REAL TIME DECISION SUPPORT SYSTEM IN AGRICULTURE

A thesis submitted by

Mr. ALOK ROY Uni roll-12000320052 Reg no-201200100310037

Ms. CHHANDA NIYOGI Uni roll-12000320077 Reg No-201200100310012

Mr. SURAJIT PATAR Uni roll-12000320080 Reg no-201200100310009

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Dr. Sarit Pal

Department of Electronics & Communication Engineering

(Affiliated to Maulana Abul Kalam Azad University of Technology)

Dr. B. C. Roy Engineering College, Durgapur

Durgapur-713 206, India

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Department of Electronics & Communication Engineering

Dr. B. C. Roy Engineering College, Durgapur

Durgapur-713 206, India

CERTIFICATE

This is to certify that this thesis entitled "**Real Time Decision Support System in Agriculture"** is a bonafide record of the thesis work carried out by **Mr. Alok Roy, Ms Chhanda Niyogi, Mr. Surajit Patar** under my supervision in the Department of Electronics & Communication Engineering, Dr. B. C. Roy Engineering College, Durgapur. The results embodied in this work or parts of it have not been presented/communicated elsewhere for degree/diploma or any other academic award.

(DR SARIT PAL)

Endorsed by______________________
(HOD, ECE department)

DECLARATION

I hereby declare that the work presented in this report entitled "**Real Time Decision Support System in Agriculture**" is a bonafide record of the thesis work done by me under the supervision of Dr. Sarit Pal, Department of Electronics & Communication Engineering, Dr. B. C. Roy Engineering College,Durgapur-713 206, India and that no part thereof has been presented/communicated elsewhere for degree/diploma or any other academic award.

Durgapur

Date-

(Alok Roy)

(Chhanda Niyogi)

(Surajit Patar)

Department of Electronics &Communication Engineering,
Dr. B. C. Roy Engineering College, Durgapur-713 206, India E-mail

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ABSTRACT

This research highlights the importance of effective water management in agriculture due to the growing global population and limited water resources. It proposes an intelligent IoT-based system that uses advanced technologies, data analytics, and automation to optimize irrigation, improving water management, crop yields, and sustainability. The system uses sensors to monitor temperature, soil moisture, and humidity, automating irrigation based on the Management Allowable Depletion (MAD) value of the crop and the Total Water Available (TAW) of the soil. It also employs the Blynk IoT cloud for live data streaming and notifications if any parameters are irregular. When soil moisture drops below the threshold, the motor turns on, and the system takes feedback from sensor readings every ‘T’ second to adjust irrigation, preventing over-irrigation. The interval 'T' is based on size of the agricultural field and the rotation per minute (RPM) of the water pump. If there's an issue, the farmer can control the water pump using an on/off button in the Blynk IoT App.

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CHAPTER -1

INTRODUCTION

In the present era, technology has become an integral part of our daily lives. With the world's population on the rise, the need for increased agricultural productivity has become paramount. However, the pursuit of higher yields often puts a strain on our already limited water resources. Agriculture, being a major consumer of freshwater, contributes to environmental degradation, escalating production costs, and water wastage. To tackle these challenges, there is now a growing trend towards adopting Smart Irrigation Systems. By leveraging advanced technologies, data analytics, and automation, these systems optimize irrigation processes, leading to better water management, higher crop yields, and improved sustainability in agriculture.

Traditional agricultural systems, despite their long-standing use, have significant drawbacks. They require more time and money and yield lower crops. Issues such as water scarcity, climate change, poor water usage, aging infrastructure, limited agricultural land, and the lack of new technologies further hinder traditional farming. In contrast, smart agriculture optimizes farming processes using cutting-edge technologies like the Internet of Things (IoT), sensors, and automation. This results in greater efficiency, allowing farmers to increase yields while using fewer resources and labor hours. Precision agricultural methods allocate resources only where and when needed, minimizing waste and reducing environmental impact, making agriculture more sustainable over time.

This research work proposes an intelligent IoT-based agricultural system designed to empower farmers with real-time access to agricultural field data such as temperature, soil moisture, and humidity. It automates the irrigation scheduling based on the threshold value determined using the Management Allowable Depletion (MAD) value of the crop and Total Available Water (TAW) of the soil. This information facilitates effective environmental monitoring, enabling farmers to engage in smart farming practices and enhance overall yield and product quality.

The system integrates an ESP32 Node MCU board and various sensors seamlessly into agriculture. Through the use of the BLYNK IoT application, live data streaming is made available to the farmers. A soil sensor is employed to assess soil moisture levels, helping to determine whether the soil is dry or moist. The system also monitors local temperature and humidity, and a decrease in soil moisture value below the threshold point triggers the irrigation of the field by turning on the water pump. Farmers receive notifications on their mobile devices and via email. By utilizing the soil moisture value as an indicator, farmers can ascertain the soil's condition, particularly when it is dry.

Our project suggests an intelligent IoT-based agriculture system that helps farmers obtain real-time data for effective environment monitoring, allowing them to practice smart farming and improve their overall yield and product quality. An ESP32 Node MCU board, a breadboard, and a variety of sensors are all integrated into this agricultural system, and a live data stream can be obtained online using platforms like BLYNK and Thingspeak. This project represents a foundational step in smart irrigation and precision agriculture, contributing to more accurate and efficient irrigation practices, thus saving time, money, and resources while enhancing sustainability in the agricultural sector.

India's population has surpassed 1.2 billion and continues to grow rapidly, leading to a potential significant food shortage in 25 to 30 years. Farmers are already struggling with insufficient rainfall and water shortages. This study aims to offer an autonomous irrigation system to help farmers save time, money, and electricity, thereby addressing some of the major challenges faced by traditional farming methods. This project is a building block in the domain of smart irrigation and precision agriculture, promising a more sustainable and efficient future for the agricultural industry.

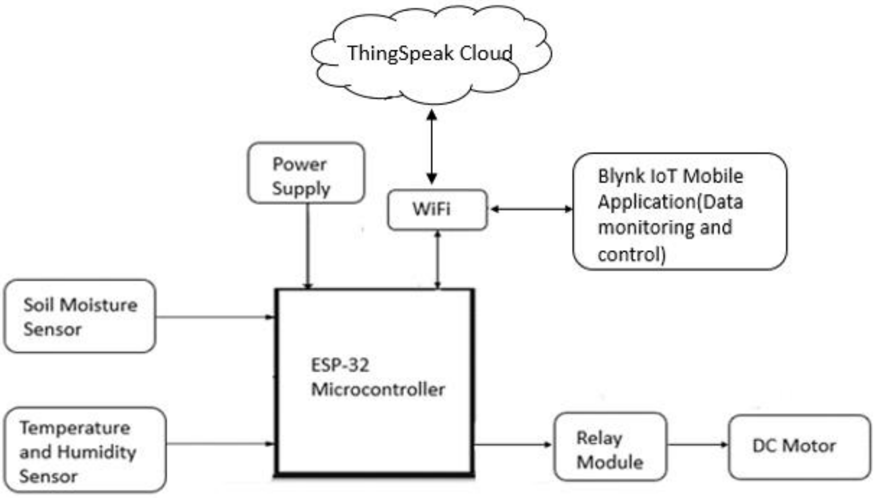


Figure 1. Block diagram of Sensor and Blynk IoT Cloud Communication with ESP32

CHAPTER -2

LITERATURE SERVEY

Smart irrigation is the practice of applying water in an efficient way at every stage of growth in crops. It benefits the utilization of resources by reducing the wastage through a data driven approach of analyzing and predicting moisture content in soil by considering the real time field data. Researchers have looked into key areas of improvements and different methods have been proposed to reduce the water consumption in scarce regions. Some of these methods explored by researchers have been discussed here.

S. Harishankar, R. Sathish Kumar, Sudharsan K.P, U. Vignesh, and T. Viveknath [1] in 2014 implemented a system using a stepper motor as an actuator for water flow control. Field moisture data, collected through a soil moisture sensor, is converted into voltage readings and sent to a decision-making circuit. The circuit, with a reference voltage, determines water requirements based on the difference between received and reference voltages. The stepper motor's rotation angle, proportional to this difference, regulates the valve, controlling water flow.

In 2017, Shweta B. Saraf et.al [2] designed a system collecting real-time environmental data, soil moisture, and water levels using sensors like soil moisture, temperature, humidity, and water level, connected to an Arduino microcontroller via a GPRS module.

Sumon Datta, Jacob Stivers and Saleh Taghvaeian, in their work in 2017 [3], discussed fundamental soil water concepts and thresholds for efficient irrigation scheduling based on soil water sensor data. They elucidate parameters like volumetric water content (VWC) and soil matric potential (SMP) and define four thresholds - saturation, field capacity (FC), permanent wilting point (PWP), and management allowable depletion (MAD). These thresholds vary with soil type, crop type, and climate, and examples are provided for interpreting soil water sensor data in VWC and SMP units to determine irrigation thresholds and prevent water loss and crop stress.

A system for measuring real-time soil moisture and temperature using sensors such as soil moisture sensors, LM35 temperature sensor, LM358, relay, and Raspberry Pi 3 was proposed by R. Nageswara Rao et al in 2018 [4]. Analog data from crops are converted into digital values and transmitted to a database via Wi-Fi. The system controls a motor based on preset threshold values for soil moisture and temperature, adjusting the threshold voltage according to different crop fields and seasons.

Yu-Chuan Chang et.al in the year of 2019 [7] have proposed a machine learning-based smart irrigation system with LoRa P2P networks to automatically and seamlessly learn the irrigation experiences from expert farmers for greenhouse organic vegetable crops. The proposed system will firstly calculate the amount of water for each irrigation based on the trained irrigation model combined with the environment data, such as air temperature/humidity, soil temperature/humidity, light intensity, etc., and then irrigate the crops automatically via the long-distance and low-power wireless LoRa P2P network.

To provide a comprehensive overview of the literature reviewed, the TABLE 1 summarizes key studies, highlighting the author's name, the area of research, their main findings, and any identified research gaps.It serves as a concise reference to understand the current state of knowledge and areas needing further investigation.

Table 1 Finding and Gaps of different related works

S. Harishankar1 , R. Sathish Kumar2 , Sudharsan K.P, U. Vignesh and T.Viveknath [1]	Smart irrigation	Automated irrigation without human involvement using solar energy as a power source.	• They have not mentioned how to determine the reference values for different crops.
Shweta B. Saraf and Dhanashri H. Gawali [2]	IoT, wireless sensor network	Maintenance of the irrigation System by controlling soil moisture through automatic irrigation and provides visual and graphical representation of the information through mobile application.	• Method of threshold value determination is unknown. • Feasibility of the method with a large farm field is not discussed.
Tajim Md. Niamat Ullah Akhund, Nishat Tasnim Newaz, Zahura Zaman, Atia Sultana, Alistair Barros, and Md Whaiduzzaman [3]	IoT, Smart farming, Smart irrigation	Time to time notification about the farmer's cultivated land's details by controlling the irrigation.	• The decision for irrigation is made by observing only water level value, other parameters are ignored. • Method of threshold value determination is unknown.
R. Nageswara Rao, B.Sridhar [4]	Precision Agriculture Irrigation system and IOT	crop development at low quantity water.	• Feasibility of the method with a large farm is not discussed. • Lack of detailed technical specifications for the proposed system • Limited discussion on the accuracy and reliability of the sensors used.

			• Limited evaluation of the system's performance under different environmental conditions. • Lacks a detailed cost-benefit analysis of implementing the proposed system
Priyadharsnee.K, Dr. S.Rathi [5]	Automated irrigation	Monitoring of the soil parameters like soil moisture, temperature and electrical conductivity and automating the irrigation process.	• Method of threshold value determination is unknown. • correlation among field parameters is not discussed. • Ambient temperature value for sustaining the plant at low soil moisture level is not discussed. • Contribution of Electrical conductivity to determine irrigation is not discussed thoroughly. • Feasibility of the method with a large farm field is not discussed. • Topology of the network is not clearly mentioned. • Powering options of the system have not been discussed. • Volume of water for irrigation is not determined.
Yu-Chuan Chang, Ting-Wei Huang, Nen-Fu Huang [6]	Automation Irrigation System and Precision Agriculture	Provides a machine learning-based precise and smart irrigation system with LoRa P2P networks to automatically and seamlessly learn the irrigation experiences from expert farmers for greenhouse organic crops.	• Total Energy consumption calculation of the model is not done. • Cost analysis of the model is not done.

Revanth Kondaveti, Akash Reddy and Supreet Palabtla [7]	Irrigation	To develop a smart irrigation system that uses IoT and machine learning to optimize crop irrigation, improving water efficiency and increasing yield.	• Lack of detailed analysis on the economic feasibility and scalability of the proposed system for large-scale farming operations.
Arif Gori, Manglesh Singh , Ojas Thanawala , Anupam Vishwakarma, Prof. Ashfaque Shaikh [8]	IOT and Smart irrigation	Detection of the moisture content of the soil and sprinkle water accordingly.Checks the availability of light and provides light to the plants when required.. Entire information will be sent to the user's device.	• Method of threshold value determination is unknown. • Not mentioned about what kind of artificial light they used for the plants.
Apurva Tyagi, Dr. J P Navani, Nina Gupta, Mr. Raghvendra Tiwari, Mrs. Anamika Gupta [9]	Irrigation	provides an automated irrigation by controlling the pumping motor	• They only consider one soil parameter

Building upon the findings and research gaps identified in TABLE 1, we can now explore specific parameters that influence agricultural productivity and the technological solutions that address these challenges. TABLE 2 summarizes the critical factors affecting crop yield, their impacts, and the innovative technologies that can be deployed to mitigate these issues.

Table 2 Key Agricultural Parameters, and their related observation

Parameter	**Influence**	**solution**	**Technology used**
Moisture of Soil	Low soil moisture effects the plant health and the availability of nutrients is less in low soil moisture that effects crops yield.	We must know about the moisture of the soil so that we can start irrigation when needed.	Soil moisture sensors can be used there.

Humidity and Temperature of the Air	Humidity and the temperature of the Air can effects the plants growth that reduces the crops yields.	We have to sense the Temperature and the humidity of the Air so that we can do farming accordingly.	DHT Sensor can be used there
Power Supply	There is less availability of power supply in the Agricultural fields.	We can use natural resources like sunlight as power source.	Solar Cells can be used there.
Unavailability of real time data	In traditional Agricultural systems the farmers do not get the real time data about the fields condition.	We can send time to time notification of the sense data to the farmers through different message technology. We can also send visual and graphical representation of the fields through mobile application using Internet.	Mobile Application, Mobile Network, SMS technology can be used
Water level of soil	Water level of the soil is one of the most important parameters for farming. Sometimes there are shortage of water supply.	We can sense the water level and start irrigation when needed using water pump. Automated irrigation also can be done using IOT.	We can use water level sensor to sense the water level and can use a water pump and springer to provide water when needed.

CHAPTER -3

DISCUSSION

3.1 EQUIPMENT USED

Smart irrigation systems utilize a variety of equipment and technologies to optimize water usage and maintain healthy plant growth. Here are some of the key equipment used in our project:

1. Esp32 Microcontroller:

   ESP32 is a powerful microcontroller that is widely used in the field of Internet of Things (IoT) development. It is a dual-core processor with built-in Wi-Fi and Bluetooth connectivity, making it an ideal choice for projects that require wireless communication. The ESP32 also has a large number of GPIO pins, which makes it highly versatile and suitable for a wide range of applications. It can be programmed using a variety of languages, including C++, Python, and MicroPython, which makes it highly customizable and adaptable to different project requirements. With its low power consumption and high processing capabilities, the ESP32 is a popular choice for IoT devices.

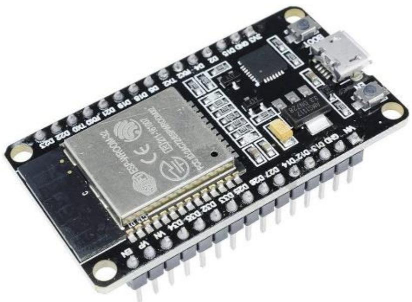


Figure 2. ESP32 microcontroller

- The ESP32 is well-suited for use in smart irrigation systems because it can handle a wide range of tasks, including data acquisition, processing, and communication.
- One of the key benefits of using the ESP32 in smart irrigation systems is its ability to communicate with sensors and other devices wirelessly. It can connect to Wi-Fi networks and Bluetooth devices, and it supports a variety of protocols, including MQTT and HTTP, which makes it easy to integrate with cloud services and other IoT platforms.
- In our project mentioned here we used Esp32 as the irrigation controller, which is the brain of the system. It receives data from sensors and uses that information to determine when and how much to water the plants.

2. Soil Moisture Sensor (Resistive and Capacitive):

   Soil moisture sensors are devices that measure the water content in soil. There are two main types of soil moisture sensors based on their sensing mechanism:

a) Resistive b) capacitive.

Resistive soil moisture sensors measure the resistance of the soil to electrical current. As the soil moisture increases, the resistance decreases, and vice versa. These sensors typically consist of two metal probes inserted. Resistance between the probes is measured. Resistive sensors are simple, low-cost, and can be used in a variety of soil types. However, they can be affected by temperature and soil conductivity, and their accuracy can degrade over time due to corrosion of the probes.

Specifications: Operating Voltage: 3.3 – 5 Volts

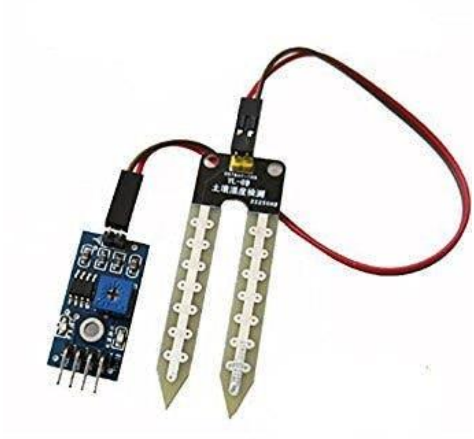


Figure 3. Soil Moisture Sensor (Resistive Type)

Capacitive soil moisture sensors measure the dielectric constant of the soil, which is related to its water content. A capacitive sensor typically consists of two electrodes, one of which is used as a reference and the other as a sensing element. The capacitance between the two electrodes is measured, and the water content is calculated based on the change in capacitance. Capacitive sensors are less affected by temperature and soil conductivity than resistive sensors and can provide more accurate readings. However, they are generally more expensive than resistive sensors and may require more complex circuitry.

Figure 4 Soil Moisture Sensor (Capacitive Type)

3. Temperature and Humidity - DHT11 Sensor:

The DHT11 sensor is a low-cost digital temperature and humidity sensor that can be used to measure the ambient temperature and relative humidity of the surrounding environment. It is commonly used in a variety of applications, such as weather stations, environmental monitoring systems, and home automation systems. The DHT11 sensor works by using a thermistor to measure temperature and a capacitive humidity sensor to measure relative humidity. The sensor has four pins, which are connected to a microcontroller or other electronic circuitry. The pins include VCC, GND, Data, and a not-used pin.

To measure the temperature and humidity using the DHT11 sensor, the microcontroller sends a start signal to the sensor, and the sensor responds by sending a 40-bit data packet back to the microcontroller. The data packet contains the temperature and humidity readings, along with other information such as checksum and parity bits to ensure data integrity.

DHT11 can be used in smart irrigation systems to provide valuable data that can help optimize watering schedules and conserve water. Temperature and humidity are important factors that affect plant growth and water requirements. By measuring these parameters, a smart irrigation system can adjust the watering schedule to provide the right amount of water at the right time. For example, during hot and dry weather, the system can increase the frequency and duration of watering to compensate for increased evaporation and transpiration rates.

Figure 5. DHT 11

The sensor can measure temperature in the range of 0 to 50°C with an accuracy of ±2°C, and humidity in the range of 20% to 80% with an accuracy of ±5%.

To use the DHT11 sensor in a smart irrigation system, the sensor can be placed in the soil near the plant roots or mounted on a post near the plants. The sensor readings can be transmitted to a microcontroller or a computer, where the data can be analyzed and used to adjust the watering schedule.

Overall, the DHT11 sensor is a useful tool in smart irrigation systems as it can provide accurate and reliable measurements of temperature and humidity, which are important factors in determining the watering requirements of plants.

Features of DHT11: -

- It measures both air temperature and moisture.
- Relative humidity expressed as a percentage.
- The output in terms of frequency range 5khz to 10khz.

4. Relay module:

   A relay module is an electronic switch that allows a low-power microcontroller to control high-power devices, such as a DC water pump. It acts as an intermediary between the microcontroller (e.g., an Arduino or Raspberry Pi) and the water pump, providing electrical isolation and enabling safe operation.

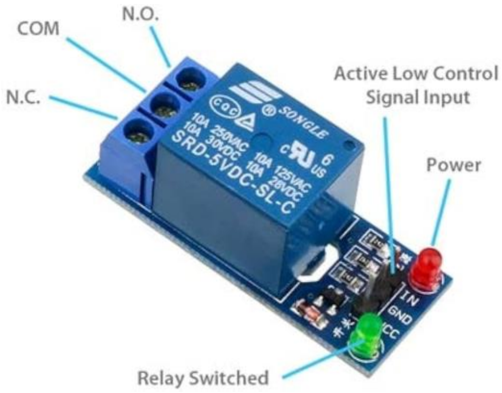


Figure 6 Single Channel Relay

Working:

- Input Signal: The relay module receives a low-voltage signal from the microcontroller, indicating when to turn the water pump on or off.

- Switching Mechanism: When the input signal is received, the relay activates an internal switch that completes the circuit, allowing the high-power device (the water pump) to operate.

- Electrical Isolation: The relay provides electrical isolation between the control circuit (microcontroller) and the power circuit (water pump), protecting the microcontroller from high voltages.

5. <u>DC Water Pump:</u>

A DC water pump is a motor-driven device that uses direct current (DC) electricity to move water. It is commonly used in irrigation systems to pump water from a source (e.g., a tank or well) to the fields where it is needed.

Figure 7 9v mini submersible dc water pump

Working:

- Power Supply: The DC water pump is powered by a DC power source, such as a battery or solar cells.

- Motor Operation: When powered, the pump's motor rotates, driving an impeller that creates a pressure difference, causing water to flow through the pump and out to the irrigation system.

- Control: The operation of the pump is controlled by the relay module, which turns the pump on or off based on signals from the microcontroller.

6. Wires and Breadboard:

Jumper wires and a breadboard are commonly used components in the setup of smart irrigation systems. These components are used to connect sensors, microcontrollers, and other electronic components together, enabling them to work together as a system.

Jumper wires are insulated wires with connectors on each end that can be easily plugged into electronic components such as sensors, microcontrollers, and breadboards. They are used to make temporary or permanent connections between components. Jumper wires come in various lengths and colors, making it easy to organize and distinguish between different connections in the system.

A breadboard, on the other hand, is a device used for prototyping electronic circuits. It consists of a grid of holes that are connected by metal strips, allowing components to be easily plugged in and out. Breadboards are often used to create temporary circuits for testing and prototyping, allowing for easy modification and experimentation before the final circuit is built.

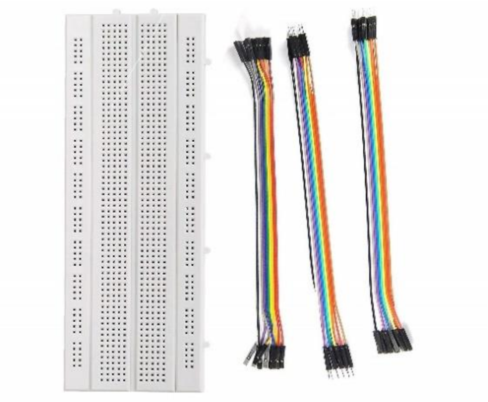


Figure 8. Jumper wires and breadboard

In a smart irrigation system, jumper wires and breadboards can be used to connect sensors such as the DHT11 temperature and humidity sensor, soil moisture sensors, and water level sensors to a microcontroller such as an Arduino or a Esp32. The breadboard can be used to prototype the circuit before it is finalized and built on a permanent board.

Overall, jumper wires and breadboards are essential components in the setup of smart irrigation systems as they enable easy and flexible connections between components, facilitating the prototyping and development process.

3.2. FIELD DATA SENSING AND ANALYSIS USING THINGSPEAK

CREATING CHANNEL IN THINGSPEAK

Thingspeak is a free web service for displaying the data online and can be accessed and monitored from thingspeak from anywhere. Here we are using ESP 32 to send sensor data to the Thingspeak cloud. We can also visualize and act on the data in thingspeak.

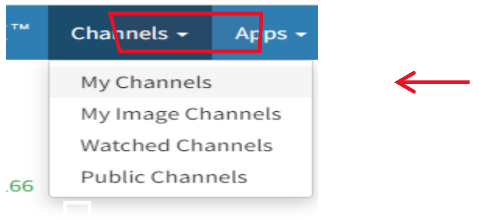
In thingspeak, we create channels to store the sensors readings and its related fluctuation plot. Channels are basically of two types – a) Public Channel and b) Private Channel

Here for the convenience, we have chosen public channel so that multiple people can access the data apart from the host of the channel, without having the prior knowledge of creating and managing channels. As our targeted users are farmers, we are aiming to provide them hustle free access to their field and crop related data from anywhere and anytime. The data can be accessed by the channel URL from any network provided by thingspeak.

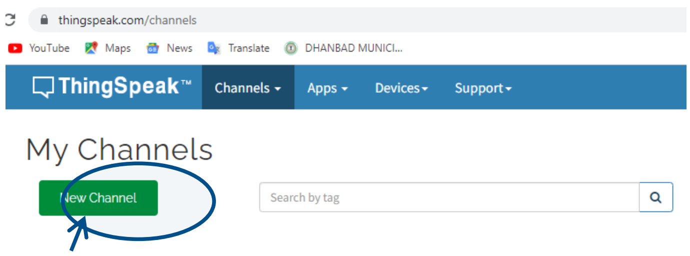
To create new channel in thingspeak: -

1. Login in the thingspeak website using mathwork credentials.

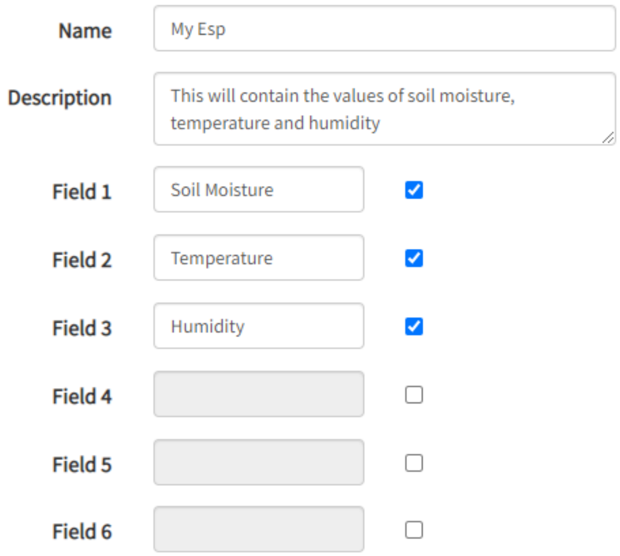
2. Open the "**Channels**" tab and select "**My Channels**".



3. Press the "New Channel" button to create a new channel.



Type a name for your channel and add a description. Here, we have named the channel as "My Esp" and published soil moisture value, temperature and humidity.



The channel screen will appear as follow –

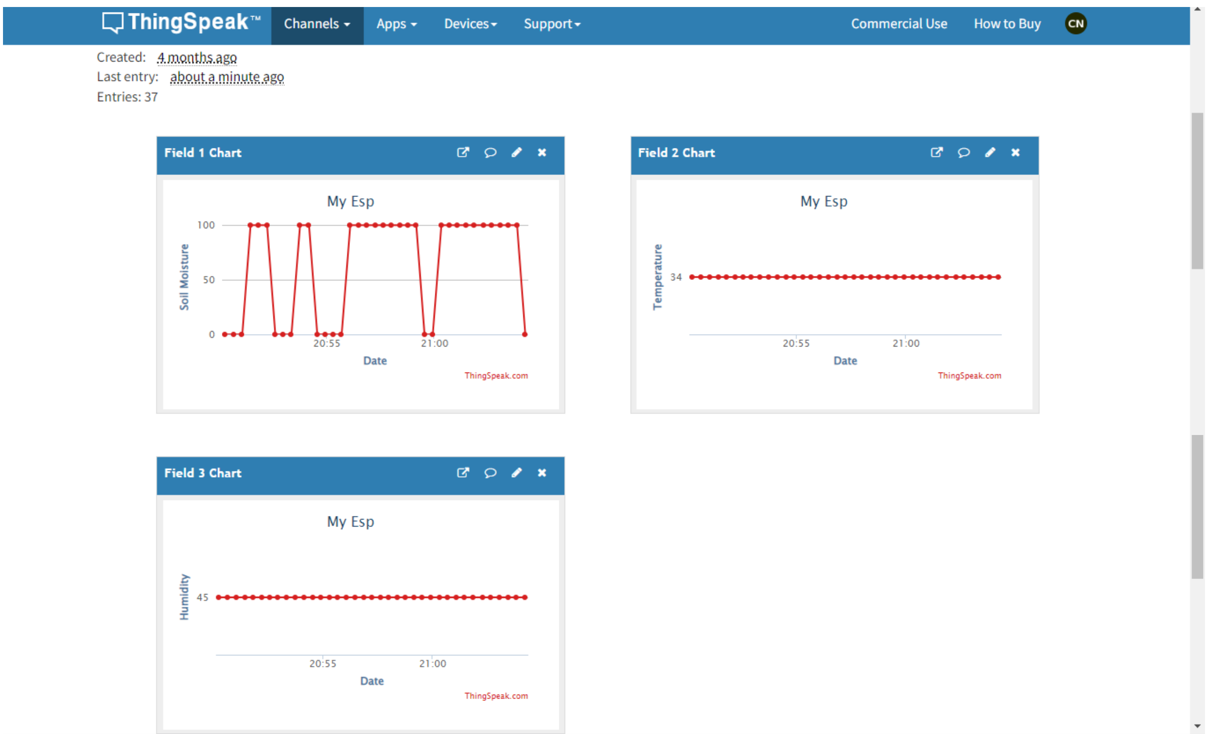


Figure 9. Sensor's data graphical representation in ThingSpeak

CODE USED FOR THINGSPEAK AND SENSOR COMMUNICATION

The code is being written in Thonny Python IDE using micropython. Code used for implementing our work is stated and described below: -

```
from machine import ADC, Pin
import time
import urequests
import dht
import network

# Configure ESP32 as Station
ssid = 'Galaxy A21sD2F3'
password = '12345678'
sta_if = network.WLAN(network.STA_IF)
sta_if.active(True)
timeout = 0

# Attempt to connect to the Wi-Fi network
if not sta_if.isconnected():
    print('connecting to network...')
    sta_if.connect(ssid, password)
    while not sta_if.isconnected() and timeout < 5:
        print(5 - timeout)
        timeout += 1
        time.sleep(1)

if sta_if.isconnected():
    print('network config:', sta_if.ifconfig())
else:
    print('Failed to connect to the network')
    # Add any additional error handling here

# Declaring the LED pin
led = Pin(2, Pin.OUT)

# Reading the DHT11 sensor
sensor = dht.DHT11(Pin(4))

# ThingSpeak configuration
HTTP_HEADERS = {'Content-Type': 'application/json'}
THINGSPEAK_WRITE_API_KEY = 'YANPMZRRBOG9H68P'
UPDATE_TIME_INTERVAL = 8000
last_update = time.ticks_ms()

# Soil moisture sensor configuration
soil = ADC(Pin(34))
soil.atten(ADC.ATTN_11DB)
soil.width(ADC.WIDTH_9BIT)

# Function to map the analog value of the sensor to a percentage
```

```
def mapping(ovalue, omin, omax, nmin, nmax):
    oldrange = (omax - omin)
    newrange = (nmax - nmin)
    newvalue = (((ovalue - omin) * newrange) / oldrange) + nmin
    return newvalue

def read_ds_sensor():
    value = soil.read()
    print(f"Soil sensor value: {value}")
    # Map the soil moisture value to a percentage (assuming 0-511 range for the ADC)
    percent = mapping(value, 0, 511, 0, 100)
    return percent

# Main loop to send data to ThingSpeak every 8 seconds
while True:
    if time.ticks_ms() - last_update >= UPDATE_TIME_INTERVAL:
        try:
            t = read_ds_sensor()
            sensor.measure()
            temp = sensor.temperature()
            hum = sensor.humidity()
            readings = {'field1': t, 'field2': temp, 'field3': hum}

            # Sending data to ThingSpeak
            request = 
urequests.post(f'https://api.thingspeak.com/update?api_key={THINGSPEAK_WRITE_API_KEY
}',
                                    json=readings, headers=HTTP_HEADERS)
            request.close()

            print(f"Sent data: {readings}")

            # Blink the LED to indicate data transmission
            led.value(not led.value())
        except Exception as e:
            print(f"Error: {e}")

        last_update = time.ticks_ms()
```

3.3 POSITIONING OF SOIL MOISTURE SENSOR FOR DATA ANALYSIS

Implemented as part of our project, Soil Moisture Sensing and Monitoring system focuses on precise soil moisture measurement in a sample plant, specifically the Impatiens balsamina. Following successful co mmunication establishment with the cloud, a soil moisture sensor was strategically placed within the plant. This innovative system employs two sensor directions to comprehensively monitor soil moisture:

1. **Vertical Placement**

A sensor is positioned vertically from the top level of the soil. This configuration enables monitoring of moisture content in the upper layers of the soil, providing insights into the plant's overall hydration status.

2. **Horizontal Placement near Root Area**

Another sensor is placed horizontally, in close proximity to the root area of the plant. This specific placement allows for the monitoring of moisture content in the soil surrounding the roots, offering a more targeted assessment of the plant's root-level hydration.

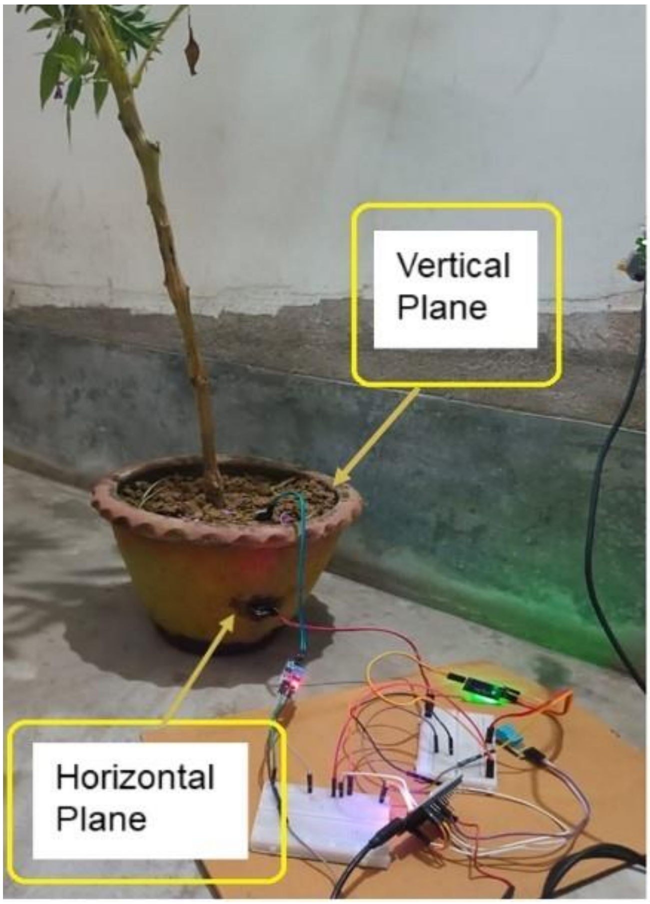


Figure 10. Two Soil moisture Sensor Position

3.3.1 Statistical Analysis of Observed Data

In our analysis, we computed daily maximum values for each parameter, focusing on temperatureand the maximum voltage value (indicating minimum moisture). Graphs were plotted to illustratethe correlation between temperature and minimum soil moisture. Soil Moisture Sensor 1 (SMS1)represents the top level, while Soil Moisture Sensor 2 (SMS2) is at the root level. These findings offer concise insights into daily extremes, aiding in precision agriculture decisions.

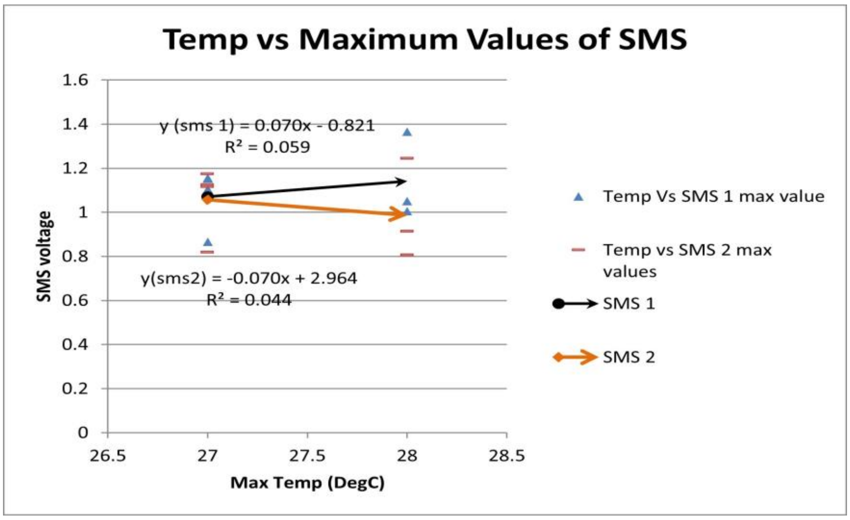


Figure 11. Soil Moisture Sensor 1 (SMS1) vs. Soil Moisture Sensor 2 (SMS2) Analysis

Analyzing the graph, we draw the following conclusions:

1. **SMS1 Decrease:**

   - Due to its location at the topsoil, SMS1 experiences quicker evaporation.
   - Evaporation leads to a decrease in SMS1 levels over time.

2. **SMS2 Evaporation Dynamics:**

   - SMS2, being deeper in the soil, experiences less evaporation compared to SMS1.
   - The presence of plant roots at this depth contributes to moisture retention in SMS2.

3. **Root Absorption Effect:**

   - The roots in the depth of SMS2 hold a significant amount of moisture, contributing toa balanced moisture level.
   - This absorption effect helps prevent SMS2 from showing a rapid decrease in moisture.

3.4 REAL TIME FIELD DATA SENSING AND MONITORING IN AGRICULTURE

Our Soil Moisture Sensing and Monitoring system is designed to provide precise soil moisture measurements for a sample plant, specifically Impatiens balsamina. This system incorporates a soil moisture sensor and utilizes the Blynk IoT platform for data communication and visualization. The soil moisture sensor is positioned vertically from the top level of the soil, enabling the monitoring of moisture content in the upper layers. This strategic placement provides valuable data on the plant's immediate hydration status, which is crucial for maintaining optimal growing conditions. Additionally, our app displays other environmental factors such as temperature and humidity, offering a comprehensive view of the plant's growing environment.

The system establishes a robust communication link between the soil moisture sensor and the Blynk cloud, allowing real-time data transmission from the sensor to the cloud, where it is processed and stored. The moisture data is accessible to farmers through the Blynk IoT application on their mobile devices. As illustrated in Figure 12, the app provides a user-friendly interface that displays the current soil moisture levels, temperature, and humidity, enabling farmers to make informed decisions about irrigation and plant care. By integrating precise moisture measurement with real-time data access, our Soil Moisture Sensing and Monitoring system enhances the ability to maintain healthy soil conditions and optimize plant growth.

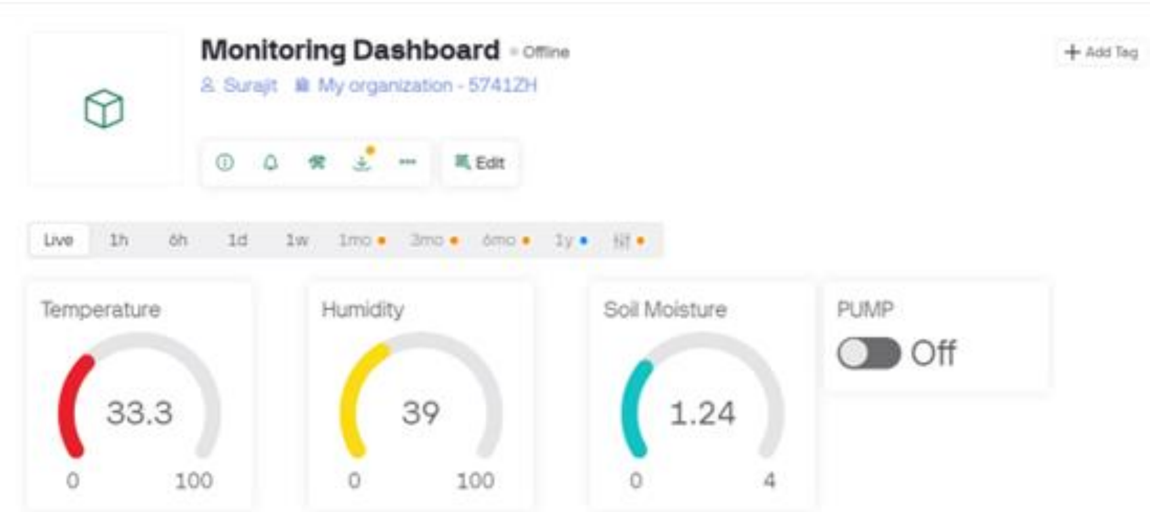


Figure 12. Blynk IoT UI

3.5 THRESHOLD VALUE OF SOIL MOISTURE FOR AUTOMATED IRRIGATION

The Threshold value of soil moisture for irrigation refers to the minimum value of soil moisture content below which the irrigation process is required to be initiated. To determine this threshold value, we proceed as follows:

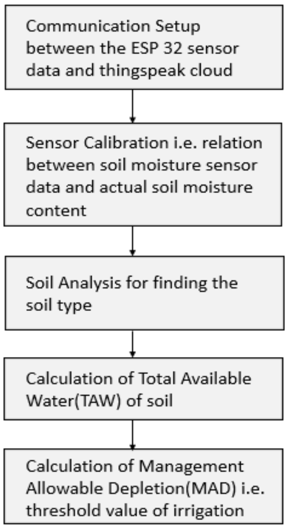


Figure 13. Process flow of the system

3.5.1 Finding the Saturation Moisture Content of Soil using Shrinkage Limit Test

A. Theory:

Soil consistency, a pivotal property determining the firmness of soil, manifests in four distinct states: liquid, plastic, semi-solid, and solid. The transitions between these states are governedby consistency limits, representing specific water content thresholds. The three primary consis- tency limits are the liquid limit, plastic limit, and shrinkage limit. Notably, the Shrinkage Limit test stands out as a method employed to ascertain the water content of soil under fully saturated conditions.

To conduct the Shrinkage Limit test, a set of apparatus is essential. This includes an Evap- orating Dish made of Porcelain, a Straight edge for precision, a Glass cup with a diameter of 50-55 mm and a height of 25 mm, a Glass plate, a Spatula for manipulation, a 600 micron IS Sieve for sieving, a Thermostatically controlled Oven to ensure consistent drying conditions, Mercury for specific measurements, and a highly sensitive Balance accurate to 0.01 g minimum. Each of these components plays a crucial role in executing a precise and reliable Shrinkage Limit test, contributing to a comprehensive understanding of the soil's behavior at its saturated state.

B. Procedure: Shrinkage Limit Test: Experiment Procedure: Determination of Shrinkage Limit and Specific Gravity

Shrinkage Limit Determination:

1. Dried soil samples were passed through a 600-micron sieve.
2. The soil was mixed with distilled water, forming a creamy paste, and then filled into a 50gcontainer.
3. The weight of the container with wet soil (W2) was measured.
4. The soil was oven-dried at 105-110°C for a minimum of 24 hours.
5. After cooling, the weight of the dish with the dry soil pat (W3) was obtained.
6. The weight of the empty container (W1) was determined.
7. The weight of the dish filled with mercury (Wf = 332.5gm) was measured.
8. The dry soil pat was dipped to displace mercury, and the weight was measured (Wp =106gm).
9. The weight of the displaced mercury (Wd = Wf - Wp = 226.5gm) was calculated.
10. The volume of the dry soil pat (V0) was calculated using the density of mercury (ρ = 13.6 gm/cm^3).
11. The volume of the wet soil pat (V) was calculated using Wf, W1, and ρ.
12. The Shrinkage Limit was calculated using the formula:

$$\text{Shrinkage limit} = \frac{w.(V-V_0).G}{W_0} \qquad (1)$$

where w = Initial water content of the soil as a percentage of the dry mass (%)

$$w = \frac{W_w}{W_0} \text{ x } 100 \qquad (2)$$

W_w= weight of the added water
W_0 = dry soil mass (gm)
V = volume of the wet soil pat (cm^3)
V_0 = volume of the dry soil pat (cm^3)
G is the Specific Gravity of the sample soil.

Specific Gravity Test:

1. A 100ml pycnometer bottle was used for the Specific Gravity test.
2. The empty pycnometer bottle was weighed ($w1 = 38$ gm).
3. The bottle was filled 1/3rd with soil, and its weight was measured ($w2 = 102$ gm).
4. The remaining space in the bottle was filled with water, and its weight was measured ($w3 = 175.5$ gm).
5. The bottle was emptied, completely filled with water, and then weighed ($w4 = 137$ gm).
6. The Specific Gravity (G) was calculated using the formula:

$$G = \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)} \quad (3)$$

w_1: The weight of the empty pycnometer bottle (initial weight),
w_2: The weight of the bottle filled one-third with soil,
w_3: The weight of the water-filled bottle,
w_4: The weight of the bottle filled with water after being emptied.

Shrinkage Limit Calculation:

From (1), the calculated shrinkage limit value as 18.7807%. The weight of Water Content (w_w) was calculated from the (2) as $(w{*}w_0)/100 = 9.3903$gm.

Table 3 Observation Table of Shrinkage Limit Test

Determination	Value
Weight of Container in gm(W1)	31.396 gm
Weight of container + weight of wet soil pat(in gm)(W2)	73.598 gm
Weight of Container + Weight of dry soil pat(in gm)(W3)	61.774 gm
Weight of oven dry soil pat(in gm)(W0)	29.635 gm
Weight of water (in gm)(Ww= W2-W3)	11.824 gm
Moisture content or water content(w) = Ww/W0 *100%	39.89 %
Volume of wet soil pat(V)(in cm3)	22.042 cm^3
Volume of dry soil particle(V0)(in cm3)	16.5812 cm^3

The saturation water content of the soil samples was determined through a shrinkage limit test. Specifically, a 50-gram sample of the soil was analyzed, and the full saturation water content was found to be 9.3903 grams. This result indicates the level of hydration that the soil can retain when it is fully saturated.

We got the Saturation Water content for the sandy clay soil sample using 'Shrinkage Limit Test'.Full Saturation Water content = 9.3903gm. This is the amount of water content required to fully saturate a 50-gm sample of sandy clay soil.

3.5.2 Sensor Calibration by Mapping of soil moisture with sensor output voltage

During the field experiments, the moisture content of the soil was measured using a soil moisture sensor. The ESP32 microcontroller's analog-to-digital converter (ADC) converted the output voltage from the soil sensor into a digital value. The ADC typically operates with a reference voltage, which in the case of the ESP32 is 3.3 volts, the ADC typically employs a 10-bit resolution, allowing it to represent 1024 different voltage levels between 0 and the reference voltage. By dividing the sensor output by 1024 and then multiplying by the reference voltage (3.3 volts), the digital value is effectively converted back into the corresponding voltage level read by the ADC. Thus, the formula used to derive the voltage value representing the soil sensor output is:

$$v = u * \frac{3.3}{1024}$$

where, v= Sensor Voltage (in Volts)
u = Sensor raw data

This necessitated the establishment of a relationship between the voltage reading and the actual moisture content of the soil, achieved by taking voltage readings at various proportions of the full saturation water content of the soil sample.

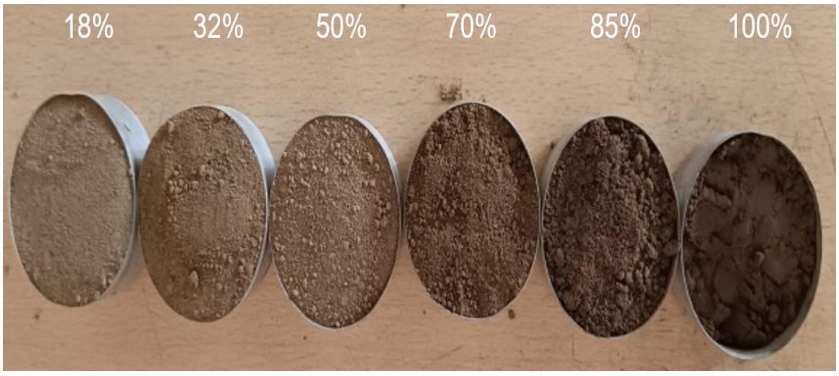


Figure 14. 50gm soil sample having different moisture content

At different water content or moisture content levels, the soil moisture reading was taken, which is listed in TABLE 4. The texture of soil for different moisture content is shown in Fig. 14.

Table 4 Observation table of soil moisture sensor output

Moisture content (in %)	Water content (in gm)	Soil Moisture Sensor raw data	Soil moisture Sensor voltage (in V)
0	00	511	1.6467467
18	1.69	504	1.624
32	3.0	449	1.44
50	4.695	395	1.27
70	6.5732	364	1.17
85	7.982	294	0.947
100	9.3903	232	0.747

The 'water content' value was plotted against the output voltage (in Volts) of the Soil Moisture Sensor using the 'Curve Fitting Method', while different amounts of water were added to the soil sample. The resulting graph is presented in Fig. 15:

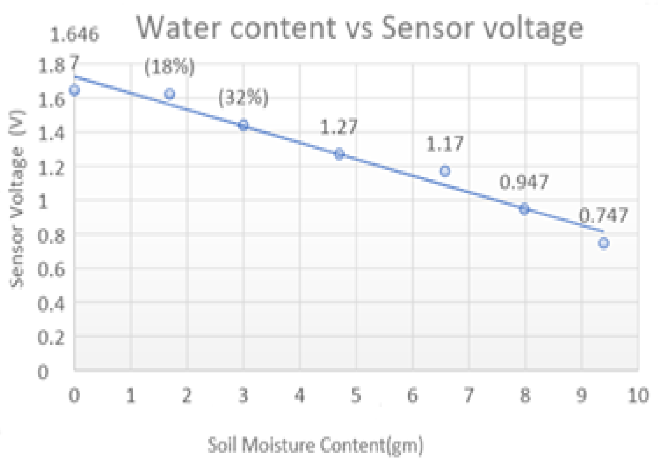


Figure 15. Water content vs moisture sensor voltage graph

The linear regression method is used to determine the linear equation of the plot.

$$y(x) = -0.097x + 1.725$$
$$R^2 = 0.968$$

After analyzing the sample values, the equation for the predicted polynomial curve has been determined. The equation is of degree 2.

$$y = -0.005x^2 - 0.0502x + 1.6644$$
$$R^2 = 0.986$$

R^2 is a statistical metric that evaluates the quality of a model's fit. It measures how closely the model fits the data when compared to a horizontal line that passes through the mean of all ‘y’ values. The range of R^2 is between 0 and 1, with a value closer to 1 indicating a better fit. A quadratic equation has a higher R^2 value than a linear equation, which means that the quadratic curve fits the data better than the linear curve. Therefore, the result obtained from a quadratic equation is more accurate and closer to the actual value than that of a linear equation. So, the relation between Soil moisture sensor voltage (y) and moisture or water content(x) of the soil is given as

$$y = -0.005x^2 - 0.0502x + 1.6644 \quad (4)$$

where y= Sensor Voltage output of the soil at x amount of moisture content.

x= Water Content or moisture Content of the Soil.

The negative slope of the equation (4) can be justified as follows. Since a resistive type of sensor has been used, an increase in soil moisture makes the soil more conducting. This decrease in the resistance value is reflected in the soil moisture sensor output value. Hence, an inverse relationship between the soil moisture sensor output and actual soil moisture content.

3.5.3 Method to find threshold value for irrigation scheduling

Irrigation scheduling is the decision of when and how much water to apply to a field. Its purpose is
to maximize irrigation efficiencies by applying the exact amount of water needed to replenish the soil moisture to the desired level. The threshold value will help us schedule irrigation according to the reading of the soil moisture sensor implanted in the field.
The threshold point for irrigation scheduling primarily depends on two factors:

1. Soil type
2. Crop type

A. Determination of soil type:

The type of the soil is being identified by visual observation. At first the soil particles are crushed completely to fine particles and then adequate amount of water is added to the soil until it gets converted to a fine paste. By observing the color and texture of the soil, it can be concluded as sandy clay soil.

A visual inspection of sandy clay soil involves examining its distinctive features. This type of soil typically consists of a blend of sandy and clay particles, which can be seen through a tactile examination. The color of the soil may vary, often displaying a muted hue influenced by both sandy lightness and clayey richness. The texture of the soil is characterized by a granular yet cohesive feel, resulting from the combination of sand's gritty texture and clay's stickiness. In addition, the soil may retain moderate moisture and have a pliable structure.

These observations collectively lead to the identification of sandy clay soil, enabling a quick and insightful classification based on visual attributes of the soil in the field.

Figure 16 Crushed soil and Soil Mixed with water

B. Determination of TAW of the Soil

After identifying the soil type, the TAW (Total Available Water) of the soil is assessed. This information is then utilized to establish the minimum threshold for irrigating various crops in that particular soil type.

Let’s first have a look at a few terminologies:

- **FIELD CAPACITY (FC):**

  Field capacity is the moisture content of the soil after excess water has drained away and the rate of downward movement has decreased. This usually occurs 2-3 days after irrigation or rainfall. At field capacity, the soil holds the maximum amount of water that is readily available for plant use. For example, sandy soils might have a field capacity of about 10% volumetric water content, whereas clayey soils might hold around 40%.

- **PERMANENT WILTING POINT (PWP):**

  Permanent wilting point is the soil moisture level at which plants can no longer extract sufficient water, leading to wilting that they cannot recover from even if water is subsequently added. This point varies by soil type but is typically around 5% for sandy soils and 25% for clayey soils. Plants are unable to use the water held at or below this moisture level.

- **TOTAL AVAILABLE WATER (TAW):**

  Total available water is the difference between the soil water content at field capacity and permanent wilting point. This is the range of moisture that plants can use for growth. For example, if a loamy soil has a field capacity of 25% and a permanent wilting point of 10%, the total available water is 15% (25% - 10%).

- **MANAGEMENT ALLOWABLE DEPLETION (MAD):**

  Management allowable depletion is a threshold used by irrigation managers to determine when to irrigate. It represents the maximum amount of soil water depletion allowed before irrigation is triggered to prevent crop stress. This threshold varies by crop and soil type. For example, for a crop with a moderate sensitivity to water stress, the MAD might be set at 50% of TAW. If TAW is 15%, the MAD would be 7.5%, meaning irrigation should begin when soil moisture content drops to FC - MAD, or 25% - 7.5% = 17.5%.

Example Application:

Consider a cornfield planted on loamy soil:

Field Capacity (FC): **25%**
Permanent Wilting Point (PWP): **10%**
Total Available Water (TAW): **15% (25% - 10%)**
Management Allowable Depletion (MAD) for corn: **50% of TAW, which is 7.5%**
In this case, the soil should be irrigated when its moisture content falls to **17.5% (25% - 7.5%).**
This ensures that the plants have adequate water to avoid stress and maintain healthy growth.

As the soil texture of the soil sample is found to be 'Sandy clay soil,' the FC, PWP, and TAW (%) values for that soil type are taken from the parametric TABLE 5 (Ratliff et al. 1983; Hanson et al. 2000).

Let's have a look at the percentage values of FC, PWP and TAW considering the saturation state as 100% and the dry state as 0% for the sandy clay soil in Fig. 17.

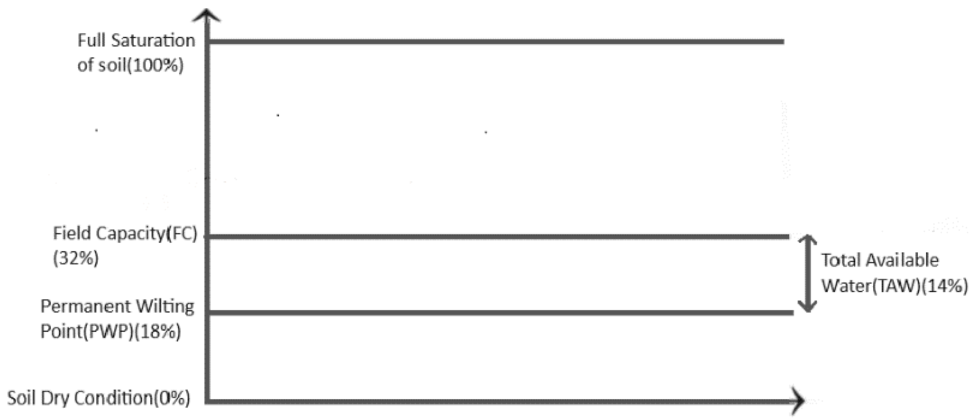


Figure 17 Pictorial representation of TAW determination

3.5.4 Calculation of the Threshold Value for Irrigation Scheduling

Management Allowable Depletion (MAD) value is the threshold value for irrigation scheduling of the crop. MAD value is the maximum amount of water that the irrigation manager chooses to allow the crop to extract from the active rooting zone between successive irrigations, and its value can be obtained from TABLE 6 based on the type of crop and its sensitivity to water stress.

TABLE 5 FC, PWP, AND TAW (%) OF SOIL TEXTURES

Soil texture	FC (%)	PWP (%)	TAW (%)
Sand	10	4	6
Loamy sand	16	7	9
Sandy loam	21	9	12
Loam	27	12	15
Slit loam	30	15	15
Sandy clay loam	36	16	20
Sandy clay	**32**	**18**	**14**
Clay loam	29	18	11
Silty clay loam	28	15	13
Silty clay	40	20	20
Clay	40	22	18
Source: Ratliff et al. (1983); Hanson et al. (2000) Referred by Sumon Datta, Saleh Taghvaeian, Jacob Stivers (2017)			

TABLE 6 MAD VALUES FOR DIFFERENT CROPS

Type of Crop	MAD	Maximum Root Depth(ft)
Rice	0.20	1.6-3.3
Beans	0.45	1.6-4.3
Soybeans	0.50	2.0-4.1
Cool Season-Turf grass	0.40	1.6-2.2
Warm season-Turf grass	0.50	1.6-2.2
Carrots	0.35	1.5-3.3
Cantaloupes/Watermelons	0.40-0.45	2.6-5.0
Potatoes	0.65	1.0-2.0
Source: Allen et al. (1998) Referred by Sumon Datta, Saleh Taghvaeian, Jacob Stivers (2017)		

According to Fig. 17,

Field Capacity (FC) = 32%
Permanent Wilting Point (PWP) = 18%
Total Available Water (TAW) = FC – PWP = (32 – 18) % =14%

The Management Allowable Depletion (MAD) for a sample plant (grass) with a 2.2-ft root depth is 50% of TAW, which is 7% i.e. (0.50 * 14). This means that the maximum amount of soil water content that can be depleted from the root zone before stress occurs is 7%. To avoid any stress, the soil water content should not drop below 25% i.e. (32% - 7%) in the effective root zone. This is equivalent to 2.3475 gm of water, which is 25% of the full saturation level for 50 gm of soil sample. Using the quadratic relation (i), it can be calculated that the sensor voltage for this soil moisture content is 1.5189V.
Therefore, this is the desired threshold value for irrigation scheduling for the sample plant.
In TABLE 6, the MAD values for various commonly grown crops by farmer has been presented. These reference values can be utilized to determine the threshold value for irrigation scheduling of different crops.

3.6 IRRIGATION SCHEDULING USING BLYNK IOT

Based on the voltage output from the soil moisture sensor, the irrigation of the field will be automatically scheduled and controlled using Blynk IoT. The threshold soil moisture sensor voltage output is compared with the actual soil moisture sensor output voltage to make the decision about irrigation. When the sensor output voltage is greater than the threshold value, the mini submersible water pump will start automatically. It will then take feedback from the sensor voltage readings every T seconds to adjust its state based on the feedback, thus preventing over-irrigation. The waiting time ‘T’ can be decided based on the area of the field and the water flow volume of the pump. In case of any mishap in the system, the farmer can control the state of the water pump using on/off button in the Blynk IoT Application.

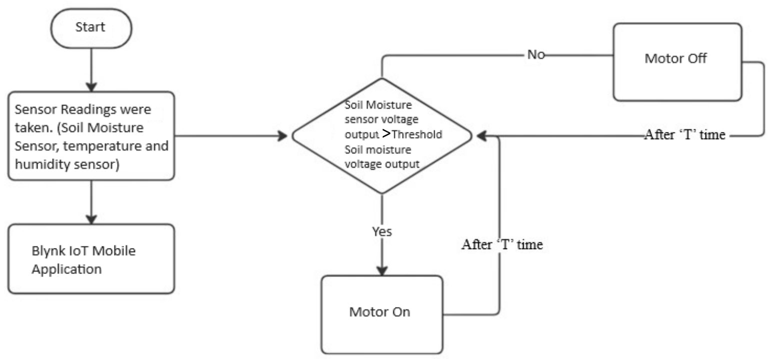


Figure 18 Flow diagram of automated decision-making system in agriculture

<u>Code that is being used for irrigation scheduling</u>

```
#define BLYNK_TEMPLATE_ID "TMPL3AiY9HxkC"
#define BLYNK_TEMPLATE_NAME "SSS"
#define BLYNK_AUTH_TOKEN "rlGX_ypx6mPwuHei2oGPK7czOMV2KNZy"

#define BLYNK_PRINT Serial
#include <WiFi.h>
#include <BlynkSimpleEsp32.h>
#include <DHT.h>
// Include the I2C LCD library

#define SOIL_MOISTURE_PIN 34
#define THRESHOLD_MOISTURE 2.0
#define PUMP_PIN 2
#define PUMP_SWITCH V2
#define DHT_PIN 4
#define DHT_TYPE DHT11

char auth[] = BLYNK_AUTH_TOKEN;
char ssid[] = "ABCD";
char pass[] = "ABCD";

DHT dht(DHT_PIN, DHT_TYPE);

BlynkTimer timer;

bool isPumpOn = false;
int adcResolution = 4095;
unsigned long pumpRunInterval = 5000; // Pump runs for 5 seconds
```

```
unsigned long checkInterval =3000;   // Check moisture every 2 seconds

void sendSensorData() {
  int rawValue = analogRead(SOIL_MOISTURE_PIN);
  float voltage = (rawValue / (float)adcResolution) * 3.3;

  float temperature = dht.readTemperature();
  float humidity = dht.readHumidity();
  Serial.print("Temperature: ");
  Serial.println(temperature);
  Serial.print("Humidity: ");
  Serial.println(humidity);
  if (!isnan(temperature) && !isnan(humidity)) {
    Blynk.virtualWrite(V0, temperature);
    Blynk.virtualWrite(V1, humidity);
  } else {
    Serial.println("Failed to read data from DHT sensor!");
  }
  Blynk.virtualWrite(V3, voltage);

  if (voltage > THRESHOLD_MOISTURE) {
    while (voltage > THRESHOLD_MOISTURE) {
      if (!isPumpOn) {
        digitalWrite(PUMP_PIN, LOW);
        isPumpOn = true;
        Serial.println("Pump turned ON due to low moisture.");
      }

      delay(pumpRunInterval);

      digitalWrite(PUMP_PIN, HIGH);
      isPumpOn = false;
      Serial.println("Pump turned OFF after running.");

      delay(checkInterval);

      rawValue = analogRead(SOIL_MOISTURE_PIN);
      voltage = (rawValue / (float)adcResolution) * 3.3;

      Serial.print("Rechecking Soil Moisture Voltage: ");
      Serial.println(voltage);
    }

    Serial.println("Moisture level sufficient. Pump remains OFF.");
  } else {
    if (isPumpOn) {
      digitalWrite(PUMP_PIN, HIGH);
      isPumpOn = false;
      Serial.println("Pump turned OFF due to sufficient moisture.");
```

```
    }
  }
}

BLYNK_WRITE(PUMP_SWITCH) {
  isPumpOn = param.asInt();
  if (isPumpOn) {
    Serial.println("Pump manually turned ON");
  } else {
    Serial.println("Pump manually turned OFF");
  }
}

void setup() {
  Serial.begin(9600);
  pinMode(PUMP_PIN, OUTPUT);
  digitalWrite(PUMP_PIN, HIGH);
  dht.begin();

  Blynk.begin(auth, ssid, pass);

  timer.setInterval(3000L, sendSensorData);

  Blynk.virtualWrite(PUMP_SWITCH, isPumpOn);
  Blynk.syncVirtual(PUMP_SWITCH);
}

void loop() {
  Blynk.run();
  timer.run();
}
```

Figure 19 Hardware setup of the proposed system

3.7 PROS AND CONS OF THE PROPOSED MODEL

Before delving into the advantages and disadvantages of smart irrigation systems, it's essential to acknowledge their pivotal role in modern agriculture and the complexity of managing water resources effectively. By integrating the parameters like temperature, humidity and soil moisture into irrigation practices, farmers can make informed decisions to optimize crop yield while conserving water resources and mitigating environmental impacts. However, it's also crucial to recognize the challenges and limitations associated with implementing these systems, considering factors such as cost, technology reliability, and the need for ongoing monitoring and maintenance. Let's explore these aspects further by examining the advantages and disadvantages in detail.

<u>ADVANTAGES</u>

1. Reduces water wastage, ensuring crops receive precisely what they need:

The system optimizes water usage by delivering the exact amount of water required by the crops. This precision prevents over-irrigation and under-irrigation, ensuring that each plant gets the necessary hydration without any wastage, which is crucial for both water conservation and plant health.

2. Ensures real-time remote monitoring of field conditions:

By utilizing advanced sensors and monitoring technologies, the system allows farmers to keep an eye on various field parameters such as soil moisture, temperature, and humidity from a remote location. This real-time data enables timely interventions and better decision-making, enhancing overall farm management efficiency.

3. Improved water management leads to improved yield and increased productivity:

Efficient water management directly impacts crop health and growth. By providing optimal watering schedules and amounts, the system helps in boosting crop yields and productivity. This not only meets the growing food demand but also increases the profitability for farmers.

4. Cost-efficient system:

While the initial setup might involve some investment, the long-term savings on water bills and the increase in crop yields make the system cost-effective. The reduction in water wastage and the improvement in resource management contribute to overall lower operational costs.

5. Both crop and soil type are considered while determining the threshold:

The system takes into account the specific needs of different crops and the characteristics of the soil in which they are planted. This tailored approach ensures that the irrigation provided is suitable for the particular crop and soil type, optimizing growth conditions and enhancing crop quality.

DISADVANTAGES

1. Time-taking calculations:

The precision and efficiency of the system rely on complex calculations and data analysis, also need to perform shrinkage limit test which can be time-consuming.

2. Climatic changes are not considered:

The system may not fully account for sudden or extreme climatic changes, such as unexpected rainfall or drought conditions. This can impact its effectiveness, as it might not be able to adapt quickly to these changes without manual intervention.

3. More environmental factors need to be considered for improving efficiency:

To achieve maximum efficiency, the system needs to integrate a wider range of environmental factors beyond just soil moisture and crop type. Factors such as evapotranspiration rates, and microclimates within the field should also be considered, which can complicate the system further and require more sophisticated technology and analysis.

CHAPTER -4

CONCLUSION AND FUTURE SCOPE

The work underscores the importance of adopting precision irrigation scheduling techniques for sustainable agriculture. The findings contribute valuable insight into optimizing water usage while maximizing crop yield. This research aims to determine the threshold condition for irrigation scheduling using the Management Allowable Depletion (MAD) value of the crop. Through a comprehensive investigation and analysis, this work emphasizes the optimization of irrigation practices, leading to enhanced water usage efficiency in crop cultivation. The findings reveal a clear correlation between the MAD value of the crop and its water requirements. This approach helps farmers to manage the water resources efficiently for sustainable crop yield and resource conservation, by identifying the threshold condition for irrigation scheduling. The utilization of MAD as a guiding metric in irrigation scheduling proves itself to be a reliable indicator for assessing variations in soil moisture and consequently, determining the optimal timing and volume of irrigation. This approach not only enhances the precision of water application but also minimizes wastage, addressing the growing concerns of water scarcity in agriculture. The significance of this research extends beyond the theoretical framework, as the proposed threshold-based irrigation scheduling methodology demonstrates its applicability across diverse agricultural settings.

This system helps farmers to monitor real-time field parameters like soil moisture, temperature, and humidity and make informed decisions based on the threshold soil moisture value. By monitoring the crop's MAD value, farmers can create an exact irrigation schedule for their crop based on the soil type of the field. When soil moisture drops below a certain level, the Blynk IoT App notifies the farmer and irrigation starts. The system works on feedback to prevent over-irrigation. If there's any abnormality marked, farmers can control the pump with an on/off button in the Blynk IoT App and take the necessary steps.

In the future, we aim to increase the precision of the system by analyzing more environmental factors and weather conditions. This will involve refining threshold values based on various types of crops, soil, and climatic conditions. By taking these additional variables into account, we hope to enhance the accuracy and effectiveness of the system, ensuring it can better accommodate the diverse needs of different agricultural settings. This comprehensive approach will ultimately lead to more informed decision-making and improved outcomes in agricultural management.

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