Development and testing of soil NPK, moisture and temperature sensing gadget

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***Abstract*— Creating nourishment economically for an ever-increasing populace is one of the most noteworthy single challenges of our time, while too adjusting the issues of climate alter, utilize of rare water and natural security. Precision farming can move forward both abdicate and benefits by utilizing less assets, whereas at the same time making agribusiness more maintainable and less contaminating. Any agriculturist with any estimate of arrive can embrace this technology-based approach. Sensor-based estimations gives more information, such as moisture levels, fertilizer viability, and plant response to varied variables, such as temperature and light. Farmers can use these sensor estimates to help them make decisions. The comes about gotten by receiving these strategies can be a boon for agriculturists and holds awesome potential for making agriculture more economical and expanding nourishment accessibility. Precision farming can address both financial and natural issues that encompass generation farming in today's world.**

Keywords*— *Sensors in precision agriculture; NPK sensors; Moisture and Temperature Sensing; Need for precision farming

I. INTRODUCTION

Precision agriculture (PA) is an approach where inputs are utilized in exact sums to urge expanded normal yields, compared to conventional development methods. An data and technology-based cultivate administration framework recognizes, investigations and oversees inconstancy in areas by conducting crop generation hones at the proper put and time and within the right way, for ideal productivity, maintainability and assurance of the arrive asset.

Economical PA is this century's most important development in cultivate administration that's based on utilizing Information and Communication Technologies (ICTs). Usually, the foremost later development innovation based on economical agriculture and solid nourishment generation and it comprises of benefit and expanding generation, financial productivity and the decrease of side impacts on the environment.

Soil macro and micronutrients, soil organic matter, pH level, soil water potential, pesticides, pathogens, and temperature are all important factors to consider when evaluating soil quality in farming. In agriculture farming soils, evaluating the nitrogen, phosphorus, and potassium macronutrient inputs can result in high-quality plant development and high crop yields. The results of soil testing are crucial in determining how much fertiliser and other soil amendments should be applied. Data on soil supplement status is imperative for ideal crop development and the premise for suitable fertilizer application and administration. Soil testing by chemical examination of Nitrogen, Phosphorus, Potassium, electric conductivity and pH levels help to decide the status of the supplements within the soil.

Farmers all over the world are looking for advanced accuracy innovation to assist them transform their operations into a more viable and effective agri-tech strategy. Within the next thirty years, the world's population will have risen to around 9 billion people, necessitating a 70 percent increase in food production. To face the issue of efficiently increasing surrender generation, farmers have relied on the overuse of agrochemicals and nitrogen fertilisers to the tune of 190 million metric tonnes per year.

However, given the negative environmental impact caused by inefficient and ineffective fertiliser application, agriculture necessitates the use of advanced innovation in order to continue meeting nourishment needs (both present and future) while minimising environmental impact. Precision agriculture is a data-gathering framework that enables farmers to survey the heterogeneity of soil physical and chemical substance, geospatial variations, and crop data in order to optimise asset utilisation based on obtained field data.

Farmers have been able to determine the best fertiliser rate application and harvest time by using real-time soil moisture profiles. In any case, the effectiveness of decision-making systems is determined by the rate of innovation and the cost (per sensor/sample). To obtain soil cores, traditional soil nutrient estimation practises employ the random grid test procedure. At that point, the cores are bundled and transported to a research facility. Furthermore, the method will necessitate the purchase of expensive laboratory equipment as well as additional extractant solutions for further chemical investigation. Kjeldahl wet digestion, Dumas combustion, and gas chromatography (GC) mass spectrometry can all be used in these procedures.

Regardless of the fact that the lab strategies are extremely precise, they require the ability to convey continuous real-time examination of cultivate soil. They are also challenged by time per sample and cost per sample, which are two major challenges faced by large scale farmers looking to outline their terrain. Among the factors that contribute to instructive challenges, need of nearby specialists, stores, knowledgeable research and extension personnel have more of an affect compared to others. PA and initial costs have more of an affect among the financial challenges compared to the other issues. With additional emphasis, farm landscape is variable, which means that what is present on one farmland may not be present on another within the landscape. As a result, precise, high-density, in-situ testing of soil conditions is critical, which has a significant advantage over traditional lab methods. To conduct study on different NPK sensors, moisture sensors and temperature sensors available in the market and to test the soil with the developed instrument.

Developing a 3 in 1 sensor gadget that is affordable and convenient for on-farm soil testing to help farmers in future so that they may have a handy equipment to measure NPK content, the moisture content and temperature of the soil independently.

II. Materials and Methods

The primary goal of this project is to create a three-in-one instrument that can be used to measure the NPK content, moisture content, and temperature of soil at a specific location and time. This chapter provides an outline of the materials used and methodology that was followed.

The setup is enclosed in a single case such that it can be carried over the shoulder like a backpack. Each of the sensors is attached to a stick that is used for detection purpose. The NPK, temperature and moisture sensors will be fixed at ends of each leg in the stick to ensure that each sensor will touch the soil for a certain depth then stabilize for recording the reading.

This reading is sent to the board, from where the NPK content, Soil Moisture, Soil Temperature in the soil can be known through the web/mobile application using Wi-Fi Module. Sensors are operated to give the respective reading instantly, thereby reducing the time needed. The methodology of the soil sensor is as follows.

A. Conceptual Design

Fig. 1. Design of the Concept

The instrument consists of the following components in order to fulfil the requirement of complete operation of the device.

1. A 3-legged holder
2. Soil NPK sensor
3. Soil moisture sensor
4. Soil temperature sensor
5. Arduino UNO Board
6. Modbus module
7. ESP32 board
8. NR24L01 module
9. Resistor
10. Connecting wires
11. DC battery

B. Legged holder

It is a mobile three-legged stick that is used as a holder to assist the sensors and ensure stability while inserting into the soil. This brings stability against downward forces, horizontal forces, and horizontal axis movements. Each leg holds a sensor, and each leg can be extended during the inserting process so that other sensors do not come into contact with the soil unnecessarily.

Fig. 2. Legged holder

C. NPK sensor

The soil NPK sensor can detect the levels of nitrogen, phosphorus, and potassium in the soil. According to [8], the majority of electrochemical methods used to determine soil nutrient levels rely on the use of an ion-selective electrode (ISE) with a glass or polymer membrane, or an ion-selective field effect transistor (ISFET). The sensor can be buried in the soil for an extended period of time and does not require any chemical reagents. It has high measurement accuracy, quick response, and interchangeability, and it can be used with any microcontroller.

Any Modbus module (such as RS485/MAX485) is required to read the NPK data. The Modbus module is linked to both the microcontroller and the sensor. The sensor is powered by a 24V battery. The measuring resolution for nitrogen, phosphorus, and potassium is up to 1mg/kg (mg/l). Many N, P, and K determination procedures that were previously only available in the lab have been adapted for portable sensing applications and now have the potential to be used for on-the-go field measurements in agriculture [12].

Fig. 3. NPK sensor

Electrochemical sensing in conjunction with ion selective membrane-based transducers is an appealing approach for monitoring soil parameters such as nitrate, phosphate, potassium, and other soil parameters [18].

D. *Soil moisture sensor, YL-69*

A typical YL-69 Soil Moisture Sensor is made up of two parts. A two-legged lead that is placed in the soil or anywhere water content must be measured. This has two header pins that connect to an amplifier/A-D circuit, which is then linked to the Arduino. The Soil Moisture Sensor measures soil moisture in response to changes in the earth's electrical conductivity (soil resistance increases with drought). The electrical resistance of the sensor is measured between its two electrodes. Soil moisture sensors, according to [23], can provide instantaneous information about soil moisture status within the root zone and thus aid in the timely application of water.

Because the working principle of each type of sensor varies depending on its application and soil type, the advantages and disadvantages of sensors must be considered as selection criteria [18]. Telemetry and its continuous near real-time measurements delivered to the irrigation manager via computer or other handheld communication devices are the main selling points for this technology [2].

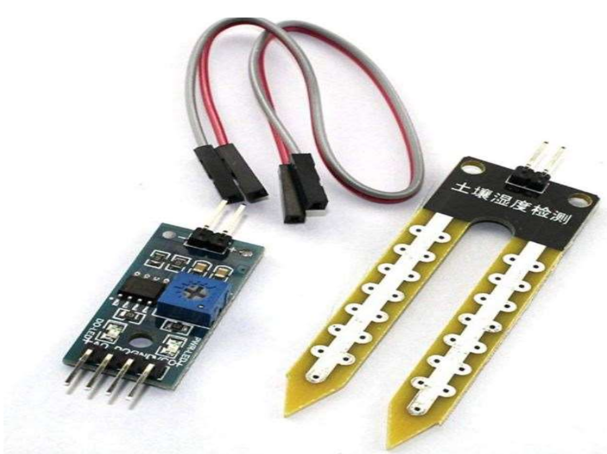

Fig. 4. Moisture sensor

E. DS18B20 Waterproof Soil Temperature Sensor

This is a pre-wired and waterproofed version of the DS18B20 Sensor that can be used to measure something from a long distance or in wet conditions. The sensor can detect temperatures ranging from -55°C to 125°C (-67°F to +257°F). The cable is protected by a PVC jacket. These 1-wire digital temperature sensors are fairly precise, with an accuracy of 0.5°C over much of the range. They work well with any microcontroller that has a single digital pin. The sensor requires two libraries: Dallas Temperature Sensor Library and One-Wire Library. It also necessitates the use of a 4.7k resistor as a pull-up from the DATA to the VCC line when using the sensor [10].

In agriculture, measuring soil temperature has numerous advantages. For example, based on soil temperature data, farmers or agricultural sector investors can determine the type of crop suitable for a particular soil, the exact time to plant the crops, and so on [3].

Fig. 5. Temperature sensor

F. *Arduino UNO board*

Arduino is an open-source programmable circuit board that can be used in a wide range of simple and complex projects. This board contains a microcontroller that can be programmed to sense and control physical goods. The Arduino can interact with a wide range of outputs such as LEDs, motors, and displays by responding to sensors and inputs.

The Arduino Uno is an open-source microcontroller board developed by Arduino.cc that is based on the Microchip ATmega328P microcontroller [22]. The Arduino/Genuino Uno has a number of communication ports for connecting to a computer, another Arduino/Genuino board, or other microcontrollers.

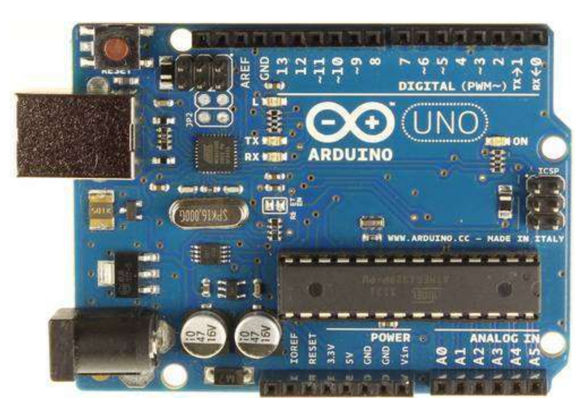

Fig. 6. Arduino UNO board

G. *Modbus module*

Modbus is a serial communication protocol created by Modicon in 1979 for use with its programmable logic controllers (PLCs). In layman's terms, it is a method of transmitting data over serial lines between electronic devices.

Fig. 7. Modbus Module

H. *ESP32 board*

The chip developed by Espressif Systems is known as the ESP32. This gives embedded devices Wi-Fi (and, in some models, dual-mode Bluetooth) connectivity. While ESP32 is technically just a chip, the manufacturer frequently refers to modules and development boards that contain this chip as "ESP32."

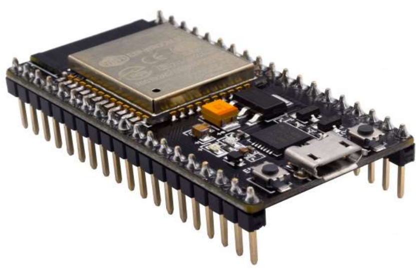

Fig. 8. ESP32 board

I. *NRF24L01 wireless transceiver module (x2)*

The nRF24L01 is a wireless transceiver module, which means it can send and receive data. It operates at a frequency of 2.4GHz. When used properly, the modules can cover a distance of 100 metres. The second version of this module, nRF24L01 PA+LNA, includes a SMA connector, duck-antenna, and a special RFX2401C chip that integrates the PA and LNA.

Fig. 9. NRF24L01 wireless transceiver module

This range extender chip, in conjunction with a duck-antenna, allows the module to achieve a significantly greater transmission range of about 1000m. The module operates at 3.3V, but its SPI pins can tolerate 5V. Because the NRF24L01 module communicates via SPI, it can be used with any microcontroller that has SPI Pins, such as the ESP32 Wi-Fi Module or Arduino Boards [10].

J. *Connecting wires*

Electricity requires a medium to go through, connecting wires enables electrical current to travel from one point on a circuit to another.

Fig. 10. Connecting wires

K. *Power supply (12V)*

A DC power source provides a consistent DC voltage to its load. In this project, a 12V, 1.3AH rechargeable battery is used to power the circuit and, ultimately, the sensors for operation.

Fig. 11. DC battery

III. WORKING PRINCIPLE

The working principle of this gadget is quite simple. The entire design, excluding the sensors, is enclosed in a single case such that it can be carried over the shoulder like a backpack. Each of the sensors is attached to a stick that is used for detection purpose.

The NPK sensor will be fixed at one part of the stick in such a way that the sensor electrodes will touch the soil for a certain depth then stabilize for recording the reading. This reading is sent to the computer, from where the NPK content in the soil can be known. Similarly, the moisture and temperature sensors are operated to give the respective reading instantly, thereby reducing the time needed.

The electrochemical sensor (NPK sensor) has 3 electrodes, each one to measure nitrogen, phosphorus and potassium content. An appropriate measurement location is selected, neglecting stones and other hard objects. The topsoil is thrown off according to the required measurement depth. For several reasons, the use of electrochemical sensors in the measurement of soil nutrients has been attractive: they have a reasonably quick answer, are rough, measurable directly in a slurry or a solution, are relatively cheap and need little hardware (Lobsey et al, (2010). Historically, ion selective electrons have been employed for conventional chemical soil testing by commercial solar laboratories and are commonly utilized for soil pH measurement [1].

The sensor should be held vertically and put into the soil while the original tightness underneath the earth is maintained. The sensor should be in soil contact for about 10 seconds for every 1m gap in the soil. The testing procedure for soil takes the many sorts of soil samples into account (sandy soil, sandy loam, silty clay and sandy clay).

Each of these samples contain different amount of NPK content in them. Using sensor, the soils will be classified into either one of the three categories according to the table given below. Based on the classification, precise quantity of the required nutrients can be estimated which can be applied to the soils. Electrochemical sensors can be combined as a sensor panel on a single chip to allow simultaneous detection in multi-targets [11].

TABLE I. OPTIMUM NPK VALUES (TNAU SOIL RATING CHART)

Nutrient	Low	Medium	High
N (in kg/ha)	<240	250-480	>480
P (in kg/ha)	<11	11-22	>22
K (in kg/ha)	<110	110-280	>280

The soil moisture sensor is made up of two samples used to measure the volumetric water content. The two samples let the current to flow through the ground and then measure the moisture value by the resistance value. The soil will lead to greater electricity, which implies less resistance, if more water is available. The moisture content is therefore greater. When there is less water, the soil will conduct less electricity, which means there is greater resistance. Dry soil is not conducting electrical power well. The humidity level is therefore lower (Arduino and Soil Moisture Sensor).

The long-term stability of these types of capacitive probes may be beneficial for botanists, agronomists, and water resource managers as a low-cost, efficient, and reliable method for monitoring and predicting water content in soils [13].

In current agronomic techniques and practices sensor-integrated precise farming can improve the costs of crop production [9]. To detect humidity levels in the soil and manage irrigated systems (turns on the system if humidity falls below a predetermined value), a lot of water and manpower waste may be avoided. The generic reference table for three main types of soil has a generally applicable 'ideal moisture level.' [16] found that sensors of ground moisture are vital for the protection and understanding of our climate. Water resources are protected.

Excess irrigation leads to soil erosion, raises the risk for surface and ground water pollution through water rinse and leach and calls for extra pesticides and fertilizers. The result and quality of certain cultivations is harmed by under-irrigation. Irrigation of very sensitive plants such as pulp (Solanum cepa) L., onions and many other crops requires precise planning [7].

TABLE II. OPTIMUM LEVEL OF IRRIGATION (TOM LAURENZI (2018)

Soil Type	No irrigation needed	Irrigation to be applied	Low soil moisture
Fine (clay) (in %)	80-100	60-80	Below 60
Medium (loamy) (in %)	88-100	70-88	Below 70
Coarse (sandy) (in %)	90-100	80-90	Below 80

The functioning of a temperature sensor depends on the diode's voltage. The change in temperature exactly corresponds to the resistance of the diode. The colder the heat, the lower the strength and vice versa. The resistance across the diode is measured and translated into readable temperature units (Fahrenheit, Celsius, Centigrade, etc.).

Ideal planting ground temperatures are between 18-24°C. Increasing the temperature of the soil improves the rate of nitrogen mineralization by increasing the microbial activity and the breakdown of organic materials in the soil, [6] said. Soil temperature drops under freezing points mineralization by limiting microbial activity and reducing the spread of soluble soil substrates. On the basis of data on soil temperatures, farmers or investors in agriculture may choose the crop type for a certain soil, the exact time when the crops will be planted, etc. The temperature of this agricultural sector can also somehow be optimized by mechanical means.

IV. RESULTS AND DISCUSSION

Tests are conducted with the of N, P, K, Moisture and Temperature Sensing Gadget developed and the results obtained are analyzed to assess the optimum value. The final picture of the design, the determination of the gadget is discussed in this chapter.

A. Completed Prototype

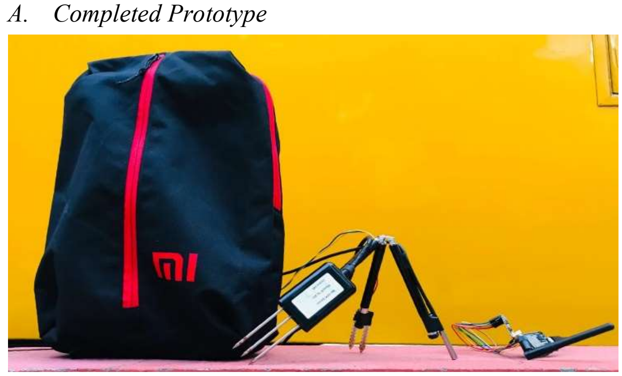

Fig. 12. Prototype

B. Circuit Diagram

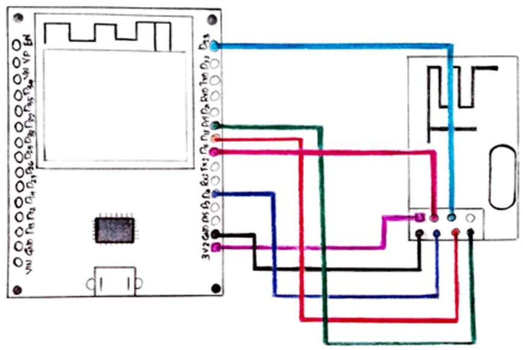

Fig. 13. Circuit (a)

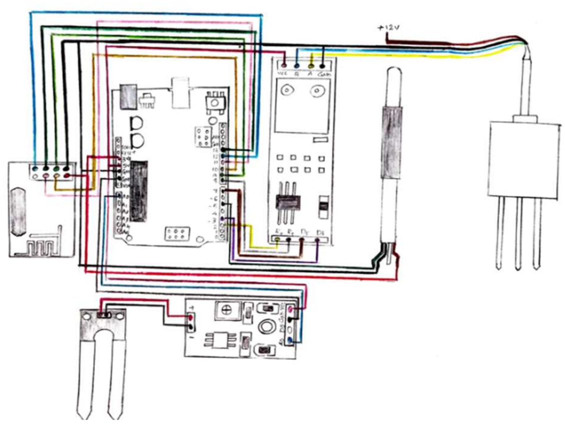

Fig. 14. Circuit (b)

C. Tests conducted

Sample (taken) 1 – Near the cricket ground

Sample (taken) 2 – Irrigation field near polyhouse

Sample (taken) 3 – Polyhouse

TABLE III. RESULTS OBTAINED BY CONVENTIONAL METHOD

Soil sample	Sample 1	Sample 2	Sample 3
Available N (In kg/ha)	160	328	473
Available P (In kg/ha)	26	29	78
Available K (In kg/ha)	818	1669	1279

TABLE IV. ACTUAL RESULTS OBTAINED BY THE USE OF SENSORS

Soil sample	Sample 1	Sample 2	Sample 3
Available N (In mg/kg)	70	151	204
Available P (In mg/kg)	11	12	35
Available K (In mg/kg)	356	730	552

D. Calculation

i. Area = 1ha = 10000 m2
ii. Depth = 10 cm = 0.1 m
iii. Bulk Density (for sandy clay loam soil) = 1500 kg/m3

Volume = area × depth = 10000 × 0.1 = 1000 m3
Mass = volume × bulk density = 1000 × 1500 = 1500000 kg per hectare
Actual nitrogen value of sample 1 obtained from the sensor = 70 mg/kg of soil
Therefore, in 1 ha (for 70 mg/kg) → 70 × 1500000 = 105000000 mg = 105 kg/ha

TABLE V. RESULTS OBTAINED AFTER CALCULATION

Soil Sample	Sample 1	Sample 2	Sample 3
Available N (In kg/ha)	105	227	306
Available P (In kg/ha)	17	18	53
Available K (In kg/ha)	534	1095	828
Moisture Content (In %)	16	78	12
Temperature (In °C)	35	37	28

V. SUMMARY AND CONCLUSION

A suitable gadget was developed and tested in the previous chapters. The summary and conclusion of the project with the benefits are discussed in this chapter. This project proposes an approach to aid farmers to be self-reliant in detecting the soil parameters. In the globe today, the pollution generated by soil contamination is the main problem generating environmental destruction. Misuse and lack of knowledge of the field parameters of fertilizers and pesticides may diminish production and harm the balance of the ecosystem in a crop area. The notable challenges observed in conventional soil testing methods are prolonged time and cost of testing. To overcome these issues, this 3 in 1 gadget provides the necessary components required for the overall growth and development of crops thereby helping farmers obtain maximum yield with minimum wastage of resources. It is evident that this strategy satisfies all the shortcomings and result in increased productivity in plants.

Precision agriculture may influence food production in the face of a growing world population and can assist farmers achieve more sustainability and preservation of the environment, higher productivity and larger economic rewards. There are various chances for farmers in many developing nations, including India, to discover better agricultural locations and a farmer really transforms into a breeder to produce better and higher rates of crops. Thus, precise agriculture appears to provide numerous benefits to farmers and landowners who choose to employ technology to manage their fields and eventually to enhance profit. The performance and testing of the 3 in 1 gadget proved to be very useful for those in the field of agriculture as it satisfies their needs.

VI. SUGGESTIONS FOR FUTURE WORK

This device for huge acres of land can be strengthened for future improvements. The soil quality and crop development of each soil may also be controlled. The sensors and microcontrollers are interfaced effectively and wireless connectivity between different nodes is accomplished. All observations and practical testing demonstrate that this idea offers a full answer to irrigation and field operations. Implementing such a method in the field may undoubtedly assist to enhance agricultural yield and output overall.

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