Eco. Env. & Cons. 30 (January Suppl. Issue) : 2024; pp. (S239-S246)
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ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2024.v30i01s.049

Monitoring of Soil Nutrients Using Soil NPK Sensor and Arduino

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(Received 3 July, 2023; Accepted 25 August, 2023)

ABSTRACT

The aim of this project is to develop a soil NPK sensor that uses an Arduino board and OLED 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. The sensor is inserted into the soil and contains a probe that measures the nutrient content. The Arduino board activates the sensor and sends the data to the OLED display for easy reading. The device also uses an interface module to connect the sensor to the Arduino. This technology has the potential to revolutionize the way farmers approach soil management by allowing for precision agriculture and efficient use of fertilizers. The NPK sensor is a faster and more convenient alternative to traditional laboratory techniques for measuring soil nutrient levels, and could help farmers to improve crop yields and soil fertility.

Key words: *Arduino board(nano), NPK sensor, Interface module, OLED.*

Introduction

Soil can be simply defined as a mixture of small rock particles/debris and organic materials/ humus which develop on the earth surface and support growth of plants. Soil fertility is the ability of a soil to provide the nutrients needed by crop plants to grow. The primary nutrients plants take up from soils include nitrogen, phosphorus, potassium, calcium and magnesium. Frequently, we need to supplement soil nutrients by adding fertilizer, manure or compost, for good crop growth. Plants take up many other nutrients from soils, but there is usually enough of these secondary nutrients in the soil, so there is no need to add more.

In India 70% of population in rural areas depends upon agriculture where soil is the key source. Having a soil rich in macro-nutrients, particularly Nitrogen, Phosphorus, and Potassium (NPK) is essential for maintaining fertile soil. is most essential, the yield of agriculture is mostly depended on nutrients in the soil. Fertilizer has been key input in augmenting food production in India, however fertilizer used in India is skewed, high in a few states having adequate irrigation and dismally low in the northern -eastern states. There is also imbalanced use of N, P and K due to the imbalanced used of plant nutrients is considered as to main cause for declining crop yield and response ratio.

Indian soils traditionally have low nitrogen and phosphorus content, but high potassium. As per the 2019-20 Soil Health Survey conducted by the Indian government, 55 percent of the country's soil is deficient in nitrogen, 42 percent in phosphorus and 44

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percent in organic carbon.

The growing plants need 17 essential elements to grow to their full genetic potential. Among these 17 elements, 14 are absorbed by plants through soil, while the remaining three come from air and water. Nitrogen, Phosphorus, and Potassium or in short NPK, are the "Big 3" primary nutrients in commercial fertilizers. Each of these fundamental nutrients plays a key role in plant nutrition. Nitrogen, Phosphorus, and Potassium are really important to soil because; Nitrogen is used by plants for lots of leaf growth and good green colour, Phosphorus is used by plants to help form new roots, make seeds, fruits, and flowers, while Potassium helps plants make strong stems and keep growing fast. It is important to know the NPK values of the soil, as you can provide your plants with right amount of external NPK fertilizers according to their requirement. A certain level of Soil nutrients like Nitrogen, Phosphorus, and Potassium should be maintained in the soil which is only possible by knowing how to measure the soil nutrients available in the soil.

In case if you add more nitrogen, your plants may look lush and green, but their ability to fruit and flower will be greatly reduced. If you add more phosphorus this will reduce the plant's ability to take up required micronutrients, particularly iron and zinc this causes the plants to grow poorly and even die. The same thing happens when you add too much Potassium to the soil this disrupts the uptake of other important nutrients, such as calcium, nitrogen, and magnesium.

Soil test based nutrient management has emerged as a key issue in efforts to increase agricultural productivity and production since optimal use of nutrients, based on soil analysis can improve crop productivity and minimize wastage of these nutrients, thus minimizing impact on environmental leading to bias through optimal production. Deficiencies of primary, secondary and micronutrients have been observed in intensive cultivated areas.

Nutrient Status of Soils

Intensive agriculture, while increasing food production, has caused second generation problems in respect of nutrient imbalance including greater mining of soil nutrients to the extent of 10 million tons every year depleting soil fertility, emerging deficiencies of secondary and micronutrients, decline of water table and its quality of water, decreasing organic carbon content, and overall deterioration in soil health.

Generally, NPK consumption ratio of 4:2:1 is considered as desirable based on recommendation of 120:60:30 NPK kg/ha dose (4:2:1) for wheat/rice. However, the fertilizer dose has to be worked out based on soil analysis to find out (i) available nutrient status of the soils and (ii) the crop requirement of the nutrients; the difference of the two (ii – i) is the required fertilizer dose for a given crop. Other factors affecting fertilizer use efficiency have to be built into the computation of fertilizer dose. There is a wide NPK use ratio in Northern Zone (13.5: 4.3:1), while it is narrower in Southern Zone (2.9: 1.6: 1). It is 5.6: 3.3: 1 in Western Zone and 5.0: 2.4: 1 in the Eastern Zone. A plant requires different amounts of these nutrients at each stage. It is important that you provide your plant with a sufficient amount of NPK and other nutrients. Previously testing the soil for NPK is only possible by collecting the sample and taking it to the laboratory where researchers perform tests on the soil which is time consuming, labor intensive, costly and not even possible to detect the soil NPK status on site. Later optical NPK sensors which uses spectrometer came to action which even failed to give the accurate results by stopping at 60-70% accuracy. So to overcome this few tech manufacturers such as JXCT developed a sensor which detects NPK values of the soil on the spot with nearly acceptable accuracy.

Role of sensor in nutrient analyzing

- Detecting the content of nitrogen, phosphorus and potassium.
- Helps in determining fertility of the soil.
- Systematic assessment of the soil condition.
- Smart agriculture is a solution to many global agricultural issues, like increasing productivity, monitoring the farm, communicating with other teams and sub units as well as controlling market tendencies. All over the world, farmsare rapidly looking into adopting IOT solutions into their farms.
- A number of different sensors like location sensors, electrochemical sensors, mechanical sensors, soil moisture sensors, airflow sensors, Ph sensor, NPK sensor, etc. are used in a precision agriculture providing data that helps farmer to monitor and manage crops in changing environmental condition.
- Sensor to create detailed maps of the farm area and to analyse the characteristics of the soil. Smartphones are used to monitor productivity,

crop growth and obtain the information on market changes.

The aim of the project is to develop a soil nutrient system which measures the soil nutrients of the soil like nitrogen, potassium, phosphorous and automatically gives the values in mg/kg(ppm.) The project requires very less human involvement once installed and gives continuous information on soil condition. The circuit is based on a soil NPK sensor. A properly configured soil NPK sensor can save time and easy monitoring of field.

Soil pollution is one of the major problems which affects the agriculture. Soil pollution is majorly caused due to excess application of fertilizers in the fields, also known as chemical pollution. Keeping in mind both utilization and conservation aspects of soil efficiency parameter is a key strategic factor. Hence, the soil NPK sensor warrant a new and conservative approach. Automation of agricultural tasks is the demand for an opportunity to improve efficiency with the assistance of devices and innovation.

The increasing population and demand for food in India has led to the need for more efficient and sustainable agricultural practices. One of the way to do this is by measuring the levels of the primary nutrients in soil, Nitrogen, Phosphorus, and Potassium (NPK), and supplementing them as needed. However, traditional methods of soil testing can be time-consuming and costly. This is where the use of NPK sensors comes in. These devices use advanced technology to provide real-time data on soil nutrient content, making it easier for farmers to manage their land and improve crop yields. The aim of this thesis is to explore the potential of using NPK sensors in India, and how they can be used to improve agricultural practices and increase productivity.

Materials and Method

ARDUINO In figure it is showing an Arduino board is an open-source platform used for building electronics projects. Arduino is a programmable circuit's board which we can write a program based on your projects. Arduino program will be uploading with IDE (Integrated Development Environment) software that runs on your computer, it is used to write and upload computer code to the Arduino physical board.

There is only 1 way to power the Arduino Nano, the board can be powered through a type-B mini-

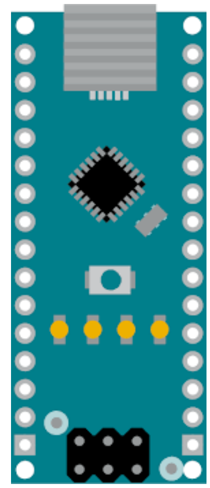

Fig. 1. Systematic view of Arduino nano

USB cable or from a 9V battery. Arduino board. The barrel jack is usually connected to a type-B mini-USB cable. The board can be powered by 5-20 volts but the manufacturer recommends to keep it between 7-12 volts

Main Microcontroller

Each Arduino board has its own microcontroller. Assume it as brain of the board. The main IC (Integrated Circuit) on the Arduino is slightly different from board to board.

It has ATMEGA328 micro controller (CPU) and runs with 16MHz and features 32kb of flash memory.

Power LED Indicator

This LED should light up when you plug your Arduino into a power source to indicate that your board is powered up correctly.

Fig. 2. OLED Display Module

OLED DISPLAY MODULE

The Organic Light Emitting Diode display that we will use in this project is the SSD1306 model, a monocolor, 0.96-inch display with 128x64 pixels as shown in following figure. The OLED display doesn't require backlight, which results in a very nice contrast in dark environments.

Soil NPK Sensor

The soil NPK Sensor. N for Nitrogen, P for Phosphorus, and Potassium 3 in 1 fertility sensor which is used for detecting the content of nitrogen, phosphorus and potassium in the soil. This soil NPK Sensor is considered to be the high precision, accurate with accuracy upto +-2%, fast speed measurement, and with increased stability. The resolution of this soil NPK Sensor is up to 1mg/l or (1mg/1), this is an easy to carry sensor and can even be used by non-professionals, all you need is to insert these stainless steel rods into the soil and read the soil content. So the soil NPK sensor gives the user an accurate understanding of the soil fertility status, thus the user can measure the soil condition at any time, and then according to the soil condition, soil fertility can be balanced to achieve a suitable growth environment for the plants.

Fig. 3. Soil NPK Sensor

Specifications

Measuring range: 0~1999 mg/kg;
Measurement accuracy: +_3% (mg/kg);
Resolution:1mg/kg(mg**/L);**
Output signal: RS485 (standard Modbus – RTU protocol, device default address:01);
supply voltage:5-24V DC;
working range :0C-50 C;
Stabilization time:1 second after power-on;
Response time :< 10 seconds;

MAX425 TTL TO RS485 converter module

The MAX485 TTL TP RS485 converter module helps to convert the TTL signals to RS485 signal by adopting half-duplex communication, This module works at 5volts power supply with 300 ma power consumption and gives long range communication upto 4000feet (1,2kms) even in the electricity noisy environments. This module lets you to communicate between multiple 32 devices at a data speed of 2,5 Mbps in the same data line through master and slave configuration which makes it useful in the industrial applications .As the distance increases the data speed decreases proportionally.

With the help of this MAX485 module we can communicate between RS485 differential signal from NPK sensor and microcontrollers such as Arduino.

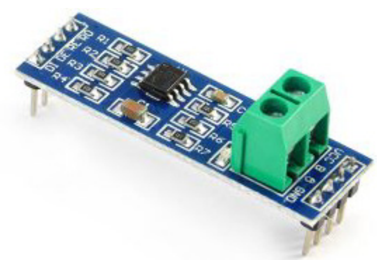

Fig. 2.4. Interface module

Connection

- Analogue pins of Arduino i.e. A4, A5 are connected to pins of OLED i.e. SDA, SLC respectively.
- On Arduino board 5v is positive and GND(Ground) is negative.
- The jumper wires. Likewise wire from 5V is made into 3 connections by combining 3 jumper, GND is also made into 3 negatives using jumper wires.
- One of the positive jumper wires of 5V and one of the Negative jumper wires of GND are connected to VCC and GND of OLED and Interface module respectively.
- Similarly, one of the positive jumper wires of 5V and one of the negative jumper wires of GND are connected to VCC and GND of soil NPK sensor respectively.
- Digital pin 2,3 of Arduino board is connected to RO and DI of Interface module.
- Digital pin 7,8 of Arduino board is connected to RE and DE of Interface module.
- The NPK sensor has 2 outputs (RS485_A&RS485_B) are connected with A & B on Interface module.
- Arduino board is powered with the help of USB

cable which is connected with Laptop or an Adaptor (5V-7V).

Procedure

- ➢ Connect the Arduino to your computer.
- ➢ Download the attached code and open it.
- ➢ Select your COM Port and your Arduino Board from Tools Option.
- ➢ Click Upload Button.

The following steps can be followed to test the programming code:

1. Connect the Arduino to power supply (5V) via USB.
2. Dip in soil sample or bury the NPK sensor in the soil. Better to place the sensor at different slopes and humid areas for accurate measurements.
3. Connect the NPK sensor to the interface module. Refer the Circuit for connection details.
4. Connect the interface module and the OLED display to the Arduino. Refer the Circuit for connection details.

Fig. 5. Testing NPK of soil with the sensor

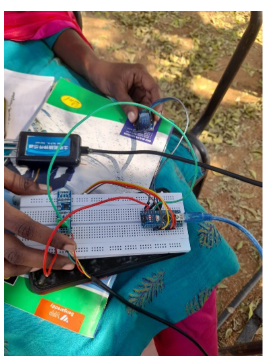

Fig. 6. Initial values of NPK sensor when it is not placed in soil

The nutrients of the soil can be monitored in 2 methods

a) By directly inserting the system in the field
b) By collecting the soil sample form the field

The difference in between these two methods is, by directly inserting in the field we can monitor the continuous soil condition of the field but by collecting the sample we can identify the nutrients present in the soil at the time when the sample is collected.

The sample should be collected from different places at various slopes and the sample should be collected 15cm below the ground surface.

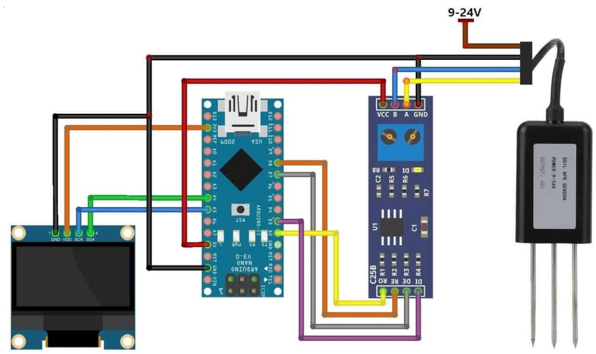

Fig. 7. Circuit connections

Results and Discussion

The Arduino Nano micro controller which is assembled with different sensors is performed at experimental location. During the process, evaluation of sensor and programming code which is performed were tested in field conditions. A total of four samples were collected for analysis, with one sample obtained from the CAES farm and three samples obtained from fields in the Mamidipalle village i.e., data point1, 2&3.

The following tables represents NPK values of laboratory and with sensor CAES farm sample.

Table. Laboratory and sensor values of CAES farm sample

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

The following pictorial representation in forms of pie chart for NPK values of laboratory and with sensor of CAES farm sample.

- From the above pie chart NPK values of both soil NPK sensor and laboratory values were nearly same with slight variation.
- In case of Nitrogen and Potassium values of both sensor and laboratory were moderately high variations are obtained.

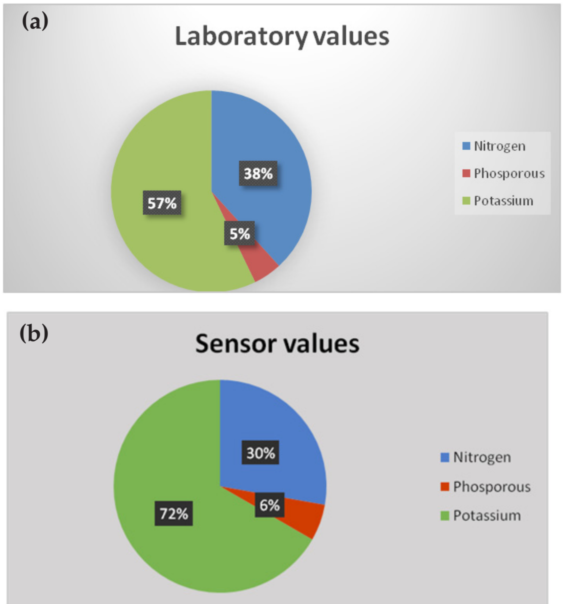

Fig. 8(a)& (b). NPK values of CAE farm in laboratory test and using sensor

- By using soil NPK sensor we got maximum NPK values 255mg/kg and minimum value is 1.
- We utilized and configured minimum system of Arduino nano optionally, by using almost all available pins.
- Efficiency of sensor compared to laboratory is up to 85%.

Laboratory and sensor values of different soil samples from mamidipalle.

Data point 1: Latitude - 17°35′15.7"N

Longitude - 78°07′56.6"E

The following pictorial representation in forms of pie chart for NPK values of laboratory and with sensor of data point 1 in the Mamidipalle village.

- Nitrogen: Laboratory values show 59 kg/acre, which represents 38% of the total. Sensor values show 47 kg/acre, which represents 34% of the total.
- Phosphorus: Laboratory values show 7 kg/acre, which represents 4% of the total. Sensor values show 6 kg/acre, which represents 4% of the total.
- Potassium: Laboratory values show 91 kg/acre, which represents 58% of the total. Sensor values show 85 kg/acre, which represents 62% of the total.

It can be observed that for Nitrogen, Laboratory values are higher than Sensor values. For Phosphorus, Laboratory values and Sensor values are almost same. For Potassium, Sensor values are higher than Laboratory values.

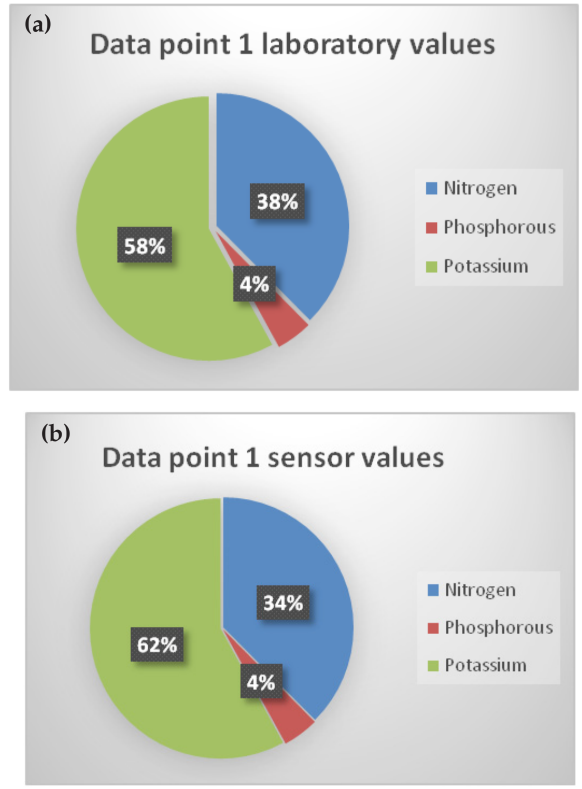

Fig. 9. (a)&(b). NPK values of Data point 1 in laboratory test and using sensor

Data point 2: Latitude - 17°35′19.1"N

Longitude - 78°07′57.6"E

The following pictorial representation in forms of pie chart for NPK values of laboratory and with sensor of data point 2 in the Mamidipalle village.

- Nitrogen: Laboratory values show 59 kg/acre, which represents 34% of the total. Sensor values show 50 kg/acre, which represents 35% of the total.
- Phosphorus: Laboratory values show 17 kg/acre, which represents 10% of the total. Sensor values show 15 kg/acre, which represents 10% of the total.
- Potassium: Laboratory values show 98 kg/acre, which represents 56% of the total. Sensor values show 80 kg/acre, which represents 55% of the total.

It can be observed that for Nitrogen, Laboratory values are higher than Sensor values. For Phosphorus, Laboratory values are slightly higher than Sensor values. For Potassium, Laboratory values are higher than Sensor values.

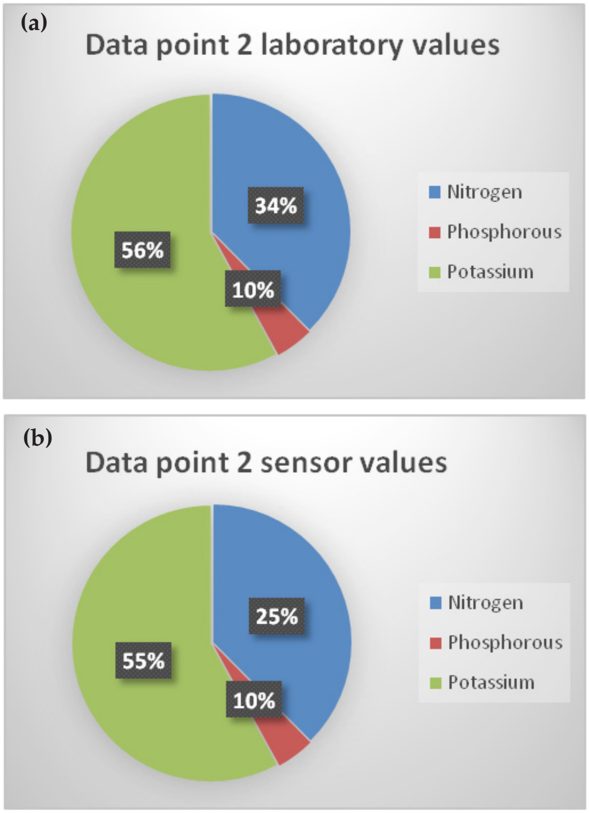

Fig. 10. (a) & (b). NPK values of Data point 2 in laboratory test and using sensor

Data point 3: Latitude - 17°35’06.8"N
Longitude - 78°07’51.3"E

The following pictorial representation in forms of pie chart for NPK values of laboratory and with sensor of data point 3 in the Mamidipalle village.

- Nitrogen: Laboratory values show 64 kg/acre, which represents 27% of the total. Sensor values show 56 kg/acre, which also represents 27% of the total.
- Phosphorus: Laboratory values show 7 kg/acre, which represents 3% of the total. Sensor values show 5 kg/acre, which also represents 3% of the total.
- Potassium: Laboratory values show 168 kg/acre, which represents 70% of the total. Sensor values show 145 kg/acre, which also represents 70% of the total.

It can be observed that for Nitrogen, Laboratory values and Sensor values are almost same. For Phosphorus, Laboratory values and Sensor values are almost same. For Potassium, Laboratory values and Sensor values are almost same.

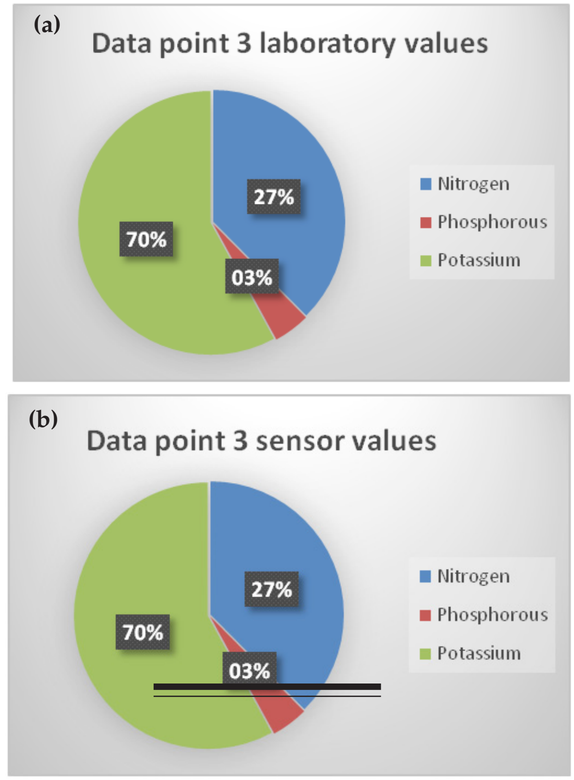

Fig. 11. (a) & (b). NPK values of Data point 3 in laboratory testand using sensor

Summary and Conclusion

This research paper explores the application of a soil NPK sensor integrated with arduino technology for monitoring soil nutrients. The study aims to access the feasibility and accuracy of this sensor based approach in providing real-time data on essential nutrients –nitrogen, phosphorus and potassium-in agricultural soil. The research conducted experiments in four various data points then the results indicate that the soil NPK sensor combined with arduino is providing the levels Nitrogen, Phosphorus and Potassium as measured by the sensor are very close to the values obtained from laboratory measurements. This suggests that sensors can provide accurate measurements of these nutrients in the field, and can be a useful tool for farmers and agricultural professionals and it is cost effective solution for continuous soil nutrient monitoring

In conclusion the integration of a soil NPK sensor with arduino technology presents a significant advancement in soil nutrient monitoring for agricultural purposes. This research demonstrates the efficiency and accuracy of the sensor system in providing real-time data on nitrogen, phosphorus and potassium levels in soil. The continuous monitoring capability offers farmers valuable insights into soil health, enabling precise and timely fertilization practices, optimizing crop yield and minimizing environmental impact through nutrient management. However, further research is warranted to address calibration requirements for diverse soil types and to explore additional parameters that enhanace the sensor's capability. Despite of these challenges, the soil NPK sensor combined with arduino showcases immense potential in revolutionizing modern agriculture and contributing to the global pursuit of food security and environmental preservation

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