IoT Based Soil Health Monitoring System Using Soil Moisture Sensor and pH Sensor

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Abstract

Soil management is a fundamental component of land management which emphases on the diverse soil forms and features that can boost the soil production capabilities. This paper proposes a process to apply an Arduino based soil monitoring framework. This framework uses two major ecological features like moisture and pH value of soil using soil moisture sensor and pH sensor probe. Data is managed by ESP32 which may be connected to Thing speak by the concept of Internet of Things (IoT). This permits the client to control water system pumps from far distances through the Thing speak App, which would assist farmers with greatest yielding and quality harvests.

Keywords: Internet of Things, ESP32, Soil moisture, pH value, Thingspeak.

1. Introduction

In agriculture, rich and healthy soil with proper nutrients can significantly contribute to a successful farming season. Soil offers the primary help to plant. Soil has a wide range of varying molecular and physical characteristics. There are many factors such as leaching and microbial activity that can make an entirely different soil type. Good soil structure includes proper management of soil. It is necessary to monitor physical and chemical features of soil, considering all the factors. Soil acts as a pantry for plants and provide human nutrition. Managing soil is important as carelessness can hamper the growth of plants, resilient to droughts and affect life of farmer and rest of the population. Proper soil management protects and enhances soil performance. It also prevents pollution and improves crop quality. Therefore, it is necessary to manage land more effectively by analysing the soil. Nowadays, smart systems are introduced for various problems in real life. IoT, more up to date innovation is a continuous thought which manages the cooperation among objects and collects data online. It is one of the essential components of smart system.

The climatic condition is also an essential reason for crop growth [1]. The combination of IoT and modern technologies can help in increasing production and quality of soil [2]. Proper water system which will conserve water and as water is essential for plant growth [3] [4]. A regular water system that can be controlled so that the soil moisture condition is balanced according to the requirement of the plant. [5] The study was aimed to develop an automatic watering process with a unit to control the motor using MQTT protocol for communication. [6], To make a less cost and automatic system to control soil moisture in rural farms using Arduino UNO. IoT enabled sensor with neural network and predict seasonal rainfall in North Karnataka. [7], Design of less price IoT structure for analysing soil status, temperature and humidity using wireless sensor network. [8] This study associates the environmental parameter like humidity, temperature with IoT based controlling using Arduino and Raspberry pi. [9], This project includes different sensors positioned over the plant and transfer the required parametric values. [10], The study is about maintaining fish in aquarium by automated system using pH, ultrasonic and servo data receiver. [11], Study suggesting high correctness crop control by data gathering and computerized farming method using ADS1115 I2C protocol. [12], This study includes smart agriculture technique like GPS remote controlling, parameter sensing and leaf dampness using IoT. [13], The study implements a wireless sensor network with different sensor using ESP-WiFi-MESH protocol to monitor small area. The parameter includes moisture of soil, temperature, humidity and sunlight intensity. [14], proposed automated system monitoring the turmeric farm by wireless sensor network technology. [15], The research proposed a smart agriculture, with sensor-based monitoring in real time with less human interaction.

The proposed study for IoT created soil health monitoring structure with two different sensors consists of a brief introduction about smart soil management, then the materials and methodology are discussed at last comes the result for the posed work.

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2. Smart Soil Management

Most of the ground is covered in loose surface material called soil. It offers actual support to plants and is additionally their wellspring of water and supplements in agribusiness. Soil management is a process to protect soil resources and make soil and crops less susceptible to pests, diseases, and weeds.

Smart soil management is an effective and efficient way of knowing the different properties of soil. It informs the farmers with real time data and monitors the soil. Checking of soil parameter is one of the main issues in horticultural practices. The creation and support of yields are straightforwardly impacted by soil boundaries. Hence, approaching a smart soil management system can help farmers to expand their yield at least expense. In the smart soil management model, we use different types of sensors for informing the real time data and the use of sprinklers to chill off the temperature of the yields. Our methodology is to make this framework open for far distance so farmers/clients can get the data and control the field 24✕7. The setup is controlled by Arduino, the information is transferred to the Wi-Fi unit in Node MCU like, ESP32.

3. Materials and Methods

The main part of the system is ESP32 board, which is a microcontroller with integrated Wi-Fi and dual mode Bluetooth network that makes it possible to create an Internet of Things (IoT) application. In this work, the process is separated into two parts. The first one is to develop the hardware setup with the sensors and setup for monitoring the soil moisture at the same time. Secondly, the transfer and storing of data to cloud. The procedure of the complete system is given below in Fig.1.

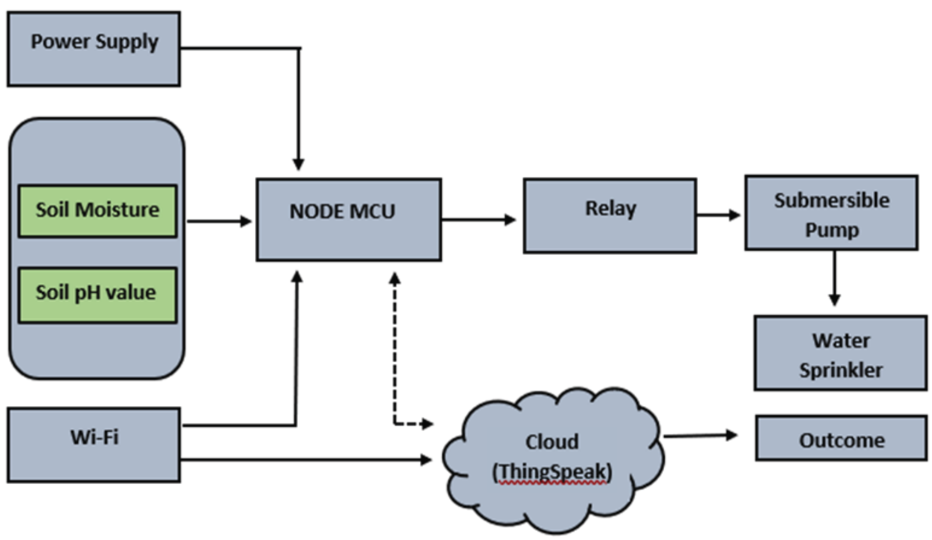

Fig.1. System workflow diagram

3.1 Hardware Specification

Here, different elements were utilized for developing the entire model. The components were put together to perform their respective tasks. The microcontroller is used as system input and the two sensors as output for the sensor readings. The subsequent components are used in this proposed system.

3.1.1 ESP32 (Wi-Fi module)

The controller named Node MCU ESP32 board, fig.2 is a chip based on Espressif product which is scalable, adaptive, and compact board with inbuilt Wi-Fi and Bluetooth capability to communicate. An ESP32 board module is utilized as the fundamental module for collecting sensor data. It can develop a program and as well as control movements of every kind in the proposed framework. Hence, the microcontroller was able to communicate with sensors and other devices.

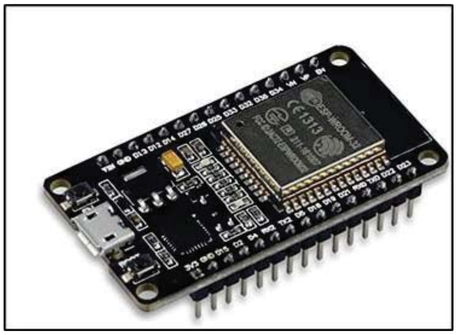

Fig.2. ESP32 microcontroller board

3.1.2 Soil Moisture Sensor

The capacitive soil moisture sensor, sensor which measures moisture level of soil by capacitive sensing. Capacitance measures dielectric permittivity of the surrounding area. It does not measure soil moisture directly, instead it measures the ions that are dissolved in the moisture. While measuring, the current cannot go through the dry soil as the water content is very low and when the soil is wet, the current can undoubtedly pass. To determine if soil is wet or dry enough, the moisture threshold number can be changed. Fig.3 shows soil moisture sensor. The moisture sensor and relay actuator were integrated into the module, which is a submersible pump of 3 – 6 V to regulate and monitor the water flow and water content in intended agricultural land as shown in Fig.4.

Fig.3 Capacitive soil moisture sensor

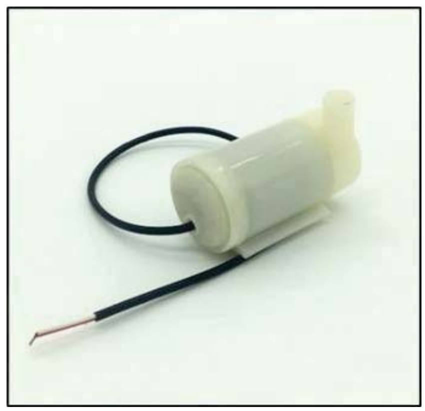

Fig.4 Submersible motor pump

3.1.3 pH Sensor

The second sensor shown in fig.5, which is used in this model is E-201-C composite electrode pH sensor probe with BNC connector. This pH sensor measures the pH value of soil, so that the chemical nature of the soil can be known in the form of acid or base. It can be interfaced directly by any microcontroller.

Fig.5 E-201-C pH sensor probe

3.2 Software Specification

In the software module, Arduino IDE 1.8.19, the open-source Arduino software where interfacing is quite simple to use. The communication process was analysed and visualized by Thingspeak, an IoT platform that allows to aggregate and analyse live information streams in the cloud. Thingspeak allows sensors, instrument to lead data to the cloud and stored in channel. It is the best open source IoT platform where sensor can continuously send data to cloud platform and the data are interpreted in form of graph. It can measure and report simple as well as complex data.

3.3 System Design

The work process of this proposed model works using ESP 32 developer kit. This device is powered using an external power supply. The two sensors which are going to give live data are soil moisture sensor and pH value sensor. The working begins when microcontroller gets power and the sensors are connected to it. ESP32 start analysing the data and keeps on displaying on arduino IDE. The Wi-Fi module which is inbuild in ESP32 helps in transferring measurement reading to IoT cloud platform. Coming to the sprinkler system we connected a relay actuator with a motor which pumps water according to the current requirement of the field, which depends on the water content. This workflow for measurement of soil moisture and the condition to control the pump is shown in Fig 6.

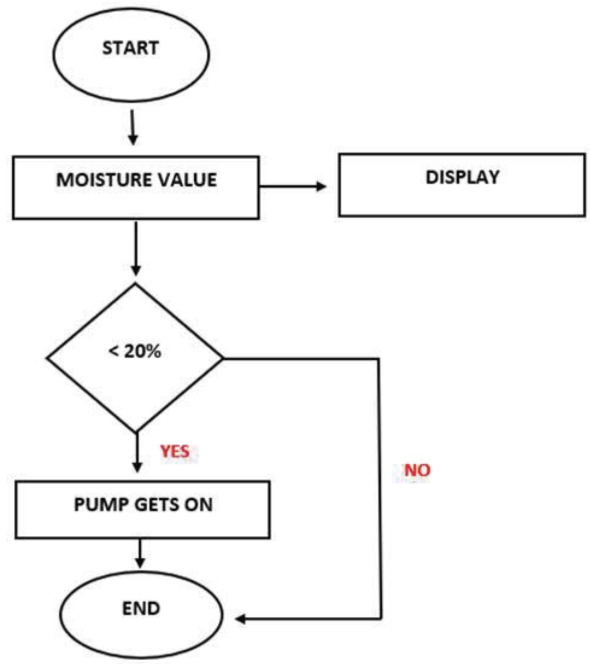

Fig.6. Pump control process

The procedure flow for configuring the water pump follows by first sensing moisture value of the soil. Referring to readings the point rate is set as 20%, the pump starts operating according to the condition of the land.

The observed data of the moisture measurement and pH value was collected by a broker where all the information were gathered. Further, the data were transferred from device over the internet to cloud platform where the data are analysed and visualized in the form of graphs with real time updated value.

4. Results

The working of the projected Arduino based smart soil management with ESP32 Wi-Fi module was tested with a real time scenario. The sensor data were received by implementing the whole module as shown in Fig.7. The pump control process is attached with the module as shown in Fig.8 which is to provide a sprinkler system according to the moisture level of the soil. The real time data was collected from the soils of Mesra, Ranchi, Jharkhand.

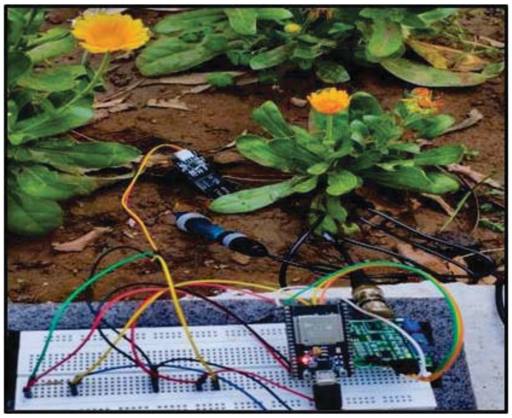

Fig.7 System model

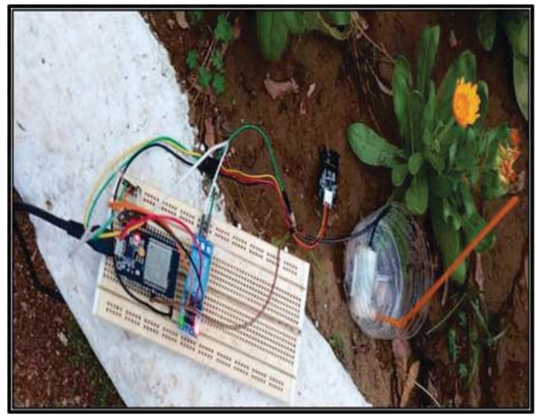

Fig.8 Pump control model

The main component in the proposed model is ESP32 Wi-Fi unit that permits to transfer and receive data via the internet. It was used in a local area network (LAN) approach for the transferring of data to the cloud. After the setup was completed, we started taking the reading for the moisture sensor and pH sensor at the same time interval for two months interval. First reading was taken in the month of November to December and second as January to February. The data collected for sample soil can be seen in Table.1 and Table.2 below.

Table 1. Sample Collected for NOVEMBER – DECEMBER (2022)

TIME STAMP	SOIL MOISTURE	SOIL pH VALUE
16:40:54	18.00%	7.9
16:40:55	18.20%	7.8
16:40:56	18.20%	7.9
16:40:57	19.40%	7.9
16:40:58	19.40%	7.5
16:40:59	19.70%	6.9
16:41:00	19.75%	7
16:41:01	19.75%	7.2
16:41:02	19.85%	7.5
16:41:03	19.88%	6.6
16:41:04	20.00%	7.2
16:41:05	20.00%	7.5
16:41:06	19.55%	7.5
16:41:07	19.89%	7.8

Table 2. Sample Collected for JANUARY – FEBRUARY (2023)

TIME STAMP	SOIL MOISTURE	SOIL pH VALUE
16:40:54	12.00%	7.9
16:40:55	12.20%	7.8
16:40:56	12.20%	7.9
16:40:57	12.40%	7.9
16:40:58	15.40%	7.5
16:40:59	15.70%	6.9
16:41:00	15.75%	7
16:41:01	15.75%	7.2
16:41:02	16.85%	7.5
16:41:03	16.88%	6.6
16:41:04	17.00%	7.2
16:41:05	17.00%	7.5
16:41:06	18.55%	7.5
16:41:07	18.89%	7.8

From the Table.1, it is states the samples collected from moisture sensor and pH sensor at same timestamp for sample soil. The soil moisture ranged from 18.5% to 20% and soil pH ranged from 7.5 to 7.9. Table.2, shows that the moisture ranged from 12% to 18% and Ph value is same as the soil and patch area was same. The moisture value can vary season to season and is also depended on temperature. The pH of the soil remains the same but if the user wants to grow.
crops that need acidic nature soil, then the user can add different fertilizers to change the pH of the soil. After the collection of data, the readings are transferred from the Arduino database to Thingspeak every minute with a common Wi-Fi network. The continuous data in the form of graphs is shown in the main page of the Thingspeak with two different fields as shown in Fig. 9 and Fig. 10 to make it simple for clients to see the historical backdrop of past information.
This working structure was able to gather information about the soil state with two different parameters. Considering Jharkhand state, Ranchi region as the samples is collected here. Different crops and plants which are commonly grown in this region having specific range for the considered parameter is mentioned as shown in table. 3. The measured value is aligned to the range mentioned in the table.3.

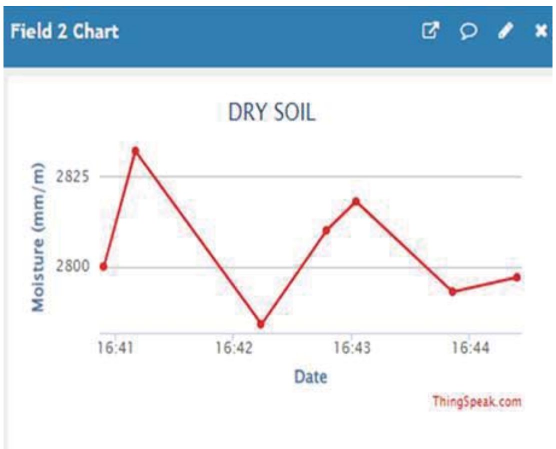

Fig.9 Graph for soil moisture

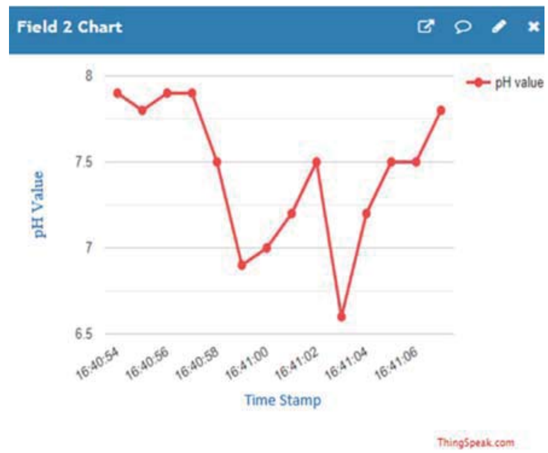

Fig.10 Graph for pH value of the soil

Table 3. Common crops grown in Ranchi region

CROPS	SOIL MOISTURE	SOIL pH VALUE
POTATO	60-70%	5.5 – 7.0
TOMATO	<50%	6.0 – 7.0
FRENCH BEANS	50 - 70%	5.5 - 6.0
PUMPKIN	30 - 50%	6.0 - 6.8
LADYFINGER	50 - 60%	6.5 - 7.0
WATERMELON	40 - 60%	6.2 - 6.8
RICE	60 - 80%	6.0
HIBISCUS	30 - 40%	5.5 - 6.5
MARIGOLD	35 - 50%	6.2 - 6.5

5. Conclusion

In the proposed methodology, a module has been explained which can monitor the moisture level and create a sprinkler structure accordingly with less human interference. The framework effectively gave the data in regards to the state of soil, particularly moisture and pH and delivered it to the cloud system. The IoT based soil health monitoring system using two different sensors was successfully designed for any season condition. Moisture level is predicted by knowing the water content of soil. The pH value validated the soil in two conditions, acidic or alkaline. The two parameters in the proposed system are equally important for soil and the growth of a good quality crop. For future development, the watering system can be changed in a more proficient and enlarge way with proper sprinkler system, alert and inform the user through web interface. The system can be modified by using other different sensors.

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