Integrated Fertilizer Recommendation and Crop Management System for Farmers

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***Abstract*— This paper proposes an IoT-based Fertilizer Recommendation system that can send the data from the soil testing kit directly to the ThingSpeak platform. An application named Earthworm has been developed which can access and retrieve data for the prediction of desired fertilizer based onthe nutrient values provided by the testing kit. This application(web app) can provide multiple features like a request for soil testing and drone service, a demo video on how to use the app, achatbot, and a purchase link for buying the recommended fertilizer. The low-cost, compact-sized, soil testing kit has been provided with a hybrid power supply model which enhances itsflexibility of usage.**

Keywords*— *Fertilizer, PCB, Arduino, NPK Sensor, Application, Soil, ThingSpeak, LCD, Soil Moisture Sensor, ESP8266.

I. Introduction

In recent times, crop yield has been drastically reduced due to the overdosage of fertilizers in the soil. Fertilizers are often added to crops without assessing the specific macronutrient that is already present in sufficient quantities. This led to the saturation of productivity in the soil and the depreciation of nutritious content in agricultural products. So, there is a need for careful identification and addition of nutrients lacking in the soil. Also, there is another possibility that if a farmer wishes to grow a crop that suits the current nutritious content in the agricultural field without adding any fertilizer, then the proposed recommendation system will play a crucial role in identifying the growth of suitable crops for the present soil condition.

Multiple nutrients have been considered while recommending the fertilizer. The soil's Nitrogen, Phosphorus, and Potassium (NPK) content can be measured using an NPK sensor [1]. Conventionally, the soil has been analyzed using chemical methods. So, a similar approach has been incorporated into the sensor measurement.

NPK sensor will have three sensors integrated into a single block with each electrode interacting with its corresponding nutrient levels using electrochemical reactions. The ion exchange process generates an electric potential thereby causing the flow of electric current.

When the stainless-steel probe of the NPK sensor is injected into the soil, it transfers the measured NPK value to the microcontroller using the RS485 communication interface. The interfacing of the NPK sensor with the microcontroller (here Arduino) is not possible without the help of the RS485 transceiver module as it converts the UART serial data stream into RS485-supported data format.

When the microcontroller asks for NPK values, Modbus RTU sends a response in the format shown below.

TABLE I

MESSAGE FORMAT OF NPK SENSOR

Slave ID	Function Code	No. of bytes of data	NPK value	Checksum

Based on the above response message obtained from the NPK sensor, NPK hexadecimal values can be decoded.

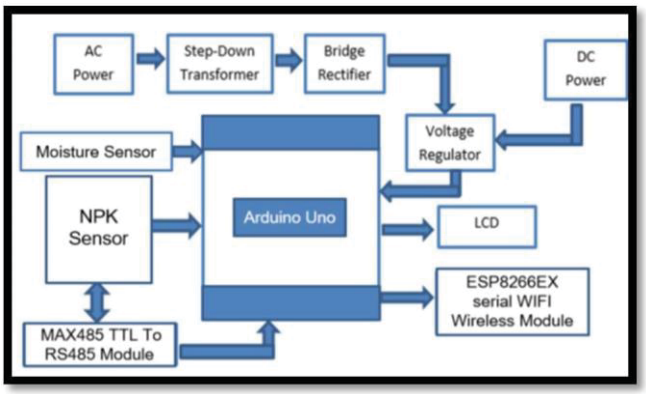

Figure.1. Block Diagram of Nutrient Analysis Kit

Figure.1 shows the block diagram of the nutrient analysis kit which measures the NPK content of the soil. The Arduino Uno microcontroller acts as the heart of the kit by controlling the operation of components in the PCB. The power source can be either a DC or an AC source which would be regulated with the help of voltage regulators. The microcontroller is interfaced with LCD, RS485 transceiver module, and

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ESP8266 Wi-Fi-Module. The NPK content of the soil is immediately sent to the internet, and it can also be seen on the LCD.

Soil Moisture sensor [2] and relay are also added as an additional sensor which would act as a provision if the farmer wanted to buy the soil testing kit and place this as a permanent setup in his farm, the motor pump can be controlled using the value read by the soil moisture sensor.

ThingSpeak acts as an IoT platform [3-4] for storing and visualizing data using cloud-based servers, which helps post-processing data.

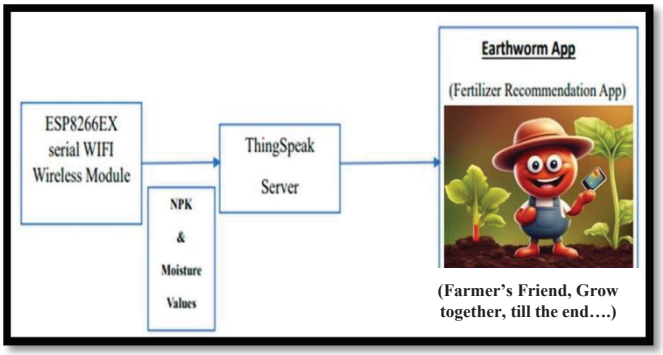

Figure.2. Data transfer from the Soil Testing Kit to the Mobile Application

Figure.2 shows how the measured NPK and soil moisture values are moved from the soil testing kit [5] to the mobile application. The data can be entered from the server as input and based on these values, the app recommends the desired fertilizer.

II. LITERATURE SURVEY

Multiple people have worked on the development of soil testing kits as well as machine learning-based crop prediction and fertilizer recommendation systems, which have pros and cons.

M.Pyingkodi, K.Thenmozhi, M.Karthikeyan, T.Kalpana, Suresh Palarimath, G.Bala Ajith Kumar proposed an Internet of Things based Soil Nutrients Analysis and Monitoring System for Smart Agriculture which detects the nitrogen, phosphorus and potassium nutrient levels in soil using NPK sensor and transfers the data to the ThingSpeak server. It compares the NPK level in soil with the help of kernel density estimation algorithm along with machine learning techniques [6].

Jeevaganesh R, Harish D, and Priya B proposed a Machine Learning-based Approach for Crop Yield Prediction and Fertilizer Recommendation using the AdaBoost algorithm to predict the crop yield based on various parameters like state, district, area, seasons, rainfall, temperature, and area. To improve the yield, fertilizer recommendation is given based on the parameters discussed above using the Random Forest algorithm [7-9].

Real-time monitoring of soil nutrient analysis using WSN by S. N. Shylaja and M. B. Veena helps the farmers to collect information about different soil types and fertility levelsusing which crops and fertilizers are suggested with the helpof a mobile app. It uses wireless sensor networks for remote monitoring of the soil [10].

The crop recommendation system for precision agriculture developed by S Pudhumalar, E Ramanujam, R Harini Rajashree, C Kavya, T Kiruthika, and J Nisha involves the recommendation of crops using an ensemble model with a majority voting technique. It uses Precision Agriculture (PA) principles to obtain better results in harsh environments [11].

The Soil Nutrients Monitoring and Analysing System using the Internet of Things by Ms. Sonia and Mr. Vincent Balu proposes a system to test the plant health level using a sensor that aids the fertilizer recommendation process. Remote monitoring of soil fertility, crop water situation, and irrigation assistant features have been included in the system using WSN [12].

M.V. Caya et al. proposed a Capacitance-Based Soil Moisture Sensor for Irrigation Scheduling Application Capacitance which assists the farmers in irrigating the field using a soil moisture sensor to prevent waterlogging issues in the field. The readout circuit detects capacitance changes based on the soil moisture values and operates wirelessly through an end device [13].

In this proposed work, an integrated system has been developed that allows the users to measure nutrient values, switch on/off the pump for irrigation, transfer the data wirelessly, visualize data in ThingSpeak software, recommend fertilizer using an application, buy fertilizer, request drone or soil test kit for testing the soil or purchase the soil test kit for permanent usage. These features make this work better than the existing ones. The low-cost [14], compact-sized soil testing kit has also been provided with a hybrid power supply module for the provision of flexibility to the users.

III. PROPOSED WORK

The proposed work involves the design of a soil testing kit, transmission of data to the ThingSpeak server followed by presenting the data as input to the Earthworm app and recommending the desired fertilizer. The data flow starting from the soil testing kit to the fertilizer recommendation is discussed in this section.

A. PCB Design and Fabrication

The schematic designed in proteus software is a prerequisite for an accurate choice of capacitors and resistors. The circuit is simulated, and voltage is measured at each node using a probe in the circuit. On completion of the circuit design and simulation in proteus, a similar circuit is reproduced in Eagle software.

The connections made in the eagle schematic are converted into a PCB layout with the help of the SCH to BRD feature. Once the board is obtained, appropriate layers are selected for the proper routing of wires. The desired track dimension and spacing at each layer have been chosen to avoid clearance, overlap, and drill distance errors. An error-

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free layout is possible only with the help of manual routing. All tracks other than power lines are drawn with 0.8mm as track width. The power lines have a broader track width of 1.5mm for uninterrupted transmission of power to all the components. Once the errors are cleared, the eagle file layout is given to the laser machine for PCB fabrication.

A copper-coated PCB with FR4 as substrate has been used for the fabrication process. After completing 40 iterations of tracing, the desired tracks have been obtained.

In the fabricated PCB, once the tracks are drawn, etching has been done to remove impurities or dust particles present in the tracks using $FeCl_3$ solution. Drilling is done in the etched PCB using drill bits of appropriate sizes for the placement of through-hole components which ends the fabrication process of PCB.

B. Assembly of Components

The component holders, connectors, and a few essential components like capacitors, resistors, diodes, etc., are placed in the PCB. Laser soldering has been done to place these through-hole components in the drilled slots.

C. Programming Of Microcontroller

The ATmega328P microcontroller was programmed in the C++-based Arduino programming language using Arduino IDE software. The <Wi-Fi.h> library is loaded, and it starts scanning for the nearby networks. In the Arduino code, the Wi-Fi network SSID and password are configured, and the serial data is transferred to the server via the ESP8266 module by using the IP address of the ThingSpeak server as the destination address.

D. Complete Hardware Setup

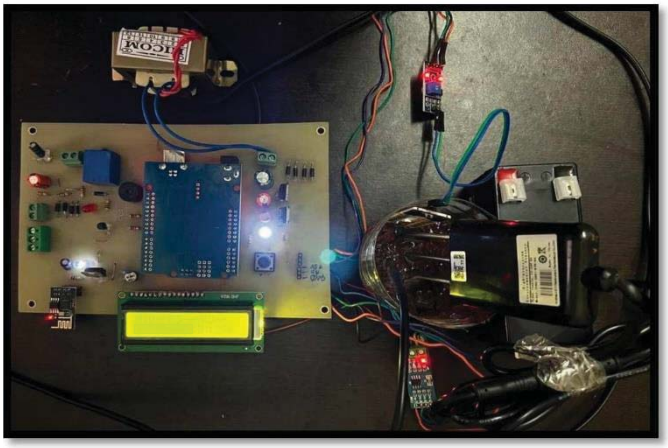

Figure.3. Complete Hardware Setup

Figure.3 displays the hardware setup of the soil testing kit. The power module is capable of supplying both AC/DC power sources to the circuit. If the input source is AC, then a step-down transformer is used to convert the 230V into 12V AC which goes as input to the bridge rectifier circuitry for the AC-DC conversion. The supply is regulated using a capacitor and divided into 5V and 12V using IC7805 and IC7812 respectively. The 5V supply is given to all the components and 12V goes to the NPK sensor module.

The output of the NPK sensor is given to MAX485 TTL to RS485 module which helps in the efficient data transfer of sensor values in a noisy environment. The RS485 module is in turn connected to the ATmega328P microcontroller.

16x2 L1602 LCD module is interfaced with the Uno for displaying NPK and Soil Moisture value and the same information will be updated in the ThingSpeak server using ESP8266 Wi-Fi transceiver module.

E. Architecture of Mobile Application

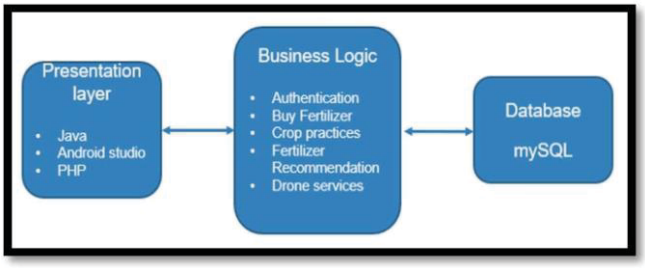

Figure.4. Architecture of Mobile Application

Figure.4 shows the three-tiered architecture of mobile applications which can be classified as the Presentation layer, business logic, and the database. The presentation layer defines the upper layer using which the application has been developed. Java Script has been used for front-end development, providing extensive support for frameworks. PHP has been used at the backend as it supportsboth webpages as well as a mobile application (Webapp). It was also easier to use CSS features for the development of thewebpage. PHP scripts have been written in XAMPP which provides platform-independent support.

Android Studio provides options for debugging the code. The Java script written in Android Studio was opened using an emulator that can be customized to look like an actual mobile application.

Business logic defines the features or operations that have been embedded into the designed application. Data validation like authentication, data processing, and management like buying fertilizer, crop practices, and analytics like buyer history, etc., are some of the features of the business layer which will be discussed in the next section.

The MySQL database forms the base layer of any application as it records and maintains the data properly. The threshold values of NPK have been updated for each crop. This information can be accessed using SQL queries for the prediction and recommendation of fertilizer. The user's Login details and buyer history will be recorded in the database along with the time and date for future usage.

F. *Features of the developed Application*

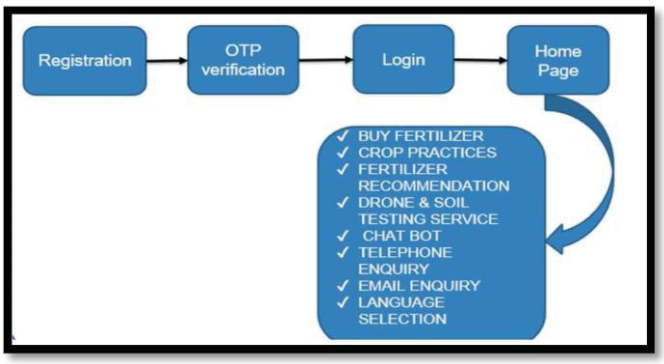

Figure.5. Block diagram of Login and Home Page

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Figure.5 shows the block diagram of the Login and Home Page. Users can register/login and proceed to the home page having multiple facilities like buying fertilizer, crop practices, fertilizer recommendations, drone, and soil testing service, chatbot, contact details for inquiry, and language selection. Each service will be discussed in the later part of this section.

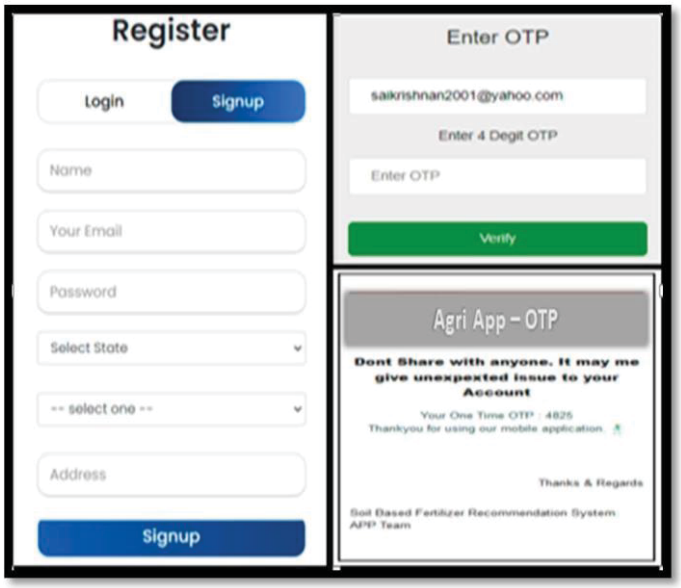

Figure.6. Login/Registration in Application

When the user is new to this application, an accountcan be created by entering their name, email, password, state,city, and address (optional) as shown in Figure.6. An OTP willbe sent to the registered email for verification and to confirm their identity.

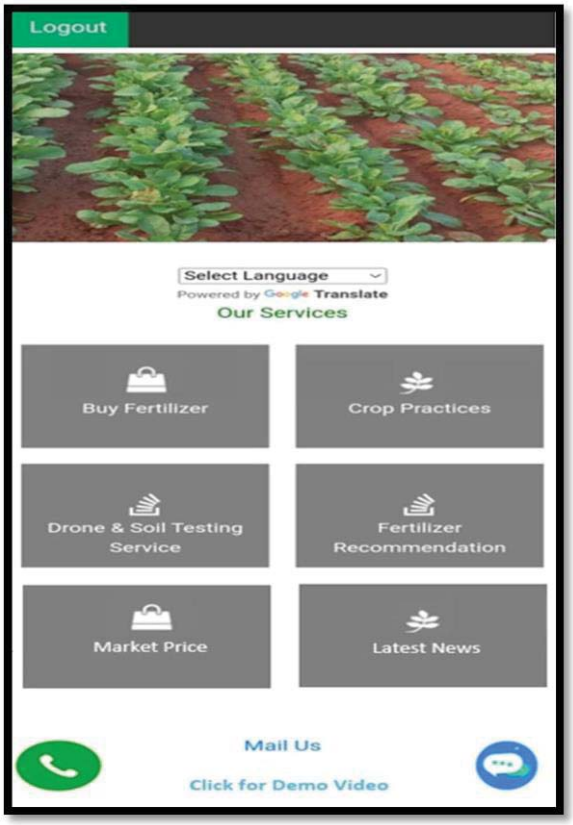

Figure.7. Home page of the Application

Once the registration is completed, the users can log in and advance to the home page as shown in Figure.7.

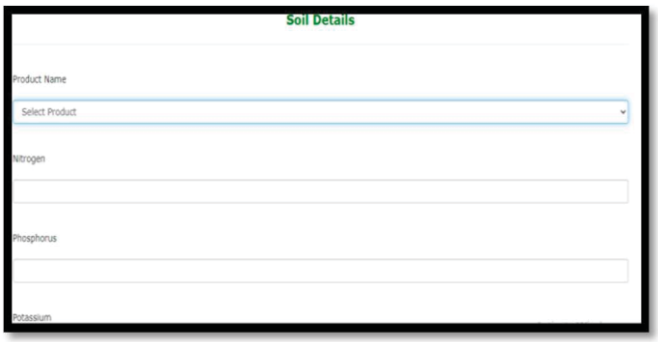

Figure.8. Fertilizer Recommendation Section

In the fertilizer recommendation section, as shown in Figure.8, users can select the crop/product name and enter the nutrient values. A set of 10 important parameters have been considered for the prediction of fertilizer although NPK has been considered as the compulsory and most important component in the prediction. The parameters that have been considered are Nitrogen, Phosphorus, Potassium, Ph Level, Sulphur, Copper, Iron, Manganese, Zinc, and Boron. So, based on the entered values, the application will predict whether the nutrient is present in the required quantities for a particular crop or not. It displays fertilizer whose nutrient is deficient in the soil. Along with this, a buy link has been enabled using which the user can buy the recommended fertilizer.

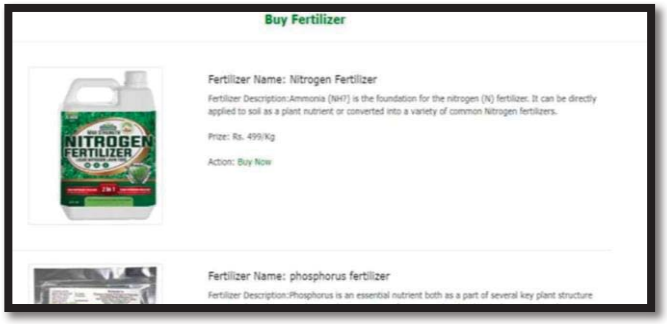

Figure.9. Buy Fertilizer Section

Apart from this, a separate 'Buy Fertilizer' section is provided for the users to buy any fertilizer that is availablein stock as shown in Figure.9. When the option 'Buy now' is sought, users may provide the quantity and delivery address and it directs to the payment page. On successful purchase of a product, an acknowledgment receipt will be sent to their registered mail.

Figure.10. Crop Practices Section

The application has a section named 'Crop Practices', which gives insights about various crops in detail like farming practices, Plant protection, Irrigation, harvesting, nutrients

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and fertilizer details as shown in Figure.10, which will help farmers grow new crops apart from their regular cropsto get higher profits. The ThingSpeak server link is also provided in this section so that users can view the sensor values. The farmers can also select the language they want touse the app by using the drop-down menu present on the topof the home page.

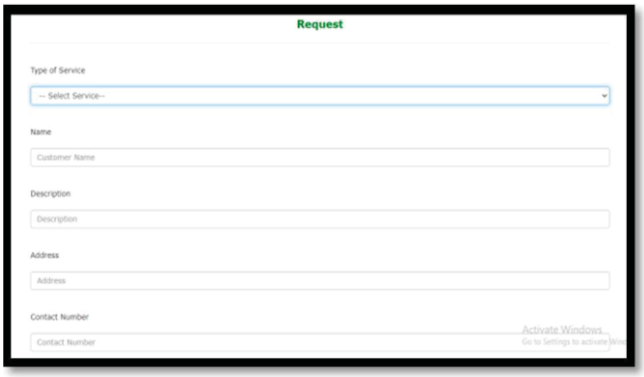

Figure.11. Request for Drone/Testing Kit

Figure.11 shows the request page where users can place requests for obtaining drone or soil testing services. The request can be placed by mentioning the type of service needed, name, description of their requirement, address, and contact number.

Figure.12. Chatbot

If the users need any help, then they can get the assistance of a chatbot which has been trained with many general questions as displayed in Figure.12. If the response is insufficient, then the users can directly contact the administrator via phone or email.

Apart from this, a market price section has been added where the current prices of seeds, fertilizers, and pesticides are available in various locations. This feature can be extended by adding vegetable and fruit prices and it provides a scope for future development. The latest news section gives updates about various government policies and subsidies available to farmers under different schemes.

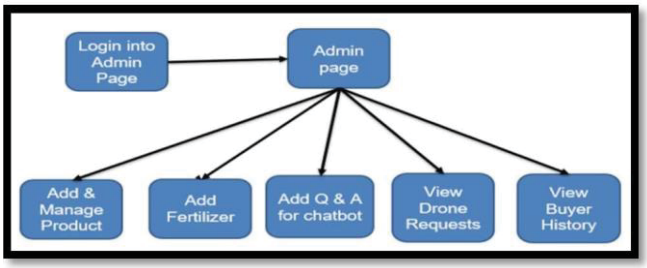

Figure.13. Block diagram of Admin Page

Figure.13 shows the block diagram of the admin page where the admin will be able to add fertilizer, manage products, train chatbot, view drone or soil testing kit requests and get the buyer history for the dispatch of purchased items.

On completion of the development phase, the APK file generated from the Android Studio was updated in a mini play store namely AppGeyser (like Google Play Store) for testing purposes. From this Play Store, the app can be downloaded easily onto any Android device.

IV. RESULTS AND DISCUSSIONS

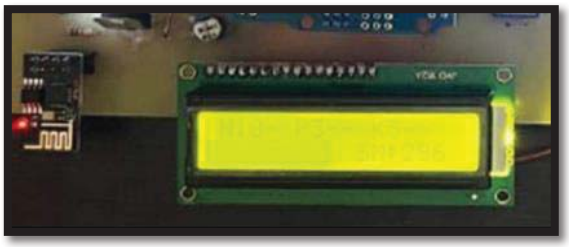

Figure.14. Sensor values displayed in LCD

The nutrient and soil moisture values have been tested by placing the probe of the NPK sensor and soil moisture sensor in the soil. The measured values are displayed in the LCD which is attached to the PCB as shown in Figure.14.

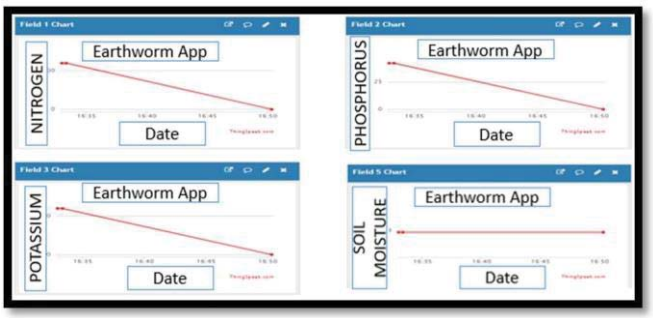

Figure.15. Values displayed in ThingSpeak Server

The obtained values are also being sent to the ThingSpeak server [15]. It's an IoT Platform where the values are being captured continuously from the ESP8266 Wi-Fi module, and the data gets updated automatically after every 2 seconds. The NPK and soil moisture values have been plotted in the form of line charts with the x-axis representing the recorded date and time and the y-axis displaying its corresponding value as shown in Figure.15. It provides easier visualization of data and enables analysis of how the values vary over a period.

To have a comparative study, the NPK values were tested with different soil types [16]. Three types of soil samples were taken, and the obtained values are listed in Table II.

TABLE II

NPK VALUES IN DIFFERENT SOIL TYPES

Soil Type	Nitrogen Content (mg/kg)	Phosphorus Content (mg/kg)	Potassium Content (mg/kg)
Black	23	8	11
Clayey	22	6	9
Sandy	5	1	2

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The obtained values are then given to the developed application. The user could obtain the nutrient levels of other nutrients like Zinc, Manganese, Iron, etc., using chemical means if it's needed for a particular crop. Once the values are entered and the crop is selected, it predicts which nutrient is deficient in that field and recommends the desired fertilizer.

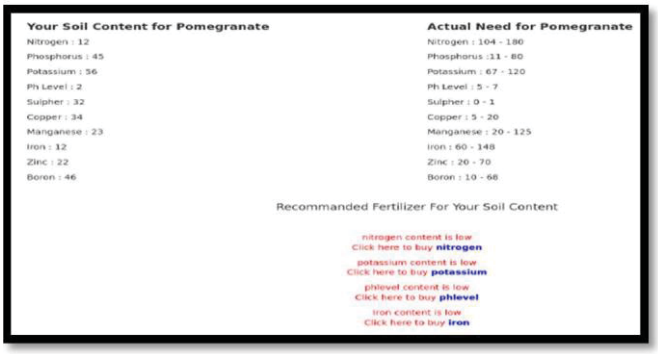

Figure.16. Fertilizer Recommendation

Figure.16 shows the fertilizer recommendation page in the developed application. On the right-hand side, the optimal values needed for the growth of crops in the soil are displayed as compared to the user-entered values shown on the left-hand side. The nutrients that do not fulfill the required amount needed for suitable growth, those nutrients are recommended for the addition of fertilizer along with a purchase link. This completes the fertilizer recommendation process.

V. CONCLUSION

The "Integrated Fertilizer Recommendation and Crop Management System for Farmers using Earthworm Application" is an initiative to support farmers by analyzing the nutrients present in the soil and aiding them to add specific fertilizers for the nutrients that are deficient in the soil. This prevents the soil from getting saturated, thereby improving crop productivity. The soil has been tested using an NPK sensor and FC-28 soil moisture sensor, those values aresent to the ThingSpeak server using an ESP8266 Wi-Fi module, and the data is given as input to the mobile application for recommending appropriate fertilizer. The buying option enables the farmers to buy and use the fertilizerto improve the productivity and yield of crops. The wholesystem of the soil testing kit and the software application was successfully implemented and executed by following the sixstages of the waterfall model.

VI. FUTURE SCOPE

The proposed work is highly scalable as provisions have been given for the addition of various features in the future. The solar harvesting system can be induced to recharge the DC power source automatically. Since a relay and soil moisture sensor have been provided, the motor or pump set can be connected and controlled easily. A few additional connectors have been included in the PCB for the addition of new sensors in the soil testing kit.

On the software side, major upgradation is possible with the inclusion of much more attractive and useful features that help farmers in a better way. Organic fertilizers and organic farming practices can be added to the application. Instead of one-way traffic of buying fertilizers, the selling of end products by the farmers can be enabled to improve the profit of farmers and to avoid wastage of their products. Apiculture is an important field that can be included as a separate section, therefore promoting farmers to do apiculture as it will not only give additional income due to honey, beeswax, bee pollen, royal jelly, etc., but also will increase yield in agriculture as honeybees are the primary source of pollination. Information about beekeeping like harvest, treatments, feedings, etc. can be given through the application which will help farmers manage apiculture more efficiently.

This application can also be extended to poultry and dairy management. Chicken manure, which is high in NPK according to research will be essential for proper plant growth and cow dung can also be used as organic fertilizer by the farmer to save a lot of money and can also earn additional income by selling milk, eggs, and additional fertilizer derive from cow and chicken. The farmers can also keep track of the vaccination schedules for farm animals as well as the timeline of various events starting from the sowing of seeds to the harvest of end products.

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