Design and Development of Cloud-IoT based Soil Health Monitoring System

Priyanka Patidar[1] Sunil Joshi[2]
[1,2]Department of Electronics and Communication Engineering
[1,2]College of Technology and Engineering, MPUAT, India

Abstract— The journey of an Agricultural crop from seed germination to the harvesting stage encounters several stages of physical and biochemical changes. The Soil parameters like moisture, macronutrients, and micronutrients play a decisive role to get a healthy agriculture crop with minimal investment and maximal productivity. The information about real-time values of Soil parameters to the end users (farmers) along with scientific advice is essential to avoid over-use or under-use of resources like water and fertilizers, leading to optimal resource utilization. The paper presents Soil sensing technique using NPK testing kit and other conventional methods with loamy soil type of Udaipur region, and its IoT interfacing to measure and digitally disseminate the real-time on-the-soil / information of soil health to the farmers. Further, a cloud based prognostic approach is adopted to assist the farmers for their pilot crops and field fertility. The proposed technique can be a novel effort in digitalization of manual Soil Health card (Mrida card), and help farmers to increase crop productivity through minimal investigation water and fertilizers.

Keywords: Soil Parameters, Internet of Things, Sensors, Gravimetric and Kjeldahi Methods, Cloud Computing

I. Introduction

India is a country of farmers in which one third of the population depends on agriculture production, with substantial impact on the food production and economic growth of Country [1]. The precision Agriculture can easily monitor and control the changes occur in the Soil parameters. The Site- Specific management IoT based platform uses the design of SmartFramNet to collect the environmental soil and fertilization irrigation data. Manually it can't able to collect such huge information on real time because there is less number of laboratories in the states of country for testing the Soil parameters. It is difficult for farmers to get correct and precise information about their Soil status [2]. Presently, chemical techniques are in practice to measure the valid soil parameters using Soil testing kits confined to laboratories to test more than about 1 crore soil samples every year, which is in the form of soil health card (Mrida card) and provide to the farmers of India [3]. This card only gets physical intervention and give information through very long process. To solve this problem, IoT can help the farmers to control their crops remotely and take appropriate action. Advantage of proposed technique is to digitalize the traditional methods and reduce the testing time, less cost and make it energy efficient [4].

In this paper, a survey of smart adaptive irrigation and fertilization technique based on IoT platform is described. The two parameters which we discussed in this paper are: Soil moisture and Macronutrients like nitrogen (N), phosphorous (P) and potassium (K) [5]. These precious resources must optimally used to maximize the crop growth. The aim of proposed paper is to develop a low-cost cloud-based module used to determine the level of soil moisture and trace macronutrients. The module is to be interfaced with gateways and cloud data to the user as agriculture input. These efforts would help farmers to increase the crop production and also for optimum resources utilizing via fertilizers and water. This paper explores the changes current manual chemical methods into digitalization, which shows the main disadvantages of time consumption for detection of soil.

In IoT research work some literature review is been described, Vani et al. [1] described he monitoring of soil parameter system using IoT with interfacing of Cloud Computing. Mekala et al. [2] explores the information of information of agriculture and sensor monitoring using Cloud IoT technology for store the performed data on field. Jayaraman et al. [4] presents the design of SmartFarmNet an IoT based information of environment of field, irrigation data etc. Athani et al. [5] had developed an automated model to monitor and measure the moisture level using Arduino microcontroller to another Wi-Fi module. This paper based on soil management for North Karnataka- India. Ferrandez et al. [8] proposed technique using IoT with low cost sensors and actuators networks to interface protocols in agriculture field.

II. Proposed System Model

The proposed system model describes hardware and processing sections are as follow:

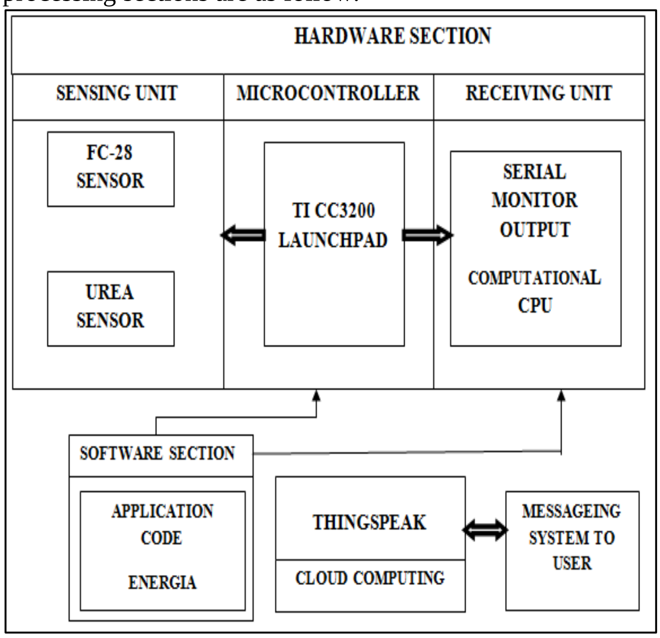

Fig. 1: Schematic Diagram of Proposed Technique

System model consist of major sections via, Hardware, software and cloud computing section. Hardware section contains sensing unit where sensors are used, microcontroller where CC3200 Launchpad used for interfacing and receiving unit to show the output data on serial monitor. While software section contains application code in Energia platform and Thingspeak application used for cloud computing. At last all the information from environment send to the user in the form of messages. "Fig. 2", describes the CC3200 Lauchpad microcontroller.

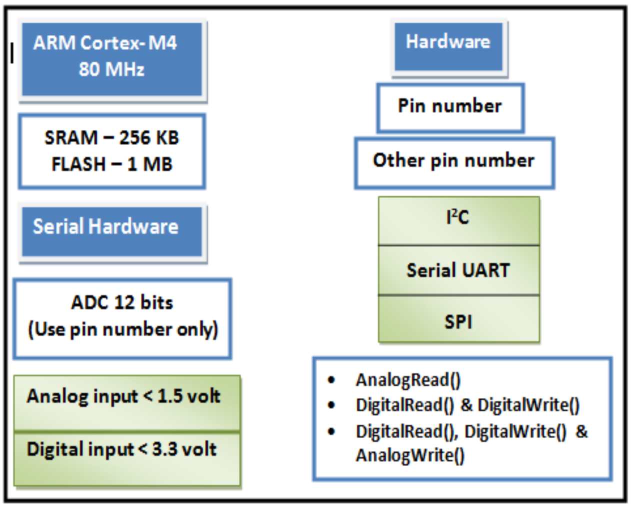

Fig. 2: CC3200 Microcontroller

CC3200 microcontroller Launchpad with Wi-Fi connectivity built with integrated Cortex-M4 ARM. The 2.4 GHz Wi-Fi controller combines PHY / MAC and TCP / IP network engines.

It supports Energia integrated development (IDE) and work on 12- bit ADC with analog input pin less than 1.5V and digital input is less than 3.3V.

Soil can easily to adopt and can depict various soil health parameters. FC-28 sensor is used for the measurement of soil moisture, it work in terms of analog voltage also the sensor module has a potentiometer to adjusting the sensitivity level. The operating voltage is 3.3 – 5v [5]. These two probes putting into soil sample and get output signals, LM293 comparator having GND, VCC A0 and D0 pins.

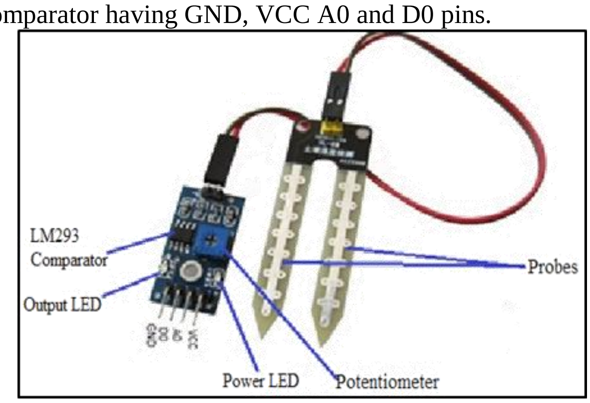

Fig. 3: The Soil Moisture Sensor

As we know that urea having mainly nitrogen content of 46 percent and this paper describes the measurement of soil urea through TCS3200 color sensor process interfaced with microcontroller. "Fig. 4", contains four white color LEDs to produce the white light which will fall on the test tube and then the reflected light will be read by the sensor.

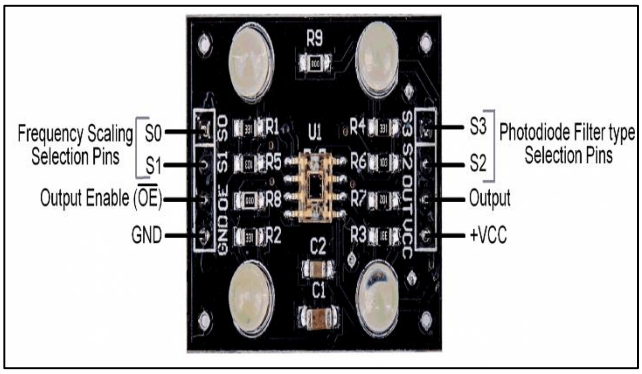

Fig. 4: TCS3200 color sensor

Sensing the Nitrogen, Phosphorous and Potassium contents in the soil are not easy as they involve some chemicals to react with the soil and give the results in form of color change due to reaction of the contents.

III. METHODOLOGY FOR LABORATORY TECHNIQUES

This research work is based on a field experiment involving the collection of soil samples and their chemical and physical analysis. To measure soil moisture, the laboratory technique uses direct and indirect techniques. Thermo-gravimetric, using methyl alcohol and volumetric methods are direct techniques. The gypsum block (resist), tensiometric, neutron probes and pressure plates are indirect techniques.

In the present work we used the thermo-gravimetric method to measure soil moisture. In this technique, the mass of soil with water content is measured according to weight before and after the drying process in an oven at 105 ° C for 24 hours. Soil water content is expressed on a gravimetric method and θg represents gravimetric water content. Here weight represent = wt.

Wt of water = wt of wet soil – wt of dry soil …. (1.1)

θg % = (wt of water/ wt of dry soil)*100 …. (1.2)

Fig. 5: Gravimetric process

For the measurement of soil urea through laboratory technique there are mineralisable nitrogen method which is also known as availability of nitrogen of kjeldahi method and estimation of exchangeable nitrogen method which is known as total nitrogen. Here we are used kjeldahi method for the nitrogen detection which is generally adopted to get a solid record of nitrogen in the soil. Calculations for 750g of soil samples, urea amount are 46% of nitrogen where 46g of N is 100g of urea so 7.5g of N having 16.30 g of urea.

Availability of N in soil (Kg/acre) = (S-B)*10^6*2.24 ..(1.3)
= (S-B)*0.8636 …(1.4)

Where S and B represents the titre value of sample and blank respectively.

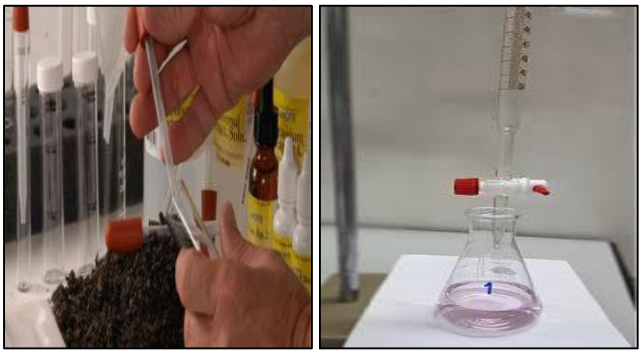

Fig. 6: Kjeldahi flask process

IV. IMPLEMENTATION PROCESS

The method to execute the proposed technique is as indicated in flow diagram of fig. 7:

1) According to the initial process, we take soil samples for interfacing the sensors with microcontroller by the use of analog to digital converter.
2) Other two sensors are active and examine the moisture level and urea content present in the given soil.
3) Developing a code with standard database in Energia IDE.
4) Now, transmit the data serially and comparing it with dry or wet condition of soil.
5) After comparison, it generates correction factor.
6) After getting decision of received information data is interface with cloud based module.
7) Finally get message on mobile phones.

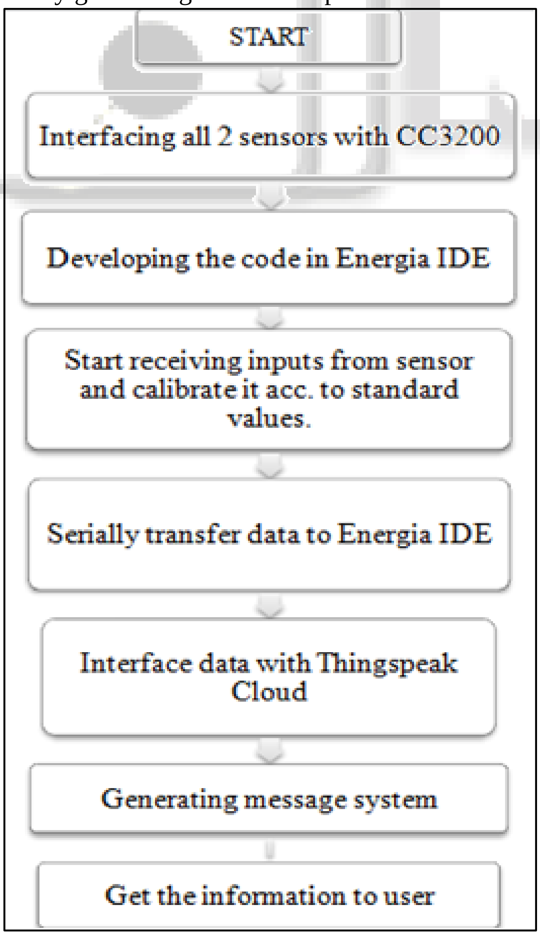

Fig. 7: Flowchart of the proposed work

A. *Integration of Sensor with Cloud*

The sensor is interfaced with microcontroller having on chip Wi-Fi connectivity which is used to send data from sensor directly to the cloud. In this research work we have been used Thinsgpeak cloud technology. Thingspeak is an open source platform that allows us to visualize, analyze and store the real-time data into the cloud. The data from your device is instantly posted on the Thingspeak cloud. The information is shown in a graphical way with respect to date and time, although we can change graphical styles. This platform makes use of APIs to store and recover information from the gadgets utilizing the HTTP protocol over the internet.

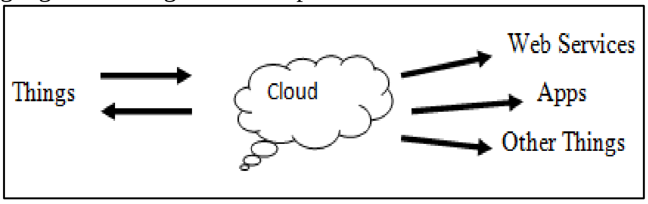

Fig. 8: Thinsgpeak cloud process

B. *MSG91 for Alert Message System*

After the completion of cloud data process we are used MSG91 application for send messages to the user to get information about soil parameters.

Develop an account of the MSG91 application and use this API key in the specific design code after connecting the MSG91 to the micro-controller, we must connect it to the Wi-Fi server and send a message according to the terms condition. Create MSG91 terms in any language, and messages in the form of SMS, voice, email, etc.

Hardware setup- Soil monitoring sensors viz. soil moisture and TCS3200 color sensor are interfaced with microcontroller module as shown in below fig. 9.

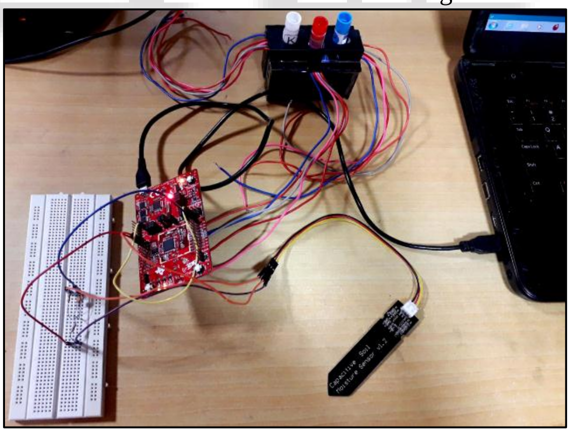

Fig. 9: The soil monitoring system

V. RESULTS ANALYSIS

In this paper we have developed a soil monitoring system prototype for two parameters viz. soil moisture and soil urea with loamy soil type of Udaipur region. The given experiment was first conducted using gravimetric method for measurement of soil moisture and kjeldahi method for measurement of availability of nitrogen. The soil moisture values having the ranges from 0-40% then sensor are in dry soil, if moisture content ranges from 40-80% then soil would be humid or optimal, or if it is above 80% moisture content then water level is excessive in amount.

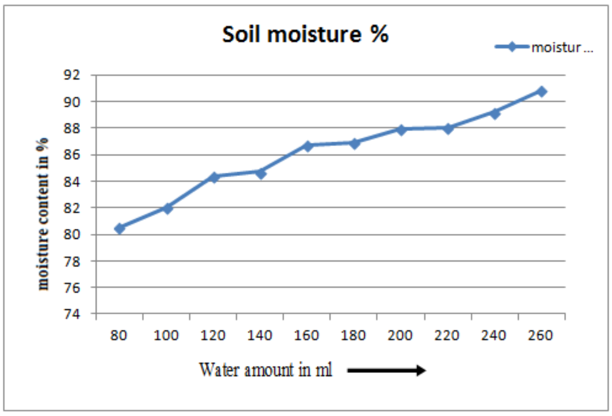

Fig. 10: Moisture data given by Gravimetric method *(weight of soil: 750g, soil type: loamy, gap of water added into soil: 20ml).

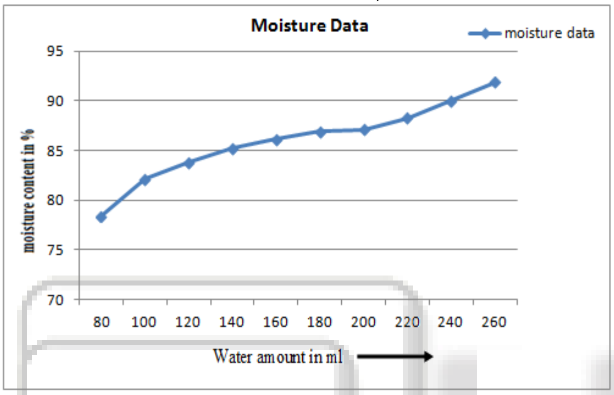

Fig. 11: Moisture data given by Proposed Sensing Technique *(weight of soil: 750g, soil type: loamy, gap of water added into soil: 20ml).

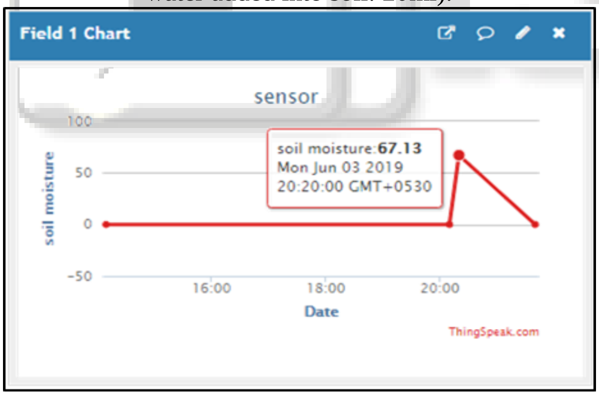

Fig. 12: Screenshot of Moisture data on cloud with respect to time, date and day.

S.No.	Moisture data by Gravimetric method in %	Observed value given by sensor in %	Deviation in %
1.	80.5	78.41	2.09
2.	82.01	82.12	0.11
3.	84.4	83.81	0.59
4.	84.7	85.20	0.5
5.	86.7	86.11	0.59
6.	86.9	86.96	0
7.	87.9	87.11	0.79
8.	88.01	88.29	0.28
9.	89.02	90.02	1.1
10.	90.8	91.88	1.08

Table 2: Comparison between Gravimetric Method Data and Sensor Data Output

*(Calibrated values in terms of percentage)

Some results have been described in table 2, that how sensing technique is much better than physical method which happens in laboratories. Comparison table shows the moisture data through gravimetric technique and proposed sensing technique data for soil moisture.

For the measurement of soil urea there is 46 percent nitrogen available but in this paper we have shown the amount of nitrogen present in soil as well as phosphorous and potassium present in the soil which man whole NPK amount. Below fig. 13, shows the soil urea measurement using kjeldahi method.

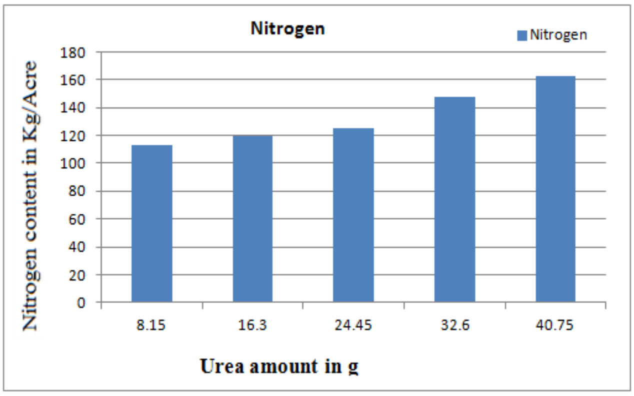

Fig. 13: Availability of Nitrogen using kjeldahi method *(weight of soil: 750g, soil type: loamy, gap of water added into soil: 140ml, urea amount added: 8.15ml to 40.75ml).

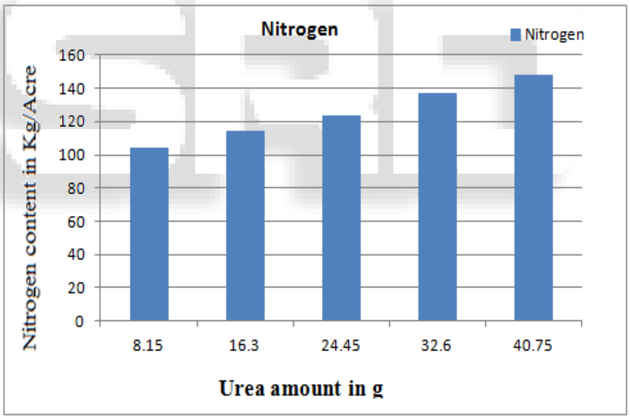

Fig. 14: Plot of Nitrogen data using Proposed Sensing Technique.

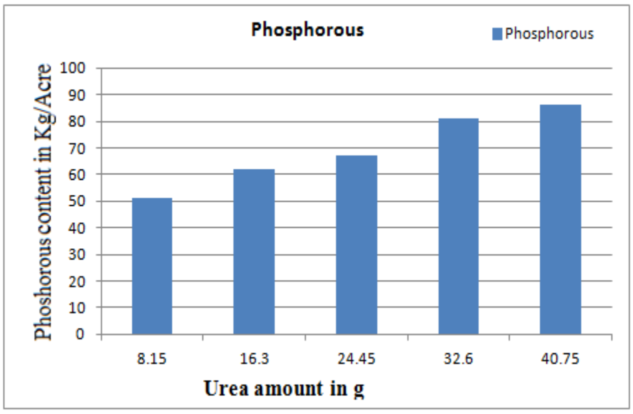

Fig. 15: Plot of Phosphorous data using Proposed Sensing Technique.

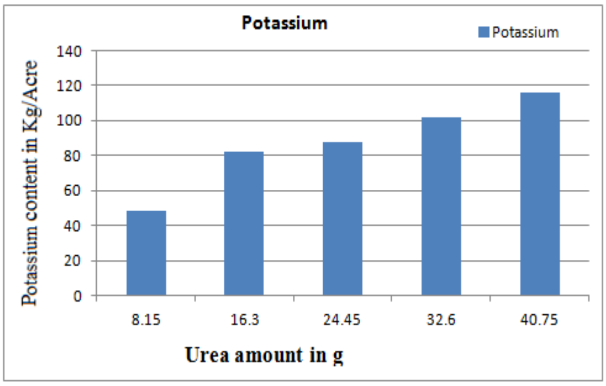

Fig. 17: Screenshot of Nitrogen data on cloud with respect to time, date and day.

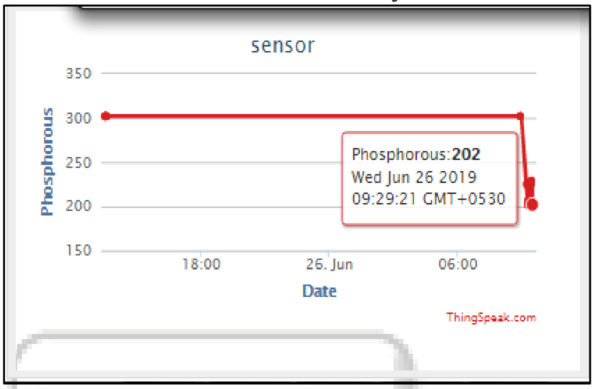

Fig. 18: Screenshot of Phosphorous data on cloud with respect to time, date and day.

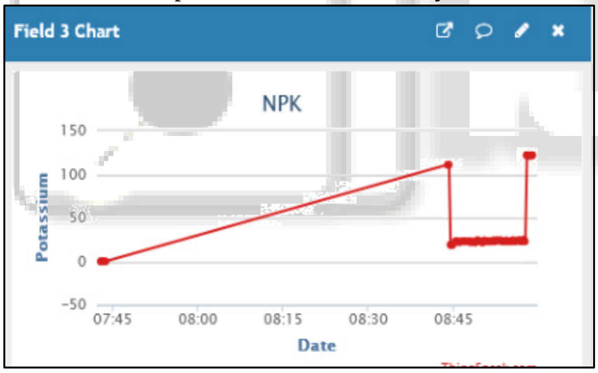

Fig. 19: Screenshot of Potassium data on cloud with respect to time, date and day.

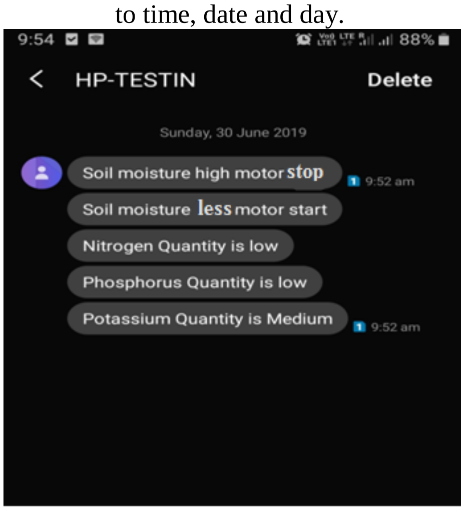

Fig. 20: Screenshot of Alert Message System on phone through MSG91 application in English.

After getting data from sensor we can interface with cloud computing and messaging system applied to give instant information to the user in English language. Thus user can also take appropriate decision according to the parameters.

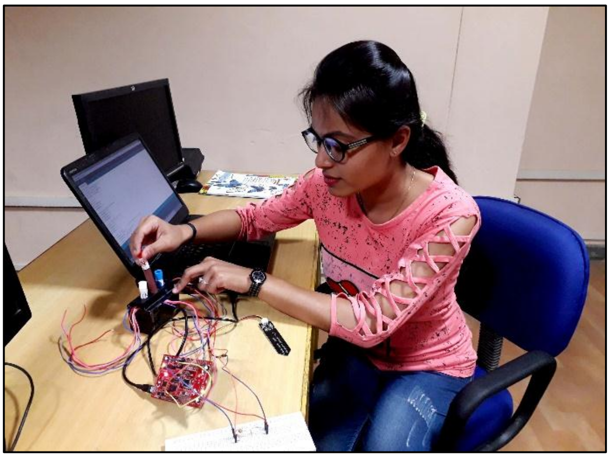

Fig. 21: Real Time Setup of Hardware System.

VI. CONCLUSION

A novel sensor based Soil Health Monitoring technique is proposed and discussed. Combining Soil moisture level and Urea concentration parameter provides a very good data results in terms of low cost, time consuming, accurate and precise data given by device and energy efficient. The accuracy of proposed soil monitoring system is 99.33% and precision is 100% and the given error percentage is 0.2%. Laboratory technique for measurement of soil moisture and soil urea takes approximately 10 days whereas proposed sensing technique performs the same measurements in approximately 2 minutes and sensor data displaying on cloud within 30 seconds. This effort would help farmers to increase the crop production and also for utilizing optimum resources viz. fertilizers and water. After comparing with existing work, it is concluded that the proposed approach delivered the best solution for soil monitoring system prototype.

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