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Assessing Soil Nutrients Through IoT for Enhanced Farming and Agricultural Intelligence

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Abstract

Soil fertility is of paramount importance in agriculture, as it directly impacts the capacity of plants to flourish and develop. Recent advancements in technology, such as soil sensors and Arduino, offer effective means to assess soil nutrients. Key nutrients for agriculture, including nitrogen, phosphorus, and potassium (NPK), are vital for plant development and are considered primary contributors to soil fertility. Monitoring these nutrients enables farmers to gauge the specific needs of the soil and determine the appropriate amount to enhance fertility. By utilizing proposed NPK sensors, this method facilitates the rapid and accurate measurement of soil fertility. While various methods exist for assessing soil nutrients, the appeal of NPK sensors lies in their cost-effectiveness and practicality. Nitrogen, potassium, and phosphorus are very well-known and vital minerals for plant growth. Correct ratios of these minerals boost plant growth but due to less scientific knowledge, farmers use these minerals mindlessly which results in wastage of these minerals and this also results in pollution. Internet of things (IoT) can give precise information on how much nutrients are really necessary. This paper explores the analysis and comparison of soil nutrient levels through the application of the kernel density estimation algorithm and machine learning approaches, providing valuable insights into soil health for informed agricultural practices.

Keywords: Soil nutrients, nitrogen, phosphorus, and potassium (NPK) sensor, machine learning, kernel density, sensor

INTRODUCTION

Farming is essential for the growth of agricultural land. Agriculture employs roughly 70% of India's population and accounts for being one of the national productions [1]. Agricultural issues have always hampered the country's development. Smart farming, which entails modernizing conventional farming methods, is the only solution to this challenge. As a result, the goal of this project is to make agriculture smarter through the use of automation and internet of things (IoT) technology [2]. Despite all these advantages of using IoT in agriculture, many farmers still use old agricultural practices which result in less agricultural produce. The advancement of IoT in recent years has significantly contributed to the agricultural sector. With the help of IoT, we can solve modern-day agriculture problems, and we can optimize crop production. IoT can even be used for livestock monitoring, smart greenhouses, predictive analysis of agricultural produce, smart irrigation and weed management. Precision farming allows farmers to make data-driven decisions tailored to the specific needs of their crops. Precision farming utilizes sensors (such as nitrogen, phosphorus, and potassium [NPK] sensors) and actuators to gather extensive data concerning environmental conditions. This data allows farmers to monitor their fields and identify abnormalities, thereby optimizing yield and minimizing resource wastage. In this paper, we will be discussing the application of kernel density algorithm (KDA) with IoT to enhance decision making in agriculture.

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METHODOLOGY

The given system uses software as well as hardware components to display nutrient concentration in the soil mainly nitrogen, phosphorous, and potassium. In real time, it helps the farmers to increase their crop production. Hardware devices used are Arduino Uno, transformer (0-12V/1A), GSM voice modem, 16 × 2 LCD, IC voltage regulator, and NPK sensor.

The Arduino Uno microcontroller board utilizes the ATmega328P microprocessor. Arduino, an open project, focuses on developing sensor tools designed for creating digital devices and connecting tangible objects with sensing and controlling capabilities. It comes equipped with all necessary components to enable the microcontroller's operation, allowing users to connect it to a computer via USB or to power it using an AC-to-DC converter for charging purposes.

Apart from this, other sensors used are soil temperature sensor, pH sensor, and soil humidity sensor to increase agricultural produce. Figure 1 shows the connection of IoT sensors.

Data Collection and Internet of Things

The initial and crucial stage of implementing IoT in agriculture involves the installation of sensors. In this study, NPK sensor, soil temperature sensor, pH sensor, and soil humidity sensor are used.

NPK Sensor

A sensor known as an NPK sensor is employed to identify and quantitatively assess the levels of nitrogen (N), phosphorus (P), and potassium (K) in soil. These three nutrients are fundamental for plant development, and their concentrations in the soil can influence both crop yield and quality [3]. NPK sensors are commonly used in agriculture to help farmers to optimize fertilizer application and manage soil nutrient levels more effectively. Figure 2 shows an NPK sensor.

Arduino Sensor

Arduino sensor detects environmental changes. It receives input from the user and transmits it to an Arduino microcontroller. The Arduino microcontroller can then process this information and perform various actions based on the sensor readings. Figure 3 shows an Arduino sensor.

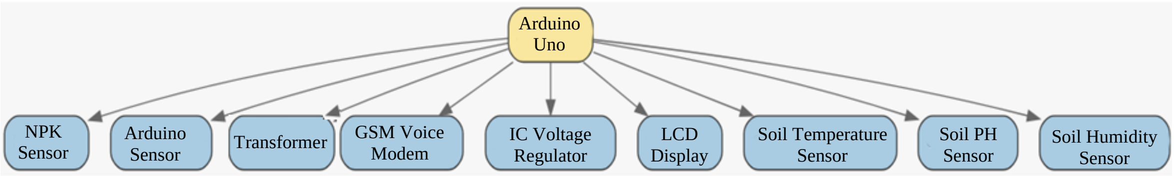

Figure 1. Connection of internet of things (IoT_ sensors).

Figure 2. Nitrogen, phosphorus, and potassium (NPK) sensor.

Figure 3. Arduino sensor.

Figure 4. Arduino Uno.

Arduino Uno

The Arduino Uno is a microcontroller board that utilizes the ATmega328P chip. It represents one of the most prevalent boards within the Arduino lineup and is extensively employed for prototyping and do-it-yourself (DIY) projects. The Arduino Uno board (Figure 4) has input/output pins that can be used to connect and interface with various sensors, making it a popular choice for projects that require sensor integration.

Transformer (0-12V/1A)

A transformer (Figure 5) utilizes electromagnetic induction to transfer the electrical energy between two or more circuits. When a conductor is uncovered to vary the magnetic fields, electromagnetic induction produces an electromotive force. In electric power applications, transformers are used to increase or decrease the alternating voltages [4].

GSM Voice Modem

GSM means a global system for mobile communications. The operational voltage range of the GSM SIM800L (as shown in Figure 6) is from 3.4 to 4.4 V [5]. GSM technology is utilized for transmitting alert messages and making calls to pre-registered contact numbers. The functionality of the GSM modem relies on AT (attention) commands, which are communicated to the GSM modem via a microcontroller. SIM800C is dual-band. GSM/GPRS is an alternative in an SMT module with a manufacturing interface. The SIM800CS is a quadrilateral band. It operates on frequency range of 850 MHz. It provides call, SMS, network, and facsimile efficiency with a slight footprint of longer battery life [6].

IC Voltage Regulator

A voltage regulator (Figure 7) is used because it gives constant output regardless of the input. The condenser is usually interconnected to the IC regulator's two terminals like input and output when using a regulator [7].

Liquid Crystal Display

An LCD 16 × 2 display (Figure 8) can be used in an IoT-based smart agriculture monitoring system to display information such as temperature, humidity, and soil moisture levels. This allows farmers to easily monitor the conditions in their fields without checking their devices. The 16 × 2 format of the LCD allows for the display of two rows of 16 characters, providing ample space for displaying multiple pieces of information at once. Additionally, LCDs consume less power than other types of displays, making them well-suited for use in remote, battery-powered monitoring systems [8].

Figure 5. Transformer (0-12V/1A).

Figure 6. GSM voice modem.

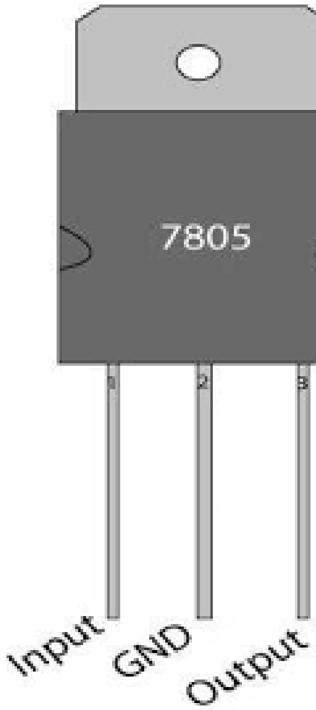

Figure 7. IC voltage regulator.

Figure 8. Liquid crystal display (LCD).

Soil Temperature Sensor

The soil temperature sensor (Figure 9) is used to calculate the temperature in the soil. Soil temperature sensor follows the principle of thermoelectric effect. It has a thermistor whose value changes with temperature which as a result changes the current through which temperature in soil can be calculated.

Soil pH Sensor

Soil pH meters (depicted in Figure 10) are instruments employed for assessing the pH level of soil. It says whether the soil is acidic or basic. They work on the principle of electrochemical reactions. The sensor has two nodes: one node is used for sensing while the other node is used for reference. The potential difference between these nodes is converted into electrical signal for ease of measurement.

Soil Humidity Sensor

The soil moisture sensor (shown in Figure 11) utilizes capacitance to gauge the dielectric permittivity of the nearby medium. In soil, the dielectric permittivity is directly related to the water content. By generating a voltage proportional to the dielectric permittivity, the sensor can accurately determine the water content of the soil.

Figure 9. Soil temperature sensor.

Figure 10. Soil pH sensor.

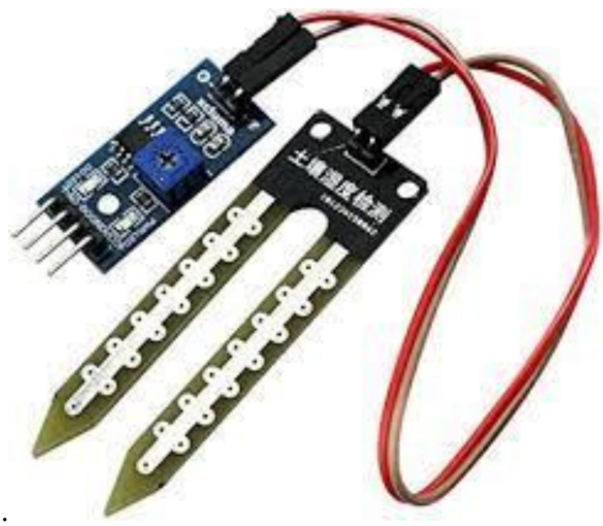

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Figure 11. Soil humidity sensor.

Data Preprocessing and Integration

Before applying the kernel density algorithm, we must pre-process the data for consistency. This procedure also includes data cleansing. By implementing this we can ensure uniform coverage of the field.

Kernal Density Algorithm

With the pre-processed data we proceed to implement a kernel density algorithm to analyze the soil condition. Utilizing the selected kernel function and bandwidth parameters, we calculated the kernel density estimate for each point in the field, representing the probability density of encountering

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specific soil health conditions at that location [9, 10]. Given below is the general formula for kernel density algorithm.

$$F_h(x) = \sum_{i=1}^{n} k_h(x - x_i)$$

RESULTS AND DISCUSSION

From the result of the kernel density algorithm, we can get a density map of hotspots of soil fertility. We can give precise farming techniques. To check the accuracy and credibility of our model we can compare our results with lab-generated results. Figure 12 shows nitrogen versus density in the soil after applying kernel density algorithm.

Figure 13 shows phosphorus versus density in the soil after applying the kernel density algorithm. Figure 14 displays the comparison results of potassium and phosphorus.

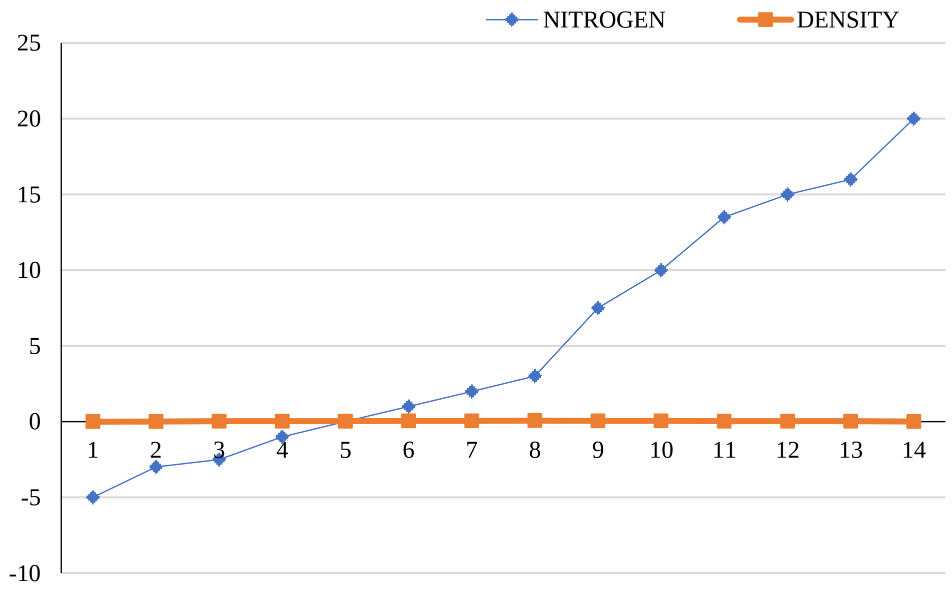

Figure 12. Nitrogen versus density.

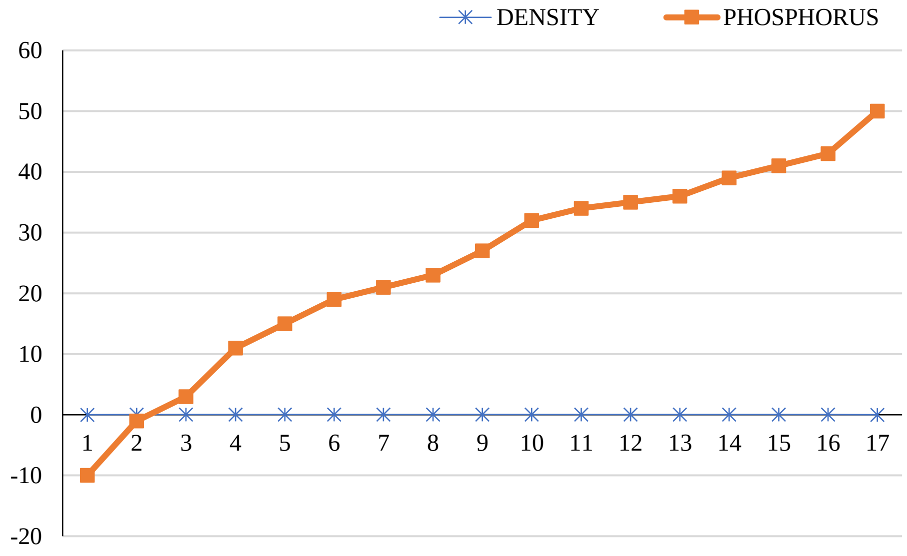

Figure 13. Phosphorus versus density.

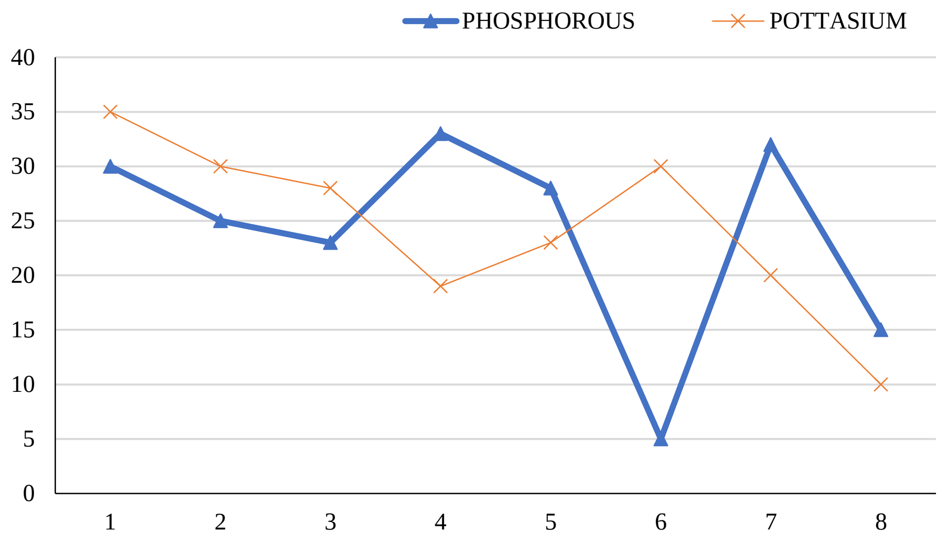

Figure 14. Potassium and phosphorus.

CONCLUSION

This study applies the precision of IoT in agriculture by using kernel density algorithm. By harnessing the power of IoT, we can empower the lives of farmers, and improve crop yield in a challenging climate change. Incorporating IoT technologies in agriculture shows great potential for transforming the industry and tackling significant challenges encountered by farmers globally. Through the deployment of smart sensors, data analytics, and automation systems, IoT enables farmers to monitor and manage various aspects of their operations with unprecedented precision and efficiency. From soil and crop monitoring to livestock management and irrigation control, IoT solutions offer real-time insights, optimize resource utilization, and enhance productivity while minimizing environmental impact.

Moreover, IoT in agriculture facilitates the transition towards more sustainable and resilient farming practices by promoting data-driven decision-making, reducing reliance on conventional inputs, and mitigating risks associated with climate change and market fluctuations. By harnessing the power of connectivity and data analytics, farmers can optimize resource allocation, improve crop yields, and ensure food security for a growing global population.

However, realizing the full potential of IoT in agriculture requires addressing several challenges, including the need for affordable and accessible technologies, data privacy and security concerns, as well as ensuring equitable access and benefits for smallholder farmers and rural communities. To surmount these obstacles and encourage the extensive uptake of IoT solutions in agriculture, cooperation among governments, industry stakeholders, and research institutions is imperative.

As we look towards the future, continued innovation and investment in IoT technologies, coupled with policies that promote digital infrastructure development and capacity building, will be key to unlocking the transformative potential of smart agriculture. By embracing IoT, farmers can not only improve their livelihoods and resilience but also contribute to building a more sustainable and food-secure future for generations to come.

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