IOT BASED SOIL NUTRIENTS MANAGEMENT SYSTEM FOR SMART AGRICULTURE

ABSTRACT- Soil fertility plays a crucial role in determining soil quality, as it indicates how effectively the soil can support plant growth in agriculture. By utilizing soil sensors and Arduino technology, it is possible to assess the nutrient content of the soil quickly. Nitrogen, phosphorus, and potassium (NPK) are key nutrients required for healthy crop production, and their levels must be measured to determine the additional nutrients needed to enhance soil fertility. NPK sensors can be employed to detect soil nutrient levels, providing valuable data to assess whether the soil is nutrient-rich or deficient. Leveraging technology in agriculture offers numerous benefits for farmers. Preparing the land for cultivating specific crops involves evaluating factors such as soil moisture, mineral content, nutrient levels, and even soil colour. Soil testing has become essential in modern farming to maximize crop yield and profitability within a shorter time frame. Moreover, it helps prevent the overuse of fertilizers, conserving resources, reducing costs, and protecting the environment. This innovative model, designed with IoT technology and sensors, enables the efficient analysis of soil nutrient levels. It is affordable, portable, user-friendly, and offers fast, precise measurements. Unlike traditional detection methods, this approach provides rapid and accurate insights, making it a practical solution for modern agricultural practices.

KEYWORDS: Internet of Things (IoT) , Nutrients, Sensors, Soil testing, soil nutrient assessment.

I. INTRODUCTION

Agriculture, as a primary source of food and raw materials, plays a critical role in supporting the global population. However, feeding the growing population remains a challenge due to the need for optimized crop production and resource management (Kaswan et al., 2020; Aziz, 2018). A significant issue lies in the lack of research and adoption of advanced technologies for nutrient management and soil monitoring (Raza et al., 2023; Hasan et al., 2018). This gap often leaves farmers making suboptimal decisions, resulting in inefficient resource use, reduced crop yields, and greater environmental impacts.

To address these challenges, there is a pressing need for innovative solutions that deliver real-time, accurate data on soil nutrient levels and provide tailored recommendations for different crops. Farmers have long faced difficulties in determining the ideal fertilizer composition to maximize crop productivity. Effective soil nutrient monitoring relies heavily on accurate soil mapping, which is often unavailable (Rehman et al., 2022; Musa et al., 2023). This lack of information about the appropriate quantity and type of fertilizer to apply across different regions and cropping systems poses a significant concern. A treatment map, which utilizes sensors to gather on-site data, offers an excellent method for monitoring crop fields and providing insights into crop development. This work focuses on developing an electrical conductivity (EC) sensor to facilitate soil nutrient monitoring, providing substantial savings in both time and cost (Yin et al., 2021; Hassan et al., 2021). By integrating such technologies, farmers can make informed decisions to enhance productivity and sustainability in agriculture. [1 – 3].

The growth of the agricultural sector is closely linked to the strengthening of a country's economy. However, many farmers continue to rely on traditional farming methods, which often lead to lower productivity and limited food production. [4]. However, yields significantly improved with the introduction of automation, where human labor was replaced by automated systems. This highlights the importance of leveraging modern science and technology to enhance productivity in the agricultural sector. For sustainable growth, these advancements must be widely adopted and effectively utilized. [5]. Numerous studies have explored the use of wireless sensor networks to collect data from various sensors and transmit it to a centralized server through wireless protocols. IoT-based automation aims to revolutionize farming practices by streamlining multiple tasks and improving efficiency. For instance, a high-level soil monitoring system can integrate sensors to measure parameters such as temperature, moisture levels, light intensity, humidity, and pH. These interconnected sensors provide real-time data, enabling farmers to make informed decisions about soil health and crop management with ease. [6]. The Internet of Things (IoT) leverages a unique framework to enhance traditional farming practices through connectivity, automation, and data analysis. Sensors, such as light-dependent devices and light-emitting diodes (LEDs), can detect nutrient levels in the soil. When deficiencies are identified, appropriate nutrients can be added to restore soil health. IoT technology enables real-time monitoring and decision-making, transforming conventional farming into a more efficient and data-driven process.

II. Literature survey

In [7], soil sampling is conducted to assess the availability of nutrients. A mathematical model is proposed to calculate the statistical averages of the nutrient levels present in the soil, providing a systematic approach to evaluating soil fertility. In [8], soil samples taken from a depth of one meter are analysed using IoT sensors to measure pH, moisture, and nutrient levels, including nitrogen (N), phosphorus (P), and potassium (K). The data collected by the sensors is transmitted to a web-based server using a GSM module integrated with Arduino technology. The sensed values are then compared with a standard dataset, and recommendations are generated based on the analysis. This information is promptly communicated to the farmer via SMS, enabling informed decision-making for improved soil and crop management. In [9], the ID3 decision tree algorithm is applied to soil nutrient management. Experimental results demonstrate that this algorithm can accurately determine the required amount of fertilizers for cultivation. Additionally, it effectively classifies soil into nutrient zones, enabling better resource allocation and targeted soil management practices. In [10], soil samples are collected using the ASD FieldSpec Pro FR device to analysed the relationship between nutrients and soil characteristics. An inversion model is employed to assess nitrogen levels and soil organic content. The experiments and results indicate that IoT sensors can remotely and accurately detect information about nitrogen and soil organic matter, providing valuable insights for soil management and agricultural practices.

Soil quality varies significantly across geographical regions, and the nutrients present in the soil may not always be suitable for all crops. As a result, crop cultivation is often location-dependent. In some cases, the soil may lack the essential nutrients required for optimal crop growth. To enhance productivity, farmers may need to apply fertilizers containing the necessary nutrients. The nutrient requirements for crops are influenced by several factors, including the geographical location, time of year, soil management practices, and climate. Effective nutrient management involves applying nitrogen (N), phosphorus (P), and potassium (K) in a manner that meets the specific needs of crops in each field. To optimize this process, proper guidelines and recommendations are essential, helping farmers determine the right quantity of fertilizers and the ideal timing for their application.

Calculating the amount of nutrients required for a crop involves several steps. First, the farmer must set a yield target. Then, the necessary nutrient levels to achieve that target must be identified. Additionally, the existing nutrient levels in the soil are crucial to understanding the nutrient deficit, which will guide the amount of supplemental fertilizer needed.

III. METHODOLOGY

Nutrient management is enhanced through the use of IoT and web applications. The proposed system utilizes various IoT devices to monitor and manage soil nutrients effectively. It is designed to be user-friendly, allowing farmers to operate it with ease if provided with proper guidance during the setup process. The system's architecture is depicted in Figure 1. Below are brief details about the devices used in this system. Brief details about the devices used are as follows:

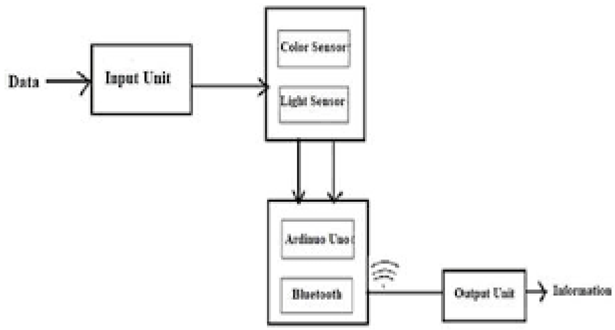

Fig. 1. Architecture diagram of Nutrient Management

A. Arduino

Arduino is a versatile microcontroller widely used in various IoT applications due to its simplicity and ease of use. It does not require an operating system to function, allowing it to boot quickly. The program can be loaded onto the memory multiple times, making it highly flexible for different tasks. Additionally, Arduino is cost-effective and compatible with a wide range of sensors, making it an ideal choice for many projects. Programs for the Arduino are written and uploaded using the Arduino Integrated Development Environment (IDE), which provides a straightforward interface for coding and debugging. Its affordability, ease of programming, and broad sensor support make Arduino an excellent platform for developing IoT-based solutions.

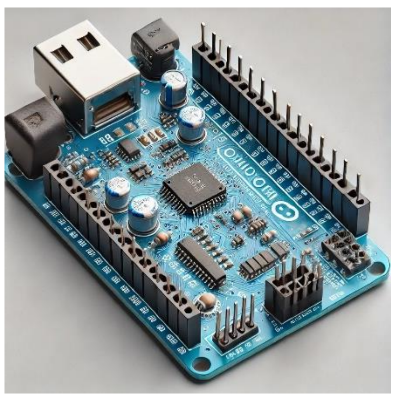

Fig 2 : **Arduino**

B. ESP8266 Node MCU

NodeMCU is a compact development board that comes with 128 KB of RAM and 4 MB of flash memory. It allows programs to be loaded and run without the need for an underlying operating system, making it efficient and quick for embedded applications. While it is smaller in scale compared to Arduino, in terms of memory, processing power, and the number of input/output pins, it is still highly effective for many IoT projects.

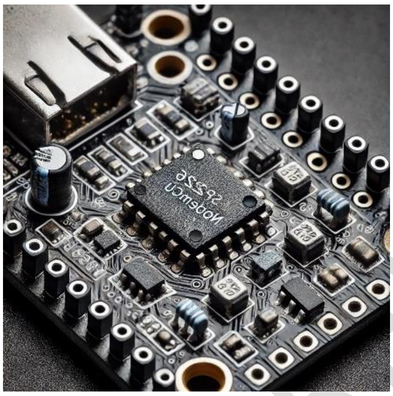

Fig 3 : **ESP8266 Node MCU**

One of the key features of NodeMCU is its built-in Wi-Fi module, which makes it ideal for Wi-Fi-based IoT applications. This capability enables it to connect to the internet and communicate with other devices, making it a popular choice for creating connected solutions in smart farming, home automation, and other IoT-driven fields.

C. TCS230 colour sensor

The TCS230 is a colour sensor that uses an 8x8 array of photodiodes to sense light. The photodiodes detect the light in different wavelengths, and this data is converted into a waveform. The Arduino processes this waveform to determine the colour of the light. The TCS230 sensor can detect a wide range of colours by measuring the intensity of red, green, and blue light.

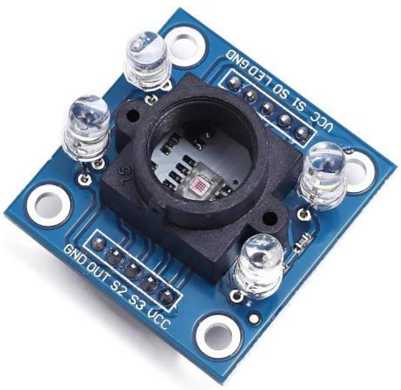

Fig 4 : TCS230 colour sensor

In addition to the TCS230 sensor, an LED display device is used to show the detected colour values in RGB format. The RGB values (Red, Green, Blue) represent the intensity of each colour, and the display provides a visual representation of the colour detected by the sensor. This setup is useful for applications where colour identification is essential, such as in environmental monitoring or quality control in agriculture.

D. Transformer (0-12V/1A)

A transformer operates on the principle of electromagnetic induction to transfer electrical energy between two or more circuits. When a conductor is exposed to a changing magnetic field, electromagnetic induction occurs, generating an electromotive force (EMF) or voltage. In electric power systems, transformers are crucial devices used to either increase or decrease alternating voltages. They work by converting high-voltage electricity to low-voltage electricity, or vice versa, depending on the needs of the power distribution system. This ability to adjust voltage levels makes transformers essential for efficient transmission and distribution of electrical energy. [11].

Fig 5 : Transformer (0-12V/1A)

E. IC Voltage Regulator

The primary purpose of an Integrated Circuit (IC) regulator in an electrical system is to maintain a stable current or voltage that the power supply provides to the circuit. The IC regulator ensures that the voltage or current remains constant despite variations in the input or load conditions. When using a regulator, a capacitor (often referred to as a condenser) is typically connected to the regulator's two terminals, which are the input and output. The capacitor helps to smooth out fluctuations, reduce noise, and improve the overall stability of the regulated voltage or current. This setup is commonly used in power supply circuits to ensure reliable operation of sensitive electronic devices. [12]

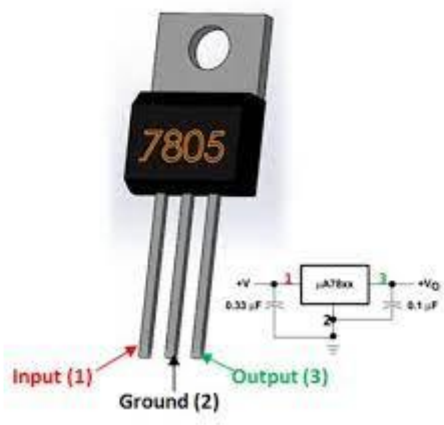

Fig 6 : IC Voltage Regulator

F. NPK Sensor

The soil's nutrient levels are measured using an NPK sensor, which is designed to detect the concentrations of nitrogen (N), phosphorus (P), and potassium (K) in the soil. This sensor can display all three values on a single device, providing a comprehensive analysis of the soil's nutrient content. One of its key advantages is its high accuracy at a relatively low cost. Additionally, the response time of the NPK sensor is impressively quick, typically taking less than ten seconds to provide results. The sensor is also highly interchangeable, making it a versatile tool for various agricultural applications. The performance of this NPK sensor remains consistent, offering reliable and precise measurements for soil nutrient management.

Fig 7 : NPK sensor

CONCLUSION

The process of checking nutrient levels in the soil can be a time-consuming and challenging task for farmers. However, by using IoT, this process can be simplified and made more efficient. In the proposed system, the data is displayed in graphical format, making it easier for farmers to visualize and understand soil conditions. Furthermore, the platform can be enhanced by incorporating information about various crops that are suitable for different soil types with varying nutrient availability. This would provide farmers with tailored recommendations for crop selection based on soil conditions.

In the future, the system could offer complete assistance in soil monitoring and fertilization, automating the process so farmers can more easily achieve their targeted yield. By identifying nutrient deficiencies in the soil, the system would suggest the necessary nutrients to be added for optimal plant growth, ensuring that farmers can make informed decisions and improve crop productivity.

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