IoT Based Automated Monitoring System for the Measurement of Soil Quality

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Abstract. Agriculture has long been the principal source of income in our country. However, agriculture is being hampered as a result of people migrating from rural to urban areas. The purpose of the study is to make a device that measures the soil and air quality on its own, not by any human action or anything. The device will automatically collect data from the soil and send it over the internet to various devices. This project includes other features like a wireless monitoring system and soil moisture and temperature sensing. This project also includes some comparisons between measured results by excel sheet for better soil quality. The sensors collect the result from the soil and supply the data through the internet. The primary focus of the paper is to demonstrate a project that helps to do farming with advanced techniques. The data obtained from the soil is pushed to the cloud for future analysis. Our motive of this research is to help the farmers and the agricultural officers in soil and weather testing.

Keywords: IoT, automated, smart, web-linked, database, API, thingspeak, realtime Data.

1 Introduction

Trending up in agriculture is a crucial objective as the globe moves toward new technologies and implementations. Many researches already held on this project and different types of research organizations are already working on this. As a result, precision agriculture and farming can be described as the art and science of utilizing technology to boost crop yields [1].

The Internet of Things (IoT) is a network of interconnected devices that are equipped with electronics, software, sensors, and a network connection to collect and exchange data. IoT-based automated system makes a massive change in farming because anybody can get information about different soil parameters without human effort. Soil parameters include temperature, moisture, and water level. Air quality management and climate monitoring are required to reduce polluting gases in the local atmosphere and to improve crop yields in the region [2]. The wireless sensors gather data from the soil and transmit it via wireless protocol. The data will give an idea about different environmental factors for increasing the yield of crops, but many factors make the decrease in productivity. As a result, simply monitoring the soil is not a complete answer for crop yields.

So, automation is required for the complete solution. The device must permanently be implanted in the soil to update the measurements. By this, we can overcome some problems by integrating such a system that will update us every time about the soil quality. This will help us to improve farming in every situation. Observing the soil quality through the device makes handling a critical case easier. The growth of plantations depends on photosynthesis methods that depend upon the radiation from the sun. So complete monitoring of soil for temperature and humidity control is required. Because of high humidity, the chances of disease are increasing. Water also affects the growth of crops. This IoT-based automated project for measuring soil quality will help farmers achieve higher crop growth in soil. This paper deals with developing the automated system for observing soil quality and providing the project to the farmers.

But everything has a disadvantage; in this project, higher cost network issues are the disadvantages. So, the main obstacle is to build the device at a minimum price because a higher price is not affordable for every farmer. So, the paper also deals with the device to make it affordable for the farmers.

2 Research Motivation

The key to good agricultural production is keeping a regular update of the local weather and soil, which is difficult for both the farmer and the agricultural officer because there are many fields that are impossible to test manually, plus we get a good database of the changing climate and soil quality. We're driven to work on this project because we want to be able to evaluate the soil and weather around the field automatically and remotely.

3 Literature Review

In previous times and nowadays, farmers will use the oldest method to measure soil quality. The oldest and existing method to determine soil quality is the manual method to measure different soil parameters. In the past, different types of soil indicators were also used to measure soil quality [3]. Then, various microbiological indicators were used to measure soil quality [4]. Now, we can determine the soil quality by collecting some soil data using sensors, and it is easier and more accurate.

Farmers must take advantage of every chance to improve production efficiency, address other difficulties, and monitor yields. Water stress is one factor that influences crop output and quality. Farmers must keep enough water in the root zone to ensure optimum crop production. For farmers, irrigation has become a vital risk control strategy [5]. Farmers must have a good understanding of soil moisture management before making irrigation management decisions. Irrigation water management and soil moisture control are the most effective ways to regulate root zone soil water. Soil moisture maintenance technology has advanced to the point that it is now a cost-effective risk management tool. This step allows you to choose the right crop without having to do anything else. It has been observed that crop growth is delayed and affected [10, 19]. The following parameters affect potential evapotranspiration if water is readily available from soil and plant surfaces: I temperature, (ii) humidity, and (iii) moisture. Water evaporates from the field surface due to two thermal sources: solar radiation and temperature. The aerodynamic forces that influence evapotranspiration are air movement and humidity. The vapor pressure grade of the atmosphere is affected by humidity, and wind mixes and changes the vapor pressure grade. The amount of water that plant roots can absorb is referred to as the total available water capacity. Between the original field capacity and the permanent wilting point water contents, the amount of water available, stored, or released. The table below shows the average quantity of total accessible water in the root zone for various soil types [6].

Table 1: Moisture Content of Different Types of Soil

Soil Type	Total Available Water, %	Total Available Water, In./ft
Loamy sand	17	2.0
Loam	32	3.8
Coarse sand	5	0.6
Sandy loam	20	2.4
Sandy clay loam	16	1.9
Fine sand	15	1.8
Silt Loam	35	4.2
Peat	50	6.0
Clay	20	2.4
Silty clay	22	2.6
Clay loam	18s	2.2
Silty clay loam	20	2.4

4 Methodology

The goal of this project is to create a system that uses ThingSpeak, an IoT platform, to display sensor data online. The procedure is split into two parts: hardware development and software development. Hardware development entails the creation of circuits and the development of prototypes. Meanwhile, IoT programming, circuit schematic diagrams, circuit simulation, and data collecting are all used by the software [7].

The system will be able to display the weather condition by analyzing the current weather with the sensor value data by using the sensors to monitor the weather parameters of temperature, humidity, and air quality. All of the data will be controlled by an ESP8266 microcontroller, with the client receiving sensor data from the ESP8266 and displaying it on a serial monitor.

This system will also be visible on the ThingSpeak channel, which was designed to make it easier for users to check online. To assure the accuracy of data and weather conditions on current conditions, the data will be examined and compared with Google weather. Without having to verify manually, the Internet of Things (IoT) will connect the system to the user wirelessly and online.

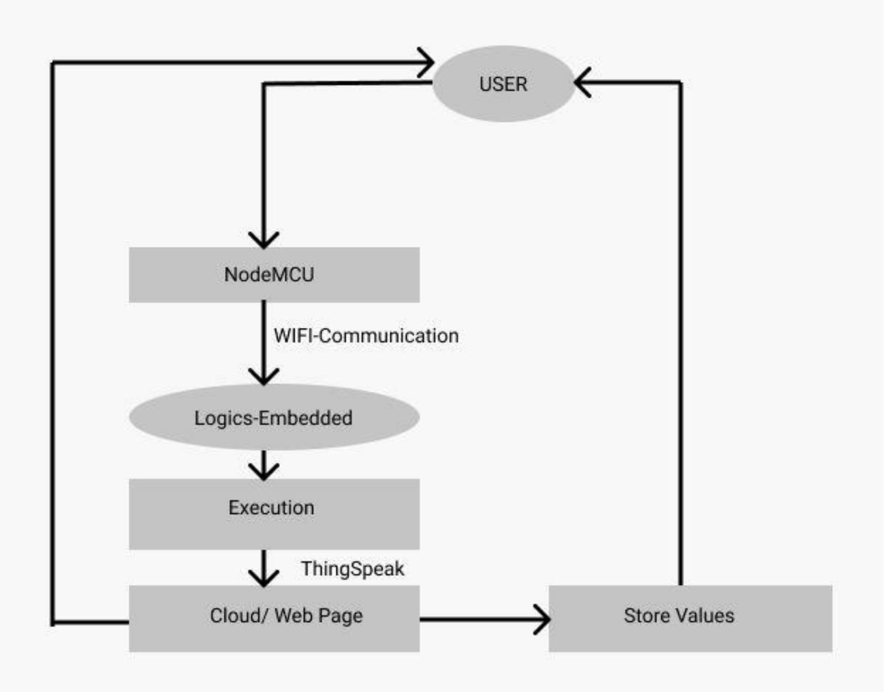


Fig. 1: Dataflow Diagram of the System.

Here we can see in the Dataflow Diagram that the user can trigger the NodeMCU to connect with ThingSpeak using local WiFi and send the sensor data in the channel, which will also show it on the web page and in the ThingSpeak channel private view as well. Besides, the data can be stored and the user can get it anytime.

5 Hardware Components

5.1 ESP8266 NodeMCU

The ESP8266 NodeMCU (Espressif module) can be used like Arduino with WIFI connectivity, making our work simple. Tensilica 32-bit RISC CPU Xtensa LX106 Microcontroller is used in the ESP8266 NodeMCU. There are 16 general-purpose input-output pins on the ESP8266 NodeMCU. One analog pin, four SPI communication pins, and two UART interfaces, UART0 (RXD0 & TXD0) and UART1 (RXD0 & TXD1) (RXD1 & TXD1). The firmware/program is uploaded through UART1. The ESP8266 NodeMCU is an open-source hardware and software platform that is simple to use [8,14].

The board has an LDO voltage regulator to maintain the voltage stable at 3.3V, while the ESP8266's operational voltage range is 3V to 3.6V. When the ESP8266 draws up to 80mA during RF transmissions, it can dependably supply up to 600mA, which should be more than enough. The output of the regulator is likewise separated off to one of the board's sides and designated as 3V3. Power can be supplied to external components via this pin. The inbuilt MicroB USB connector provides power to the ESP8266 NodeMCU. Alternatively, the ESP8266 and its peripherals can be powered directly from the VIN pin. The maximum voltage in this scenario is 5V [9,15].

Fig. 2: ESP8266 NodeMCU (Own captured).

5.2 DHT11

The DHT11 (digital temperature and humidity sensor) is a must-have. It measures the ambient air with a capacitive humidity sensor and a thermistor and outputs a digital signal on the data pin. It's easy to use, and we can acquire new data from it once every two seconds. It includes a 4.7K or 10K resistor that can be used to pull up the data pin to VCC [10]. The sensor includes a separate NTC for temperature measurement and an 8-bit microprocessor for serial data output of temperature and humidity measurements [11]. The sensor comes factory calibrated and is simple to connect to other microcontrollers. With an accuracy of 1°C and 1 percent, the sensor can monitor temperature from 0°C to 50°C and humidity from 20% to 90% [12].

Fig. 3: DHT11 sensor (Own captured).

5.3 Soil Mositure Sensor

The moisture of the soil is detected with this soil moisture sensor. It determines the volumetric water content of the soil and outputs the moisture level. There are digital and analog outputs on the module, as well as a potentiometer for adjusting the threshold level. It has four pins, VCC, GND, DO, AO. Here VCC pin powers the sensor, GND supplies the Ground, AO is for analog output, and DO is for digital output. It runs on +5V [10]. It’s divided into two parts, those are:

The Probe: The sensor contains a bifurcated probe with two exposed conductors inserted on the ground or elsewhere to measure moisture content. It works as a variable resistor whose resistance varies with the amount of moisture in the soil.

The Module: Based on the resistance of the probe, the module will generate an output voltage that will be available on the analog output (AO) pins. The identical signal is delivered to the precision LM393 comparator, which converts it to digital data and makes it available on the digital output (DO) pin. The module contains a built-in potentiometer for adjusting the digital output (DO) sensitivity [11, 16].

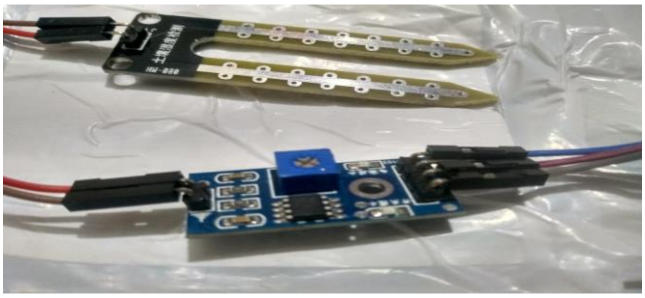


Fig. 4: Soil Moisture Sensor (Own captured).

6 System Architecture

The temperature and humidity sensor DHT11, capacitive soil moisture sensor, PC, and ESP8266 NodeMCU module make up the system.

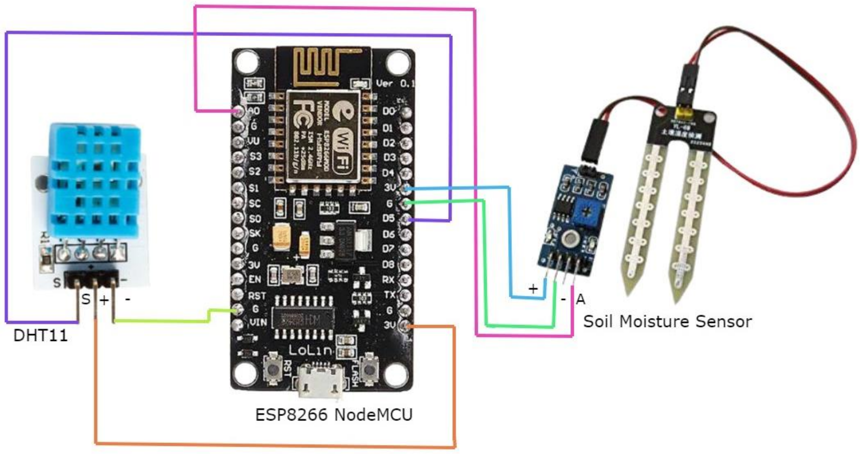


Fig. 5: Soil Monitoring System Diagram (Own made).

The DHT11 temperature and humidity sensor module provides the Microcontroller with a digital value for temperature and relative humidity. The soil moisture sensor detects moisture in the soil and outputs an analog voltage proportional to moisture content. The output voltage is then converted into soil moisture by the NodeMCU. The data is then transmitted to the ESP8266 through the serial port. It sends the data over the internet to the ThingSpeak server. The data can be accessed remotely once it has been uploaded to the cloud server. The temperature, relative humidity, and soil moisture data can all be found on the ThingSpeak channels [12, 13]. The data sent to the ThingSpeak channel can be accessed and shown in any app or website using API, and we can export the data as a CSV file. The data is displayed like this fig. 6, 7, and 8.

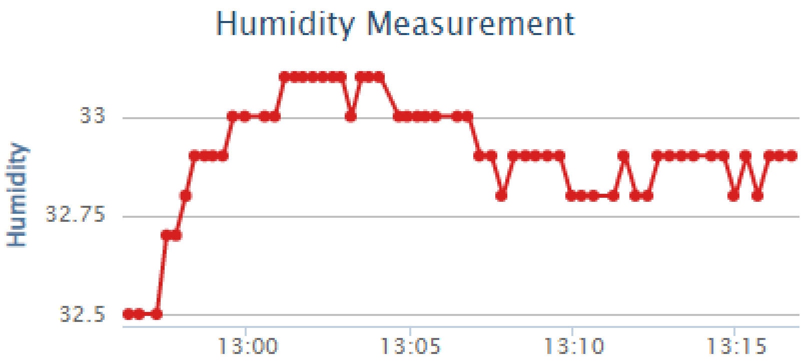


Fig. 6: Humidity Measurement.

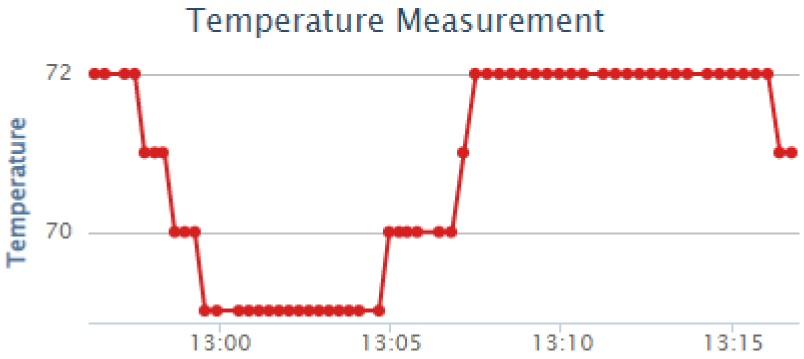


Fig. 7: Temperature Measurement.

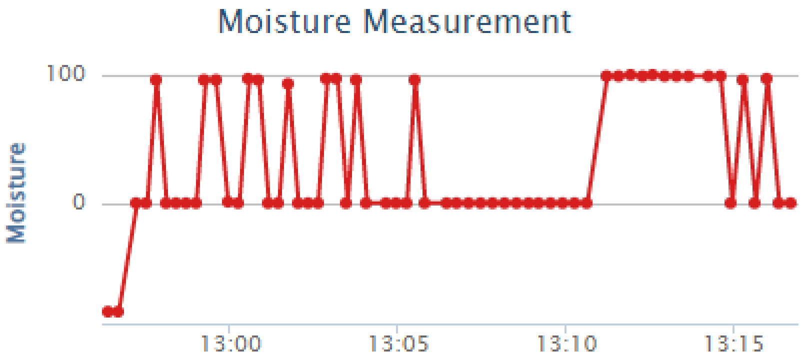


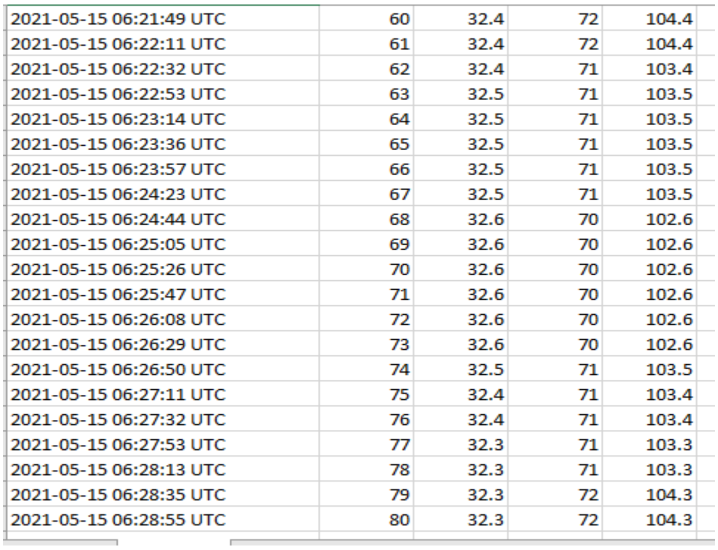
Fig. 8: Moisture Measurement.

Soil moisture sensors monitor the amount of water in the soil. It is a crucial parameter in agricultural environment studies. Measurement and monitoring of soil moisture are required to know when and how much to water the crops. Here the soil moisture is calculated using the gravimetric method. At first, a soil sample is oven-dried to remove the moisture content from the model and weighed. The dry sample is then weighed after a small amount of water is introduced. The weight of the dry sample and the weight of the wet sample are then used to compute the moisture. Both soil moisture sensors are put into a dried soil sample, and the resulting voltages are recorded. These voltages are then passed through the ESP8266 NodeMCU, which transforms them to moisture values [18,19].

In the graphs, Fig. 6, shows us the humidity data we captured while testing. We can see that it was near 32.75 to 33 most of the time. We took the data every 15 seconds. Fig. 7 shows us 72 degrees Fahrenheit most of the time. It was also measered in every 15 seconds [20]. In Fig. 8, we can see the soil moisture, which is 0, when we inserted the probe into dry soil and more than 0, when we inserted the probe into wet soil. So basically, we can get more perfect data if we average the data we get every 15 seconds over a longer period of time, like if we took all the data we got in 6 hours, we will get a proper value.

7 System Implimentation and Testing

The diagram depicts the system's general design. Using NodeMCU, the data input controller collects soil data via sensors. On a cloud platform, the collected data may be processed, and the results are presented in the form of charts, using CSV files as values stored in the cloud. The user will be able to examine the outcome of the data analysis.



2021-05-15 06:21:49 UTC	60	32.4	72	104.4
2021-05-15 06:22:11 UTC	61	32.4	72	104.4
2021-05-15 06:22:32 UTC	62	32.4	71	103.4
2021-05-15 06:22:53 UTC	63	32.5	71	103.5
2021-05-15 06:23:14 UTC	64	32.5	71	103.5
2021-05-15 06:23:36 UTC	65	32.5	71	103.5
2021-05-15 06:23:57 UTC	66	32.5	71	103.5
2021-05-15 06:24:23 UTC	67	32.5	71	103.5
2021-05-15 06:24:44 UTC	68	32.6	70	102.6
2021-05-15 06:25:05 UTC	69	32.6	70	102.6
2021-05-15 06:25:26 UTC	70	32.6	70	102.6
2021-05-15 06:25:47 UTC	71	32.6	70	102.6
2021-05-15 06:26:08 UTC	72	32.6	70	102.6
2021-05-15 06:26:29 UTC	73	32.6	70	102.6
2021-05-15 06:26:50 UTC	74	32.5	71	103.5
2021-05-15 06:27:11 UTC	75	32.4	71	103.4
2021-05-15 06:27:32 UTC	76	32.4	71	103.4
2021-05-15 06:27:53 UTC	77	32.3	71	103.3
2021-05-15 06:28:13 UTC	78	32.3	71	103.3
2021-05-15 06:28:35 UTC	79	32.3	72	104.3
2021-05-15 06:28:55 UTC	80	32.3	72	104.3

Fig. 9: Exported Data as CSV file.

In Fig. 9, we are getting real-time sensor values with the time and date in the CSV file. We can also get those values by using the write API key [17]. Here, we have tested our project in Dhaka on 15 May 2021 and got those results.

It gave a good result in testing, and the data was accurate. We got about 94% accuracy while we compared it with obtained data from Google and other devices as well. The data flow was flawless as well.

8 Conclusion

In agriculture, the technology is used to remotely measure temperature, relative humidity, and soil moisture. The purpose of the inquiry is to determine the temperature and humidity using DHT11 and soil quality using soil moisture sensor, so that we can measure the soil and weather quality and help the farmers by analyzing the data we achieved.

9 Acknowledgment

The success of this initiative is primarily dependent on the support and guidance of many others. Md. Sadekur Rahman, Faculty of Computer Science & Engineering, Daffodil International University, has my heartfelt gratitude for his encouragement, support, and direct engagement in the successful completion of this project.

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