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IoT-based Crop Recommendation System Using NPK sensor

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Abstract- **Agriculture is the sector on which the survival of human beings hangs, largely because of crop yield improvement - for the sake of food security and sustainability.**

Improving crop production levels is quite dependent on how fertile the soil is-that is, which levels of Nitrogen (N), Phosphorus (P), and Potassium (K) exist in the soil. The key contribution of this research is the development of a 7-in-1 NPK sensor-based IoT crop recommendation system. This system analyses the soil nutrients and provides recommendations to farmers in real-time data-driven decisions on the right crops and the required NPK fertilizers to grow them. The system utilizes an ESP8266 microcontroller in acquiring and transmitting data to the said cloud-based web application, which in turn has been developed using PHP and MySQL. This system will provide accurate information regarding the nutrient levels in the soil and will assist the operators of agricultural activities to select crops more prudently and then apply the appropriate fertilizers, thus yielding a better outcome with sustainability in farming. This research presents the design and implementation of an advanced 7-in-1 NPK sensor-based IoT Crop Recommendation System, aimed at transforming traditional agricultural practices into data-driven, precision farming solutions

Index Terms- **NPK sensor, IoT, crop recommendation system, precision agriculture, ESP8266, RS485, PHP, MySQL.**

1. INTRODUCTION

Agriculture is the backbone of most economies, and it serves to feed a growing world population. However, the productivity of farming is highly dependent on soil fertility, which in turn is a function of a few key nutrients: Nitrogen (N), Phosphorus (P), and Potassium (K) [1]. Nutrient deficiency or excess usage often can be quite damaging to the crop yield and the environment because most farmers are not able to ascertain the nutrient levels in their soil so accurately, which leads to improper amounts of fertilizers being applied [2].

The Internet of Things has effectively led to real-time monitoring and control of various agricultural processes in recent years [3]. IoT technology is used in measuring soil nutrient values with accurate data requirements for crop selection and application of fertilizer [4].

The work outlines an IoT-based system that measures the soil's NPK values using a 7-in-1 NPK sensor interfaced with an ESP8266 microcontroller. The sensor data is transmitted to a cloud- based web application that gives the farmer recommendations for the best crop suited for this soil and the precise amount of NPK fertilizer required for optimal growth [5]. The system aims at solving the problems faced by farmers in the production aspect - dealing with issues related to soil fertility management and crop selection hence improving productivity and sustainability [6].

2. RELATED WORK

Various studies have explored IoT-based solutions in precision agriculture. Several soil monitoring systems have been developed using pH and moisture sensors, but they lacked real-time NPK analysis. Other studies have proposed machine- learning-based crop recommendation systems that relied on historical data rather than real-time soil conditions. Similarly, some fertilizer management algorithms have been designed but did not integrate dynamic soil assessments. Unlike existing methods, this research introduces an IoT-driven approach for real-time NPK monitoring, ensuring immediate and accurate crop recommendations based on current soil conditions.

3. LITERATURE REVIEW

There are a number of studies that investigated the use of precision agriculture in enhancing farming activities. Those studies found that sensor monitoring in the determination of soil parameters improved the decision-making of irrigation, crop selection, and fertilizer management [7]. But traditional methods rely on laboratory analysis of determining soil parameters, which takes much time, is costly, and only gives static information that does not account for real-time changes in the conditions of the soil [8].

Several IoT-based solutions have been developed to monitor soil moisture, temperature, and pH; however, few focused on the real-time monitoring of NPK values, which is as crucial for crop growth [9]. Several current crop recommendation systems only rely on historical data and predefined crop databases but do not integrate real-time analysis of soil nutrients [10]. Hence, this research bridges the gap by developing a system that offers NPK real-time monitoring and dynamically provides crop recommendations based on the current status of the soil [11].

4. SYSTEM DESIGN AND ARCHITECTURE

4.1 Hardware Components

NPK Sensor (7-in-1): The backbone of the system is the 7-in-1 NPK sensor, which allows measuring Nitrogen (N), Phosphorus (P), and Potassium (K) levels in the soil. It also monitors other key parameters such as moisture in the soil, temperature, and pH to make it very powerful for the analysis of soil fertility [12]. This sensor takes advantage of the RS485 communication protocol for long-distance transmission of data and avoids electrical noises to provide accurate and reliable measurement [13].

Fig 1 (NPK Sensor)

ESP8266 Microcontroller: This is a Wi-Fi-enabled microcontroller that constitutes the main interface between the NPK sensor and the cloud-based web application. The ESP8266 reads the data coming from the NPK sensor by using RS485 protocol and feeds the same into the cloud server by using the Wi- Fi. Its low cost, low power consumption and ability to have Wi-Fi built in allows it to be useful in remote agriculture settings [14].

Fig 2 (ESP8266 Microcontroller)

RS485 Protocol: The RS485 is a standard serial communication protocol which will permit long-distance data transfer and support multi-device operations from the same bus. Therefore, RS485 is mainly found in industrial and farm settings where robust communication is required. The RS485 protocol supports interference-free data transfer from the NPK sensor to the ESP8266 microcontroller even over long distances [15].

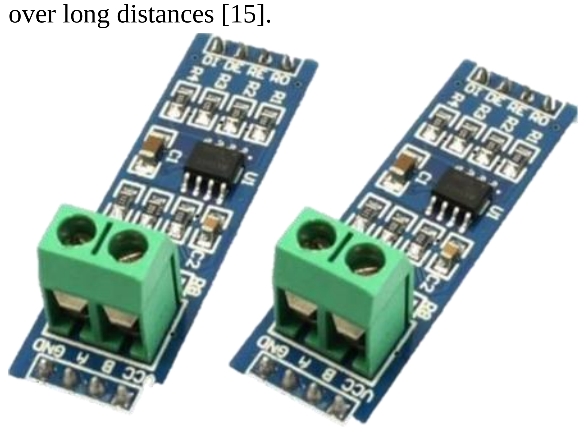

Fig 3 (RS485 Protocol)

4.2 Software Components

Cloud Web Application: The cloud-based web application is developed using PHP and MySQL. It serves as the backend system for receiving, storing, and processing the NPK sensor data. The application provides a user-friendly interface where farmers can log in to view real-time soil data and receive crop recommendations [16].

Database (MySQL): A MySQL database is used to store the NPK sensor data and other relevant information, such as historical soil readings and crop suggestions. The database enables efficient data storage and retrieval, allowing for the analysis of historical trends in soil fertility [17].

Fig 4 (SQL Database)

Data Transmission via POST Method: The ESP8266 microcontroller sends the sensor data to the cloud server using the HTTP POST method. The POST method allows the microcontroller to upload the sensor data in real time, ensuring that the web application receives the latest soil readings for analysis [18].

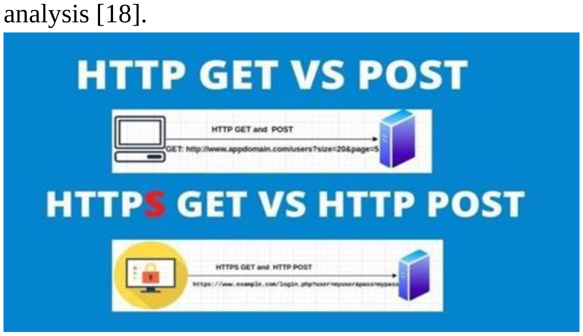

Fig 5 (Data Transmission via POST Method)

5. METHODOLOGY

The crop recommendation system operates in four distinct phases:

5.1 Data Acquisition

The nutrient levels in the soil, that includes N (Nitrogen), P (Phosphorus), K (Potassium), and other parameters like moisture within the soil, temperature, and pH are actually captured by the NPK sensor. All this data is transmitted to the ESP8266 microcontroller, which is actually the central processing unit of the system via the RS485 protocol [19].

5.2 Data Transmission

The sensor data is received by the ESP 8266 microcontroller, which processes and formats the information to send to the cloud server. The data has been transmitted by Wi-Fi to the cloud server using the HTTP POST method, ensuring safe and efficient transfer into the web server, where it is stored into the MySQL database for further analysis [20].

5.3 Data Storage and Analysis

It will store all the data in a MySQL database where all analysis will be retrieved. The web application looks at the NPK values with a predefined dataset correlating soil nutrient levels to the most appropriate crops within different soil types. The analysis engine uses algorithms that consider the current nutrient composition and suggests suitable crops that will thrive in those conditions [21]. In addition, the system computes the amount of NPK fertilizer necessary to bring the soil nutrient balance to ideal levels through the crop selection process.

5.4 Crop and Fertilizer Recommendation

It lets the farmer know two important points: (1) the best crops best suited for their soil and (2) the amount of NPK fertilizers needed to be added to the soil to achieve the desired level of nutrients. These recommendations are based on a model that combines current real-time data from the soil with historical trends, as stated in [23]. The recommendations for the farmers' cropping and application of fertilizers can be accessed through a web interface to ensure that decisions are made according to certain situations [24].

6. IMPLEMENTATION

6.1 Sensor Calibration

Calibration is necessary before the sensor is sent into the field to ensure good readings are achieved. Calibration applies the sensor readings against known reference values for Nitrogen, Phosphorus, and Potassium. This shall minimize errors and ensure that the sensor provides reliable data [25].

6.2 Data Flow Diagram

The data flow within the system is as follows:

1. NPK Sensor → ESP8266 Microcontroller via RS485 → Wi-Fi → Cloud Server (PHP & MySQL).

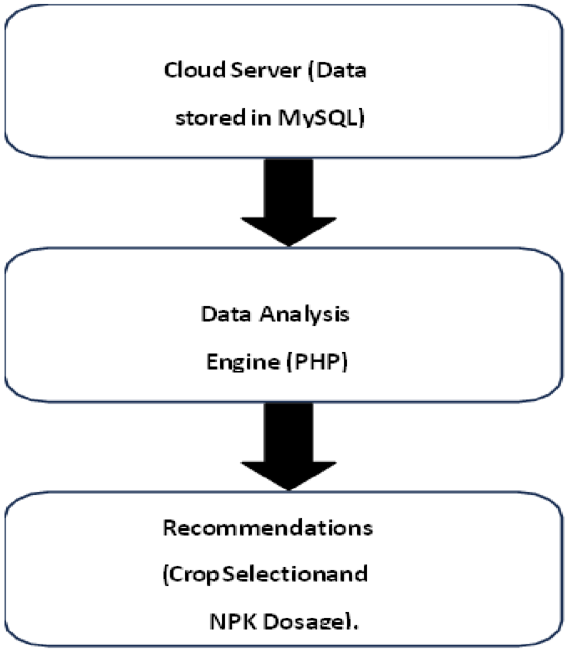

Fig 6 (NPK Sensor Flowchart)

2. Cloud Server (Data stored in MySQL) → Data Analysis Engine (PHP) → Recommendations (Crop Selection and NPK Dosage).

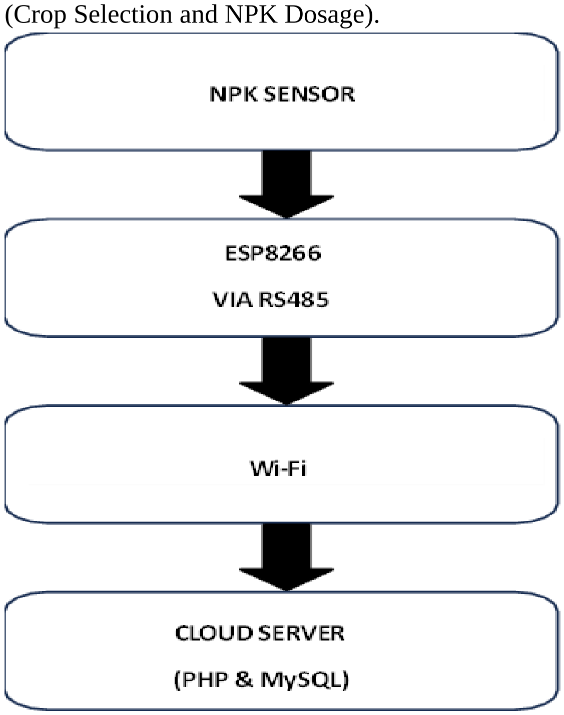

Fig 6.1 (Cloud Server Flowchart)

6.3 Web Interface

The interface of the web is user-friendly and can be easily accessed for farmers having different technical knowledge. Users can access in a login process, and access soil real-time data, suggestions on crop, or fertilizer guidelines. Such an interface offers graphical illustrations of nutrient levels in soils, historical trends, and comparison charts to the farmers for data-driven decision-making [26].

7. RESULTS AND DISCUSSION

7.1 System Accuracy and Performance

The 7-in-1 NPK sensor had a high accuracy in soil nutrient level estimation. Deviations were all within accepted ranges, hence suitable in agricultural applications [27]. RS485 was used in the system, which ensures stable, reliable communication between the sensor and the microcontroller over a significant distance [28]. The ESP8266 microcontroller transmitted the data to the cloud server with minimal delay and hence served efficiently in the system, increasing responsiveness [29].

7.2 Crop Recommendation Efficacy

The system was tested under different soil types including sandy soils, clay soils among others to check the performance. In all these, it gave good crop recommendations based on the NPK values it measured. Application of such a system has resulted in improved crop yield on the various farms that utilized it because crops were more accurately selected for planting in addition to fertilizer application [30].

7.3 Limitations

The limitation of the system is that connectivity relies on Wi-Fi. Thus its application would be limited only to areas where internet is not available. Future editions of this system can add modules for GSM and satellite communications for extended coverage [31]. In addition to NPK values, the system can include organic matter content and micronutrients in the soil for an expanded scope of recommendations [32].

8. CONCLUSION

The development of the IoT-based crop recommendation system using a 7-in-1 NPK sensor marks a significant step forward in precision agriculture. By leveraging real-time soil nutrient data, the system provides accurate recommendations for crop selection and fertilizer application, directly addressing challenges in soil fertility management. The integration of ESP8266 microcontrollers, RS485 communication, and cloud-based data analytics ensures a robust, scalable, and user-friendly solution that can assist farmers in optimizing crop yield while minimizing environmental impacts.

This research demonstrates that the application of IoT technologies can significantly enhance the decision-making process in agriculture by providing data-driven insights. The system's ability to dynamically analyze soil nutrient levels and adjust recommendations in real-time helps farmers make informed decisions, which can lead to increased agricultural productivity and sustainable farming practices.

However, while this system shows promising results, there are areas for further improvement. Future work could explore integrating additional sensors to measure other critical soil parameters, such as organic matter content, soil salinity, and micronutrient levels, thereby expanding the scope of recommendations. Additionally, enhancing the system with machine learning algorithms can refine crop and fertilizer recommendations based on historical data and predictive modeling. Expanding connectivity options beyond Wi-Fi, such as GSM or satellite communication, would allow the system to function effectively in remote regions with limited internet access.

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