IoT-Based Analysis of Soil Moisture Impact in Agriculture through Real-time Monitoring of Atmospheric Humidity and Temperature

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ABSTRACT

This M.Tech project introduces an innovative approach to agricultural soil management by leveraging Internet of Things (IoT) technology. It centers on the development of a sophisticated IoT-based system for real-time soil moisture monitoring, coupled with the analysis of the dynamic relationship between soil conditions and atmospheric factors, specifically humidity and temperature. The project integrates IoT sensors, including soil moisture level sensors and atmospheric sensors, with data processing conducted using C++ or Python programming languages. Data is collected and logged at 30-second intervals, enabling comprehensive insights into soil moisture dynamics. A key feature of the system is its ability to transmit data directly to Google Sheets via Wi-Fi connectivity, ensuring real-time access for remote monitoring and analysis. The project's primary objectives are to facilitate precision agriculture, improve crop yield, and optimize resource allocation. By providing real-time, data-driven insights into soil moisture levels and their correlation with atmospheric conditions, this project empowers farmers and agronomists with valuable tools for informed decision-making. Furthermore, it contributes to sustainable farming practices by enabling efficient irrigation and resource management, ultimately fostering increased agricultural productivity and resource conservation. In conclusion, the IoT-Based Analysis of Soil Moisture Impact in Agriculture through Real-time Monitoring of Atmospheric Humidity and Temperature" represents a pivotal advancement in modern agriculture, aligning technology with environmental stewardship and agricultural sustainability.

Keywords*: M.Tech project, IoT technology, soil moisture monitoring, atmospheric sensors, precision agriculture.*

1.1 INTRODUCTION

The rapid evolution of technology has significantly influenced various sectors, and agriculture is no exception. In this context, the Internet of Things (IoT) emerges as a transformative force in agricultural soil management. This introduction delves into an innovative M.Tech project that harnesses IoT technology to revolutionize the understanding and optimization of soil conditions in agriculture. The project revolves around the development of a sophisticated IoT-based system specifically designed for real-time monitoring of soil moisture and the dynamic interplay between soil conditions and atmospheric factors, focusing on humidity and temperature. Through the integration of cutting-edge IoT sensors, such as soil moisture level sensors and atmospheric sensors, the system captures crucial data points essential for a comprehensive analysis. Utilizing C++ or Python programming languages for data processing, the project ensures a robust analytical framework. The collected data is logged at short intervals of 30 seconds, providing a high-resolution view into the intricacies of soil moisture dynamics. A standout feature of this system is its capability to transmit data directly to Google Sheets via Wi-Fi connectivity, offering real-time accessibility for remote monitoring and in-depth analysis.

The primary objectives of this project encompass advancing precision agriculture, enhancing crop yield, and optimizing resource allocation. By offering real-time, data-driven insights into soil moisture levels and their correlation with atmospheric conditions, the project equips farmers and agronomists with valuable tools for informed decision-making. Beyond immediate benefits, it contributes significantly to sustainable farming practices by facilitating efficient irrigation and resource management, ultimately fostering increased agricultural productivity and conservation of vital resources.In conclusion, the IoT-Based Analysis of Soil Moisture Impact in Agriculture through Real-time Monitoring of Atmospheric Humidity and Temperature" marks a pivotal advancement in modern agriculture. By aligning technology with environmental stewardship, this project stands at the forefront of promoting agricultural sustainability, paving the way for a more efficient and resource-conscious farming future.

Plants play a pivotal role in sustaining human life by providing essential oxygen. Simultaneously, agriculture serves as a fundamental component for ensuring food security. The key determinants for achieving optimal crop yield include the judicious application of accurate fertilizers, efficient irrigation practices, and employing best-in-class cultivation methods. A precise balance of fertilizers contributes significantly to enhancing both the quality and quantity of crop production, addressing the escalating demands of the global economy for food resources. Given that over 58% of the rural population relies on agriculture for their livelihood, with agricultural exports constituting 10% of the country's total exports, it underscores the sector's critical economic importance. Any inadequacy in agricultural productivity, stemming from a lack of understanding of soil characteristics and water scarcity, can have adverse consequences on both individual farmers and the broader national economy. To avert such challenges, it is imperative for the Indian government to implement strategic measures, fostering informed agricultural practices for sustainable and profitable outcomes.

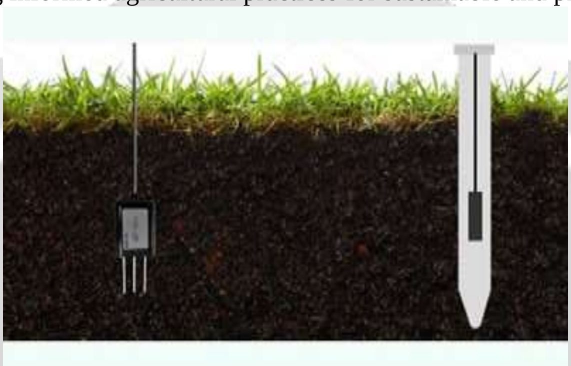

Fig1.1 : soil moisture sensor inside soil

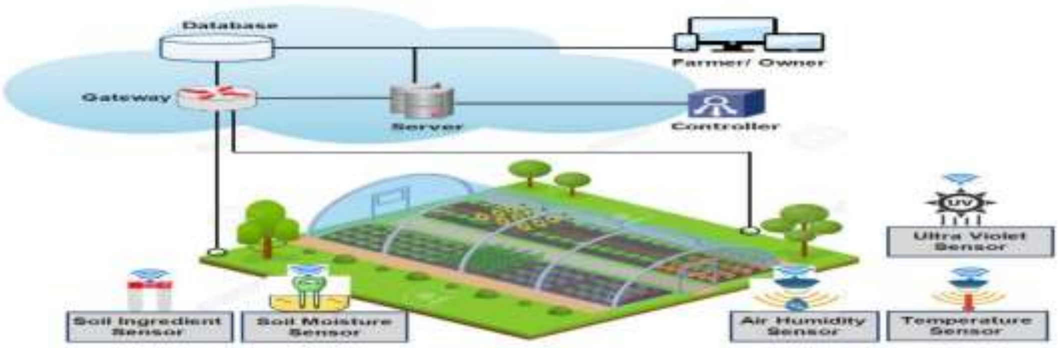

Fig 1.2 Use of Iot in agriculture parameters monitoring

1.2 System Structure:

1. Hardware Components:

1. NodeMCU ESP8266 Microcontroller Module: This module serves as the brain of the system, responsible for interfacing with various sensors, processing data, and transmitting it to the cloud.
2. DHT11 Temperature and Humidity Sensor: This sensor measures the ambient temperature and humidity levels in the surrounding environment.
3. Capacitive Soil Moisture Sensor: This sensor measures the volumetric water content in the soil, providing crucial data for soil moisture analysis.
4. Power Supply: The system requires a stable power source to operate the NodeMCU and sensors reliably.

Fig 1.3 : Iot Data Logger with dht11 and soil moisture level sensor in real time testing mode

2. Software Components:

1. Embedded Firmware: Programmed using C++ or Python, the firmware controls the operation of the NodeMCU, reads sensor data, processes it, and manages data transmission.
2. Wi-Fi Connectivity: The firmware includes Wi-Fi connectivity functionality to connect the NodeMCU to a designated Wi-Fi network. Default SSID and password are "TRONIX" and "TRONIX_2023" respectively.
3. Data Processing: Utilizing C++ or Python programming languages, the firmware processes the collected sensor data to derive meaningful insights and perform necessary calculations.
4. Google Sheets Integration: The firmware is configured to transmit data directly to Google Sheets, enabling real-time data logging and remote accessibility for monitoring and analysis.

3. System Operation:

1. Sensor Data Collection: At regular intervals (e.g., every 30 seconds), the NodeMCU reads data from the DHT11 temperature and humidity sensor and the capacitive soil moisture sensor.
2. Data Processing: The collected sensor data is processed onboard the NodeMCU using the embedded firmware, performing necessary computations and formatting the data for transmission.
3. Data Transmission: Processed data is transmitted over Wi-Fi to a designated Google Sheets document. The NodeMCU authenticates with the specified Wi-Fi network using the programmed SSID and password.
4. Real-Time Monitoring and Analysis: Data logged in Google Sheets is instantly accessible for remote monitoring and in-depth analysis. Stakeholders can visualize trends, make informed decisions, and optimize soil management practices based on real-time data insights.

4. System Configuration:

a. Initial Setup: Upon deployment, the NodeMCU is configured with the appropriate firmware and connected to the designated Wi-Fi network using the provided SSID and password.
b. Sensor Calibration: The system may require initial calibration to ensure accurate sensor readings and optimal performance.
c. Google Sheets Integration: The NodeMCU is configured to interface with a specific Google Sheets document, allowing seamless data transmission and logging.

5. Benefits:

a. Real-Time Monitoring: Enables farmers and agricultural practitioners to monitor soil conditions continuously and make timely interventions as needed.
b. Data-Driven Decision Making: Access to high-resolution soil moisture and environmental data empowers stakeholders to make informed decisions regarding irrigation, fertilization, and crop management.
c. Enhanced Efficiency: Automation of data collection and logging processes reduces manual effort and minimizes the risk of human error.
d. Scalability: The system can be scaled to accommodate additional sensors or expanded to cover larger agricultural areas, providing flexibility for future upgrades and enhancements.

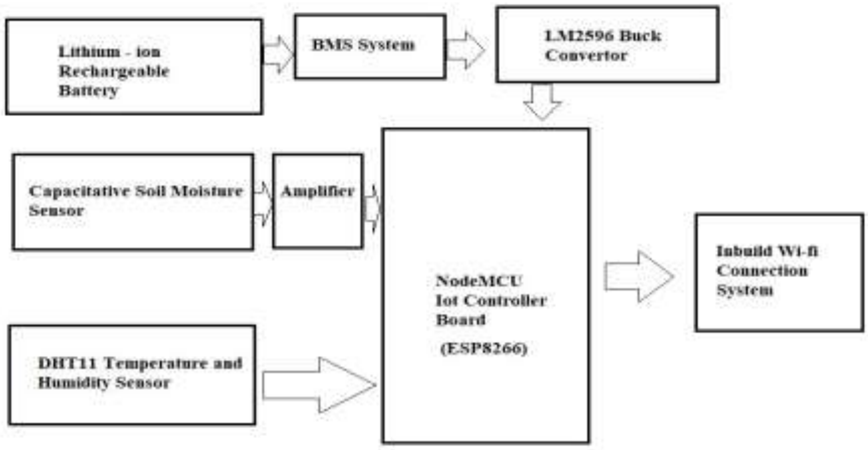

Fig 1.4 : System Block Diagram

1.3 Objective:

1. Implement an IoT-based system using NodeMCU (ESP8266) microcontroller programmed in C and Python for real-time monitoring of soil moisture, atmospheric humidity, and temperature in agricultural fields.
2. Develop firmware for the NodeMCU to collect data from soil moisture sensors, humidity sensors, and temperature sensors deployed in the field.
3. Establish wireless connectivity between the NodeMCU and a central server for transmitting collected data to an online Google Sheet.
4. Utilize Google Sheets API for logging temperature and humidity values in real-time onto an online spreadsheet accessible to authorized users.
5. Design algorithms to convert tabular data logged in Google Sheets into graphical representations, facilitating visualization and analysis of the collected data.
6. Perform differential graphical analysis to compare soil moisture data with respect to variations in temperature and humidity levels, both in constant or room temperature conditions and with variable changing temperature.
7. Explore statistical methods and machine learning techniques to analyze the relationship between soil moisture levels, atmospheric conditions (humidity and temperature), and agricultural productivity.
8. Evaluate the effectiveness of the IoT-based monitoring system in providing actionable insights to farmers for optimizing irrigation scheduling and improving crop yield and quality.
9. Assess the scalability, reliability, and cost-effectiveness of the proposed system in real-world agricultural settings.

10. Document the research findings, methodologies, and implementation details in a comprehensive M.Tech thesis report, highlighting the significance and implications of the study for the field of precision agriculture and IoT-based environmental monitoring.

Chapter -2
Literature Review:

1. IoT Based Smart Agriculture System Kajal N. Dhawale, Dr. Narendra Bawane M.Tech VLSI, Jhulelal Institute of Technology, Nagpur Nagpur, India Professor, Principal, Jhulelal Institute of Technology, Nagpur Nagpur, India, IOSR Journal of Engineering (IOSRJEN), Vol. 09, Issue 5 (May. 2019).

A substantial volume of data is gathered by sensors deployed in the field. This amassed data requires efficient processing, analysis, and storage solutions to be implemented cost-effectively. Our focus lies in the integration of cutting-edge technologies like sensors and IoT (Internet of Things) to revolutionize agricultural methodologies. By capturing data pertaining to diverse soil parameters, we aim to analyze and compute this information, thereby delivering optimal farming solutions. The utilization of computational techniques in the agricultural sector holds immense potential, including but not limited to, extensive storage of agricultural data, cloud-based management of production processes, storage of economic data related to agriculture, early-warning systems, and policy formulation based on market trends in agricultural products.

2. Utilization of IoT for Soil Moisture and Temperature Monitoring System for Onion Growth Izak Habel Wayangkau , Yosehi Mekiuw , Rachmat Rachmat , Suwarjono Suwarjono , Hariyanto Hariyanto. Emerging Science Journal Vol. 4, Special Issue "IoT, IoV, and Blockchain", (2020, 2021).

Utilizing IoT technology in precision agriculture plays a pivotal role in enhancing crop production. In Merauke Regency, the local supply of onions falls short of meeting demand, resulting in elevated market prices. Consequently, a significant portion of the onion demand is met from external sources due to suboptimal production by local farmers. Weather conditions have been identified as a key factor influencing onion quality. This study endeavors to develop an automated monitoring system employing an Arduino microcontroller to measure soil moisture and temperature in onion fields. The methodology involves designing an automated monitoring device capable of assessing soil moisture and temperature to furnish insights into onion growth and maintenance. The Arduino microcontroller interfaces with sensors for data acquisition, integrated with component devices to regulate temperature and soil moisture levels. All components are tailored to function within a customized greenhouse prototype environment. Findings from this study demonstrate the efficacy of the tool and system in capturing soil moisture and temperature data, while effectively maintaining optimal soil conditions across varying weather scenarios, including cloudy, wet, and hot conditions.

3. A novel soil moisture, temperature and humidity measuring system- an iot approach , larry elikplim kodjo akpalu, , rose-mary owusuaa mensah gyening, osman yakubu, isaac nkrumah jr. Garden City University College, Department of Computer Science, Ghana. Journal of Theoretical and Applied Information Technology 15th March 2021. Vol.99. No 5.

The burgeoning global population amplifies food demand, urging cost-effective agricultural practices to avert famine, especially in low-income nations. Soil quality is pivotal for effective food production, necessitating precise measurement of moisture, humidity, and temperature to enhance farming efficiency. In Sub-Saharan African countries like Ghana, reliance on manual soil assessment proves laborious and ineffective. To address this, an IoT-based system for soil parameter measurement is proposed, integrating moisture probe, temperature, and humidity sensors, and Wi-Fi for data transmission. Rigorous field testing validates its efficacy, electronically alerting farmers to optimal crops based on real-time data. This system represents a significant advancement, offering tailored crop recommendations grounded on comprehensive soil parameter analysis.

4. An IOT-Based Soil Moisture Management System for Precision Agriculture: Real-Time Monitoring and Automated Irrigation Control Conference Paper · September 2023.

Managing soil moisture is vital for crop growth and yield. Leveraging IoT advancements, an innovative soil moisture management system is introduced for precision agriculture at Siksha 'O' Anusandhan (SOA) University. Integrating sensor nodes, wireless communication, and cloud computing enables real-time monitoring and automated irrigation. This overcomes limitations of manual methods, revolutionizing soil moisture management practices. Low-cost sensor nodes strategically gather data across fields, transmitted wirelessly for analysis. Thorough testing validates its reliability, enhancing water use efficiency. The scalable IoT architecture allows adaptation to various crops and field conditions, contributing significantly to precision agriculture. Implementation at SOA University underscores commitment to technology integration, promoting sustainable crop growth and resource management.

5. INFLUENCE OF ATMOSPHERIC CONDITIONS ON SOIL PROPERTIES IN VIDARBHA REGION: AN IoT BASED REMOTE MONITORING SYSTEM J. S. Tated , C. M. Jadhao, Research Scholar, Post Graduate Department of Electronics, Brijlal Biyani Science College, Amravati, Dist. Amravati, M.S., India Principal, Mauli College of Engineering & technology, Shegaon Dist. Buldhana, M.S., India. 2022 IJCRT | Volume 10, Issue 2 February 2022.

It is anticipated that air temperatures will continue to rise for the foreseeable future. In the context of climate change and its extremes, it is critical to comprehend the complex interactions among soil moisture, near-surface air temperature, and relative humidity. The purpose of this essay is to examine how soil qualities are affected by meteorological variables like relative humidity and air temperature. We use an Arduino Nano microcontroller V3.0, a DHT22 sensor, and a corrosion-resistant Capacitive Soil Moisture sensor V2.0 to do this. The ESP8266 Wi-Fi module enables the data to be transported to the cloud in an effortless manner.

6. IoT- Based Smart Agriculture Using Solar Energy Mohammad Kaif Devlapur, Mustaqeen Nimbargi, Omkar Patil, Ruchita M Angadi Institute of Technology and Management, Savagoan Road, Nanawadi Belgaum , International Journal of Research Publication and Reviews, Vol 4, no 5, pp 5028-5032 May 2023.

IoT (Internet of Things) based smart agriculture encompasses the utilization of cutting-edge technologies such as sensors, data analytics, and automation within the agricultural domain, aiming to enhance crop yields, diminish expenses, and augment efficiency. This methodology entails the collection and analysis of data pertaining to various variables including soil moisture, temperature, humidity, and plant growth, which is then utilized to optimize farming operations. Smart agriculture systems offer real-time alerts and recommendations to farmers, empowering them to make informed decisions concerning irrigation, fertilization, and pest management. By harnessing the capabilities of IoT, smart agriculture holds the promise of revolutionizing the farming sector, rendering it more sustainable, productive, and profitable.

7. IOT BASED SYSTEM FOR CONTINUOUS MEASUREMENT AND MONITORING OF TEMPERATURE, SOIL MOISTURE AND RELATIVE HUMIDITY, International Journal of Electrical Engineering & Technology (IJEET) Volume 9, Issue 3, May-June 2018.

This paper introduces a highly efficient and economically viable system designed to assist farmers in monitoring crucial environmental parameters essential for crop growth, including temperature, relative humidity, and moisture levels. Additionally, it conducts a comparative analysis between two distinct types of soil moisture sensors to facilitate the selection of the optimal option. The system operates by measuring ambient temperature, soil moisture, and relative humidity employing DHT11, a capacitive soil moisture sensing circuit, and a resistive soil moisture sensing circuit. Subsequently, the collected data is transmitted to a cloud server, enabling remote access and management.

CHAPTER – 3
PROBLEM IDENTIFICATION

1. Lack of Traditional Soil Monitoring Methods: The paragraph implies that traditional methods of soil monitoring may not be adequate, prompting the need for technological intervention.
2. Insufficient Real-time Data: The mention of real-time monitoring suggests that current data collection methods might not offer timely insights into soil conditions.
3. Limited Understanding of Soil-Atmosphere Interaction: The project's focus on the interplay between soil conditions and atmospheric factors implies a gap in understanding this complex relationship.
4. Inadequate Soil Moisture Monitoring: There's a suggestion that existing soil moisture monitoring methods may not be comprehensive or efficient enough.
5. Absence of Advanced Sensor Integration: The reliance on cutting-edge IoT sensors indicates a lack of integration of advanced sensor technologies in current soil monitoring practices.
6. Programming Language Compatibility Issues: The mention of specific programming languages like C++ or Python suggests potential compatibility issues with existing systems or tools.
7. Data Logging Interval Concerns: The short data logging intervals highlight concerns about the frequency and resolution of data collection in current soil monitoring approaches.
8. Limited Accessibility to Monitoring Data: The need for direct transmission of data to Google Sheets implies a lack of accessible and user-friendly platforms for monitoring and analysis.
9. Challenges in Remote Monitoring: The emphasis on Wi-Fi connectivity for remote monitoring suggests challenges in accessing real-time data from remote locations.
10. Potential for Inadequate Analysis: The need for a robust analytical framework implies concerns about the depth and accuracy of current soil data analysis methods.
11. Critical Soil Moisture Management: The problem of effectively managing soil moisture levels is central to agricultural productivity and sustainability.
12. Inconsistent Soil Moisture: Inconsistent soil moisture levels can lead to reduced crop yields, increased resource consumption, and environmental impacts.
13. Limited Real-time Data: Traditional soil moisture monitoring methods lack real-time capabilities, impeding timely interventions and decision-making.

14. Need for Precision Agriculture: The challenge lies in achieving precision agriculture, where resources like water and fertilizers are applied optimally based on real-time soil conditions.
15. Data Integration Challenges: Integrating IoT sensors for soil moisture with atmospheric sensors poses data integration challenges that need to be addressed.

16. Environmental Sustainability: Achieving sustainable farming practices is essential, and optimizing irrigation through accurate soil moisture data is a key element of this goal.
17. Resource Efficiency: Effective soil moisture management contributes to resource efficiency by reducing water wastage and minimizing the environmental impact of agriculture.
18. Complex Interdependencies: Soil moisture levels are influenced by various factors, including atmospheric humidity and temperature, making the problem multifaceted.
19. Remote Monitoring Needs: With the expansion of agriculture into larger, remote areas, the need for remote soil moisture monitoring solutions becomes increasingly crucial.
20. Data-Driven Solutions: The problem identification highlights the shift towards data-driven solutions, where IoT-based technology provides real-time insights for improved soil moisture management.

CHAPTER – 4
METHEDOLOGY

4.1 Methodology
The methodology for the proposed system involves the following steps and components:

1. Hardware Setup: Utilize NodeMCU, programmed via Arduino IDE with ESP8266 board library, for its built-in WiFi module to connect to any hotspot. Program the Arduino IDE interface with the SSID and password of the mobile hotspot. Enclose the system in a hard plastic box, incorporating three LED indicators for power, WiFi connection, and server connection.

2. Connection Establishment: Once powered on, the NodeMCU establishes a connection to the designated mobile hotspot, enabling communication with the Google API to link with Google Sheets for data logging.

3. Data Sensing and Transmission: Employ a DHT11 sensor to collect atmospheric temperature and humidity data. Utilize a soil moisture level analog indicator to capture soil moisture levels, sending this data in analog form to Google Sheets. The system initiates data transmission to Google Sheets every 5-10 seconds when all LED indicators are illuminated, indicating online status and connectivity.

4. Soil Moisture Monitoring: Monitor the soil moisture level using the analog indicator. An increase in analog value suggests low soil moisture, while a decrease indicates high soil moisture. This information is transmitted to Google Sheets for real-time monitoring and analysis.

5. Data Logging and Analysis: Data collected from both the DHT11 sensor and the soil moisture level indicator is logged onto Google Sheets, facilitating continuous monitoring and analysis of soil conditions and atmospheric parameters.

6. Operational Feedback: LED indicators provide visual feedback on system status, ensuring easy monitoring of power, WiFi connectivity, and server connection. This allows for prompt identification of any operational issues.

7. Continuous Monitoring: The system operates continuously, providing real-time data updates to Google Sheets, allowing users to make informed decisions regarding soil management and irrigation practices based on current conditions.

4.2 Methods used For this Study is as Follows:
1.Power On and Initialization: The NodeMCU initializes and starts the setup procedure when the system is powered on.
2.WiFi Connection Establishment: By utilizing the preprogrammed SSID and password, the NodeMCU establishes a connection to the specified mobile hotspot, allowing for internet access.
3.Google API Authentication: To create a secure connection with Google Sheets for data recording, the system first authenticates with the Google API.
4.Sensor Data Collection: The soil moisture level analog indicator captures data on soil moisture level, while the DHT11 sensor measures air temperature and humidity
5.Data Transmission to Google Sheets: To ensure real-time updates, the gathered sensor data is analyzed and sent to Google Sheets on a frequent basis, usually every 5 to 10 seconds.
6.Analog to Digital Conversion (Soil Moisture): This process transforms the analog data on soil moisture levels into a digital format that can be accessed by signing into Google Sheets.
7.LED Indicator Display: LED indicators light up to show the power, WiFi, and server connection status of the

system. When every LED is lighted, the system is up and operating as intended.

8.Constant Monitoring: The system keeps track of soil moisture content and atmospheric conditions, sending the most recent information for analysis to Google Sheets.

9.Threshold Detection (Soil Moisture): Using the received analog data as a basis, an algorithm determines changes in the amounts of soil moisture. A drop denotes high moisture, whereas an increase points to low moisture.

10.User Accessibility: Users may make educated decisions about soil health and irrigation management by remotely accessing the real-time data recorded on Google Sheets.

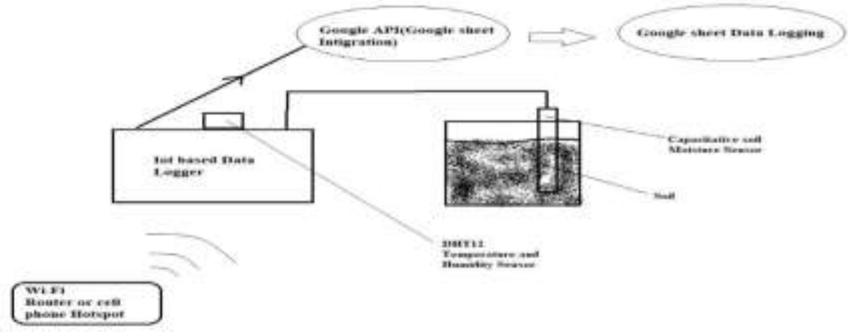

Fig 4.1: Block Diagram Explanation Of system

4.3 Working Procedure:

1) DHT11 is used to measure ambient temperature and humidity, while Soil Moisture Sensor is used to measure moisture levels ranging from 0 -1024 unit.
2) The NodeMCU Microcontroller is utilized to receive data from sensors and calculate the surrounding parameters based on the computations in the Header File.
3) Using the serial Communication Program, send the data output to the NodeMCU.
4) The NodeMCU receives serial communication and filters the data from the characters.
5) Identify the specific character sign and filter the data.
6) Using logical operations, convert the character to an integer.
7) Use the configured wifi id and password to connect.
8) Use the Googlw API ID to upload the data to the google sheet.
9)All programming is done in the Arduino IDE software in C and C++.

Fig 4.2: Iot Data Logger with DHT11 and Soil Moisture Level sensor

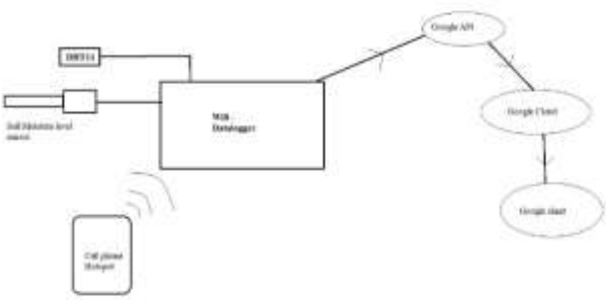

Fig 4.3: Block Diagram For Wi fi Communication

4.4 Google sheet setup:

4.4.1 Process step:

1.Get the Spreadsheet ID from the URL.
For example, if the URL is:
https://docs.google.com/spreadsheets/d/1sqp9hIM5VvDGEf8i9H-W1Z72lm0O5-ZxC16sMMS-cgo/edit#gid=0
2. Then the Spreadsheet ID is:
1sqp9hIM5VvDGEf8i9H-W1Z72lm0O5-ZxC16sMMS-cgo
Selection_006-3
3. From the Google Sheets menu, go to Extensions > Apps Script
4.Delete all of the default text in the script editor, and paste the GoogleScripts-example.gs code.
5.Update the Spreadsheet ID (line 9) with the ID obtained in step 3, and click Save.
Note: The Spreadsheet ID must be contained in single quotation marks as shown in the example code, and the script must be saved before continuing to the next step.
6.Click the blue Deploy button at the top right of the page, and select New Deployment.
7.Click the gear icon next to Select Type, and select Web App and modify the following:
8.Enter a Description (optional)
Who has access: Anyone (note: do not select Anyone with a Google Account - you must scroll down to the bottom to find Anyone)
9.Click Deploy
10.Click Authorize access then select your Google account.
11.On the "Google hasn't verified this app" screen, select Advanced > Go to Untitled project (unsafe) > Allow
12.Copy and save the Deployment ID for use in the ESP8266 code, and click Done.
From the script editor, click Save and then Run.

4.4.2 Description steps and details

1. Start a Project on Google Cloud Platform: Using the Google Cloud Platform (GCP) console, start by establishing a project.

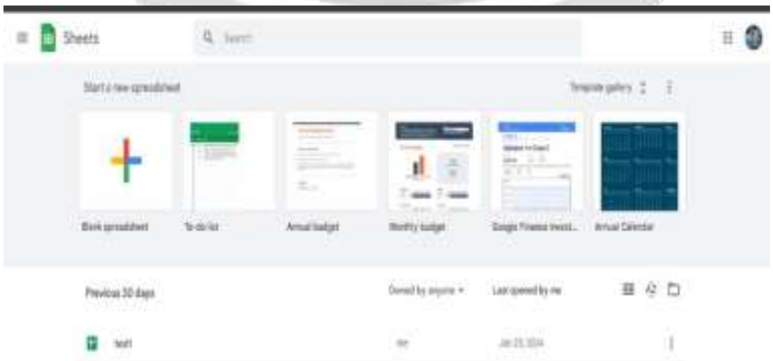

Fig4.4: Creating Google sheet

2. Enable Google Sheets API: Set up the Google Sheets API for your project in the GCP interface.

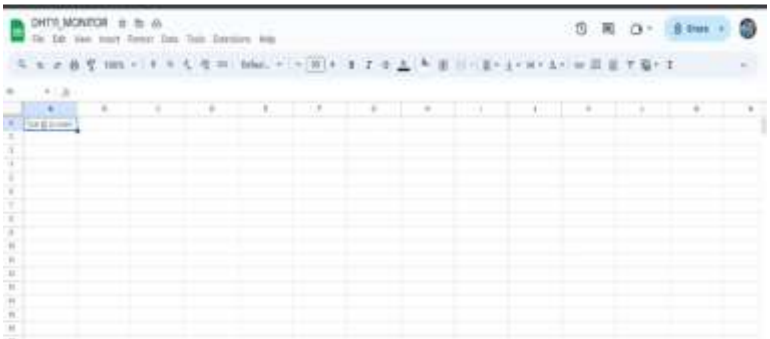

Fig: 4.5: After creating google sheet

3. Create OAuth 2.0 Credentials: To authenticate access to Google Sheets, generate OAuth 2.0 credentials (client ID and client secret) for your project.
4.The OAuth 2.0 credentials JSON file, which includes the details required for authentication, may be downloaded by selecting Download Credentials JSON File.
5. Install Required Libraries: Open the Arduino IDE for NodeMCU and install the necessary libraries, like the Google Sheets API library.

Fig 4.6 : adding google script programming in google scrip web app

6. Include Libraries in Arduino project: To facilitate communication with Google Sheets, incorporate the required libraries into your Arduino project.

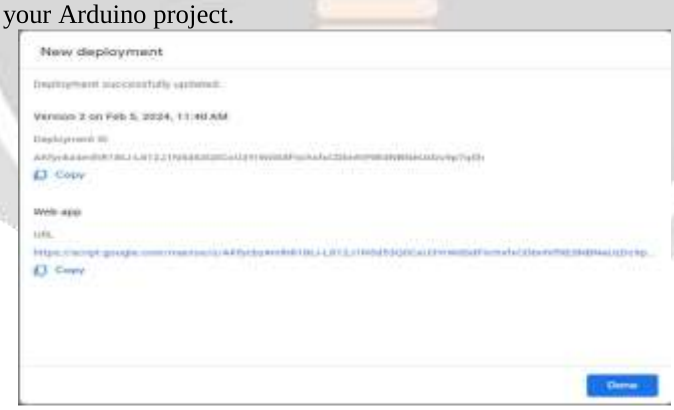

Fig 4.7 : After creating scipt ,deployment ID is copied for NodeMCU programming.

CHAPTER – 5
RESULT

5.1 Observations for Data Logger for Moist soil with variable temperature difference:

Let's interpret the provided table in the context of the effect of temperature and humidity on soil moisture level:

a. Temperature (°C): The temperature readings vary between 52°C and 26°C.
b. Humidity (%): Humidity levels range from 1% to 34%.
c. Soil Moisture Unit (AU): This column represents the readings from the soil

moisture sensor, presumably in arbitrary units (AU).

Fig 5.12 : Iot data logger with external variable Temperature source by hot air gun

Observations:

1. Effect of Temperature:

As the temperature decreases from 52°C to 26°C, there isn't a clear correlation with the soil moisture readings. This suggests that temperature fluctuations may not significantly impact soil moisture levels in this context.

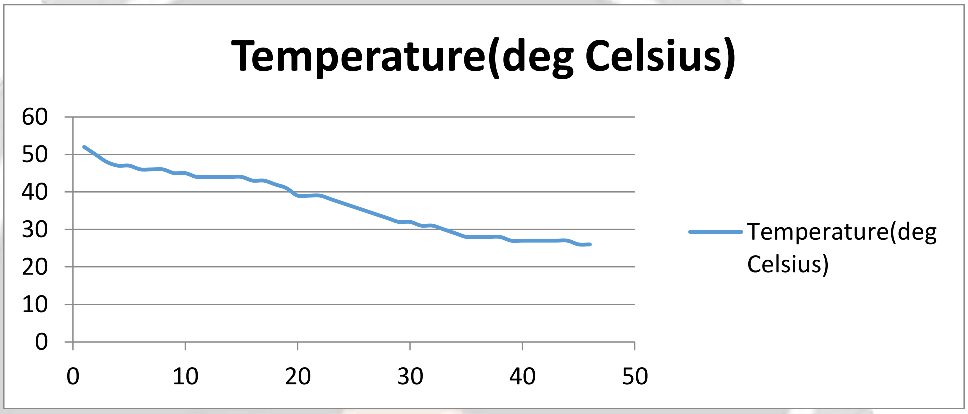

Fig 5.13 : Graph in case of external variable temperature

2. Effect of Humidity:

a. Initially, when humidity levels are very low (1% to 4%), the soil moisture unit readings vary between 315 AU and 329 AU.
b. As humidity levels increase beyond 4%, the soil moisture unit readings start to stabilize around 320 AU to 325 AU.
c. Higher humidity levels above 20% do not seem to have a significant impact on soil moisture readings, as they remain relatively consistent around 288 AU.

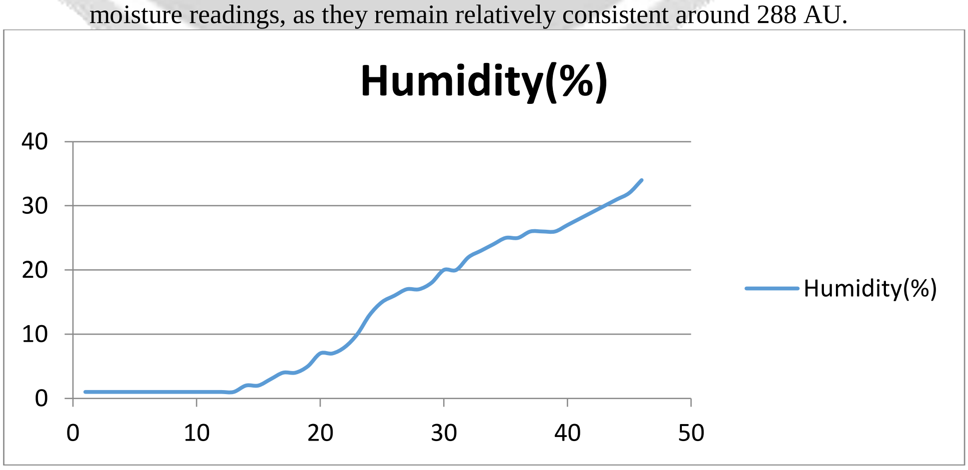

Fig5.14 : Humidity Graph in case of external variable temperature

3. Interpretation:

a. At extremely low humidity levels, the soil moisture unit readings vary widely, suggesting sensitivity to even minor changes in moisture content.

b. As humidity levels increase, the soil moisture unit readings stabilize within a narrower range, indicating a more consistent soil moisture level.

c. Beyond a certain threshold (around 20% humidity), further increases in humidity do not lead to noticeable changes in soil moisture readings, suggesting a potential saturation point where additional moisture does not significantly impact soil moisture levels.

Overall, the data suggests that humidity has a more pronounced effect on soil moisture levels compared to temperature in this context. Higher humidity levels correspond to higher soil moisture readings, indicating a greater presence of moisture in the soil. However, beyond a certain threshold, additional increases in humidity do not lead to significant changes in soil moisture readings.

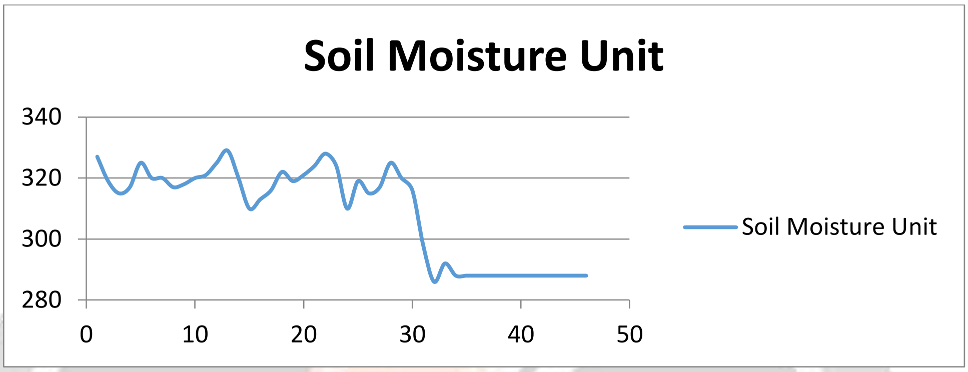

Fig 5.15 : Soil Moisture unit in case of variable external temperature

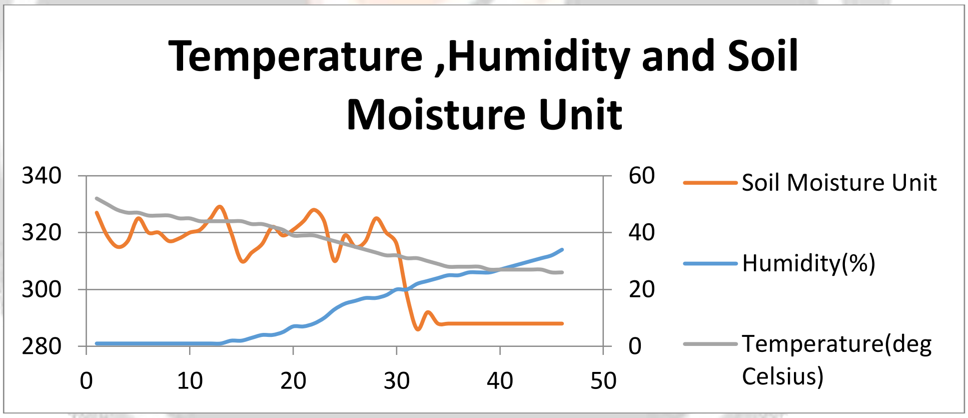

Fig 5.16 : Comparison graph between temperature, humidity and soil moisture level in case of external variable temperature

a. Temperature (°C): Temperature readings range from 26°C to 52°C, with 26°C being the starting point and 52°C being the final reading.

b. Soil Moisture AU (Analog Unit): Soil moisture unit readings vary throughout the dataset.

Relation between Changing Temperature and Soil Moisture Unit:

The data suggests a clear correlation between temperature difference and soil moisture units, with increasing temperature generally associated with decreasing soil moisture units. This relationship underscores the importance of considering temperature variations in soil moisture monitoring and management practices. Understanding these dynamics is crucial for effective water resource management, agricultural planning, and environmental conservation efforts.

CHAPTER – 6

CONCLUSION& FUTURE SCOPE

6.1 Conclusion

Final Overall Conclusion:

The implementation of an IoT-based data logging system for agricultural monitoring proved highly effective in enhancing monitoring capabilities and decision-making processes. By leveraging real-time data collection and remote accessibility features, stakeholders could gain valuable insights into environmental conditions, leading to improved crop management practices, resource utilization, and overall agricultural productivity. The system's scalability further ensures its applicability across various agricultural settings, ranging from small-scale farms to large agricultural estates. Overall, the integration of IoT technology in agricultural monitoring represents a significant advancement, with the potential to revolutionize the way agriculture is managed and sustained.

The integration of IoT-based data logging for agricultural monitoring presents a promising solution to address the challenges associated with traditional monitoring methods. By leveraging real-time data collection, high accuracy, remote accessibility, and scalability features, this technology offers substantial benefits for agricultural stakeholders. From small-scale farmers to large agricultural enterprises, the ability to monitor temperature, humidity, and soil moisture levels in real-time enables informed decision-making, proactive interventions, and optimized resource management. As agriculture continues to evolve in the digital age, the adoption of IoT-based solutions is poised to play a pivotal role in enhancing productivity, sustainability, and resilience in agricultural systems worldwide

6.2 Future Scope of IoT-Based Agricultural Monitoring Systems:

1. **Advancements in Sensor Technologies:** Continued research and development will lead to the creation of more sophisticated, precise, and cost-effective sensors tailored for monitoring various environmental factors like temperature, humidity, soil moisture, and nutrient levels in agricultural settings.
2. **Integration of Artificial Intelligence (AI) and Machine Learning (ML):** The incorporation of AI and ML algorithms will enable predictive analytics and decision support systems, empowering farmers to make informed decisions based on historical data and real-time insights. This could include predicting crop yields, identifying optimal planting times, and recommending appropriate irrigation schedules.
3. **Precision Agriculture Implementation:** IoT-based systems will facilitate the widespread adoption of precision agriculture techniques, allowing for precise and site-specific management of agricultural inputs such as water, fertilizers, and pesticides. This will lead to improved resource efficiency, reduced environmental impact, and increased crop yields.
4. **Standardization of Wireless Communication Protocols:** The standardization and widespread adoption of wireless communication protocols like LoRaWAN and NB-IoT will promote interoperability and seamless integration among IoT devices, enabling scalable and interconnected agricultural monitoring networks.
5. **Smart Irrigation Solutions:** Integration of IoT sensors with smart irrigation systems will enable automated irrigation scheduling based on real-time data on soil moisture levels, weather forecasts, and crop water requirements. This will help conserve water resources while optimizing crop production.

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