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OPTIMIZING AGRICULTURAL YIELD THROUGH SENSOR-BASED SOIL NUTRIENT ANALYSIS

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Abstract-The creation and use of sensing technology is one of the chief components in achieving sustainability in agricultural production through precision agriculture. This article outlines the primary sensing methodologies used for tracking soil nutrients in opinion of recent improvements in the sensing devices utilised in literature. To locate the macro-nutrients in the soil, the designed prototype has AS73211 colour sensors that work with a NODE MCU. Two comparative soil sample scrutiny were used for the measurement. Testing on various samples showed that Nitrogen Phosphorous and Potassium is more that the threshold values of 445-485nm, 505-565 and 625 – 685nm respectively in both the soil samples. The method developed is more useful and suitable for use in farming.

Keywords: NPK, soil sensor, NODE MCU.

I. INTRODUCTION

India's economy relies heavily on agriculture, with the majority of its population directly or indirectly dependent on this sector. Consequently, farmers devote significant time to nurturing their fields. Soil is rich in both micro and macro-nutrients, crucial for crop growth. Among the macro-nutrients like Nitrogen (N), phosphorus (P), and potassium (K) are pivotal. Insufficient levels of these nutrients can severely impact crop productivity, leading to crop wastage. Conversely, excessive nutrient levels can also have harmful effects. Therefore, maintaining optimal nutrient levels is vital for maximizing crop yields. Commercial fertilizers containing N, P, and K have played a crucial role in enhancing agricultural productivity by providing these essential nutrients to the soil.

This study introduces the usage of wireless sensor network technology (WSN) for real-time monitoring and assessment of soil chemical conditions. Based on the measured levels of chemical deficits or excess, appropriate amounts of fertilizer and compost are administered to the soil. The initial phase involves deploying various sensor nodes across different areas of interest within the soil, which are then interconnected to a central base station via the network. These base stations, in turn, communicate with local management systems through gateway networks, enabling the control and monitoring of crop and field conditions. This approach, known as precision agriculture, entails a comprehensive soil and crop management system that evaluates variations in soil properties such as pH levels and nutrient content.

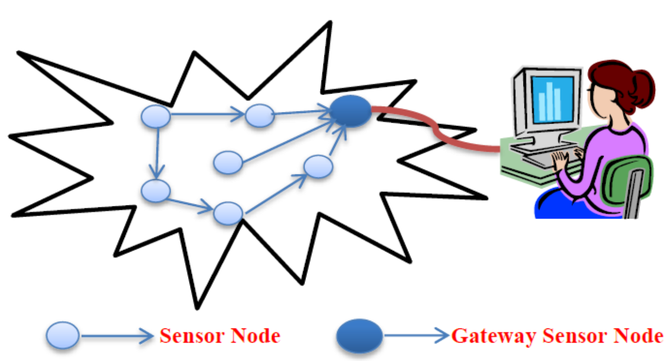

Figure – 1: Wireless Sensor Network Architecture.

The figure-1 shows the architecture of wireless sensor network. Sensor nodes utilize optical methods to gather data on various soil macro-nutrients within their range and transmit this information to a central database server via Wireless Sensor Networks (WSN). These sensors continuously monitor the chemical composition of the soil, sending the collected data wirelessly to the farmer's system. This real-time feedback allows farmers to promptly assess the chemical levels in their fields and formulate educated choices concerning the utilization of fertilizers.

Many sorts of technology have now been developed in the ground of advanced technology to make it easier for people to go about their everyday lives. Numerous devices have been industrialised in agricultural technology and elsewhere to aid farmers in booming out their agricultural actions and producing healthy crops. Land with sufficient fertiliser is one of the chief elements that should be present for a decent yield. In instruction to see the demands of a society that is increasingly dependent on food supply, enough fertiliser may help plants generate good yields and volumes. Every nation must have enough nutrients (NPK) quantity of crops. These three nutrients each support different aspects of plant growth: nitrogen supports the development of leaves, phosphorus supports the evolve of roots, and potassium supports the development of flowers and fruits while maintaining nutrient and water balance in plant cells. A change of techniques, including optical method, electrochemical method, acoustic technique, electrical and electromagnetic, and automatic ones, have been employed by previous researchers to construct NPK finding devices [2]. [3] Provides a useful overview of sensors for precision agriculture. For the reason that of its exceptional sensitivity and quick reaction, the optical detection technique has newly been found to offer a better potential for real-time detection [4]. Many studies on the finding of NPK soil using optical methods [1, 5-7] have been published. In these experiments, the soil is lit by a light. To determination the light to the earth, the normal of the produced systems included additional optical components such fibre optics [7, 8].

An optical detection approach based on colour detection is used in this work. The detection method is regarded as a shortest detection method since it does not demand supplementary components. Using a photodiode that can change light into electricity. The AS73211 chip is employed for both colour conversion and this function. The current output is altered and displayed as an outcome of the NODE MCU's manipulation of the chip's output.

II. METHODOLOGY

Figur-2 depicts a combined optical transducer with NODE MCU for detecting NPK in the soil. The light source was measured by the microcontroller (NODE MCU) in a transmission system. In addition, it served as a statistics collecting system for light detecting systems and offered control features for the display. In our current system, an AS73211 chip with low power and low integration is employed as the optical transducer. Three channels create a continuous or triggered measurement by converting light signals from photodiodes to a digital output. The photodiodes transform the incoming light into a photo current, which is then converted to digital data by a later current-to-digital converter. Using an external resistor, an internal reference generator supplies all essential references for the A/D conversion and the photodiodes.

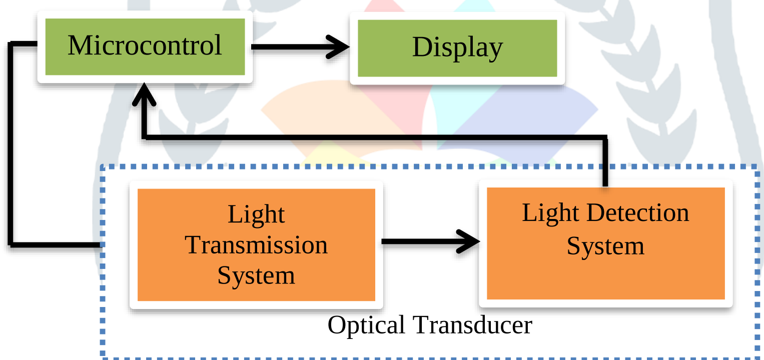

Figure-2: Block-diagram-of-integrated-optical-transducer-with-microcontroller

Three 16-bit registers hold the A/D conversion's output and may be accessed through the I2C interface. The input pin SYN can be utilised for the measurement's externally driven start or start and stop. The state of the conversion is exposed in the output, READY. The AS73211 is ideal as an optical converter for three distinct wave lengths due to its great versatility.

Figure-3 illustrates the employment of a colour sensor for the detection of nutrition levels in soil. This sensor functions by emitting white light onto a soil sample and gauging the intensity of the reflected light using the AS73211 chip integrated within the sensor. To regulate the light intensity reaching the soil sample, the Node MCU microcontroller is utilized. Additionally, the Node MCU facilitates the storage of nutrition values in a data repository via the ESP8266 Wi-Fi module and exhibits the results on an LCD display.

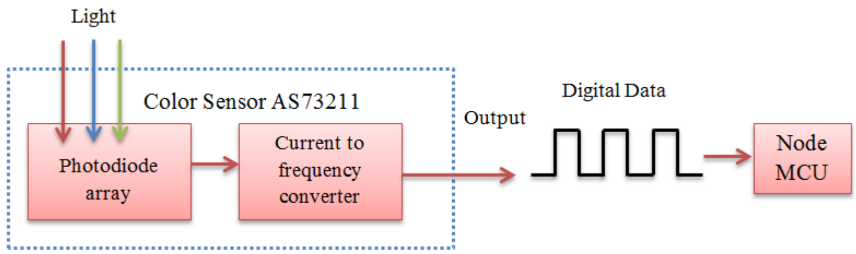

Figure-3: Functional Block Diagram for working of color sensor and Node MCU

The colour sensor operates by harnessing the wavelengths of three distinct colours: Red, Green, and Blue, each correlated with the levels of Nitrogen, Phosphorus, and Potassium in the soil. By comparing the absorption wavelengths of the sample to standard values, the sensor determines the concentration of nutrients present. Light reflected from the soil is captured by a photodiode, while the soil itself receives light emitted from a light-transmitting source. This process enables the sensor to assess nutrient levels accurately and provide valuable insights for agricultural management.

Node MCU, a Microcontroller, is a LUA-based firmware that has been created for the ESP8266 wifi chip, operating under an open-source license. It is packaged with the ESP8266 Development board, commonly referred to as the Node MCU Development board. Being open-source, the hardware design of Node MCU is accessible for customization, modification, and building. The Node MCU Development Kit/board is equipped with the ESP8266 wifi-enabled chip.

The ESP8266 is a low price Wi-Fi chip established by Espresso Systems with TCP/IP protocol. Node MCU Kit has Arduino like Analog (i.e. A0) and Digital (D0-D8) pins on its board. Table-1 provides a visual representation of the various wavelengths involved in the process.

Table-1: Illustrate different wavelengths.

Nutrient	Absorption wavelength(nm)	Colour	Standard Wavelength(nm)
Nitrogen(N)	445-485	Blue (Z)	450-495
Phosphorous(P)	505-565	Green (Y)	495-570
Potassium(K)	625-685	Red (X)	635-700

III. EXPERIMENTAL SETUP

The primary components of a sensor node are a microcontroller, Transceiver it is built in communication system, power source and more sensors. Microcontroller controls and monitors various sensors deployed and their input data. Transceiver is a built in communication system and it used to produce radio waves to transmit data obtained from sensors over wireless communications. The communication occurs between a gateway and sensor nodes, as well as between two sensor nodes. Power supply options include primary or secondary batteries. Wireless sensor nodes utilize sensors to gather data from their surroundings. These nodes, typically small electronic devices, operate on limited power sources of less than 0.5-2 ampere-hour and 1.2-3.7 volts. Sensors' continuous analog signals are digitized by analog-to-digital converters and forwarded to controllers for processing. The sensor nodes then transmit data carefully to the gateway for further communication. Subsequently, the gateway relays the data to either a server or the cloud. The server or cloud analyses the received data for appropriate applications. The whole network is based on the occurrence of multi routing algorithm which is also called as wireless ad hoc networking. As shown in the below figure-4.

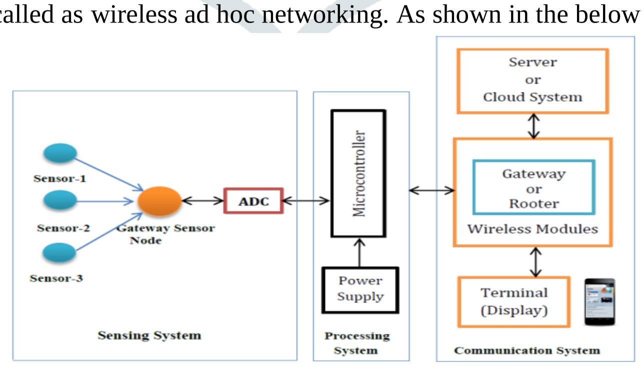

Figure-4: Typical Architecture of Sensor Node

Figure-5 depicts the schematic layout of the experimental setup used to measure soil macro nutrients. The AS73211 chip and LED were placed parallel to one another for the measurement. The sensor chip registers light once it has bounced off the reflector. To estimate the optical path length, the consequence of the incident light that the detector emits was examined. Based on the specification of the LED datasheet, the LED considerably collimated the incoming light in the region of 1 to 5 cm. The calculations were made by moving the LED and sensor chip from the closest to the furthest positions.

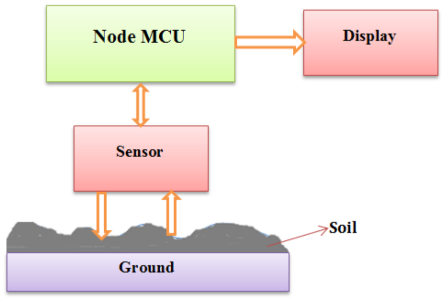

Figure-5: Schematic diagram for measuring nutrient in soil sample

(a)

(b)

Figure-6:(a) AS73211 Colour sensor Board **(b)** Photodiode array of XYZ true colour sensor

The figure-6(a) shows AS73211 Colour sensor board, the AS73211 is a low power, low noise integrated color sensor. Three channels convert light signals via photodiodes to a digital result and realize a continuous or triggered measurement. In front of the three photodiodes there are optical filter mounted for X-, Y- and Z-signals respectively.

An in-depth study utilizing the AS73211 chip assessed soil absorption properties. Two distinct soil samples were analysed under controlled conditions. The AS73211 chip, integrated into the experimental setup, accurately measured soil responses to LED light irradiation. Carefully selected LED wavelengths optimized the analysis. The resulting data was meticulously recorded and analysed to understand soil behaviour and characteristics.

Valuable insights into soil absorption properties were gained by analysing the reflected light after exposing the samples to LED light. The AS73211 chip, known for its precision, accurately measured light intensity and absorption levels. This data helped assess soil characteristics, nutrient content, and quality. Compiled into a table, the recorded data provided a clear overview for researchers and agronomists to compare absorption characteristics under different conditions, aiding informed decisions in agriculture and land management.

The AS73211 chip integrated with the experimental setup offered a dependable method for evaluating soil absorption. Precise measurements provided valuable visions into absorption properties, laying the groundwork for enhancing agricultural practices and improving soil health and crop productivity through optimized nutrient management strategies.

The AS73211 chip was utilized to regulate the soil test absorption using two soil samples, as shown in Figure.-3. The table contains a list of the example specifications. Under the irradiation of LED light, each unique soil specimen that had the ideal density was exposed to the reflector.

Table-2: Soil Characteristics of different samples.

Sample	Soil Characteristics
1	Dry and sandy
2	Grassy and damp

$$\begin{pmatrix} X_{sensor} \\ Y_{sensor} \\ Z_{sensor} \end{pmatrix} = K. \begin{pmatrix} adcX \\ adcY \\ adcZ \end{pmatrix} \rightarrow \quad (1)$$

X_{sensor}, Y_{sensor} and Z_{sensor} in (1) are corrected sensor values in ADS73211 chips that determines the colour. adcX, adcY and adcZ are different absorbed readings of the photodiodes of the sensor. The NODE MCU established a set of predefined limit values that were employed to compare the measured wavelengths for each nutrient to. These voltages levels—High, Mid, and Low—were used to categorise the degrees of nutrient shortage in the soil.

IV. RESULTS AND DISCUSSIONS

Figure.-7 depicts the sensor module's reactions to LED illumination for various lengths of the path. To find the ideal route length between 1.0 and 9.0 cm, all of these replies will be compared. Consequently as a result of the ADS73211 chip's sensitivity, as illustrated in Figure-7 the received light was greatly dispersed at both shorter and longer distances. Thus, a 5 cm optimal route length among the sensor chip and soil sample was selected founded on the analytical results.

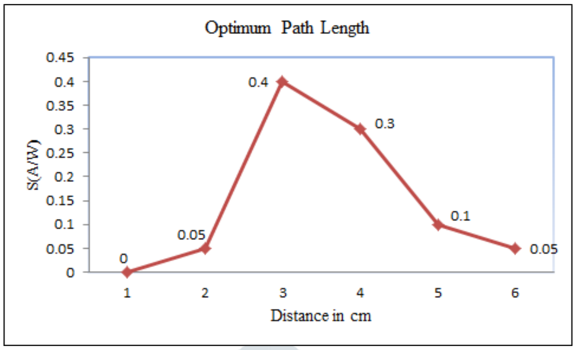

Figure-7: Determination of optimum path length

The threshold wavelengths of NPK content in the soil are illustrated as shown in Table-3. The obtained wavelengths of NPK presence in soil samples 1 and 2 are displayed as bar graphs in Fig.-8. According to the value above the 485 nm threshold wavelength, soil sample 2 has the maximum quantity of nitrogen.

Table-3: Bandwidth of wavelengths for NPK soil

Nutrient	Wavelengths in nm
Nitrogen	445-485
Phosphorous	505-565
Potassium	625-685

Nitrogen is present in sufficient amounts in Sample 1. Phosphorous is present in sufficient amounts in both samples 1 and 2. Whereas sample 2 has an acceptable quantity of potassium, sample 1 has low potassium content. As a result, it is simple to compute the NPK soil concentration in each sample when just a specific nutrient is applied to the sample.

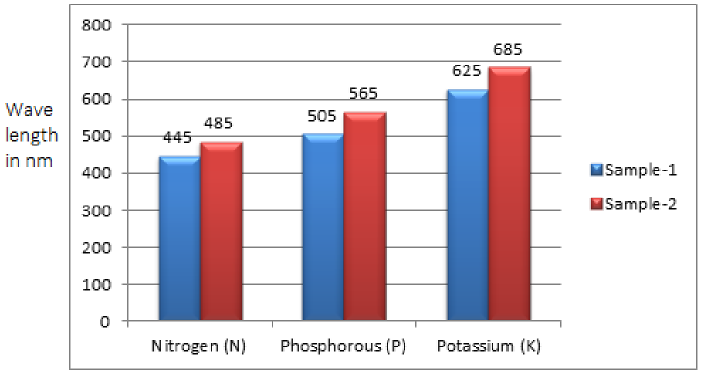

Figure-8: Absorbed Wavelengths of NPK in Soil Sample 1 and Sample 2

CONCLUSION

The findings of this investigation reveal that utilizing the AS73211 sensor in conjunction with Node MCU offers a viable method for accurately gauging the levels of nitrogen (N) and potassium (K) present in soil samples. This research holds promise in aiding farmers who encounter challenges in accurately assessing the nutrient makeup of their soil, all at a reduced expense compared to existing technologies. Furthermore, this innovation has the potential to mitigate the inadvertent over-application of soil fertilizers. Through the utilization of LED colour sensor technology to measure nutrient light absorption, it becomes feasible to compute and visually represent the nitrogen, phosphorus, and potassium (NPK) content of the soil, providing farmers with valuable insights into soil health and nutrient management practices.

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