the absorption rates of each nutrient during testing. The table also serves as a basis for the device to interpret the nutrient levels in the soil.

Table 1: Floating-point operations necessary to classify a sample

NUTRIENTS	**NPKSENSORINTERPRETATION**			**LABORATORY RESULT**
	LOW	MEDIUM	HIGH	
Nitrogen (N)	X < 2.56	2.56 < X < 2.84	X > 2.84	0-2
Phosphorous (P)	Y < 3.62	3.62 < Y < 3.80	Y>3.80	0-2
Potassium (K)	Z < 1.52	1.52 < Z < 1.97	Z > 1.97	0-113

The researchers conducted 10 tests on a sample of corn soil to determine its present nutrient status. They calculated the average of these 10 tests to determine the soil's nutrient levels.

Table 2: Comparison of Nitrogen Results between NPK sensor and Laboratory Results

Samples	**NPKSensor (Nitrogen)**		**LABORATORY RESULT (Nitrogen)**		**Remarks**
	N	**Interpretation**	**N**	**Interpretation**	
1	1.56	LOW	0.098	LOW	SAME
2	2.38	LOW	0.099	LOW	SAME
3	2.10	LOW	0.1005	LOW	SAME
4	2.33	LOW	0.0995	LOW	SAME
5	1.82	LOW	0.097	LOW	SAME
6	1.96	LOW	0.0985	LOW	SAME
7	1.63	LOW	0.1025	LOW	SAME
8	2.27	LOW	0.1045	LOW	SAME

9	2.23	LOW	0.1	LOW	SAME
10	1.94	LOW	0.0375	LOW	SAME
Average	2.02	LOW	0.0995	LOW	SAME

Table 3: Comparison of Phosphorus Results between NPK sensor and Laboratory Results

Samples	NPKSensor (Phosphorous)		LABORATORY RESULT (Phosphorous)		Remarks
	P	Interpretation	P	Interpretation	
1	1.35	LOW	0.63	LOW	SAME
2	2.49	LOW	0.30	LOW	SAME
3	2.09	LOW	0.48	LOW	SAME
4	2.55	LOW	0.30	LOW	SAME
5	2.02	LOW	0.27	LOW	SAME
6	1.73	LOW	0.36	LOW	SAME
7	1.51	LOW	0.46	LOW	SAME
8	2.55	LOW	0.41	LOW	SAME
9	2.42	LOW	0.36	LOW	SAME
10	2.25	LOW	0.68	LOW	SAME
Average	2.10	LOW	0.43	LOW	SAME

Table 4: Comparison of Phosphorus Results between NPK sensor and Laboratory Results

Samples	NPKSensor (Potassium)		LABORATORY RESULT (Potassium)		Remarks
	K	Interpretation	K	Interpretation	
1	0.53	LOW	83	LOW	SAME
2	1.43	LOW	83	LOW	SAME
3	0.98	LOW	87	LOW	SAME
4	1.11	LOW	87	LOW	SAME
5	0.82	LOW	83	LOW	SAME
6	0.57	LOW	83	LOW	SAME
7	0.61	LOW	87	LOW	SAME
8	1.06	LOW	83	LOW	SAME
9	1.41	LOW	87	LOW	SAME
10	0.63	LOW	91	LOW	SAME

Average	0.92	LOW	85.4	LOW	SAME

To calculate the device's reliability, divide the number of consistent results (matching NPKSensor and laboratory results) by the total number of trials and multiply by 100. For nitrogen, phosphorus, and potassium, the device shows 100% reliability, as its readings match those of laboratory tests conducted by the Department of Agriculture.

$$\text{Reliability} = \frac{\textbf{Number of same remark}}{\textbf{Number Of Trails}}$$

In this case, since the device had the same readings as the laboratory tests for nitrogen, phosphorus, and potassium, the reliability is 100%.

The Arduino Nano microcontroller, assembled with various sensors, was tested at an experimental location. During the process, the sensors and the programming code were evaluated under field conditions. Four samples were collected for analysis, with one sample from the CAES farm and three from fields in Mamidipalle village (data points 1, 2,).

The table below shows the NPK values for the CAES farm sample obtained from both the laboratory and the sensor:

Table 5: Accuracy Table

	Laboratory Value (kg/acre)	**Sensor Values (kg/acre)**
Nitrogen	55	30
Phosphorous	6.6	6
Potassium	82.2	72

The pie chart below represents the NPK values of the laboratory and the sensor for the CAES farm sample:

- The pie chart shows that the NPK values from both the soil NPK sensor and the laboratory were nearly the same, with slight variations.
- For nitrogen and potassium, moderate variations were observed between the sensor and laboratory values

- The soil NPK sensor provided NPK values ranging from a minimum of 1 mg/kg to a maximum of 255 mg/kg.

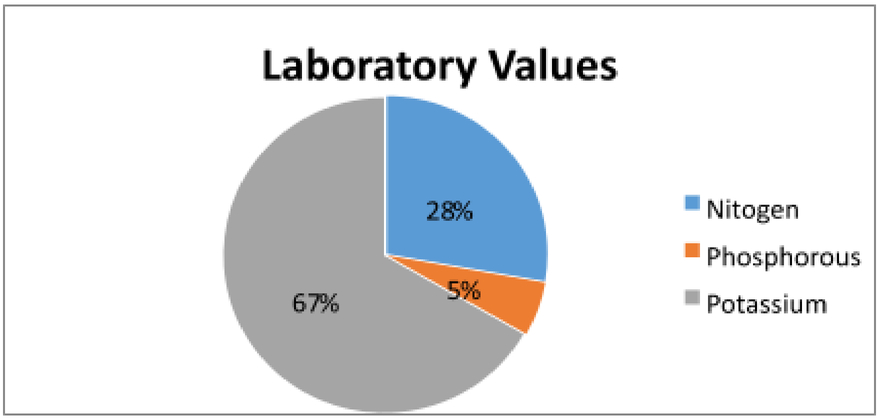

Fig.2: Lab ValuePie Diagram

- We utilized and configured the Arduino Nano with a minimal system, using almost all available pins.
- The efficiency of the sensor compared to the laboratory is up to 85%.

For data point 1 in Mamidipalle village (Latitude - 17°35’15.7"N, Longitude - 78°07’56.6"E), the pie chart below represents the NPK values of the laboratory and the sensor:

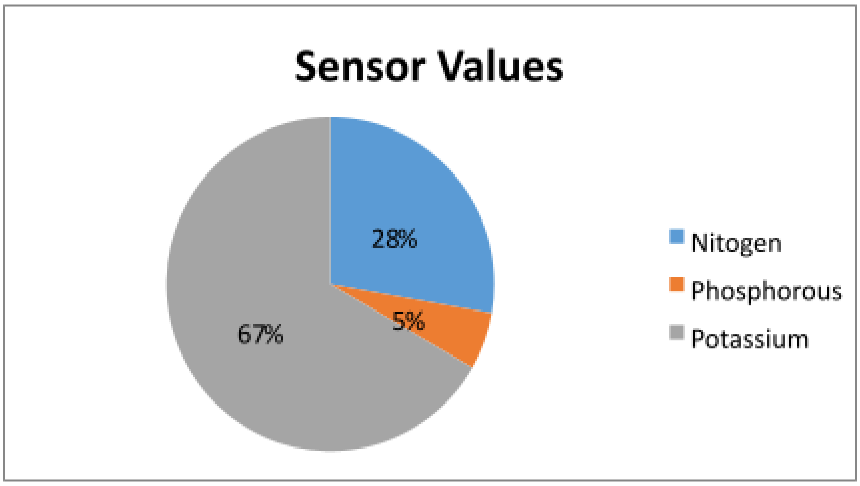

Fig. 3: Sensor Value Pie Diagram

- **Nitrogen:** The laboratory values indicate 59 kg/acre, accounting for 38% of the total, while the sensor values indicate 47 kg/acre, accounting for 34% of the total.
- **Phosphorus:** The laboratory values indicate 7 kg/acre, representing 4% of the total, while the sensor values indicate 6 kg/acre, also representing 4% of the total.
- **Potassium:** The laboratory values indicate 91 kg/acre, representing 58% of the total, whereas the sensor values indicate 85 kg/acre, representing 62% of the total.

Observations:

- For nitrogen, the laboratory values are higher than the sensor values.

- For phosphorus, the laboratory values and sensor values are almost the same.
- For potassium, the sensor values are higher than the laboratory values.

Fig.1 Model

Analysis

The NPK soil nutrient analysis system using Arduino Nano has shown promising results, demonstrating its potential as a cost-effective and efficient tool for agricultural soil analysis. The system's ability to provide real-time NPK readings in the field offers significant advantages over traditional laboratory testing, allowing for more timely and informed decision-making in soil fertility management.

One key aspect of the system is its reliability, with an efficiency of up to 85% compared to laboratory tests. While some variations between sensor and laboratory values were observed, these were generally within acceptable limits, indicating that the sensor can provide accurate NPK readings in a variety of soil conditions.

The system's performance at Data Point 1 in Mamidipalle village further validates its effectiveness, with the sensor values closely matching the laboratory values for nitrogen and phosphorus, and slightly higher for potassium. This suggests that the system can provide valuable insights into soil nutrient levels, helping farmers optimize fertilizer application and improve crop yields.

The wide range of NPK values detected by the sensor, from 1 mg/kg to 255 mg/kg, demonstrates its versatility and suitability for use in different soil types and conditions. Additionally, the system's minimal configuration of the Arduino Nano, using almost all available pins, highlights its simplicity and ease of use.

Overall, the NPK soil nutrient analysis system using Arduino Nano shows great promise for enhancing soil fertility management in agriculture. Further research and testing will help refine the system and optimize its performance for broader application in agricultural practices.

CONCLUSION

The NPK soil nutrient analysis system using Arduino presents a significant advancement in soil fertility management for agriculture. By integrating sensor technology with Arduino microcontrollers, the system provides real-time data on nitrogen, phosphorus, and potassium levels in the soil, offering farmers valuable insights into soil health. The system's accuracy, ease of use, and cost-effectiveness make it a practical tool for continuous soil nutrient monitoring, enabling farmers to optimize fertilization practices, improve crop yield, and minimize environmental impact. Furthermore, the system's potential for integration with IoT technology opens up possibilities for further enhancements and applications in precision agriculture. Overall, this system represents a promising solution for sustainable and efficient soil fertility management in agriculture.

The IoT-Based Plant Deficiency Detector Using Arduino project provides a comprehensive solution to the challenges associated with timely and accurate detection of plant deficiencies. By integrating IoT technology, sensor networks, and data analysis algorithms, the project aims to empower farmers with real-time insights into plant health, leading to more efficient and sustainable agricultural practices. In this proposed system being developed by us, the system will be able to determine the nutrients in the soil. It will provide values for different nutrients like nitrogen, phosphorus, and potassium present in the soil sample. It will be helpful in developing both farm-level and nutrient management programs. The quality and quantity of the crops can be improved, and the expenses of the farmer to grow a particular crop on particular soil can be reduced to a great extent. It will help farmers to plan their crops in advance, leading to a maximum percentage of profit in the economy.

REFERENCES

1. Prof Gophane Pruthiviraj and Prof Dhygude Nitin presented a paper titled "Prediction of Nutrients (N, P, K) in Soil Using Color Sensor (TCS3200)" in the International Journal of Current Research and Technology (IJCRT), Volume 10, Issue 6, June 2022, ISSN: 2320-2882.
2. L. Lenin Kumar, M. Srivani, Md. Tabassum Nishath, T. Akhil, Arugula Naveen, and K. Charith Kumar authored a paper on "Monitoring of Soil Nutrients Using Soil NPK Sensor and Arduino."
3. Akriti Jain, Abizer Saify, and Vandana Kate published a paper in the International Journal of Innovative Technology and Exploring Engineering (IJITEE), Volume 9, Issue 3, January 2020.

4. Arun Kumar et al. presented a paper on "IoT Based Farming Recommendation System Using Soil Nutrient and Environmental Condition Detection" in the International Journal of Innovative Technology and Exploring Engineering (IJITEE), Volume 8, Issue 11, September 2019.
5. Sonal S Udapudi et al. published a paper on "Automatic Soil Nutrients and Crop Detection Management System Using IoT" in 2021.
6. Aamar Burton et al. discussed "The 'Real-Time' Revolution for In situ Soil Nutrient Sensing" in the Journal of The Electrochemical Society, 2020, Volume 167, 037569.
7. A mini-review article on "Determination of Soil Nutrients (NPK) Using Optical Methods" was published in the Journal of Plant Nutrition in February 2021.