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Real-Time Soil Monitoring with IoT Enabled System for Crop Prediction

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ABSTRACT

Background: Sustainable crop production in the vast populated countries such as India has always been challenging problem since ancient times. The mismanagement of crops has led to reduced yields. It is of utmost important to study the Soil conditions and predict the suitable crop for cultivation under such conditions.

Methods: In the present investigation a gadget is developed based on IoT and Arduino to monitor the soil based on parameters like pH, temperature and moisture, which helps in identifying soil conditions and decide the suitable crop and their management practices. For this purpose, the dataset of different crops has been passed with their parameters. Blynk application is used for remote monitoring. Hence the user can remotely view sensor data, log and view data, *etc*.

Result: The results suggested that even after 24 hours of irrigation the black soil holds the high volumetric moisture. The device was correctly able to identify the suitable crops under the investigating environment *viz* Wheat, Lemon and Sunflower for Black soil. The system recommends the type of fertilizers that may be used and also the microbial condition of the soil. The system would enable farmers for better selection of crops under different conditions.

Key words: Crop prediction, IoT application, IoT sensors, Moisture sensor, pH sensor, Real-time monitoring, Temperature sensors.

INTRODUCTION

Since improving the agricultural sector has become the most difficult problem for countries with vast populations, such as India, new technology must be used. For agriculture to advance, new technology must be introduced into the farming sector. The objective of this study is to investigate crop mismanagement based on soil parameters. Due to their various parameters such as soil moisture, temperature, pH, nitrogen, phosphorus and potassium different types of soils are appropriate for different types of crops. Soil is composed of mainly five ingredients namely soil organic matter, soil air, minerals, living organisms and water and its composition changes from one location to another.

Various studies have been conducted to monitor water and temperature of the soil, however only limited studies have focused on the favourable conditions for crops and their prediction. Pravallika *et al*., (2020) gives insight into model of the system for crop prediction using IoT, however the paper has not provided the information about the mineral deficiencies and solution by which we may improve the soil conditions and make it favourable for a particular crop. Chen and Yang, (2019) refers to the IoT solution architecture, application, processing, transport perception.

In this paper, the proposed set up not only gives the favourable crops for the soil, but also provides data by which one may make soil more favourable for crop production. For this purpose, various sensors such as moisture, temperature, pH sensor have been interconnected with Arduino. In this set up, temperature and moisture sensors are placed at various locations of the farm area for soil monitoring of crops (Nandurkar *et al*., 2014). pH sensor is also located at single point to measure the pH of the soil. Arduino is programmed to read the moisture, temperature, pH of the soil using Arduino IDE. The algorithm of program is designed in such a way that the system may predict the crops to be sown under various soil conditions. In addition, predicting the soil parameters and crops the gadget also gives valuable information by which the farmer may improve soil condition and make it more nutritious. These Information may be viewed on serial monitor of the computer. IOT is used to obtain stored data monitoring and real time monitoring of various contents of soil (Shamiur and Al 2021). The proposed device works in real time and it is very cost effective. The sensor node sends the data to the microcontroller connected to the Wi-Fi module that sends the data to the smart phone. Here, the utility is used to show soil traits through IoT. The proposed set up (gadget) may

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be used with reliability because the soil sensors have proven great results. The proposed system not only finds the basic parameters of the soil but also gives a good look inside the soil nutrients and crop prediction. This work will provide equipment for distant monitoring of soil properties, make an important contribution and take a step towards integrating IoT and agriculture to reach the goals of smart agriculture.

Poornima and Ayyanagowadar (2018) refers to the various research that has been conducted to improve the agricultural practices and to implement new technologies in agriculture using IoT. Approximately, more than 90% of Indian soil samples exhibited low nitrogen and phosphorus content, while 50% of soil samples were low in potassium (Karthik and Uma Maheswari 2021). Sowmiya and Sivaranjani (2017) gives information about the suggestion of pesticide. This reduces the workload of the farmer because they get information about the crop yield and soil. The role of IoT has increased for auto pumping and to send information wirelessly (Vanaja *et al.* 2018, Vijayakumar and Rosario 2011). Around 73 mobile applications are used by the Indian farmers in various agricultural sectors (*viz* Farm management, livestock, animal husbandry *etc*) (Balkrishna *et al*., 2021). IoT devices can exchange data with other connected devices and application or collect data from other devices and process the data either locally or send the data to centralized servers or cloud-based applications backend for processing the data (Ray 2017). Chopra *et al*. (2019) refers to the functional block for IoT system. Rawal (2017) gives the flowchart of the data transmitted from the sensors to the mobile application. For soil moisture content estimation, the inverse relation between soil resistance and soil moisture has been utilized and corresponding circuitry has been developed. The determination of soil temperature is done using the DS18B20 sensor working on Dallas one wire protocol (Ahmad *et al*., 2016).

The proposed device works in real time and it is very cost effective. The sensor node sends the data to the microcontroller connected to the Wi-Fi module that sends the data to the smartphone. Here, the utility is used to show soil traits through IoT. The proposed set up (gadget) may be used with reliability because the soil sensors have proven great results. The proposed system not only finds the basic parameters of the soil but also gives a good look inside the soil nutrients and crop prediction. This work will provide equipment for distant monitoring of soil properties, make an important contribution and take a step towards integrating IoT and agriculture to reach the goals of smart agriculture.

MATERIALS AND METHODS

The experiment was conducted during August 2020-2021 at Rajkiya Engineering College, Ambedkar Nagar Uttar Pradesh. Majorly 3 soils were used for experimental studies. The soil is Black soil, locally known as *regur* mostly found in the areas of Maharashtra, Gujrat and Western Madhya Pradesh. It is Clayey in texture, Deep black to Gray in colour. The pH of the soil varies from slightly alkaline to slightly acidic. The alluvial soil locally known as *khadar* found in regions of Indo-gangetic planes, Punjab, Haryana, Uttar Pradesh etc are used in the experiment. It is loamy in texture, light and porous. The Red Loam soil found in the states of Tamil Nadu, Madhya Pradesh Orissa etc are used in the experiment. It is cloddy, porous and deficient in concretionary Material. The soil was 1-1.25 meters deep. Using Several sensors, the real- time soil Monitoring system measures the various parameters and send them to the user via cloud to BLYNK Application. The system used 2 requirements mainly hardware and software. Arduino microcontroller, Soil Moisture Sensor, Temperature Sensor, pH sensor, Node MCU was used as hardware requirement. Arduino IDE and BLYNK application was used as software requirement. Table 1 shows hardware and Software requirements.

The proposed system works on the data obtained from the sensors. In this project moisture and temperature sensors are placed at different points in the field. In order to know the acidity of soil pH sensors has also been placed. Soil pH gives the hint of necessary nutrients present in the soil. All of these sensors are connected to the Arduino board. The Arduino board is programmed to read the data from the sensors**.** An array of dataset for different crops had been programmed in the Arduino. These datasets are in such a way that it gives the ambient moisture, Temperature and pH for the various crops as given in Table 2. Data accumulated from the sensors is collected in the Arduino and proper mapping is done from the given dataset. Those crops which satisfy the range of moisture, pH and Temperature are the suitable crops to be grown. ESP8266 wi-fi module is used for wi-fi conversation with the android. When powered on, microcontroller initializes the peripherals for conversation with the sensors. The microcontroller unit takes samples separately from the sensor and analyzes them primarily based on a user-supplied program. Arduino then serially communicate with NodeMCU and the statistics is dispatched to the cell utility via wi-fi transmission. The data may be seen on any mobile application or website that is compatible with NodeMCU. The circuit Diagram is shown in Fig 1.

The system gives the list of crops that may be sown under the analyzed soil condition on serial monitor of Arduino IDE. It also gives the information about the soil conditions, bacterial growth and methods to improve the soil conditions. In order to obtain such information, the Arduino is given certain set of instruction such that it may give correct information according to the parameters that have been measured by the sensors. In this proposed system, most of the data such as fertility of soil, bacterial growth, fertilizers recommendation and crop prediction are solely based on the pH sensor. Therefore, the accuracy of pH sensor used in the system should be high.

RESULTS AND DISCUSSION

In this section the experimental analysis of the setup has been performed for different soils. The data is presented in the tabular and graphical format. The data was taken during the month of November 2021. Field was irrigated at 2 p.m.

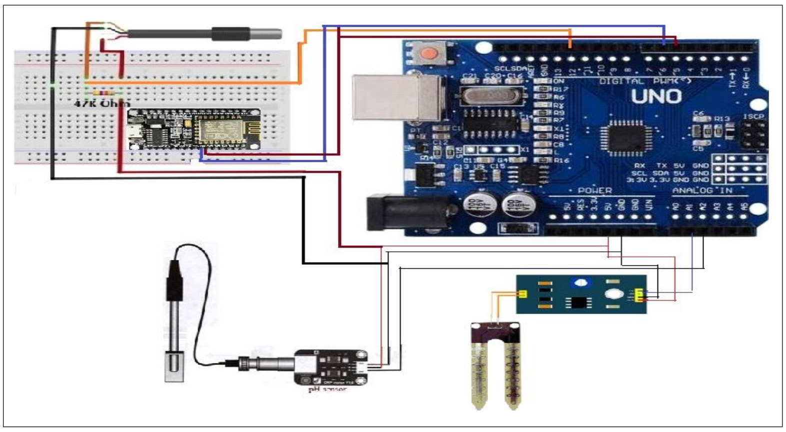

Fig 1: The circuit used in the experiment.

Table 1: Hardware and software requirement.

	Hardware requirement	
Hardware	Configuration	Function
Arduino uno	Arduino Uno operate at 5 to 12 DC voltage. It has ample computing power to run the program and to read many sensors at single time	Arduino uno was the main part of this system and the sensor data was fed and read by Arduino microcontroller.
Soil moisture sensor	Operating voltage is 5 volts. The current required is <20 mA	Used to measure the volumetric water content of the soil.
Temperature sensor	DS 18B20 sensor is used. The temperature range is from 55°C to 125°C.	Used to measure the temperature of the soil.
pH sensor	Operating Voltage is + 5 V.	Used to Measure the pH of the soil.
Node MCU	Operating Voltage is 3.3 V. It has computing power to read the data from the sensors and communicate with Arduino	It is used to serially communicate with the Arduino and send data to the mobile application.
	Software requirement	
Software		Functions
Arduino IDE		Used to program Arduino to read,map and display the data from the sensors
BLYNK		Used as and IoT platform to display the sensor data

and data was recorded each hour. Fig 2 represents the flowchart for different types of actions or steps in the process.

Algorithm

Input

Real time agricultural data (temperature, soil moisture, pH).

Output

1. As per the sensor data from the agricultural farm the required libraries are imported.
2. Coding the microcontroller to read the moisture, temperature and pH data.
3. Setting the code to constantly monitor the changes is field environment at constant interval.
4. Collection of real-time data from the agricultural farm.
5. Load the array of dataset of different crops for various soil conditions.
6. Predict the crop for real-time data by choosing appropriate crops from the given dataset.
7. Send the data accumulated over internet for remote monitoring.

Table 3, 4, 5 illustrates the data obtained by the sensors for different soils. The data is taken over the course of 24 hours before and after irrigation to get the idea of water holding capacity of the soil. The moisture content, temperature, pH of the soil is collected for different time before and after irrigation. Plants display symptoms of extreme water deficiency when the required levels of moisture are unavailable in their habitat soil (Chadha *et al*., 2019). while excess water may produce plant stress, water logging, runoff and leaching of fertilizers. Heavy rain or over irrigation can cause soil to be saturated.

Table 4 presents the data obtained from the black soil. The study illustrates that even after 24 hours the moisture content in the soil is around 32.11%. This is due to the

Table 2: The ambient moisture, temperature, pH for different crops.

Crops	Moisture in %	Temperature (°C)	pH
Rice	70-95	15-36	5.5-7
Wheat	25-45	10-30	6-7.3
Carrot	70-85	18-26	4.5-6
Potato	50-75	12-25	4.8-6.5
Apple	20-30	4-30	5-6.5
Lemon	40-60	21-38	6-7.5
Sunflower	50-58	20-25	6-7.5
Blueberry	35-45	20-26	4-6
Tobacco	40-60	14-35	5.5-6
Pumpkin	50-75	21-32	6-6.5

Table 3: Sensor evaluation of the data on alluvial soil.

Alluvial soil	Moisture in %	Temperature (°C)	pH
Pre irrigation	5.77%	30.21	-
After irrigation	89.18%	24.15	6.1
After 12 hours	31.15%	26	6.2
After 24 hours	20.52%	28	6.2

Table 4: Sensor evaluation of the data on black soil.

Black soil	Moisture in %	Temperature (°C)	pH
Pre irrigation	4.12%	26.04	-
After irrigation	84.22%	21.51	7.1
After 12 hours	51.62%	22.72	7.2
After 24 hours	32.11%	23.33	7.2

Table 5: Sensor evaluation of the data on red soil.

Red soil	Moisture in %	Temperature (°C)	pH
Pre irrigation	9.1%	26.34	-
After irrigation	79.42%	22.33	5.5
After 12 hours	42.23%	22.82	5.6
After 24 hours	17.4%	23.2	5.8

presence of Clayey nature of the soil proving its high-water retention capability. While Table 5, presents the water holding capacity of red soil which is lesser than black soil, similar results were reported by (Malavath and Rajeshwar 2015). Hence the water retention capacity of different soils under study were black soil > alluvial soil > Red soil.

Fig 3 (a), (b), (c) shows the trend of moisture, temperature and pH of all 3 soils. The negative slope of Moisture indicates the decrease in volumetric content of water over the period of time. Slope is steeper just after the irrigation as most of the water moves in the large pores of the soil and drains quickly. The slope at night is gradual incline indicating the lower loss of moisture during night.

Soil temperature is the essential aspect that drives the germination of the crops. Most soil organism work best at optimum soil temperature. The temperature range for maximum growth of most agricultural plants is between 15! and 40°C. The solubility of various substances in plants depends on temperature.

Soil pH play an important role in availability of nutrients essential for plant growth. The solubility of nutrients as well as chemicals in water are affected by its pH value. Some minerals are readily available under acidic conditions, but some exist under alkaline conditions. Optimum pH is between 6.0 to 7.0. Low pH (<5.5) indicate acidic soils and higher pH (>8) indicate alkaline soils.

From the Tables 3, 4, 5 above it may be concluded that red soil is slight acidic in nature, while alluvial soil and black soil may be considered as neutral and slightly alkaline. (Dora Neina 2019) refers that acidic soils may lead to aluminum toxicity, manganese toxicity, magnesium deficiency and calcium-deficiency in soil. Alkaline soils can cause a deficiency in zinc, copper *etc*. Fertilizers such as ground sulfur and ammonium-based nitrogen fertilizers are used to lower the pH and naturally acidify the soil. Lime or dolomite may be used to increase the pH rate of the soil.

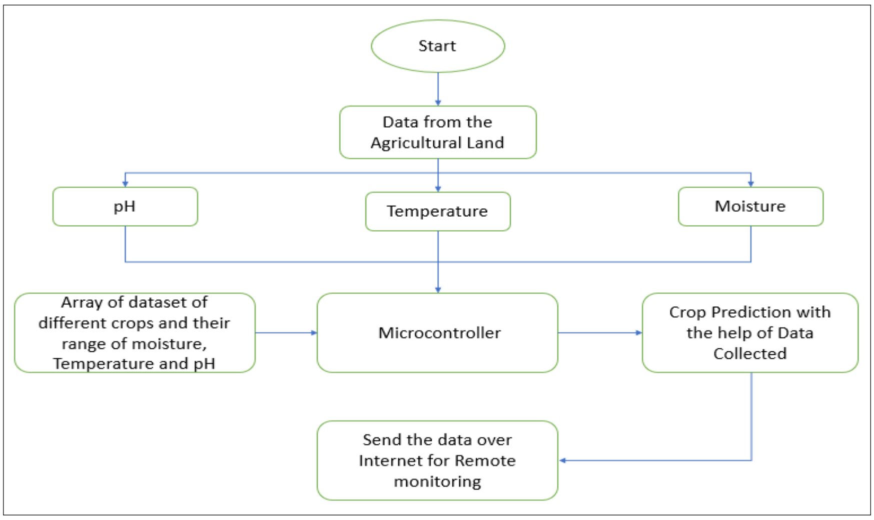

Fig 2: Flowchart of the system.

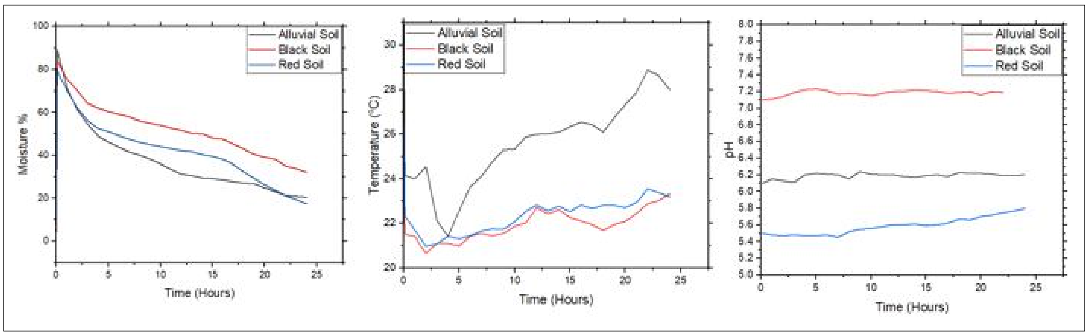

Fig 3: Comparison of soils for (a) Moisture (b)Temperature (c) pH.

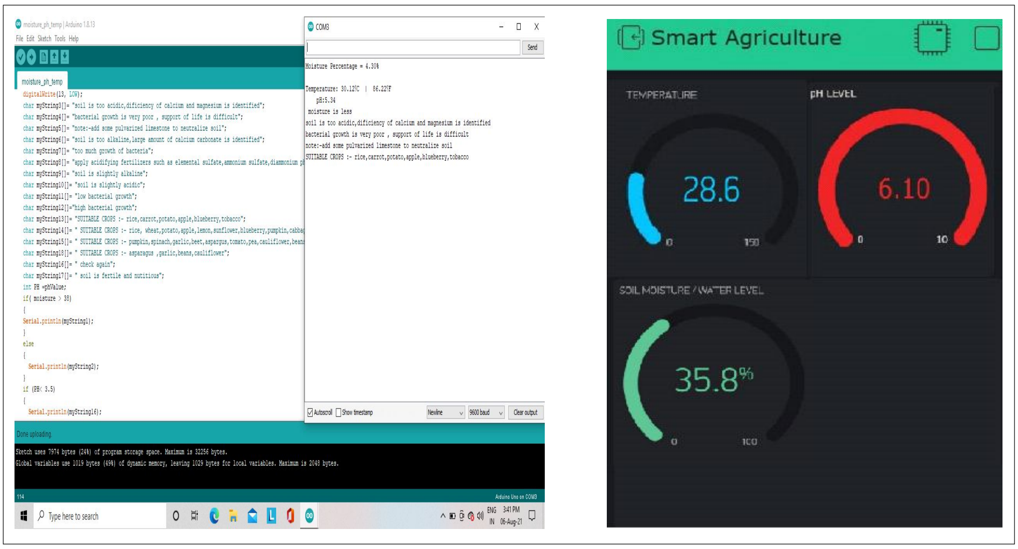

Fig 4: Results displayed on the a) Arduino IDE (b) BLYNK.

Table 6: List of suitable crops recommended by system.

Type of soil	Suitable crops
Alluvial soil	Rice, Wheat, Potato, Apple, Lemon Sunflower and Pumpkin
Black soil	Wheat, Lemon and Sunflower
Red soil	Rice, Carrot, Potato, apple, Blueberry and Tobacco

The experiment performed with this device on various soils measured all three parameters and display on the devices as shown in Fig 4 (a), (b). Based on these parameters the system recommends appropriate crop from the array of dataset passed initially. Table 6 lists down the suitable crop for different soil recommended by the system.

Based on the pH of soil the basic and acidic condition of soil is identified. The system also recommeds the type of fertilizers that may be used and also the bacterial condition of the soil as given in Fig 4(a). The user may take the decisions based on the condition of the farm and crops.

CONCLUSION

Agricultural activities consume too much water. The proposed system uses information from sensors to irrigate the soil, prevent over-irrigation or under-irrigation of the soil and prevent damage to crops. The system is a good example of water management. Farm owners can monitor their processes online through the application. Distant control mechanism improves the efficiency of the system. It is very useful for the farmer since it is wireless and the system also predicts crops and type of fertilizer to be used to neutralize the soil. Through this system we can conclude that there is considerable development in agriculture utilizing IoT and automation. Several new parameters may also be included in the system to check the plant growth and for analysis of the soil.

Conflict of interest: None.

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