Automation in Agriculture-An IoT and Machine Learning based Approach

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***Abstract*—Agriculture is a sector which contributes a lot to the economy of a country and to get better yield with good quality, proper irrigation and monitoring needs to be performed. Hence proper water, fertilizer management is a must. With the concept of IoT, Cloud and Machine Learning, it is possible to use low cost devices to monitor and be informed about the status of an agricultural area in real time. Thus, the proposed project provides the design and implementation of a smart irrigation and monitoring system which makes use of IoT to monitor the status of the moisture level of soil, temperature and humidity of atmosphere, Machine learning to predict the right type of fertilizer. The proposed system is made up of sensors which collect data such as air humidity, temperature, and soil moisture data. These data are used to monitor the air temperature and humidity and moisture content of the soil. The raw data are transmitted to the cloud platform and then the farmer is informed through a mobile app. The mobile app is provided with switches to turn ON/OFF the irrigation motors accordingly. Machine Learning is used predict the type of fertilizer required for the particular plant. The results obtained from the proposed project are promising and justifies the work.**

***Index Terms*—Smart Irrigation, Internet of Things, Machine Learning.**

I. INTRODUCTION

Now a days, water shortage, crop yield and quality are becoming one of the biggest problems in the world. Farming is one of the fields where water is required in huge amount. Wastage of water is a major problem in agriculture, due to excess of water given to the fields. Hence, with smart irrigation controller system, user can reduce the wastage of water. The main motivation behind the proposed system is to save the water during the irrigation system and use of fertilizer judiciously. The unplanned use of water and fertilizer results in wastage of water, slowed growth rate of plants, lighter weight fruit, and quality deficiency. In the proposed project, the most significant advantage is that water is supplied when the moisture in soil goes below a pre-set threshold value, along with manual control. And with the help of machine learning, the amount and type of fertilizer to be used can be determined to suit a particular crop.

A. Objective

The objective of the proposed project is, to design a smart irrigation system for agricultural fields that would use water in a more efficient way in order to prevent water loss and minimize the cost of labour, to create a real time irrigation system at the farms based on the moisture content of the soil, to monitor the temperature and humidity (i.e. rainfall) of the field, to predict the amount and type of fertilizer to be used to suit the particular crop/ plant.

II. RELATED WORKS

An approach is there combining Internet of Things (IoT) and Cloud Computing in order to construct an efficient method to handle the enormous data involved in agriculture [1]. The system described in [2], has a distributed wireless network of soil-moisture and temperature sensors placed in the root zone of the plants, with an algorithm developed to control water quantity by using threshold values. The system is powered by photovoltaic panels. The usage of remote sensor arranges innovation to build up a framework for constant ecological checking is depicted in [3] and [4]. The system helps in distributed data collection and monitoring, irrigation and nutrient supply, improvement in crop health etc. This technology reduces the cost of production, increases the efficiency and crop quality. The implementation of a smart agriculture system [5], equipped with inexpensive smart phones which have various sensors. Thus up-to-date agricultural information (e.g., market, weather, and crop disease news) and assistance from agricultural experts and government extension workers is readily provided to farmers. Machine learning approaches, (especially, Kernel Methods, Gaussian Processes, and Deep Neural Networks) have been discussed in [6], which can be implemented for decision taking. An approach in [7], addresses the issues towards the deployment of robust communication services, namely, energy consumption by development of a wireless sensor node for fog computing platforms addressing. The solution is based on the integration of network hardware platforms already available on the market supplemented by smart power management. In [8], the fundamental motivation behind creators was to build up a watering and roofing framework for open air farming locales. The system comprised mainly of data where physical factors such as moisture, humidity, etc., are provided by sensors. The authors make use of a decision tree model to determine when it is appropriate to start watering using certain standards.

A mobile application has been developed where the user can see the sensor data from the cultivation field, and can control the watering and roofing system directly from his phone. It evaluates fundamentally the physical information from sensors and after that contrast they and climate conjecture by the utilization of a choice tree demonstrate. The decision tree model has been devised to allow the author to take decision for watering the crops. The author uses node.js library in order to compute the decision. The node.js library used by the authors is an integration of machine learning libraries.

In [5], the paper proposes a smart irrigation system with the use of IoT together with smart technologies, taking into consideration the wrong usage of water in the southern Algeria, a smart irrigation system that can be controlled and monitored has been devised to manage the usage of water more efficiently. The irrigation system is ensured to be cost- effective and detailed. Wireless Sensor Network (WSN) and IoT technologies have been used to develop the system. Constrained Application protocol (CoAP) and web application has been used to complete the implementation of the system where the web application was mainly for controlling the irrigation through the Internet.

In [7], IoT has been used in order to analyze sensor devices which take in some physical information and address it back to the user. The paper is based on highlighting the methods used to solve problems such as recognition of rodents, risks to crops, and transfer of real time notification without the interference of human beings. Python scripts were used to incorporate the sensors and electronic devices.

In this paper, IoT was used to improve the security of crops from pests and insects in grain stores.

In [8], the concept of IoT and web services have been used in order to handle the huge data involved in the cultivation of land. The proposed work gives a brief idea of an experimental model of how IoT can be used to enhance agriculture field. A model blueprint of how IoT concepts have been suggested to be used in agriculture for better productivity. DHT11 sensors have been used in this system to predict both temperature and humidity simultaneously. The ZigBee sensor nodes which have been used in the prototype can detect natural factors such as temperature, humidity and light which are then addressed to the remote monitoring center. The sensor nodes and the data centers are connected by the CDMA, 3G, and 2G wireless broadband networks. WLAN 802.11 and Bluetooth are used for communications of nearest node. The sensor control module is liable for tracking the incoming information and process appropriately. Apart from all these, a cloud system could have been implemented in this prototype in order to have a better analytics and control on the system. In [9], [10] the author discusses about the soil type, moisture and other properties and their impacts. The authors in [11], [12] discussed the method of crop yield predictions and machine learning approach and perspectives to realize the same. In [13], [14] the authors discussed the methodologies to realize the wheat yield prediction usingmachine learning and soil data analysis using classification techniques.

We proposed a Smart Irrigation and Monitoring System which provides farmers with real time insights of their crops through the use of a cloud platform and machine learning (taking into account weather forecast for that region). The data is then transformed into a more meaningful way like graphs. The prediction is then generated by comparing the raw sensor data with weather forecast through a machine learning process. The weather forecast is obtained from Accuweather.com. The results obtained from the machine learning processing will enable farmer to take an informed decision as to when the water tap needs to be opened, that is, the farmer is informed about the probability of rain and whether he should irrigate or not. Consequently, the farmer is able to send a command to open the water taps remotely through a mobile application or web app. This will enable the farmer to save valuable time in terms of starting the irrigation process and thus water will be better managed. An app has also been developed in order to have a better view about the statistical data of the sensor values by means of graphs and also for any inquiry purposes about the application app.

III. Block Diagram of the Implemented System

The block diagram shown in figure 1 includes mainly the Sensor Node, Internet/Cloud, the User Node and the machine leaning which are described below.

1) **Sensor Node**
   It consists of sensors and appliances that are to be controlled. Sensors and appliances are connected to Arduino. It decides what sensor data are to be transferred to the cloud.
2) **Internet/Cloud Backend**
   For the implementation of proposed functionalities, Thingspeak cloud is used. All the sensor data sent by the Arduino using Wi-Fi module gets displayed in here. These data can be viewed and analyzed, by logging-in with right credentials.
3) **User Node**
   This is a user support layer. It is a platform from where user can access the Sensor data. An android app is used as a user node, where the authorized person can access data.

DHT-11, YL-69, are the temperature and moisture sensors will act as input to the controller, and will provide real time data regarding humidity, temperature of the atmosphere and moisture value of the soil on which crop will be grown. The Arduino communicates with the Thingspeak cloud and sends all the values for display. In the cloud data will be displayed in form of graph or discrete analog values.

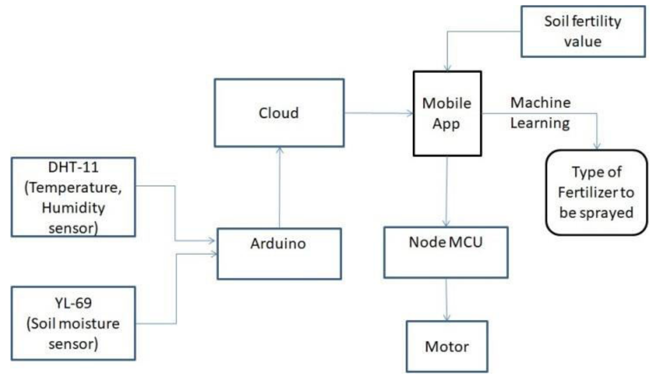

Fig. 1. Block diagram of IOT Based Irrigation System.

These values will also be displayed in the mobile app. The farmer will decide whether to turn ON or OFF the motor by comparing the soil moisture values with threshold values for optimum growth of the crop. From the mobile app, motor control commands will be sent to the Thingspeak account. With the help of Read API key of the Thingspeak, the Node MCU will receive the control signals and turn ON/OFF the motor accordingly. Machine Learning is used for prediction of the type of fertilizer to be used. With the help of formulas the amount of fertilizer is also found out.

A. System Architecture

The architecture of the system is shown in Fig. 1, which includes mainly the Sensor Node, Internet/Cloud and the User Node which are described below with their associated functionally.

1) System Features: The system is concerned with three major issues – Remote Access and Efficiency.

1) Accessing water motor
   The motor used for irrigation can be switched on or off remotely via internet. This allows user to optimize their electrical usage. The soil moisture is monitored constantly so that the motor can be switched on only when needed.
2) Efficiency
   With the addition of machine learning with IoT, the machine can be trained to give the type and amount of fertilizer to be used can be determined to suit the particular soil type. This will reduce redundancy and increase efficiency.
3) Appliances Monitor
   The work not only emphasizes on accessing the motor but also their status can be constantly monitored using Android App. Hence, unnecessary appliances consuming power can beturned off making the system power efficient when the soil moisture is apt for plant growth.

IV. Implementation

The implementation of the entire system is categorized in terms of Hardware and Software. The hardware part refers to sensor node assembly with Arduino and controlling the irrigation through Node MCU, and deployment of software and machine learning to integrate, process and analyze the data is the software part. Fig. 6 shows the overall flow and implementation steps of the proposed work.

A. Physical Environment

The first part is the plant section where sensors DHT11, YL- 100 Soil Moisture are for sensing the plant's atmosphere and moisture level of the soil respectively. The DHT11 is a cost-effective sensor that is used for monitoring both the air temperature and the humidity of air. The figure 2 depicts the DHT-11 connection with Arduino.

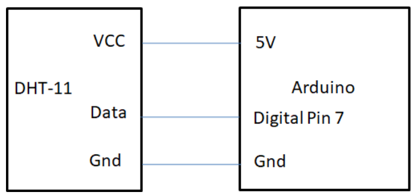

Fig. 2. Pin connection of DHT11 and Arduino

YL-69 soil moisture sensor is used to measure the soil moisture content. The moisture sensor outputs a high level when the soil lacks water otherwise it outputs a low level. Besides, the sensitivity of the soil moisture sensor is flexible and unlike other soil moisture sensors, the YL-69 sensor does not require any additional convertor to operate. The sensors send the readings to the Arduino through data pins. Figure 3 describes the connection between YL-69 and Arduino.

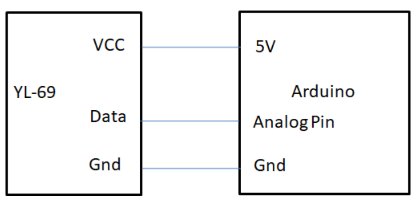

Fig. 3. Pin connection of YL-69 and Arduino

ESP-8266 Wi-Fi module has been used to provide the Arduino access any Wi-Fi network. The Arduino sketch has the Write API Key of the Thingspeak account in order to write the readings and display in graphical way. This describes the system hardware used at the sensor node end. The following figure 4 describes the Wi-Fi and Arduino connection.

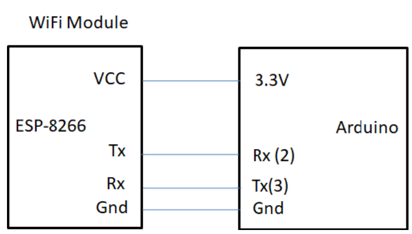

Fig. 4. Pin connection of ESP-8266 and Arduino

On the user end, submersible motors are used to irrigate the plants. Each motor is connected to relay which in turn is connected to Node MCU. When the switches in the mobile app are turned ON/OFF, the app also updates the motor ON/OFF status in the Thingspeak in terms of 1 (ON) or 0(OFF). The Node MCU which comes with integrated Wi-Fi module reads the status from the Thingspeak and sends respective commands to the relay which in turn drives the motors ON or OFF based on the decision taken by the user according the threshold moisture values of that particular crop to suit its best growth. Since threshold soil moisture values are not fixed for a particular crop as the crop may need different amount of moisture based on its growth period, it is left to the user to decide the threshold value and water the crop suitably. The motors controlled by the Node MCU are depicted in the following figure 5.

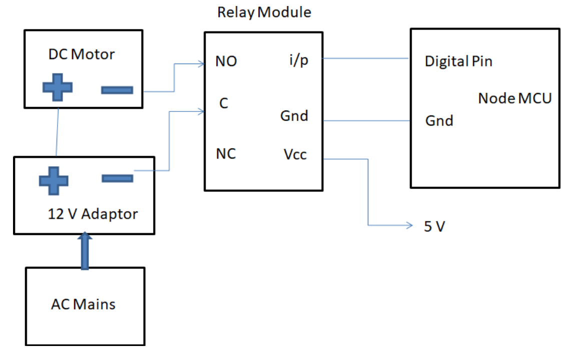

Fig. 5. Pin connection of Relay with Node MCU

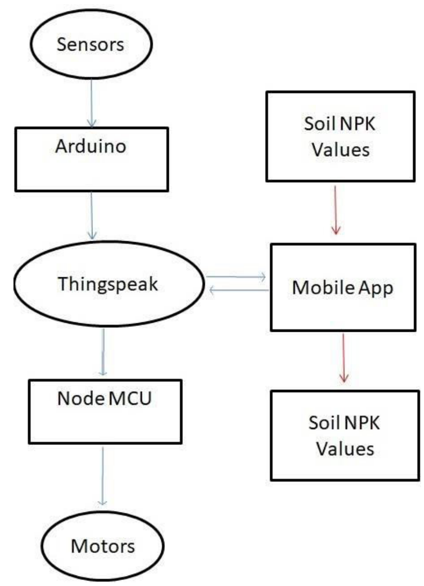

Fig. 6. Flowchart of the proposed work

B. Thingspeak IoT platform

The IoT is a service that allows bi-directional communication among devices. The IoT hub acts as a middleman between different services and the physical environment, that is, device to cloud communication and vice versa. It receives updated data from sensors regularly. In general, the job of the IoT platform is mainly for monitoring every IoT devices and links them together. For better precision, weather forecasts from Accuweather is included with the aim of knowing whether the water pump needs to be opened.

In the proposed project, all the sensor values are displayed. Arduino updates the sensor values by writing the values with the help of Write API Key available for every Thingspeak channel. The mobile app at the user end also displays the sensor values with the help of Read API Key from the Thingspeak channel. When the user switches ON/OFF the motors, the status of the motors gets uploaded to the Thingspeak channel by using the Update URL in the channel. The Thingspeak platform acts as a bridge which connects sensor node to the user in this proposed project.

C. Machine Learning

The machine learning is the core logic of the proposed system. Machine Learning is used for prediction of the type of fertilizer needed for a particular crop. The user enters N-P-K ratios of the soil which is tested for soil fertility. The dataset needed to train the machine contains N-P-K values of the fertilizers which are available for that particular crop. Decision Tree classifier is used to predict the best N-P-K ratio of fertilizer among the database. In general, a dataset is needed to train the machine to find patterns in the data in order to decide the type of the fertilizer. The data for soil fertility values and nutrient values of fertilizers ideal for the growth of a particular plant.

Decision Tree algorithm belongs to the family of supervised learning algorithms, and can be used for solving regression and classification problems too. The general motive of using Decision Tree is to create a training model which can used to predict class or value of target variables by learning decision rules inferred from prior data (training data). The Decision Trees algorithm is easy to understand as compared with other classification algorithms.

D. Mobile Application

All the sensor data displayed on the cloud platform will also be available in the mobile application. The mobile app also contains the prediction of fertilizer page.

The Registration allows the user to register his device with a password through which only he can login. This registration is important in cases where multiple farmers will use the app for automating the irrigation. The mobile application contains a navigation drawer which provides the farmer with a list of choices. There are three options which are available to the farmers in the navigation menu i.e. current temperature and humidity of the atmosphere, moisture level of the array of plants taken from DHT-11 and YL-69 sensors respectively are shown in Fig. 7 , and the fertilizer prediction option as shown in Fig. 8. This page will take the tested soil fertility values as input and gives the best fertilizer type and amount as the output.

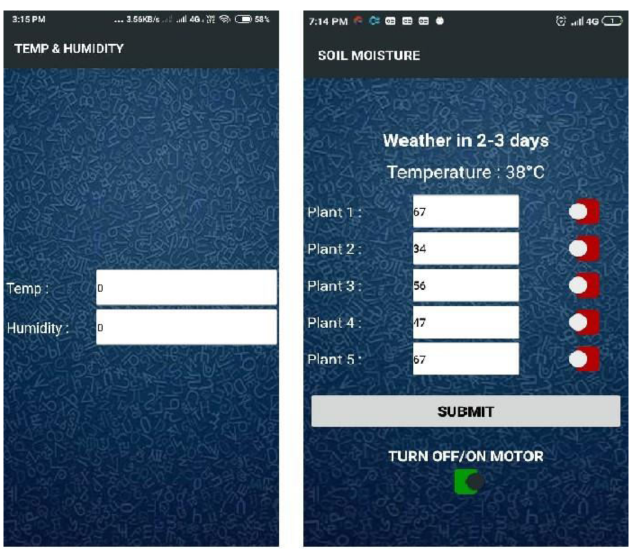

Fig. 7. interface showing the temp, humidity of atmosphere and moisture level of plants

In the Action menu, option to open the water pump with the switch ON/OFF button is provided, included with the separate buttons to open individual valve of the plants are also provided in case if anyone needs moisture .

In the case the third option is selected, the app will lead to the page where it will request the user to input the N-P-K values of the soil tested in lab. Based on the machine learning algorithm used, the app will predict the type of fertilizer and amount to be used.

Android Studio has been used to develop the mobile application as it is cross platform and hence it can target a maximum number of

Fig. 8. Interface showing the prediction of NPK values of fertilizer

users. Broadly, the mobile application notifies the user to open the water pump if irrigation needs to be done. The user will have the flexibility not to irrigate if he feels that it is not necessary to irrigate even if he has been notified to open the water pump. Assuming that the user chooses to irrigate, once the button “ON” is clicked on the mobile application, the signal will be sent Cloud which will in turn forward the signal to the microcontroller board to open the water pump for irrigation.

All the communication between the Arduino, Thingspeak cloud, Node MCU and the mobile app is with the help of API Keys provided for each Thingspeak account. These keys marked in the figure 9 help in writing, reading or updating the values onto the Thingspeak account.

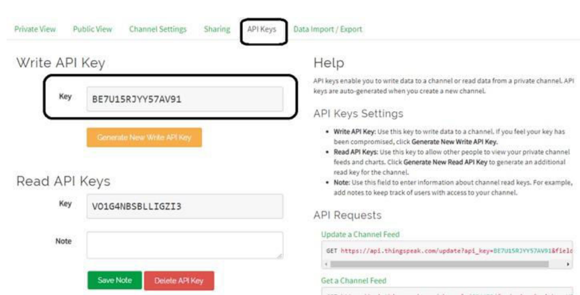

Fig. 9. Read and Write API Keys of the channel

The following diagram 10 shows the communication pathway between the Arduino, Thingspeak cloud, Node MCU and the mobile app through API Keys.

V. EVALUATION

The system mainly monitors the behavior of soil moisture, air humidity, and air temperature and sees how it contributes to evaluate the needs of fertilizer and correct amount of nutrients in a plant. The system uses simple if-else statement to compare actual values obtained from sensors with a threshold value that has been fed to the controller for analysis, cross checks the result obtained with weather forecast and then decides whether irrigation needs to be done or not.

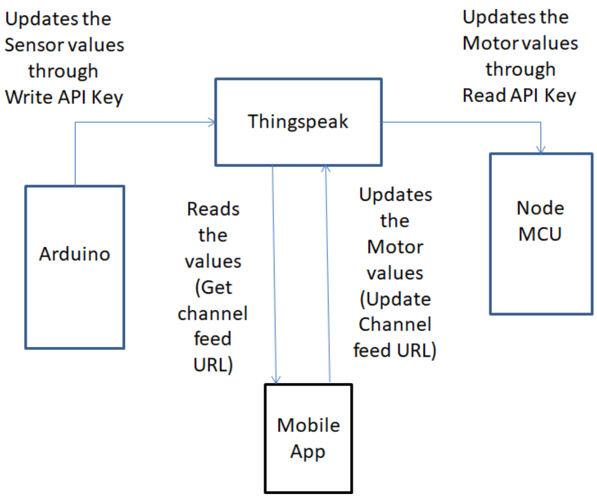

Fig. 10. Updating and reading of sensor and motor

The farmer receives a notification on his smart phone. Furthermore, the system also uses machine learning to predict the type of fertilizer needed and the right amount to optimize the plant growth. The machine learning can be calibrated for different types of plants i.e., the user is provided with a list of plant's choices in his mobile app. With this, a specific type of plant can be selected that is being cultivated.

VI. RESULT

The moisture values get displayed on authorized user's smartphone and get updated regularly. The data are also stored in the Thingspeak and timings are also recorded.

The implemented system is resource efficient. The right amount of water to be provided can be found out by measuring the moisture values of the soil. Depending upon the temperature level of the atmosphere surrounding the area, the motor can be enabled or disabled. If temperature is low, then the moisture level will not be less than the threshold value. Thus there is no need to water the plants. For this purpose, the motor switch button in the app is disabled.

The system consists of two subsystems, i.e., automating the irrigation and Prediction of fertilizer. Automating the irrigation part is again divided to reading the sensor values and switching ON/OFF the motors through app.

The sensor readings are also displayed on the Thingspeak platform as shown in the following figure. The mobile app displaying the DHT-11 values and individual moisture values of the plants are shown in figure 11 and 12.

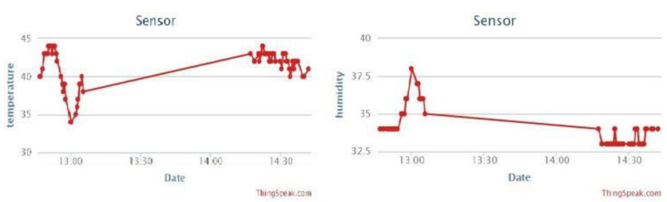

Fig. 11. Humidity and Temperature values displayed in Thingspeak

The Thingspeak account also displays the motor status, i.e. 1 or 0 for ON or OFF respectively. Depending upon the status of motor switches, Thingspeak shows the ON/OFF state of the motors as shown in figure 13. The following figure depicts the working. After reading

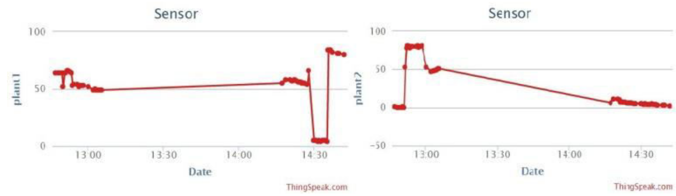

Fig. 12. Soil moisture values displayed in Thingspeak

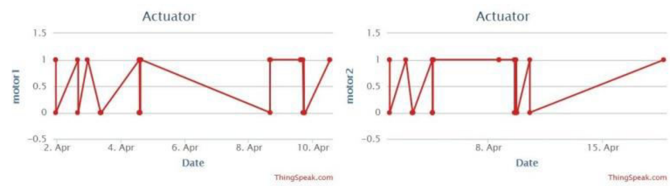

Fig. 13. Motor status shown in Thingspeak (1 = ON, 0 = OFF)

the updated states of the motors from Thingspeak Read API Key, Node MCU turns the motors ON or OFF.

The second subsystem consists of the prediction of the type of fertilizer suited for a particular plant.

In the app, the user inputs the fertility ratios of the tested soil. The app based on Machine Learning algorithm predicts the type of fertilizer. Then the amount of fertilizer to be sprayed in kg/hc or lb/acre unit is found with the help of proper formula. The app is also provided with the online retailer link of the fertilizer where the user can buy. The app uses Decision Tree classifier () to predict the type of fertilizer. The database of the NPK values required for the training of the algorithm is stored in the local server set up by Xampp server. The following figure 14 depicts the prediction part.

After getting the type of fertilizer, the amount to be sprayed is calculated by subtracting the predicted NPK values of the fertilizer with the tested soil NPK values which the farmer has entered in the app. The largest difference is then divided by the respective N, P or K of the entered value. This gives the amount of fertilizer in terms of lbs per acre. To get the amount in standard value in Indian market, the value is multiplied with 1.12 to obtain the amount in kg per hectare. 1.12 is the conversion factor from lbs/acre to kg/hc.

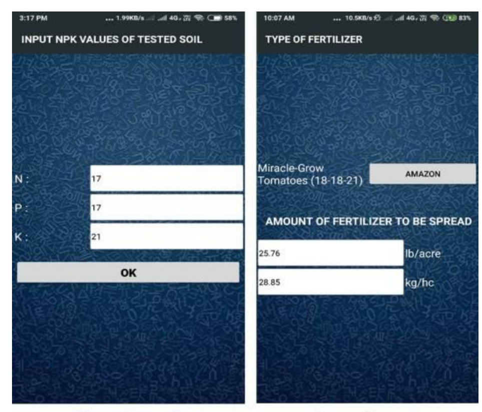

Fig. 14. The app showing the prediction of fertilizer

VII. CONCLUSION

IoT and Machine Learning based Agriculture system includes sensing of humidity and temperature of the environment, reading the soil moisture values of the array of plants and uploading the values to the Thingspeak platform and android app. The user can see the updated readings of the sensors in the android app also. Based on the type of crop and its growth stage, the user decides the threshold level of moisture in the soil. In case the moisture falls below the threshold, the motors are controlled through the app.

Another subsystem part of the project is prediction of the type of fertilizer to be sprayed on the fields. The tested soil report details the fertility of the soil in terms of N-P-K ratio. Upon entering the values of the fertility ratios of the tested soil, the app based on Machine Learning predicts the type and amount of fertilizer to be sprayed in kg/hc or lb/acre unit by using Decision Tree algorithm. The app is also provided with the online retailer link of the fertilizer where the user can buy the fertilizer online if interested.

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