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Intelligent Agriculture: Using IoT to Measure Soil Parameters to Improve Crop Selection and Yield Optimization

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Abstract:
In India, agribusiness is the foundation of the country's economy. Unfortunately, because of soil erosion and nutrient depletion, farmers frequently experience reduced crop yields while using traditional farming techniques. In this regard, pH is one of the most commonly measured parameters used to monitor soil fertility and the loss of nutrients including nitrogen (N), phosphorus (P), and potassium (K), which are crucial for plant growth, can also cause a drop in soil fertility. To overcome these challenges, there is a need for smart farming techniques that leverage the power of IoT devices. Therefore in this study, we suggest an unique method for detecting and measuring the proportion of important soil nutrients, such as nitrogen, phosphorus, and potassium, using an electrochemical sensor.

Keywords: Nitrogen (N), Phosphorus (P), Potassium (K), pH, moisture, IoT, Farming, Soil, electrochemical sensors and Nutrients, Crop, Prediction.

I. Introduction

Human existence is completely dependent on agriculture, and IoT technology is proven to be an invaluable foundation for precision farming. Food production is becoming more and more necessary as the world's population rises, and IoT applications in agriculture are rising quickly. Technology is essential for implementing sustainable farming methods while reducing negative environmental effects and financial losses, in addition to nutrients. The size of the worldwide smart agriculture market is anticipated to quadruple by 2025, from little over $5 billion in 2016 to $15.3 billion [1], according to current market research.

Crop production is primarily influenced by soil characteristics, and crop development is greatly reliant on the availability of nutrients in the soil, especially nitrogen (N), potassium (K), and phosphorus (P) [1]. Plants take nutrients and water through their roots, but the fertility of the soil decreases with each harvest. Farmers must assess the fertility of the soil and modify fertiliser and crop selection in order to maintain or improve crop fertility levels. For farmers to produce crops successfully and sustainably, soil testing and monitoring are therefore essential [1] [2] [3]. A farmer can use this useful tool to assess the soil fertility for more productive and cost-effective crop growth.

Soil samples will be taken from various crops in order to ensure effective monitoring and evaluation of soil quality. A PH sensor will be used to evaluate the hydrogen ion activity and find out if the soil is acidic or alkaline [4]. The PH sensor will be coupled with an Arduino microcontroller, which will track and store the data, to achieve this. Then, a Wi-Fi module will be used to save this data in a database. The data will be divided into groups according to the amount of nutrients contained in the soil. Farmers will have access to data on crop lists, soil values, and more through the use of a mobile application [5] [6].

2. Literature Review

As indicated in Table 1, numerous researchers have investigated various methods and techniques for soil testing and monitoring utilising IoT to address the issue of crop prediction and fertility level.

For instance, Sujatha Anand [1] proposed a technique that makes use of a sensor to gauge the value and transmits information to a cloud-based platform where fertiliser improvement predictions are created. The right amount of fertiliser to use on the crop is specified in this paper. The crop displays the nutrient value that is present in the soil, according to a method for identifying soil nutrients that was described by R. Sindhuja [2]. A technique developed by Lokesh K. [3] involved gathering soil nutrients with a sensor and sending the information to a database.
Farmers received SMS notifications on the crop and soil type based on the information. The Raspberry Pi was used to store the data in the database, and the SMS alert system utilised the GSM.
With the use of a Raspberry Pi board and a few sensors, including a pH sensor, humidity sensor, and temperature sensor, Fenila Naomi J [4] discussed an existing system that aids farmers in choosing the best crop for their yield. To anticipate the future value under long-term conditions, the system employs the RNN-LSTM technique. The system can detect the suitable crop and recommend the preferred irrigation for the crop to the farmers through a mobile application based on the forecasted temperature, humidity, and NPK levels. This app shows the soil nutrients, temperature, and humidity and notifies farmers when there is a need for irrigation in low humidity areas. Based on the projected temperature and nutrients, the best yield is examined. Yet, this technology is unable to forecast the weather in advance.

R. Sujatha [5] delved into the application of IoT and cloud technology in soil monitoring and testing for smart agriculture. The integration of IoT capabilities with mobile cloud is crucial for achieving a flexible and feasible technological system in smart agriculture.

P. Sukumar [6] described how identifying soil nutrients is time-sensitive because the amounts of these nutrients might vary, necessitating expensive and time-consuming chemical analysis and complicated testing of soil particles. Electrochemical sensors, however, have the potential to streamline the testing procedure and lower costs for nutrient detection in soil. New testing techniques that adhere to the KIS (Keep It Simple) standard have been developed as a result of advanced engineering technology.

S. Panchamurthi [7] talked about the application of soil analysis and yield prediction using several soil parameter processing. This idea replaces the outdated, inefficient way of soil testing by providing farmers with doorstep soil testing services. This project's findings aid farmers in making educated decisions and preventing the use of ineffective fertilisers. Small farmers will especially benefit from this project. This project uses the supervised machine learning technique and incorporates data from sensors and the Department of Agriculture and Agribusiness into the ML Python. Two values are taken into account by the algorithm, which clearly matches them, and the results are shown on the screen. Farmers can then predict the suitable yield for their soil and recommend the necessary fertilizer based on the nutritional status of their soil, which plays a crucial role in the development of the farmer.

The important part that agriculture plays in a nation like India, where it is one of the most important sectors, was discussed by MadhuriKommineni [9]. She emphasised how information technology may transform agricultural decision-making and assist farmers and designers in producing greater yields. In this situation, data mining techniques are crucial for making well-informed choices on a range of agricultural-related topics.

The article goes on to address the use of data mining in the agricultural industry, notably in the control of fertile soil and farming soil. Together with the methods used to collect information from them, several soil types are also covered. The quality of the soil, which is essential for the growth of crops, can be improved with the help of this information.

In addition to, Madhuri's work, Sk Al Zaminur Rahman and Kaushik Chandra Mitra [9] also put up a model for forecasting soil composition and offering suggestions for agricultural yields based on the particular soil type. Their study was based on soil data from six Upazila in Bangladesh's Khulna district. Several machine learning techniques were used to evaluate their model, and they discovered that SVM (Support Vector Machines) had the highest accuracy for classifying soils.

The accuracy of soil categorization and crop recommendations are higher with the proposed model than with many other existing approaches since it is built on a carefully constructed dataset and machine learning techniques. This study emphasises the potential advantages of data mining and machine learning methods in agriculture, particularly in terms of enhancing crop output and soil quality.

In order to increase agricultural output, BalajiBhanu, K. RaghavRao, J. V. N. Ramesh, and Mohammed Ali Hussain [10] emphasised the significance of safeguarding the farming industry from the effects of the climate and pest infestations. In order to do this, the agricultural industry is seeing an increase in the use of wireless sensor network (WSN) technologies for greenhouse atmospheric monitoring and control. This wireless technology aids in overcoming the restrictions of wired systems and provides real-time monitoring of numerous factors in the greenhouse environment, including temperature, humidity, and carbon dioxide levels. The design of the system's subsystems and modules is included in the authors' comprehensive explanation of the WSN system architecture and data structure. The comprehensive information provided in this report is valuable for agricultural engineers who are interested in implementing WSN technology for better monitoring and control of the greenhouse environment. By leveraging the power of wireless communication, the WSN system is expected to significantly enhance the overall efficiency of greenhouse management and contribute to sustainable farming practices.

Muhammad Ayaz [11] emphasised the urgent for for better and more effective farming techniques to deal with the rising food demand brought on by the expanding world population and the dwindling supply of arable land. Technology has a key role to play in the development and adoption of new approaches that will increase crop yields and productivity. The author emphasised the value of numerous technologies, particularly the Internet of Things (IoT), in improving the productivity and intelligence of agriculture. The study gave an overview of IoT-based models and platforms for farming applications and examined the usage of remote sensors, unmanned aerial vehicles (UAVs), cloud computing, and communication technologies. The author also discussed the challenges facing the industry and the expectations for the future. The article emphasized that every bit of farmland is essential for maximizing crop production, and to manage each inch of land effectively, the use of affordable IoT-based sensors and communication technologies is not optional but rather essential. With this in mind, the paper offers valuable guidance for researchers and engineers to tackle these challenges and develop innovative solutions to make agriculture more sustainable, efficient, and productive for the future.

N. Rajput [13] emphasised in his study that India, which has the second-largest area under apple production globally, trails other apple-producing nations in terms of yield. The author presented the benefits of using wireless sensor networks (WSN) in agriculture to boost apple production as a solution to this problem. The financial viability of WSN deployment and the related installation expenses must be taken into account, though. The author also stressed that until new designs and domestic manufacturing options are investigated, sensor costs will stay high. Several crops in India may benefit from the usage of WSN for precision agriculture, which is essential for developing nations like India to satisfy the rising need for food production.

V. Rajeswari and K. Arunesh [15] explored various classification algorithms and compared the results of Naïve Bayes, JRip, and J48 algorithms. The study found that JRip classification algorithm provides better results for the dataset and accurately classifies it into a maximum number of categories compared to the other two algorithms. Based on the results, JRip can be recommended for predicting soil types.

Table 1: Comparison Table

Author	Year	Approach	Description
Sujatha Anand [1]	2019	PH sensor, Ultrasonic sensor, PIR sensor, Cloud based,	By utilizing the analyzed data, it is possible to optimize the fertilizers and use the appropriate amount of compost in the yield. This approach ensures that fertilizers are added according to the requirements.

R. Sindhuja [2]	2017	Electro chemical sensor,	The utilization of soil sensors can enhance the quality of the soil and increase crop yield by measuring soil nutrients. These sensors not only provide information about the nutrients in the soil but also the dissolved water or aqueous solution. This data can then be used to optimize fertilizer usage and ensure that the appropriate amount of compost is added to the soil based on its nutrient requirements.
Lokesh K [3]	2016	RaspberryPI,GSM, Database, Sensor	The sensor will transmit the collected data to a database, which will then be used to send SMS notifications via GSM to farmers regarding the harvest and soil type.
Fenila Naomi [4]	2019	PH sensor, temperature sensor, Stickiness Sensor, Raspberry pi, RNN- LSTM Strategy	The existing system utilizes Raspberry Pi board and sensors to collect data on soil characteristics, enabling farmers to determine the most suitable crops for their yield. The gathered data is then sent to the cloud for viewing by farmers through an app. However, this system has limitations in that it does not provide information on weather conditions in advance or recommend the best crops to grow. Additionally, it does not provide guidance on irrigation scheduling.
R. Sujatha [5]	2017	IOT And Cloud platform	The paper provides an overview of smart agriculture and its implementation through the integration of IoT and cloud platform, aimed at creating a planting system that is both scalable and feasible.
P. Sukumar [6]	2018	Electro chemical sensor, Android app	In this paper the data will be taken from sensors and displayed nutrients value on android app. And predict which crop is suitable for that particular soil through nutrient value.
S. Panchamurthi [7]	2019	PH meter, Dataset, ML	The readings obtained from the PH meter will be recorded in a dataset. Machine learning algorithms will then analyze this data to generate a list of suitable crops and recommend appropriate fertilizers for each crop.
MadhuriKommineni [8]	2018	Data mining	This paper presents a survey on the application of data mining techniques for analyzing large datasets and extracting useful information for predicting and analyzing soil properties in various crops.
Sk Al Zaminur Rahman [9]	2018	Bagged tree, K- Nearest Neighbors , Support Vector Machine	The study involved the utilization of three algorithms to analyze datasets from six Upazilas in the Khulna district of Bangladesh.
Balaji Bhanu [10]	2014	Wireless Sensor Network, Datasets, Applicatio n	The data is collected in different areas using WSN, then categorized and the outcome is displayed on a web application.
Muhammad Ayaz [11]	2019	IOT, , remote sensors, UAVs, Cloud- processing,	The article discusses the potential and challenges of using IOT in agriculture and its future implications.

Dr.Muralidhara [12]	2018	WSN, RFID UAV	They talk about various technologies.
N. Rajput [13]	2012	WSN	This paper proposes the use of WSN to enhance apple farming in India.
J. Jayaprahasl [14]	2014	PH sensor, EC sensor,	The PH value of soil will be measured and analyzed to determine the nutrient levels, which will then be used to recommend the most suitable crop for cultivation.
V.Rajeswari [15]	2016	Data mining using Naïve based, JRip, J48	Three algorithms were used to classify and improve yield in this study. Among the three, JRIP algorithm yielded better results than the other two.

Problem Statement & Objectives

Due to a lack of automation and limited access to cutting-edge technologies, the Indian agriculture sector is currently experiencing various problems. While contemporary agricultural technology necessitates significant capital investment, agriculture technology in India is primarily labour-intensive. Changes in temperature, precipitation, carbon dioxide, ground-level ozone concentrations, and nutrient content are just a few of the ways that climate change affects agriculture. IoT can be used to improve the effective use of inputs like soil, fertiliser, and pesticides. Farmers require a variety of information and services to improve agricultural productivity. Farmers can interface with technology using less expensive gadgets like sensors, smartphones, scanners, etc.

The proposed system offers an automated and remotely monitored technique to replace the traditional farming method of testing soil fertility. This new system provides real-time updates on the current soil fertility status of the land to the farmers. The quality of soil is determined using sensors to calculate the concentration of NPK, while the electrochemical sensor method is employed for multiple tests. The results of each test are averaged to determine the approximate fertility of the entire land, which is displayed on a screen. The PH sensor is a critical parameter in this system to determine soil fertility. Based on the PH values, the nutrient values and suggested crops are displayed on an Android application. The application also provides a list of suitable crops.

Proposed System

The proposed system replaces traditional soil fertility testing methods with an automated, remotely monitored system. Through the use of sensors, the system provides real-time information about soil fertility and calculates the NPK concentration. The pH sensor is a key component that determines soil fertility and the accompanying Android app provides crop recommendations and necessary fertilizer based on the pH readings.

- **IoT Recommender System:**

An IoT recommender system provides tailored recommendations based on user interests and usage habits, utilizing data from various IoT sensors and devices to assess user activity. The system can suggest ways to increase energy efficiency by evaluating user behavioural patterns, and machine learning algorithms improve recommendations over time. Customized product recommendations can also be made based on browsing and shopping history.

- Tool Design: Soil nutrient measurement systems for citrus plants are designed using npk soil sensors and the internet of things with Fritzing schematic circuit software. Analog and current-giving pins from the sensor to Modbus are used, transformed into analog data signals for the nodemcu.

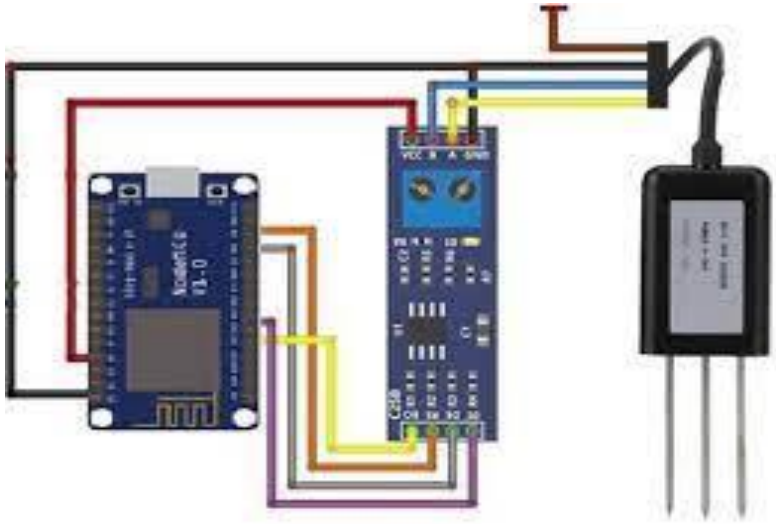
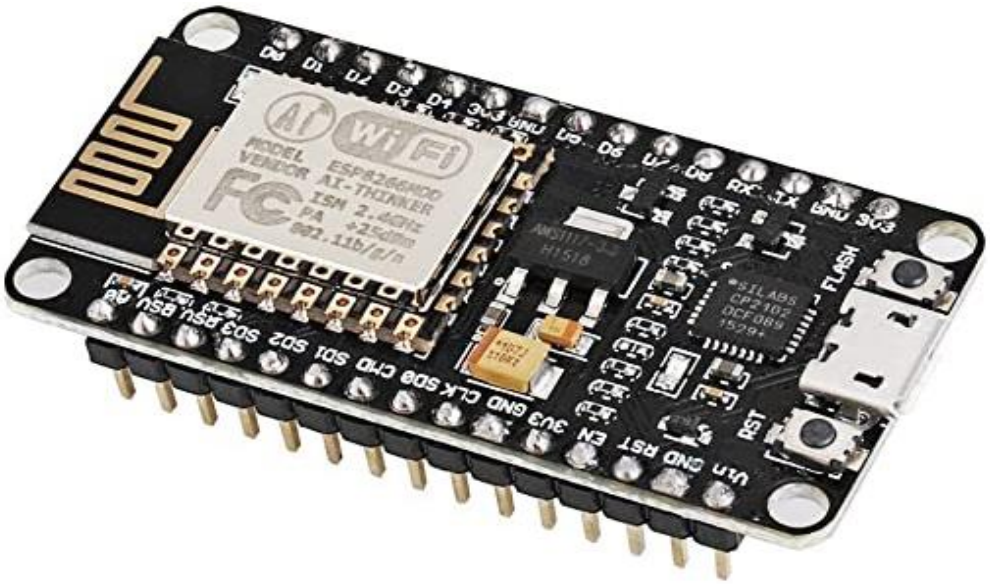
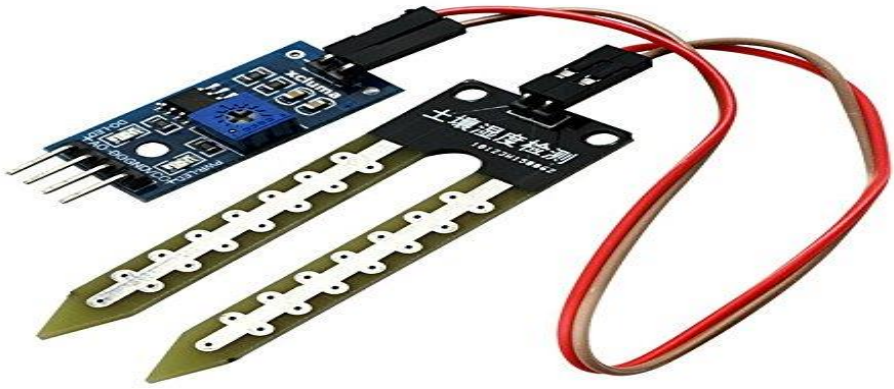


Figure 5.1: Tool Design

- NodeMCU Microcontroller: NodeMCU is a small computer board that allows you to easily connect your projects to the internet. It's based on a tiny WiFi module and comes with built-in features such as input/output pins and communication interfaces. You can program it using a scripting language called Lua, which is easy to learn and use. With NodeMCU, you can build projects that can sense and respond to the world around them, and communicate with other devices or servers over the internet. Whether you want to build a smart home device, a weather station, or a remote control car, NodeMCU makes it easy to get started with Internet of Things (IoT) projects.



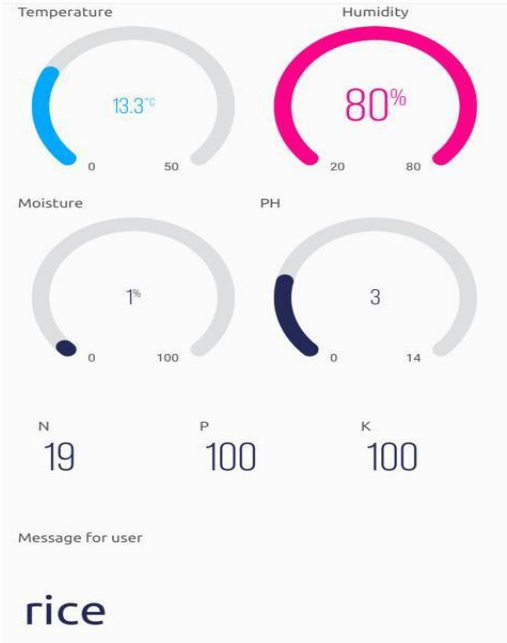
- Moisture Sensor: The moisture sensor allows for monitoring of soil wetness using two probes that conduct current through the soil and read resistance to determine moisture content.



- Figure 5.3 : Moisture sensor

II. Experimental Results:

The Android application provides outputs, displaying the amount of nutrients and providing crop recommendations based on soil characteristics like temperature and humidity.



3. Conclusions

Because of the variability in their levels, nutrient detection in soil requires quick action. Time-consuming traditional techniques are used for soil testing and chemical analysis. But by reacting to concentrated ions, electrochemical sensors can swiftly find soil nutrients. The process of detection may be automated thanks to these sensors. By using cutting-edge engineering technologies, new methods for evaluating soil have been developed that adhere to the KIS (Keep It Simple) philosophy while streamlining complicated processes and lowering expenses.

With the use of the Internet of Things and machine learning, this initiative intends to increase agriculture's productivity and accuracy by fully automating the process. Additionally, it tries to stop the overuse of vital resources that could lead to their future depletion. Every farmer would want it because it is a full bundle that is

entirely devoted to their wellbeing and the advancement of agriculture. From the beginning to the completion of the farming process, our project aids farmers. By producing a good yield at the end, taking proper care of these crops enables farmers to overcome poverty. Additionally, it makes sure the crops are healthy and well-fed. Addressing all these issues is not only an advantage of this project but also an essential thing for the development of any country's welfare. This project not only saves money and resources but also time and labour. With so many advantages, every farmer dreams of having this implemented in their fields. Since this project is cost-effective and affordable for most farmers in India, there is no doubt that it would be a market hit.

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