

A Smart Soil Nutrient Management System with IoT Integration

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Abstract— India's economy is based mostly on agriculture, and providing farmers with cutting-edge information is essential to enable them to make well-informed decisions on a range of farming tasks, including preparing the soil, planting seeds, and distributing fertilizer. The goal of the proposed project is to improve agricultural operations by determining the NPK (nitrogen, phosphorus, and potassium) content of the soil. An LCD panel is utilized by the device to show these nutritional levels. The innovation lies in the integration of dispensing of fertilizers into the soil based on the specific NPK requirements through water Pump, thereby diminishing the necessity for substantial human labor and effort.

Index Terms— Internet of Things (IoT), NPK, Soil Management, modernized approach, Soil nutrient assessment.

I. INTRODUCTION

India's economy is based mostly on agriculture, although most of the techniques used are still age-old. There is an urgent need to switch to more sophisticated agricultural techniques to significantly improve performance and achieve larger yields. The methods that farmers now prefer to use are frequently labor-intensive, time-consuming, and implemented in a way that negatively affects crop quality, soil quality, and total output. It is essential to replace these antiquated methods with more effective and space-saving ones as agricultural areas gradually decrease.

While modern techniques have made their way into plowing, seeding, and excavating, fertilizer delivery is still mostly done by hand using antiquated, haphazard methods. This disorganized distribution has a negative impact on soil quality, which in turn has an impact on plant development and crop quality. To tackle these issues and progress sustainable agriculture, it is imperative that sophisticated technologies that can enhance fertilization procedures are widely used. By doing this, farmers may protect agricultural land and increase yields, which will guarantee the critical agricultural industry in India continues to grow. Three essential elements are critical to plant growth: nitrogen (N), phosphorus (P), and potassium (K). As nitrogen is essential for promoting the growth of leaves and other plants, it is regarded as the most important component of soil. In a similar vein, phosphorus is a crucial element for the growth of the plant's roots and general structure. The third important element, potassium, affects critical stages such as blooming and fruiting by helping to regulate water and nutrients inside plant cells. It is critical to maintain the proper ratio of these necessary elements. When the right balance is struck, the soil's quality is guaranteed, and crop growth is generally improved. Every component has a distinct role in fostering the growth and health of plants. Achieving the ideal balance of potassium, phosphorus, and nitrogen in the soil

promotes plant growth and results in healthier crops, higher yields, and sustainable farming methods.

II. PROBLEM STATEMENT

The difficulties of Indian farming, such as labor intensive methods, a strong dependence on human labor, and a lack of information, highlight the necessity for sophisticated farming methods. India has made strides in automation, but the agriculture industry continues to use antiquated practices. Given that India's economy is heavily dependent on agriculture and that the country's population is growing, there is an urgent need for more food supplies. For the best crop development, the essential elements of soil health nitrogen, phosphorus, and potassium must be balanced. Innovative fertilizer delivery networks are crucial to addressing these issues and guaranteeing sustainable and effective farming techniques that meet India's changing agricultural demands. The current methods lack real-time monitoring and control of environmental factors like temperature and humidity, crucial for optimizing crop growth.

III. LITERATURE

Ilknur ŞEN [1]. In this paper authors says that the symbiotic link between soil, nutrients, and plant development is explored in the literature review. It draws attention to how important it is to apply fertilizer correctly to improve food output and quality. Inadequate or excessive fertilizer application can result in problems such as poor crop quality, sickly plants, elevated expenses, and contamination of the environment. The report identifies potassium, phosphorus, and nitrogen as the three essential elements and stresses the value of soil sampling and laboratory analysis in determining soil fertility. There is an urgent need to replace traditional farming methods with advanced techniques to enhance performance and achieve higher yields. The current practices, often preferred by farmers, are time-consuming, demand a significant amount of manpower, and are executed in inappropriate ways.

Vedpathak et al. [2]. The main goal of the proposed system is to measure the levels of nitrogen (N), phosphorus (P), and potassium (K) in the soil and accordingly add the necessary elements for optimal plant growth. The system determines the N, P, and K amounts by comparing a solution with a color chart, indicating the levels as high, medium, low, or none. The soil contains both macronutrients (needed in large quantities) and micronutrients (needed in smaller quantities), with nitrogen, phosphorus, and potassium being essential in larger amounts. The automated system, which includes NPK measurement, automatic seeding, and fertilizer dispensing by a robot, checks and dispenses the required amount of the three main fertilizers. While there is an existing NPK kit for soil testing, the manual dispensing of fertilizers poses a challenge, which this system aims to address. By doing so, it saves labor, time, and optimizes fertilizer use, providing better results. Additionally, the system can be utilized for seeding, offering a comprehensive solution for efficient and automated agricultural practices.

Rahaman et al. [3]. In this paper author talks about how soil factors like type, fertilizers, pH, temperature, humidity, and moisture influence plant growth. To improve traditional farming, the project suggests using automation, image processing, and the Internet of Things (IoT). The goal is to make farming smarter. The system introduced in the paper gives farmers info on soil factors through a mobile app. It can detect the NPK ratio using image processing with an SVM algorithm. It also automates irrigation based on soil moisture and monitors environmental factors like temperature, humidity, and ph. With these details, farmers can decide the best crops to grow and take care of plant growth for better yields. The use of modern tech in agriculture offers a practical way to improve efficiency and productivity.

Guruprasad et al. [4]. Author says that the use of IoT and LoRa technologies in smart farming aims to improve agriculture by boosting yield and reducing human effort. The goal is to maintain high accuracy while minimizing electricity usage. A method has been developed to control water flow into fields based on soil moisture levels, crucial for crop health. Temperature and humidity sensors help guide the farmer's actions. The data, detected through LoRa technology, which can cover significant distances, up to 20 km in rural areas and 8 km in urban settings, is transferred efficiently to enable effective decision-making in farming practices.

Zermas et al. [5]. In this paper the work introduces a smart automation framework designed to address shortcomings in existing methods for detecting and characterizing plant deficiencies in corn cultivation. Utilizing modern computer vision techniques and drone collected images with low-cost RGB sensors, the framework focuses on nitrogen (N) deficiencies in maize fields. The methodology employs a straightforward recommendation scheme to identify plants with N deficiency, facilitating the creation of a training dataset for a deep neural network. Results from experimental fields demonstrate its effectiveness, achieving a mean average precision of 82.3% in detecting N-deficient leaves. This approach holds promise for significant economic benefits by improving nutrient

deficiency detection in widespread crops like corn, contributing to more efficient and sustainable farming practices.

Masrie et al. [6]. In this paper author focuses on creating a detection system for key soil nutrients like Nitrogen, Phosphorus, and Potassium (NPK) are essential for plant growth. The system incorporates an optical sensor with two components: a transmission system and a detection system. The transmission system employs an Arduino UNO powered LED to direct light onto soil containing nutrients in a transparent container. The detection system utilizes two photodiodes with a signal conditioner and an amplification circuit to measure the intensity of soil nutrients based on the remaining light and amplify the signal in terms of potential differences. Results indicate absorption response voltages of 32.0 V for Nitrogen (N), 4.6 V for Phosphorus (P), and 19.8 V for Potassium (K). The system detects nutrient presence and intensity by assessing the rate of light absorption, where higher absorption indicates higher nutrient intensity and vice versa.

JP et al. [7]. In this paper the exponential growth of the world population, the imperative for adopting modern agricultural practices to ensure food safety is evident. This paper delves into the utilization of intelligent sensor networks to gather crucial data about soil conditions, focusing on moisture levels and nutrient deficiencies. Leveraging this data, automated irrigation systems can be implemented, and farmers can receive timely alerts about nutrient deficiencies. The acquired soil data is then transmitted to the cloud, where robust processing capabilities come into play, offering an essential solution for storing the substantial amount of information generated by the wireless sensor network. Farmers can conveniently access this data through a Smartphone application, providing them with valuable insights. The paper introduces and assesses the practical deployment of a wireless sensor network based on an Internet of Things (IoT) platform, highlighting the significance of integrating modern technologies into agriculture for improved efficiency and productivity.

S.V et al. [8]. The authors claimed in this research that because of the problems posed by agriculture and climatic circumstances, it is essential to use agricultural resources efficiently. Careful supervision is required for factors including excessive fertilizer usage, depletion of land reservoirs, and inadequate rainfall. With the help of this technology, a wireless sensor network that can track temperature, humidity, soil pH, and NPK levels among other agricultural indicators is introduced. By giving information on the acidity of the soil, pH sensors allow for the targeted application of fertilizer while avoiding overfertilization. Humidity sensors also help with weather monitoring, which enables farmers to plan irrigation strategies and predict rainfall.

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Jerlin I et al. [9]. In paper gives the information that growth and yield of crops are directly influenced by soil nutrients and seasonal variations. Imbalances in soil nutrient levels can lead to plant diseases, and excessive fertilizer application may have detrimental effects on crop development. Moreover, soil nutrient compositions change with shifting seasons, transitioning from wet to dry conditions. This study aims to develop a fuzzy logic-based program to intelligently recommend an appropriate amount of fertilizer for the soil. Input parameters include season, nitrogen, phosphorus, and potassium levels, which are fed into the fuzzy logic system. The researchers propose four types of fertilizers—Complete, Urea, Solo Phos, and Muriate of Potash—for use in this study. The combination and quantity of these fertilizers are determined based on input parameters and fuzzy rules. This fuzzy logic system provides soil fertilizer recommendations tailored for rice cultivation in inbred light soil.

Madhumathi et al. [10]. This paper give the information about the challenges of time-consuming and manual methods for measuring soil nutrients, a proposed system adopts precision agriculture through Wireless Sensor Networks. This innovative approach enables remote monitoring of soil fertility, soil moisture, pH, and temperature, providing real-time data transmitted to the cloud. The corresponding values are then accessible through a mobile application. The Internet of Things (IoT)-based software system intelligently recommends the quantity of water and fertilizer required, contributing to improved soil quality, and ensuring optimal crop growth. This advancement offers a practical solution for farmers who may hesitate to perform traditional laboratory soil testing, ultimately promoting sustainable and efficient agricultural practices.

Joseph et al. [11]. The paper delves into diverse techniques for the assessment of soil micronutrients, emphasizing their effectiveness. The employed strategy for determining the total phosphorous content in the soil yields promising results, exhibiting an R-squared (r^2) value ranging approximately from 0.63 to 0.68. Regarding potassium assessment, the study explores reflectance spectroscopy and potassium ion-selective electrode methods, revealing an r^2 value of approximately 0.7. These findings emphasize the viability of these techniques for precise

soil nutrient evaluation, offering valuable insights for agricultural practices and ensuring optimal nutrient management.

Kim et al. [12]. In this article, the three macronutrients— nitrogen, phosphorus, and potassium—in soil are evaluated using two different detection techniques. It turns out that a mobile vehicle-based sensing system is a quick and effective way to characterize soil nutrient variability in the field. Nitrate ion-selective membranes and electrodes show the best reactivity to nitrate presence in the soil when using the electrochemical approach. This technique shows promise for a rapid and precise assessment of the macronutrient contents in the soil, offering insightful information for effective nutrient management and farming techniques.

Raj et al. [13]. In this paper the system includes a mobile app, an IoT platform, and sensors for detecting soil nutrients, providing farmers with real-time information through a user friendly mobile application. The NPK sensor determines nitrogen, phosphorus, and potassium levels, while the pH sensor gauges soil acidity or alkalinity, and the CO₂ sensor measures carbon dioxide content. These sensors, combined with an Arduino microcontroller and a wireless communication module, make up the system. The collected data is sent to the IoT platform for analysis, enabling the platform to offer crop management suggestions based on the soil's nutrient levels. The study confirms the precision and reliability of the IoT-based soil nutrient monitoring device, offering an affordable and easily integrable solution for farmers to enhance their crop management practices.

Singh et al. [14]. In this paper the robot's main goal is to determine the soil's levels of nitrogen (N), phosphorous (P), and potassium (K) and add the appropriate components based on those findings. By comparing the solution to a color chart, the amounts of N, P, and K in the soil sample are identified and classified as high, medium, low, or none. Differentiating between macronutrients, which are needed in greater quantities, and micronutrients, which are needed in lesser amounts, the approach emphasizes the importance of nitrogen, phosphorus, and potassium in soil. To overcome the drawback of manual fertilizer dispensing in the current system, the "NPK measurement in soil and automatic soil fertilizer dispensing robot" attempts to assess and distribute the lacking nutrients automatically. The suggested solution is made to reduce labor costs and accomplish.

Patokar et al. [15]. This review study emphasizes the relevance of monitoring pH levels, water content, and macro and micronutrient levels to anticipate plant life. Phosphorous, potassium, and nitrogen are the three main nutrients that the suggested automated system measures using chemical reactions and sensors to overcome the difficulties involved with applying fertilizer by hand. The exact amount of fertilizer is then automatically dispensed by the system, providing a proactive way to promote plant development and optimize productivity. This method offers a clear and thorough plan for maximizing farming techniques while reducing the dangers related to both excessive and insufficient fertilizer application in soil.

Pyngkodi et al. [16]. This review paper underscores the pivotal role of soil fertility in determining soil quality and its implications for supporting plant growth in agriculture. The integration of soil sensors and Arduino technology emerges as a rapid and effective approach for assessing soil nutrient content, with a particular focus on the essential components—nitrogen, phosphorus, and potassium. NPK sensors are identified as instrumental in gauging soil fertility, offering insights into nutrient deficiencies or excess that are crucial for informed agricultural practices. The paper critically examines various methods, including sensing elements and mass spectrograms, for obtaining soil nutrient concentration data. Notably, the limitations of the conventional spectral analysis method, marked by an accuracy range of 60-70%, are highlighted. To address these challenges, the review advocates for the application of soil NPK sensors, emphasizing their affordability, speed, simplicity, portability, and enhanced accuracy in detecting nitrogen, phosphorus, and potassium. The paper delves into an in-depth analysis and comparison of different soil nutrient assessment methodologies, incorporating the kernel density estimation algorithm and machine learning.

IV. WORKING PRINCIPLE

Our project involves creating an advanced agricultural system using IoT technology to detect and monitor essential plant nutrients, specifically Nitrogen (N), Phosphorus (P), and Potassium (K). The system employs an NPK soil sensor to identify any deficiencies in these nutrients within the soil. Once detected, the system transmits this data to an Arduino microcontroller. The Arduino, programmed with standard nutrient data, compares the real-time values with the predefined benchmarks. If a nutrient deficiency is confirmed, the Arduino activates a solenoid valve system. The solenoid valve, corresponding to the deficient nutrient (such as potassium, nitrogen, or phosphorus), opens, allowing the dispensing of the required nutrient from the respective tank. The duration of the solenoid valve opening is controlled to dispense the appropriate quantity of the nutrient based on the deficiency level in the soil.

Additionally, the system incorporates a soil moisture sensor to gauge soil hydration levels. The data from this sensor is relayed to the Arduino, which, in turn, activates the pump for irrigation based on the moisture requirements of the soil. Furthermore, temperature and humidity sensors are implemented to monitor environmental conditions. The Arduino uses this data to regulate the temperature and humidity levels within the system, creating an optimal environment for crop growth. This automated process ensures precise and timely nutrient supplementation, optimizing soil health for enhanced plant growth and agricultural productivity.

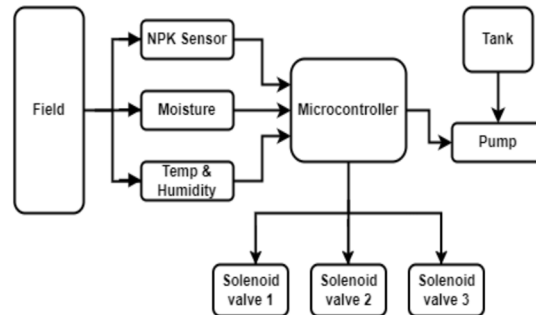


Figure 3. Block Diagram

V. CONCLUSIONS

Agricultural development practices over a while have been perceived to exploit natural resources faster than they could be renewed. Exponential growth in the human population has resulted in demand for food and shelter, which the “natural” carrying capacity of the land is under pressure to provide. Natural imbalance is visible in pollution, soil degradation, wildlife population decline, and human created alterations of flora and fauna. It is reasonable to assume that human population growth will continue and place greater demands on the Agri-ecosystem. Thus, technology has and will continue to play a major role in agriculture and sustainable development going forward. Technology has a major role in farming and agriculture practices; and with the advent of digital technology, the scope has widened. Innovation in agriculture is leading an evolution in agricultural practices, thereby reducing losses, and increasing efficiency. This is positively impacting farmers. The use of digital and analytic tools is driving continuous improvement in agriculture, and the trend is here to stay, resulting in improving crop yields.

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