Design And Implementation of Portable Soil Fertility Testing Device

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Abstract—**The main goal of the project is to design a portable soil fertility testing device which helps the farmer in deciding the best fertilizer to use for their farm depending on the NPK (Nitrogen, Potassium and Phosphorous) value of the soil. To grow and obtain best yield of crop, the most essential elements are carbon(C), hydrogen(H), oxygen(O) nitrogen (N), phosphorus(P), potassium(K), if the soil is fertile and nutrient rich then the farmer is at an advantage of growing any crop and earn some workable profit. In the last six decades, the consumption of reactive nitrogen (Nr) in the form of fertilizer in India has been growing rapidly, while the nitrogen use efficiency (NUE) of cropping systems has been decreasing as it causes a deficiency of Sodium and Potassium in the soil. Our Project aims to read the number of macronutrients (NPK) in the soil at a faster pace compared to the traditional existing chemical analysis mechanism.**

Index Terms—**NPK Sensor, Soil Fertility, Mositure, Arduino, IoT**

I. Introduction

In India, agriculture is considered as the key for human progress since ancient times. Agriculture plays a vital role in Indian economy. To grow and obtain best yield of crop, the most essential elements are carbon(C), hydrogen(H), oxygen(O) nitrogen (N), phosphorus(P), potassium(K), if the soil is fertile and nutrient rich then the farmer is at an advantage of growing any crop and earn some feasible profit hence the Soil fertility plays a vital role in finding the productivity and yield of crops. The nutrient content of soil, including nitrogen (N), phosphorus (P), and potassium (K), affects the growth and development of plants. Testing soil fertility is therefore essential for perfecting crop growth and ensuring food security. But in recent years due to multiple fertilizers present in market, farmers get confused and apply the fertilizer

famous around his locality without any second thought. This leads to two major problems: low yield or soil pollution. This report aims to present the design and implementation of a portable soil fertility testing device that uses NPK sensors to accurately measure NPK levels in soil and predict which fertilizer is needed for best crop growth. This device offers a more reliable and efficient alternative to current soil testing methods, which can be time-consuming and costly and the web interface recommends the amount of fertilizer to be added. We will then discuss the method used to design and implement the device, as well as the results of testing the device in a variety of soil types and conditions. Finally, we will conclude with a summary of our findings and the potential applications and benefits of this device

II. Mathematical Modelling

A. Communication Protocol of the sensor with microcontroller

The NPK Sensor has 3 different inquiry frames for reading the value of Nitrogen(N), Phosphorous(P) and Potassium(K). The inquiry frame is provided along with the instruction manual. For the NPK data the following individual inquiry frameworks:

	Address code	Function code	Register start address	Register length
Nitrogen	0x01	0x03	0x00 0x1E	0x00 0x01
Phosphorous	0x01	0x03	0x00 0x1F	0x00 0x01
Potassium	0x01	0x03	0x00 0x20	0x00 0x01

TABLE I
MODBUS COMMAND FOR NPK SENSOR

The following is obtained as response from the NPK sensor when the above mentioned MODBUS commands are sent from the Microcontroller

	Address code	Function code	Register start address	Register length
Nitrogen	0x01	0x03	0x02	0x00 0x20
Phosphorous	0x01	0x03	0x02	0x00 0x025
Potassium	0x01	0x03	0x02	0x00 0x30

TABLE II
RESPONSE OF THE NPK SENSOR

We can calculate the Soil nutrient value from the Response you receive. For example, if you get 0030 as a response when the potassium command is sent to the NPK Sensor then Soil Potassium Value will be:

0030H=48(Decimal) which indicates that 48mg/kg of Potassium is present in the soil sample.

B. Formulas utilized

The soil NPK sensor sends the value in mg/Kg, the amount of fertilizer to be added is recommended in Kg/Ha hence for converting mg/Kg to Kg/Ha, we use the following formula:

mg/ha = (mg/Kg x pb x 10 x 10000) / d   -(1)

Where,

pb is the soil bulk density in kg/m³

depth of the soil sample (d) in meters

10 is the conversion factor from mg to g

10000 is the conversion factor from m² to ha.

Now to convert mg/Ha to Kg/Ha the equation is implemented as shown below

Kg/ha= (mg/ha)/10^6   -(2)

Arduino NANO converts NPK values to Kg/Ha, sends to web interface. Program compares current NPK with recommended values, calculates required fertilizer amounts (urea, SSP, MOP) for soil fertility using the following:

Kg/Ha of urea = recommended dose of N * 2.17   -(3)

Kg/Ha of SSP= recommended dose of P* 6.25   -(4)

Kg/Ha of MOP = recommended dose of K * 1.66   -(5)

III. DESIGN

A. Block Diagram

The design features an Arduino Nano as the main microcontroller. It is connected to both an NPK sensor and a Moisture sensor. These sensors gather data related to the NPK content and moisture level in the soil. The device is equipped with an OLED display, which serves the purpose of showing the measured NPK content. The basic layout and connections of this system are illustrated in the block diagram depicted in Fig. 1.The power supply consists of a battery which can be charged using a Mobile Phone Charger.
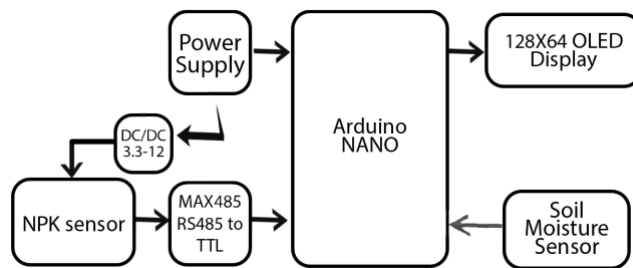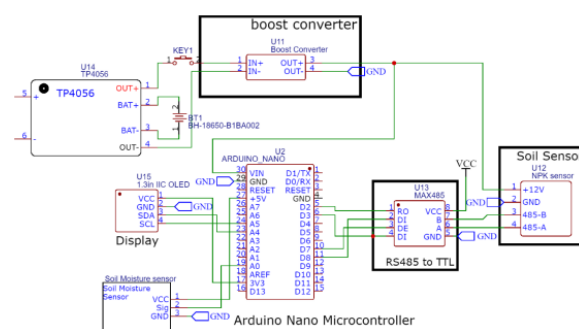

Fig. 1. Block Diagram of the Device

Fig. 2. Circuit Diagram of the Device

B. Circuit Diagram

Figure 2 illustrates the circuit connections involving various components of the device: Arduino Nano, battery, boost converter, OLED Display, NPK sensor, and Moisture sensor. The battery is charged using the TP4056 IC Module. In order to accommodate the NPK sensor, which operates at 12V, a boost converter is integrated into the circuit.

C. Comminication between NPK Sensor and Arduino Nano

The NPK Sensor and Arduino Nano use different communication logic: RS485 for the sensor and TTL for the Arduino Nano. To enable communication between them, the MAX485 IC Module is used as an interface, converting the RS485 signals to TTL signals and vice versa.The communication protocol is mentioned in the mathematical modelling.

D. Battery capacity needed to power up the prototype

To calculate the battery capacity needed ,the following formula is used:

Battery capacity (in mAh) = (power consumption in watts × operating time in hours) / battery voltage   -(6)

We require about 370 milliwatts to power up the prototype.So, Substituting values into the Equation (1) and assuming a nominal voltage of 3.7V for an LiPo battery:

Battery capacity (in mAh) = (0.37 watts × 8 hours) / 3.7V = 0.8 Ah or 800 mAh   -(7)

Therefore, from equation (2) a LiPo battery with a capacity of at least 800 mAh to power the prototype for 8 hours
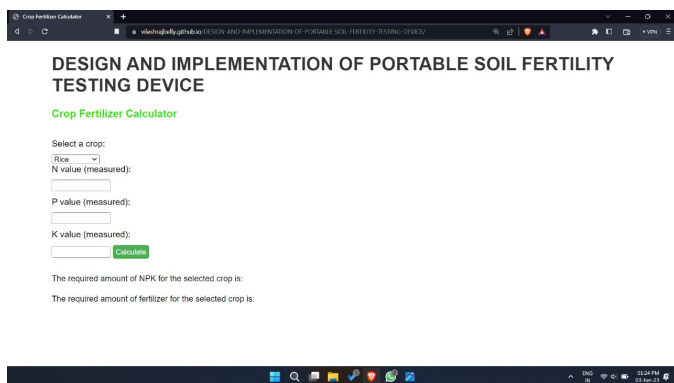
Fig. 3. Web Interface

with a power consumption of 370 milliwatts. However, a LiPo battery with a capacity of around 2000 mAh is used to provide some additional margin.

E. Design of the Web Interface

A Web Interface is developed to calculate the fertilizers to be added to make the soil fertile to grow a particular crop.The *NAAS 2009 Policy No.42* gives the required information for calculating the required fertilizers to be added.The Fig. 3 shows the Web Interface developed.

IV. IMPLEMENTATION

The NPK sensor, equipped with three electrodes, is placed directly into the soil alongside a moisture sensor for testing. NPK values are read only when the soil's moisture level falls within a specific range. If the moisture levels meet the desired criteria, the NPK sensor retrieves the NPK values and transmits them to the Arduino Nano. The Arduino Nano then displays the data on the OLED display.

A. Checking the accuracy of the sensor

The accuracy of the device is being tested against laboratory-tested values of the soil samples. Two samples have been tested and compared for this purpose.

- Sample 1:The sample is obtained from the Fertilizer Quality Control Laboratory which operates under the Deputy Director of Agriculture Fertilizer,Bangalore.The results from the laboratory and the sensor is as follows:

Macrocutrients	Test results from the lab in Kg/ha	Result obtained from the NPK sensor in Kg/ha
Nitrogen	70	63
Phosphorous	28	22
Potassium	31	30

TABLE III
COMPARISION OF THE RESULTS OF SAMPLE 1

- Sample 2:The sample is obtained from GKVK College of Agriculture in Bangalore.The results from the laboratory

Macrocutrients	Test results from the lab in Kg/ha	Result obtained from the NPK sensor in Kg/ha
Nitrogen	237	229
Phosphorous	53	57
Potassium	169	179

TABLE IV
COMPARISION OF THE RESULTS OF SAMPLE 2

and the sensor is as follows:

There is a noticeable disparity between the readings obtained from the sensor and the results obtained through laboratory testing. Hence, it can be deduced that the accuracy of the sensor is about 95 percent.

B. Testing of various soil samples

After testing the accuracy of the sensor,various soil samples at various conditions is tested.

- Sample 1:Sample 1 was collected from a land which produces rice.The NPK value obtained from our device is mentioned in *TABLE V*.
- Sample 2:Sample 2 was taken from a garden to which no fertilizer was added.The NPK value obtained from our device is mentioned in *TABLE V*.
- Sample 3:Sample 3 was taken from a garden to which fertilizer were added.The NPK value obtained from our device is mentioned in *TABLE V*.

Macrocutrients	Sample 1	Sample 2	Sample 3
Nitrogen	108	99	120
Phosphorous	54	23	34
Potassium	23	38	54

TABLE V
NPK CONTENT OF VARIOUS SOIL SAMPLES

C. Calculation of the fertilizer

The NPK Values obtained is fed into the Web Interface.The NPK content required for different crops is different.The web interface provides option to select a particular crop for which the NPK content is compared.The interface displays the deficiency in the NPK content required for the crop and suggests the amount of fertilizer to be added to overcome the deficiency.The Fig.4 shows the fertilizer recommendation for the sample taken from a rice field mentioned above in *TABLE V*.

V. APPLICATION

The soil fertility testing device developed has a wide range of applications. Farmers and gardeners can use it to assess the nutrient levels in their soil, specifically nitrogen, phosphorus, and potassium (NPK), which are essential for plant growth. By providing accurate measurements, the device enables users to optimize fertilization strategies, ensuring that crops receive the necessary nutrients for healthy development. The inclusion of a moisture sensor also allows for monitoring soil moisture levels, helping users make informed irrigation decisions.
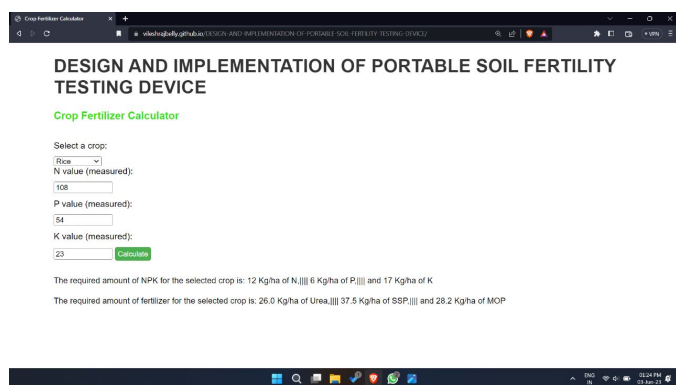
Fig. 4. Web Interface

Ultimately, this device empowers agricultural professionals to enhance soil fertility, maximize crop yield, and promote sustainable farming practices.

In the future, the device could be expanded to include additional sensors such as a pH sensor and electrical conductivity sensor. The pH sensor would measure soil acidity or alkalinity, aiding in nutrient availability. An electrical conductivity sensor would assess soil fertility and salinity levels. Integrating these sensors would enhance the device's functionality, allowing users to make informed decisions about pH adjustment, nutrient application, irrigation schedules, and overall soil management strategies.

The future scope of the device would provide a comprehensive analysis of soil conditions, taking into account not only NPK levels but also pH and electrical conductivity. This expanded functionality would empower farmers and gardeners with a holistic understanding of their soil's health, enabling them to make precise adjustments and optimize their agricultural practices. It would contribute to sustainable farming by promoting efficient resource utilization, improved crop yield, and better environmental stewardship. The device holds great potential to revolutionize soil testing and management practices, supporting the goal of sustainable and productive agriculture.

VI. Conclusion

The project successfully addresses the critical need for a portable and efficient soil fertility testing device in India. Recognizing the significance of agriculture in the Indian economy, the project aims to empower farmers with the necessary tools and knowledge to maximize crop yields and profitability. By designing and implementing a device that provides immediate feedback on soil nutrient levels and suggests appropriate fertilizers, the project offers a practical solution to the time-consuming laboratory testing process.

The device's portability ensures accessibility for small-scale farmers, bridging the gap in accessing time consuming laboratory facilities. Furthermore, the user-friendly interface helps the farmers with limited technical expertise, enabling them to effectively utilize the device. By promoting sustainable agricultural practices and increasing food security, the project strived to contribute to the overall development of the agricultural sector in India.

The immediate availability of soil health information empowers farmers to make informed decisions and optimize their crop management strategies. the project aims to play a crucial role in driving agricultural progress, fostering sustainable practices, and ultimately contributing to the well-being of Indian farmers.

REFERENCES

[1] Subramanian, Kanaga Suba. (2020). Design and Implementation of Fertilizer Recommendation System for Farmers.

[2] N. Ananthi, J. Divya, M. Divya and V. Janani, "IoT based smart soil monitoring system for agricultural production," 2017 IEEE Technological Innovations in ICT for Agriculture and Rural Development (TIAR), 2017, pp. 209-214

[3] Misbah K, Laamrani A, Khechba K, Dhiba D, Chehbouni A. Multi-Sensors Remote Sensing Applications for Assessing, Monitoring, and Mapping NPK Content in Soil and Crops in African Agricultural Land. Remote Sensing. 2022; 14(1):81.

[4] Neina, Dora. (2019). The Role of Soil pH in Plant Nutrition and Soil Remediation. Applied and Environmental Soil Science. 2019. 10.1155/2019/5794869.

[5] NAAS 2009 "Crop Response and Nutrient Ratio". Policy No.42, National Academy of Agricultual Sciences, New Delhi.

[6]] Dube, Agnes. (2019). Re: How to convert C, N, P, K, percentage of fertilizer into kg/hectare.