Soil Nutrient Analysis using Colorimetry Method

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Abstract — **In most parts of the world, agriculture is an important source of livelihood. This entails hard work, but it contributes to the nation's food safety and health. The harvest majorly depends on soil fertility, moisture level and also the level of fertilizers used. Time and distance are the major factors that limits farmers in performing the laboratory analysis of nutrients. Due to this inconvenience caused, nutrient testing is not performed regularly, which results the soil to lose its fertility. Using the concept of Internet of Things (IoT) a system is proposed which adopts precision agriculture in order to overcome such drawbacks and to remotely monitor the soil characteristics like soil moisture and its nutrients. Awareness about the quantity of nutrients present in the soil is essential to ensure optimum usage of fertilizers and constant monitoring of irrigation is also required for better productivity. The sensors are integrated with arduino microcontroller and the values obtained from the sensors are transmitted to the cloud and displayed in a mobile application. The proposed IoT based software system has the intelligence to measure the moisture level and quantity of the nutrients using colorimetry which improves the quality of the soil and ensures optimum growth of the crop.**

Keywords—Soil Moisture, Colorimetry, Sensors, Nitrogen, Phosphorus, Potassium, Mobile Application

I. INTRODUCTION

Agriculture is the most peaceful and an environmentally friendly method of living. Soil is one of the most valuable resources in agriculture. Soil analysis helps in determining the inputs needed for efficient and economical production. Crop maintenance majorly depends on the amount of water and fertilizers added. Nitrogen, Phosphorus and Potassium (NPK) are the major nutrients required for plant growth and food production. Balancing these nutrients becomes an important task to ensure crop's maintenance and this is done by effective application of fertilizers. Fertilizer management is essential to increase the production rates and reduce the expenses incurred. Over and under provisioning of the fertilizers can greatly reduce the yield and result in degradation of agricultural products in terms of quality, taste, size, color and quantity. The world population is increasing gradually and to meet the growing demands, it is essential to switch into a smarter agricultural practice. Precision farming utilizes precise amount of inputs than conventional farming. It prevents soil degradation, increases scalability, ensures cleaner process, reduces cost and conserves resources.

Internet of things is one of the emerging technologies that would help in sensing many agricultural parameters. The benefits that the agriculturists are getting by adopting IoT technology is multifold. NPK values are determined using arduino and electrochemical sensors which is a real-time application of IoT [1-3]. Smart agriculture is implemented through a cloud model by providing real-time insights of various plant and soil characteristics [4]. Soil moisture detection plays a vital role in the irrigation management when implemented through IoT [5]. Precision agriculture also provides fertilizer recommendation for crops thereby improving the harvest and production rates [6,7].

To maximize the crop yield and to minimize the infertility of the soil, a solution is proposed which optimizes yield where a structured and balanced framework is developed. The proposed system works on colorimetry technique for detecting the values of NPK. Colorimetry principle directly relates the amount of light absorbed to the concentration of the sample which has to be determined. Thus, the results obtained are discussed and the mobile application developed helps in viewing the nutrient values and moisture of the soil in real-time which assists farmers for better harvest.

II. RELATED WORK

An IoT based system was proposed which integrates various sensors and aims at optimizing the soil productivity through site specific fertilizer recommendation [8]. This system reports the NPK values, pH and the environmental conditions using various chemicals and sensors. The soil test reports, and the fertilizer recommendation values are viewed on a mobile application. A survey is carried out based on the current and potential applications of IoT in arable farming which is data-driven [9]. An arduino based soil monitoring system is developed using sensors and effective monitoring of irrigation is performed through this smart automation [10]. A mobile

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application is developed which provides the user interface for monitoring the quantity of fertilizers, irrigation, temperature and humidity values.

Colorimetric method is used to determine NPK values by preparing the soil sample with certain reagents. Based on the color developed, the results are obtained [11]. Naïve Bayes classifier is used to classify the values as low, medium or high which verifies the correctness of the system by predicting the accuracy. A raspberry pi based IoT system is developed by integrating several sensors for detecting pH, temperature, and humidity. Colorimetry principle through soil test kit is used for NPK detection [12]. Based on the NPK values present in the soil, the crop which is sufficient for plantation is suggested in the mobile application developed. A system is developed using optical transducer where the soil fertility is determined through light absorption and transmission system [13]. An arduino Microcontroller is used for data acquisition and the amounts of NPK are obtained as low, medium or high.

III. PROPOSED SYSTEM

The proposed system determines the soil moisture using the soil moisture sensor and the NPK values using colorimetry principle. This principle is implemented using color sensor. The readings obtained from the colour sensor is compared with the standard ranges and the exact value of NPK is determined. The data from sensors is sent to the firebase real-time database. A mobile application is developed which provides information related to the NPK values and the moisture value present in the soil and hence the farmers can efficiently utilize the tested ranges to increase productivity.

A. Methodology

The proposed methodology consists of soil moisture sensor and the color sensor integrated with an arduino microcontroller and ESP8266 Wi-Fi module as shown in fig. 1. The arduino Integrated Development Environment (IDE) is the software used for arduino programming. The NodeMCU is connected to the arduino board through the Rx and Tx pins for transmission and receival of sensor data. The NodeMCU communicates with the arduino through the pins 10 and 11 and the data is serially parsed through Java Script Open Notation (JSON) and stored in the firebase database. Firebase consist of an authentication system which provides security for storing and synchronizing the data. Firebase cloud messaging system sends notifications and messages to the targeted audiences. The desired Application Program Interface (API's) are provided in the android app to receive the sensor data serially from the firebase. The mobile application is developed using android studio which provides information about the water content and the nutrients present in the soil. Using this information, the farmer manages the irrigation and fertigation systems effectively.

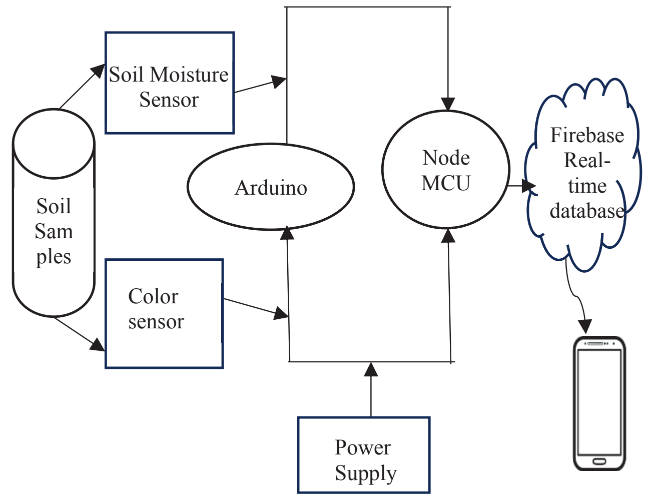

Fig. 1. Block Diagram of the Proposed System

B. Soil Moisture Sensor

Soil moisture sensor measures the percentage of wetness in the soil. Soil moisture sensors commercially available are of two types both resistive and capacitive. The resistive type moisture sensor is used which consists of two probes that allows the flow of current between them. The soil conducts more electricity and the resistance is less when there is more water, resulting in high wetness. If the soil conducts less electricity, the resistance is high, hence the moisture value is low. An analog value ranging between 0 to 1023 is obtained which is mapped and converted into percentage value. For effective monitoring of irrigation systems in agriculture, moisture sensors are useful. The specifications of FC 28 soil moisture sensor are mentioned in table 1 and fig. 2 represents the hardware integration of the moisture sensor.

TABLE I. SPECIFICATIONS OF SOIL MOISTURE SENSOR

Sensor Model	FC28
Range	0-1023
Soil Probe Dimension	6cm×3cm
PCB Dimension	3cm×1.5cm
Input Voltage	3.3- 5V
Output Signal	Analog

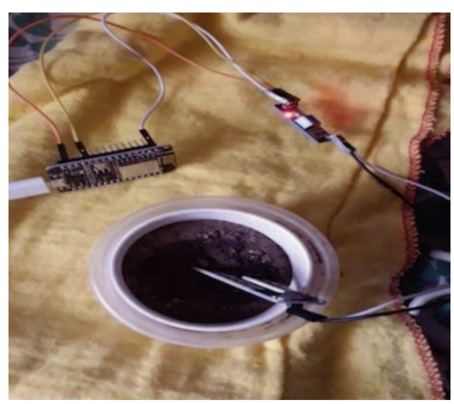
Fig. 2. Hardware Integration of Soil Moisture Sensor

C. Color Sensor

A color sensor detects the color of any material in RGB scale ranging from 0 to 255. The sensor comprises of red, green, blue, clear filters along with a light to voltage converter. Based on the activation of these filters, the color of the material is recognized. The concept of Beer-Lambert's law is used where the amount of light absorbed and reflected by the sample is calculated and the RGB values are obtained. This RGB value is mapped with the standard NPK ranges in kg/ha and the resulting value gives the exact amount of NPK present in soil. The specifications of the color sensor are listed in table 2 and the hardware integration of the color sensor is shown in fig. 3.

TABLE II. SPECIFICATIONS OF COLOR SENSOR

Sensor Model	TCS3200
Working Voltage	2.7V to 5.5V
Interface Type	Digital TTL
Size	28.4 × 28.4 mm

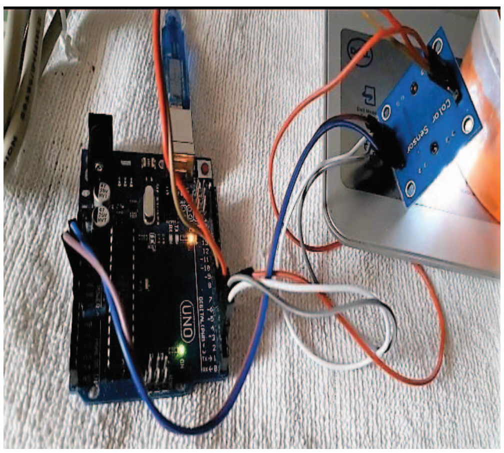

Fig. 3. Hardware Integration of the Color Sensor

IV. RESULTS

The output for soil moisture and the NPK values are obtained through this system which eventually monitors the usage of water and fertilizers. This system assists farmers to conserve resources and increase cultivation by reaping large number of high-quality crops. The data collected from the sensors improves the decision-making process of farmers by determining the optimal time for identifying planting and harvesting intervals. Accurate tracking of production rates predicts the future yield and also manages the system effectively. Fig. 4 shows the moisture frame of the mobile app where the moisture value stored in the firebase cloud is displayed and fig. 5 shows the graphical representation of the percentage of soil moisture present in the soil sample.

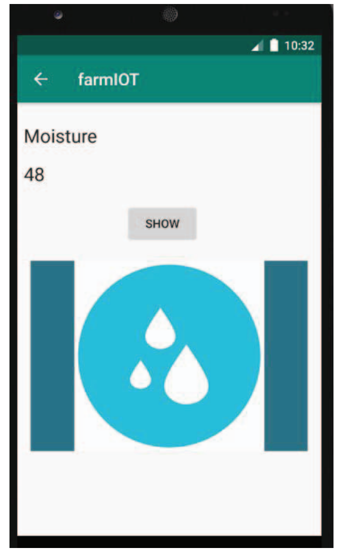

Fig. 4. Moisture Value Displayed in Mobile Application

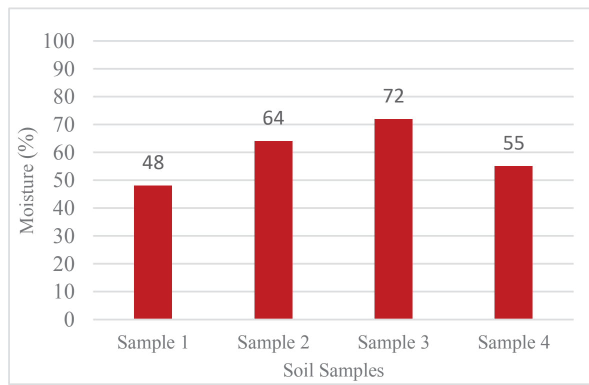

Fig. 5. Percentage of Soil Moisture for Different Samples

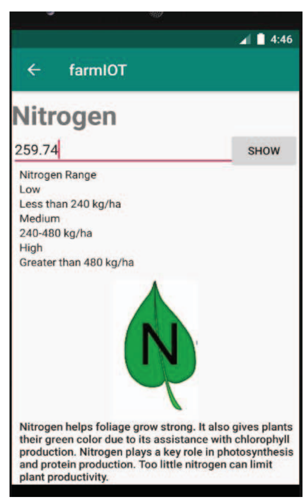

Fig. 6. Nitrogen Value Displayed in Mobile App

Fig. 6 show the Nitrogen value displayed in the mobile application. Similarly, the values of P and K are calculated using the color sensor. The values obtained are compared with the standard ranges of NPK as shown in table 3.

TABLE III. STANDARD RANGES OF NPK

Nutrient	Low	Medium	High
Available Nitrogen(N)	<240 kg/ha	240-480 kg/ha	>480 kg/ha
Available Phosphorous(P)	<11.0 kg/ha	11-22 kg/ha	>22 kg/ha
Available Potassium(K)	<110 kg/ha	110-280 kg/ha	>280 kg/ha

This assists farmers to calculate the quantity of fertilizers to be added for the crops. The amount of the NPK found from the colorimetry method is also compared with the traditional way of soil analysis. Four soil samples are taken, and the traditional method was performed to obtain the NPK values. These values are compared with the colorimetry output as shown in table 4, resulting in an accuracy of approximately 80%. The graph comparing the traditional and colorimetry method is shown in fig. 7.

TABLE IV. COMPARISON OF NITROGEN VALUES FOR TRADITIONAL AND COLORIMETRY METHOD

Soil Samples	Type of soil	Value of Nitrogen obtained in traditional method	Value of Nitrogen obtained in colorimetry method
Sample 1	Full Wet Clay soil	175	159.5
Sample 2	Normal Wet Clay soil	242	255.06
Sample 3	Full Wet Loam soil	206	221
Sample 4	Normal Wet Loam soil	257	264.42

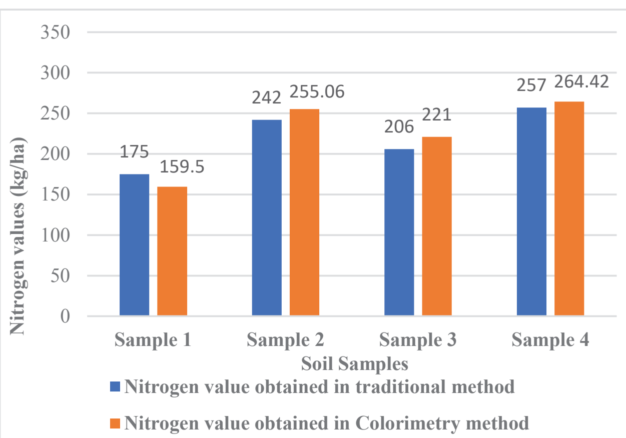

Fig 7. Comparison of Nitrogen values for Traditional and Colorimetry Method

V. CONCLUSION AND FUTURE ENHANCEMENT

Thus, the system proposed senses the soil moisture and the nutrients in the soil. The values obtained after sensing is stored in the firebase and displayed in the mobile application developed. Such a monitoring of soil moisture and the nutrients will be of great use to the farmers and also for improving the nation's economy. Farmers could easily view the values in the mobile application in a convenient manner. Hence this system is highly effective for farmers in achieving better crop yield. In addition to this, the system can be enhanced further by recommending the required amount of fertilizers for crops and also by measuring the micronutrients like zinc, calcium etc. present in the soil.

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