HOLY CROSS COLLEGE OF CALINAN, INC
DAVAO – BUKIDNON HIGHWAY, CALINAN POBLACION, DAVAO CITY

INTEGRATING SHORT MESSAGE SERVICE AND INTERNET OF THINGS SENSOR FOR ADVANCED SOIL MOISTURE AND TEMPERATURE MONITORING SYSTEM IN AGRICULTURE

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April 2025

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A Science Investigatory Project
Presented to the Faculty of the Basic Education Department
of the Holy Cross College of Calinan, Inc.

In Partial Fullfilment of the Requirements
In Science, Math, and English 10

By

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April 2025

TABLE OF CONTENTS

ACKNOWLEDGEMENT

The researchers would like to express their deepest gratitude to the following people who assisted, helped, and provided them encouragement to make this study a reality:

To Melina C. Gonzales, Ed.D., their Science Investigatory Project adviser, for generously offering her time, patience, and expertise despite her demanding schedule. The researchers deeply appreciate her insightful guidance, instruction, and unwavering support throughout the research process.

To Ms. Regine C. Sampolio, their science teacher, for her invaluable assistance throughout the entire research process, as well as for her thoughtful advice and encouragement that greatly contributed to the success of this study.

To Mr. Jayvee S. Centeno, the Computer Laboratory In-Charge, along with the Internet Laboratory student assistants, Ms. Donna Sumalinog and Mr. Arvine Macadine, for their patience and support—especially during times they had to extend beyond regular hours to assist with the submission of the researchers' final manuscript.

To Holy Cross College of Calinan, Inc., for providing the facilities that enabled the researchers to conduct their study and for the quality education they received.

To the families of the researchers, the Maravilla, Bautista, Catague, and Alcomendras households for the moral and financial support.

To the Grade 10 students, especially Mr. Charles Patrick Bernat, for his help in printing and preparing the researchers' final manuscript, even at a late hour.

To those who were not mentioned by name but contributed in various ways, the researchers extend their sincere thanks.

Above all, the researchers offer their deepest gratitude and praise to Almighty God, whose boundless mercy, wisdom, strength, perseverance, and providence sustained them throughout this journey. His guidance served as their light through the challenges of their study. All glory and honor belong to Him, now and forever.

The Researchers

ABSTRACT

Agriculture is a crucial sector in the Philippine economy, providing livelihood, food production, and trade, but it faces challenges like weather irregularities, droughts, and soil instability—particularly in moisture and temperature. Thus, this study was conducted to evaluate the effectiveness of an integrated IoT- and SMS-based soil monitoring system that tracks soil moisture and temperature in real time. It developed a soil monitoring device using an SHT10 sensor and a GSM module to analyze soil moisture and temperature while sending real-time SMS notifications. When tested on loamy soil under various conditions, the gadget exhibited little variation from commercial sensors, validating its accuracy. It provides alerts both manually (22–28 seconds) and automatically (5-minute intervals). While effective, it requires battery replacement and physical verification due to similar results in dry and wet situations. Despite these limitations, the device is useful for farmers enhancing irrigation and crop management. Future upgrades include solar power, display, and soil-type testing.

Keywords: Agriculture, sensor, soil moisture, soil temperature, IoT, SMS-based monitoring,

LIST OF FIGURES

INTRODUCTION

Background of the Study

Agriculture is the world's largest industry, playing a significant role in the Philippine economy. Additionally, it supports livelihoods by providing food, shelter, and work, as well as raw materials for production and fostering strong economies through trade (Rodriguez, 2024). To ensure the sustainability of agricultural productivity, monitoring soil moisture and temperature is crucial, as these factors directly affect crop growth and yield (Zhang et al., 2020). However, we encounter challenges in maintaining optimal soil moisture levels and stable temperatures.

Soil moisture, essential for plant growth, refers to the water content in the soil (Soil Moisture | Drought.gov, 2021). Soil moisture stress occurs when crops do not receive enough water, impairing root absorption and soil fertility, which ultimately restricts growth and yields (Gahlaut et al., 2023). On the other hand, soil temperature impacts crop development—cold soils slow absorption and photosynthesis, while warmer soils boost water and nutrient uptake (Cherlinka, 2024). Also, temperature affects germination by influencing hormone production, enzyme activity, and moisture availability. It is also said that warmer weather increases evaporation, reducing moisture and negatively impacting seed germination (Khaeim et al., 2022). In the Philippines, irregular weather patterns and droughts worsen soil moisture stress and temperature instability, causing crop damage and reduced production (Del Rosario et al., 2020).

Robots are revolutionizing agriculture by streamlining tasks, improving efficiency, and optimizing resources. They enable precise data collection, better decision-making for resource management, and crop yield optimization. The integration of robotics and automation is driving sustainability and productivity (Moshayedi et al., 2024). Moreover, the sustainability and productivity of agriculture largely depend on precise soil moisture evaluation, which is crucial for optimizing agricultural practices and enhancing yields (Islam et al., 2023).

In response to these issues, this study aims to improve agriculture by integrating an SMS and IoT sensor that provides accurate data and SMS alerts for real-time monitoring of soil moisture and temperature. This will enable farmers to make informed decisions, increase crop yields, and promote food security.

Statement of the Problem

This study aims to examine the broader effect of sensors in agriculture problem through monitoring the plants temperature and soil moisture with SMS integration for real time monitoring. Specifically, this study seeks to answer the following questions:

1. Is the sensor effective and accurate in monitoring/providing the following factors through sending SMS:
    1.1 soil moisture; and
    1.2 soil temperature?
2. Is the sensor effective in tracking the fluctuations of:
    2.1 soil moisture; and
    2.2 soil temperature?
3. Does integrating SMS alerts with sensors reduce the delay between the detection of soil conditions and the notification sent via SMS?

Hypothesis

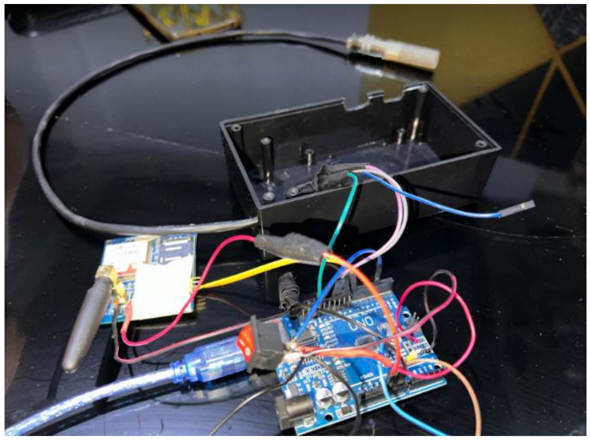
If the sensory device can accurately detect soil moisture and temperature, it will provide timely SMS alerts to farmers, leading to more efficient irrigation practices and improved crop management. By integrating soil moisture and temperature data, the device will enhance farmers' decision-making through real-time updates, allowing them to optimize water usage and ensure better crop health.

METHODS AND MATERIALS

This study consists of Phase I – Materials Used, Phase II – Connecting the components, Phase III – Programming the Controller, Phase IV – Testing and Gathering of Data, and Phase V - Analysis. The sensor used in the experiment will be created at Holy Cross College of Calinan, specifically in the computer/internet lab. The evaluation and data collection will take place at Barangay Wangan. The unit of analysis for this study will be the sensor's readings on simulated moisture and temperature in the loamy soil placed in a pot, with data collected to assess sensor accuracy and the integration of SMS for improved management practices and long-term sustainability.

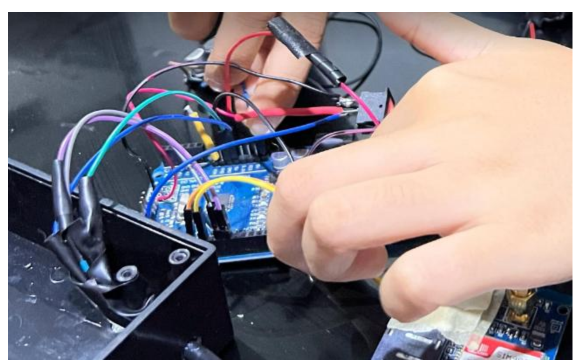
Phase I - Materials Used

The study used sensirion SHT10 soil temperature and moisture sensor a GSM module, an Arduino Uno controller, a power supply, batteries, and a protective plastic case, all purchased in online shops. The SHT10 sensor is the material that monitors the temperature and moisture of the soil, providing real-time data for analysis. The GSM module enabled remote communication, notifying external devices with updates regarding the soil conditions. The Arduino Uno controller acted as the system's core, processed the sensor data detected from the SHT10, and managed its transmission via the GSM module. Batteries and a power source were employed to ensure continuous functioning, and a plastic cover shielded the device from potential environmental elements including dust and rain. The experiment also used loamy soil for it possesses a specific texture that retains water well for a long duration, yet it eventually drains well; it also can hold sufficient nutrients (Iannotti, 2024).



Phase II - Connecting the Components

The SHT10 sensor and GSM module were both connected to the Arduino controller. Using the data clock pins the SHT10 sensor sent a reading straight to the controller. The GSM module is connected to Arduino uno allowing the sensor data to be sent via SMS to external devices. This setup is an effective system in which the sensor readings efficiently capture, interpret, and communicate sensory readings.



Phase III – Programming the Controller

Using the Arduino IDE application, the Arduino Uno controller was programmed to interpret and process data from the SHT10 sensor readings. The sensor's power and communication pins were connected to the controller, enabling it to monitor soil temperature continuously spanned from of -40°C to 125°C (-40°C to -10°C as the EXTREMELY COLD range, -9°C to 10°C as the COLD range, 11°C to 30°C as the NORMAL range, 31°C to 50°C as the WARM range, and 51°C to 125°C as the EXTREMELY WARM range) and soil moisture levels within a range of 0–100% (0–10% as the DRY+ range, 11–30% as the DRY range, 31-60% as the NORMAL range, 61 – 85% as the WET range and 86–100% as the WET+ range). The Arduino was programmed to read and transmit the data whenever the user sent the word "status" via the GSM module determining how the data was clocked recorded and stored. Upon receiving this command, the device responded with a message following the format: level of range: precise moisture measurement, along with the corresponding temperature. This setup ensures consistency detects real-time changes and automatically sends updates through the GSM module. The users can receive information upon request or be alerted to significant fluctuations like extreme or low soil conditions.

Phase IV - Testing and Gathering of Data

To test the accuracy of the device, its sensor readings were compared to those of a store-bought sensor. These instruments measured simulated extreme conditions of temperature and moisture, as well as normal soil conditions using loamy soil in a pot, allowing the evaluation of the device's responsiveness to varied conditions. Furthermore, the pot was placed in a location that provided environmental conditions similar to those of an agricultural field (e.g., exposure to sunlight and air) for observation.

Phase V – Data Analysis

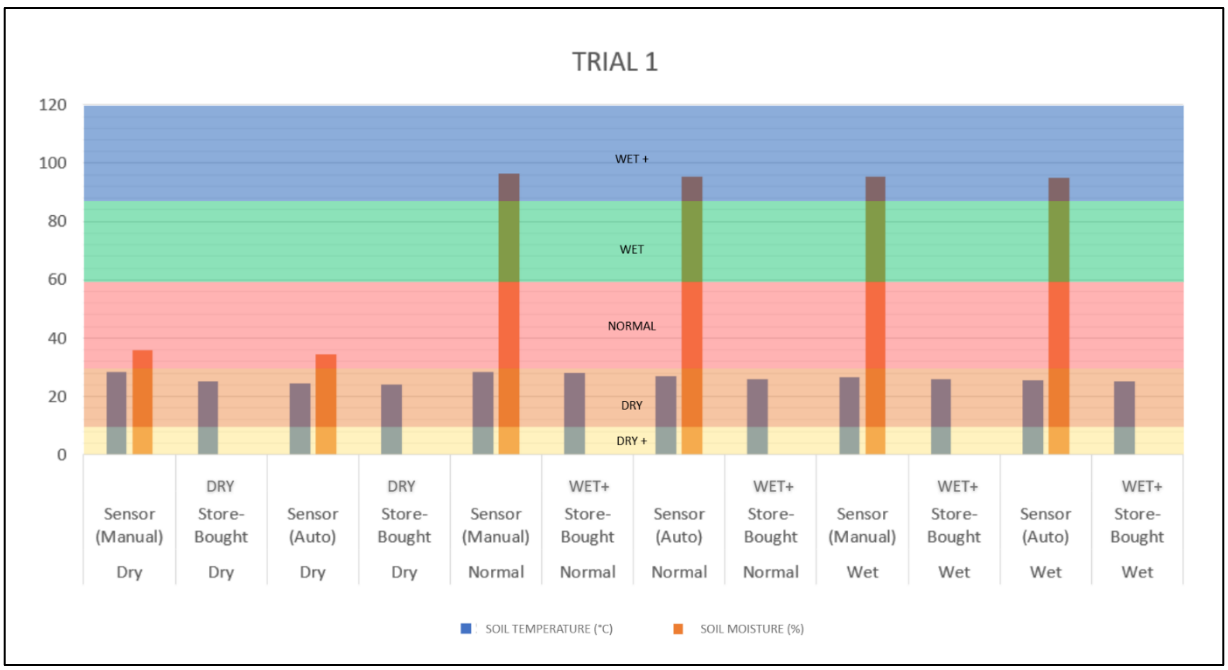
The accuracy of the device was evaluated by comparing its readings with those of a store-bought sensor, assessing its reliability in measuring soil temperature and moisture. Its performance was tested under both extreme and normal soil conditions to ensure consistent operation. Furthermore, the integration of SMS alerts with the sensors was analyzed to determine its effectiveness in reducing delays between detecting soil conditions and sending notifications via SMS, thereby enhancing real-time responsiveness and aiding farmer decision-making.

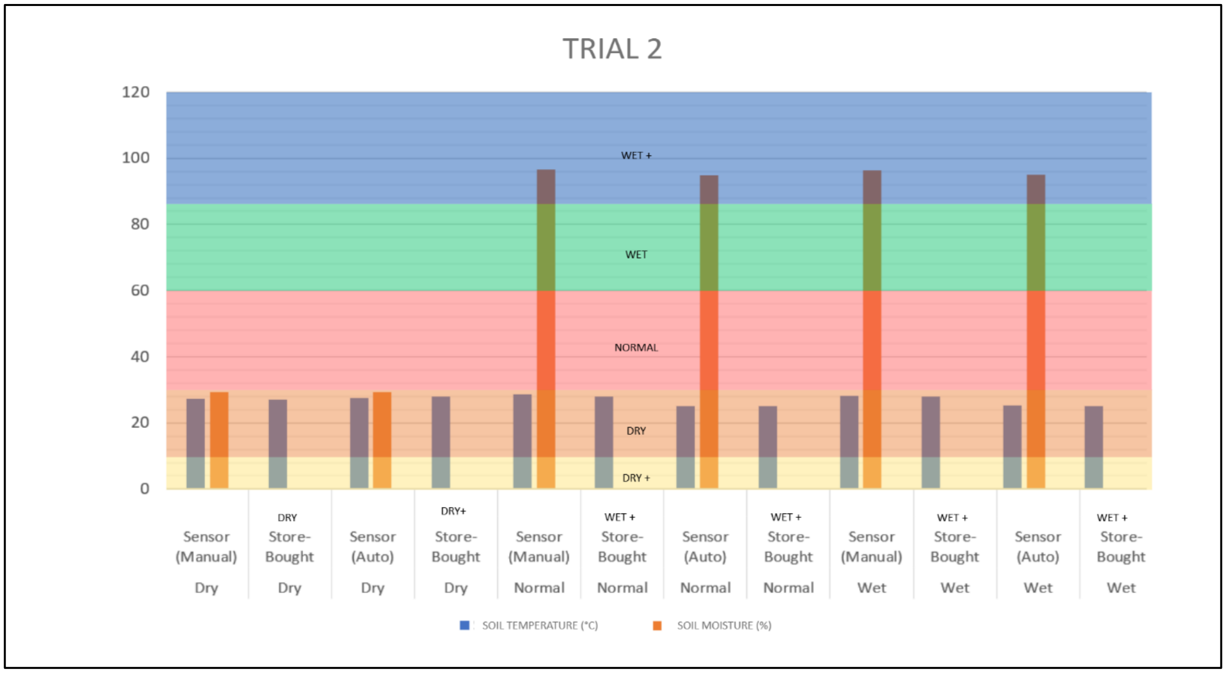
RESULTS

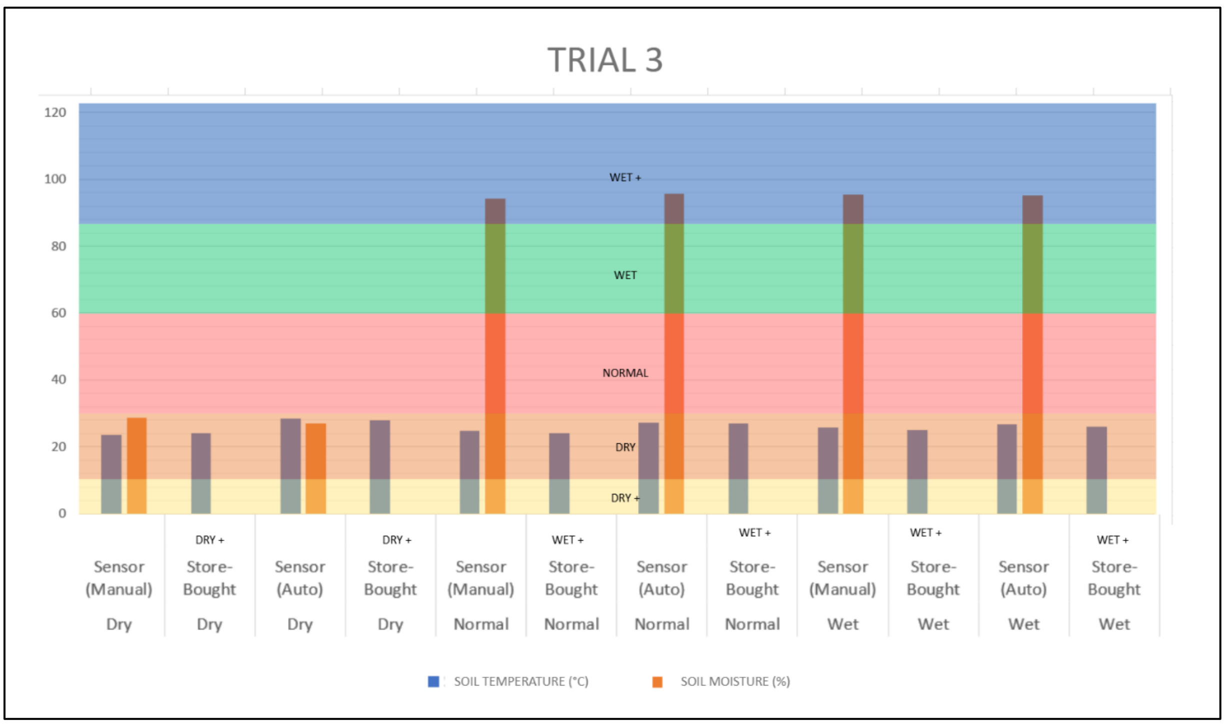
This chapter summarized the data obtained as well as the experiment's results. The study's findings were presented in the form of a table, which included the outcomes of the experiment as well as the researchers' previous research. This study determined the accuracy of the device in distinguishing soil moisture and temperature with the help of its SMS capabilities as presented by the following tables:

Research Question 1: Is the sensor effective and accurate in monitoring/providing the soil moisture and temperature through sending SMS?

Figure 1,2, and 3: Soil moisture and temperature readings across trials 1, 2, and 3 in manual and automatic modes, compared with store-bought data.





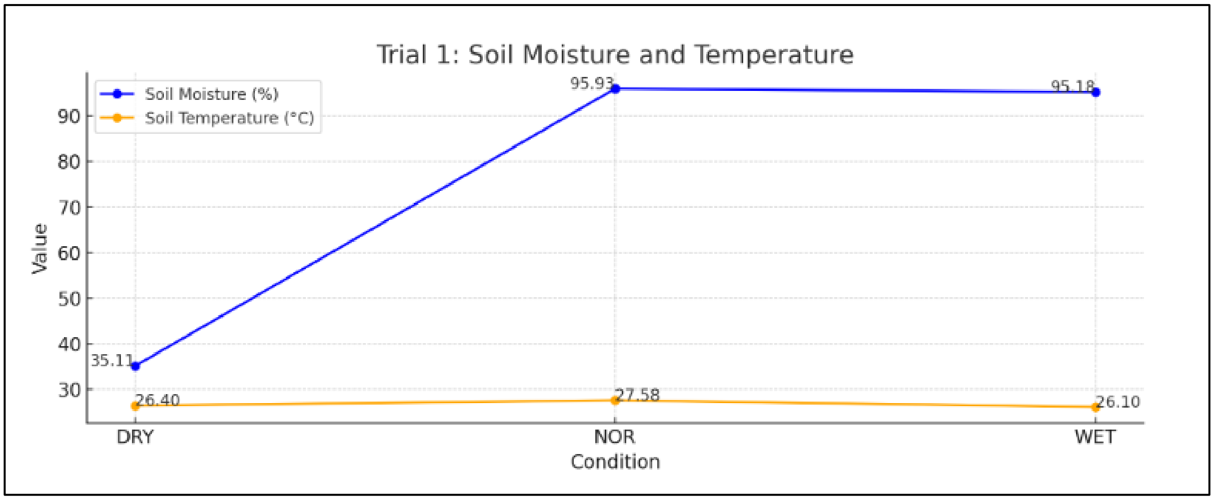


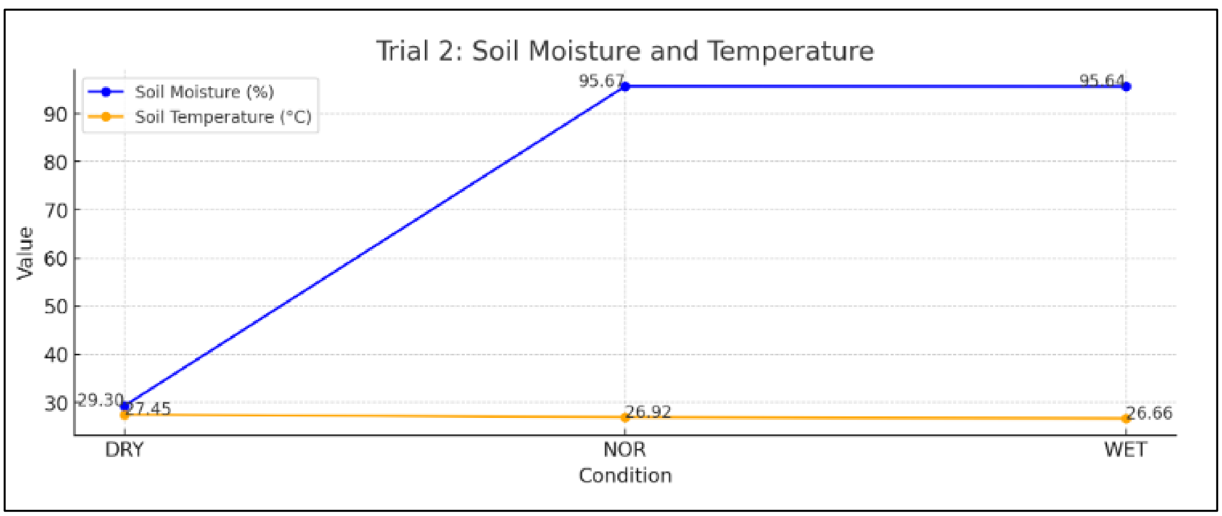
In comparing the soil temperature and moisture across the three trials with varying soil conditions, the researchers have noticed consistent trends wherein higher moisture levels are recorded in wet conditions while lower values return in dry conditions. Both the device the researchers made and the store-bought sensor showed comparable results although slight variations were present. Notably, the data returned in normal and wet soil conditions were similar across all trials, most specifically in their soil moisture readings, possibly leading to confusion and misinterpretation among future users. This minimal difference could affect the overall perception of the soil's actual state hence potentially leading to inaccurate assessments—whether the soil requires watering or drainage, poor decision-making, and management practices.

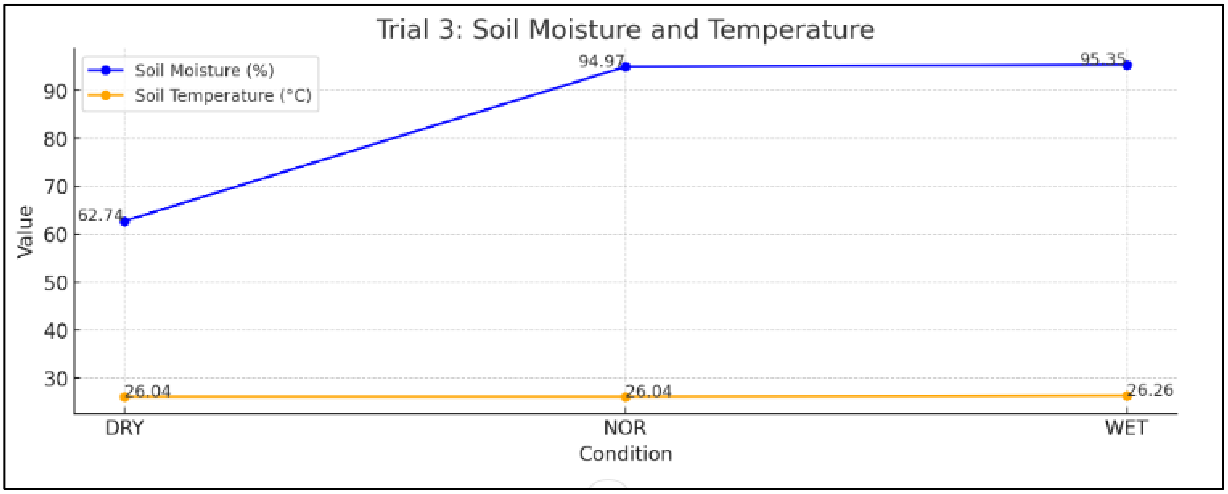
Similar studies have tested the ability of soil moisture sensors to differentiate normal and wet soil conditions, yielding mixed outcomes. A study conducted by Zhang et al. (2022) assessed the capacitance-based soil moisture sensors and emphasized the necessity of calibration to enhance the accuracy of measurements, as these sensors are extensively utilized. Similarly, Oliveira et al. (2024) evaluated low-cost sensors and discovered that, without proper calibration, these sensors may struggle to distinguish varied soil conditions, potentially leading to ambiguity. In their laboratory calibration and performance evaluation of low-cost capacitive and resistive soil moisture sensors, Adla et al. (2020) concluded that while inexpensive capacitive sensors, equipped with soil-specific calibration, can match the performance of higher-end sensors, uncalibrated sensors may yield less accurate outcomes. Furthermore, Souza et al. (2023) discussed the trade-offs between acquisition cost and accuracy in automated low-cost soil moisture sensors. They proposed that although low-cost sensors have medium accuracy, they allow for spatial monitoring through multiple-point measurements, which makes them appropriate for projects with medium accuracy requirements and budget constraints. These studies collectively highlight the importance of proper calibration and consideration of sensor quality to ensure accurate soil moisture measurements and effective agricultural management accuracy.

Research Question 2: Is the sensor effective in tracking the soil moisture and temperature fluctuations?

Figure 4, 5, and 6: Soil moisture and temperature fluctuations of the device across trials 1, 2, and 3.







The values presented in the line graphs above are the calculated arithmetic mean of the manual and automated sensor readings, done to ensure accuracy and consistency. The line graphs above illustrate the relationship between soil moisture and temperature. As indicated, the soil moisture increases greatly with a huge difference from dry to wet conditions, with the returned readings ranging from an estimated 35.11% to 95.64%, while soil temperature remains stable, only fluctuating between 26.04% and 27.58%. Overall, the consistent trends in moisture and minimal temperature changes show reliable sensor performance across the three identified conditions.

The analysis exhibited above is supported by vast existing literature that highlights the varying sensitivity of soil moisture sensors to temperature changes. Vaz et al. (2015) demonstrated that temperature changes might affect capacitance-based soil moisture sensors, especially at higher moisture levels, hence proper calibration is required to guarantee data accuracy. Similarly, Bogena et al. (2017) emphasized the importance of correcting for environmental temperature effects, noting that unadjusted temperature fluctuations can lead to measurement drift in soil moisture sensors. Liu et al. (2023), on the other hand, discovered that some modern sensors show very little temperature dependence, exhibiting insignificant changes in sensor values with slight temperature fluctuations. These findings reinforce the validity of using averaged manual and automated sensor data to capture accurate soil moisture readings under controlled temperature conditions. The minimal variation in temperature recorded across the three trials in this study likely contributed to the consistent sensor outputs.

While the graphs indicate a substantial increase in soil moisture from dry to normal conditions, the difference between normal and wet conditions is comparatively minimal across all trials. This trend suggests that the sensors may be reaching a saturation point or threshold in their moisture detection range, beyond which changes in actual soil water content do not significantly influence sensor readings. Such behavior is supported by Jiang et al. (2023), who found that several soil moisture profile sensors demonstrated reduced sensitivity at higher moisture levels, where readings began to plateau even as soil water content increased. Similarly, Suárez et al. (2024) observed greater variability and diminished reliability in capacitive soil moisture sensors when approaching saturation levels, with a coefficient of variation between 10% and 16% above 30% moisture content. Therefore, while the sensors in this study demonstrate reliability and minimal thermal interference, the data also imply a possible upper limit in measurement sensitivity—an important consideration for future calibration or field deployment.

Research Question 3: Does integrating SMS alerts with sensors reduce the delay between the detection of soil conditions and the notification sent via SMS?

Table 7: Time duration for the device to send current soil condition notification updates via SMS.

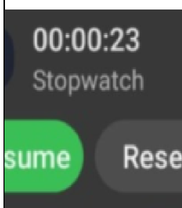
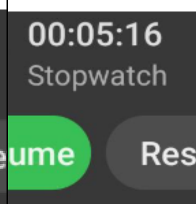
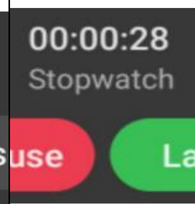
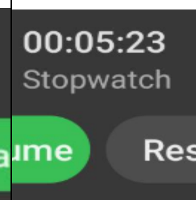
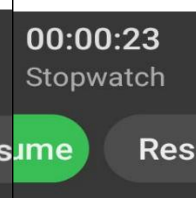
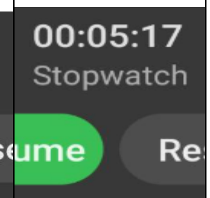
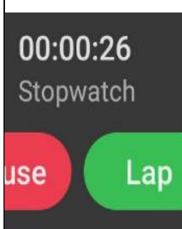
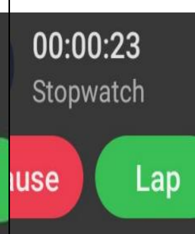
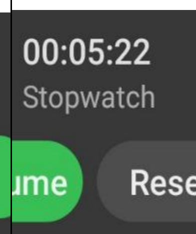
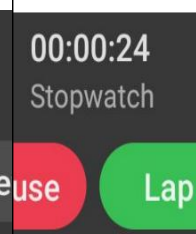
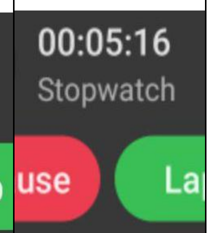
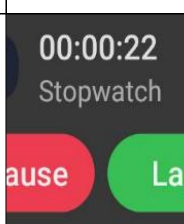
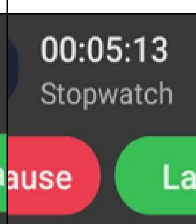
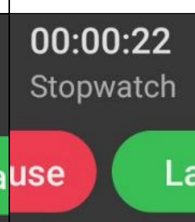
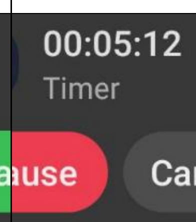
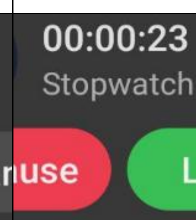
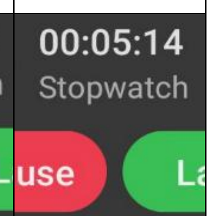
Set-ups	Trials					
	Trial 1		Trial 2		Trial 3	
	Manual	Automatic	Manual	Automatic	Manual	Automatic
Dry Loam						
	The device took 23 seconds to send SMS	The device took 5 minutes and 16 seconds to send SMS	The device took 28 seconds to send SMS	The device took 5 minutes and 23 seconds to send SMS	The device took 23 seconds to send SMS	The device took 5 minutes and 17 seconds to send SMS
Normal Loam Condition						
	The device took 26 seconds to send SMS	The device took 5 minutes and 8 seconds to send SMS	The device took 23 seconds to send SMS	The device took 5 minutes and 22 seconds to send SMS	The device took 24 seconds to send SMS	The device took 5 minutes and 16 seconds to send SMS
Wet Loam						
	The device took 22 seconds to send SMS	The device took 5 minutes and 13 seconds to send SMS	The device took 22 seconds to send SMS	The device took 5 minutes and 12 seconds to send SMS	The device took 23 seconds to send SMS	The device took 5 minutes and 14 seconds to send SMS

Table 7 shows the time duration for the device to send current soil condition notification updates via SMS upon sending a message for manual mode and waiting five minutes, as set on the program, to receive an update through the automatic mode. In using the manual mode, it takes an approximate duration of 22 – 28 seconds for the device to send SMS notifications.

Meanwhile, in utilizing the automatic mode, it took an estimation of 5:08 – 5:23 minutes, accurately matching with the program set to send every five minutes.

The device's SMS-based soil condition update time intervals are consistent with results from other SMS-based agricultural monitoring systems. In order to support the 22–28 second range seen in manual mode of the current device, Adejo et al. (2018) developed a GSM-based farm monitoring system that can send timely alerts based on soil conditions. SMS transmission takes place shortly after sensor data collection. Similar to the 5:08 to 5:23-minute results from this study, Patil and Lokhande (2021) also installed a smart irrigation system that operates on automated intervals of nearly five minutes and sends SMS alerts when soil moisture falls below a threshold. The accuracy and usefulness of GSM-based alert systems in agricultural settings are further supported by the invention of Adewale et al. (2021) of a low-cost IoT-based notification system, which reliably sends soil and environmental data via SMS to rural farmers. Kumar (2016) illustrated the adaptability of such systems in real-time monitoring by showing that, despite their lack of technical complexity, GSM modules can still send SMS alerts with plant data using a do-it-yourself method. These studies affirm the reliability and timeliness of the current device’s SMS-based reporting in both manual and automatic modes.

CONCLUSION AND RECOMMENDATIONS

Conclusion

The developed sensor device effectively detected both soil moisture and temperature, demonstrating its reliability in monitoring soil conditions. However, its sole SMS notifications were insufficient, as soil conditions like normal and wet loam exhibited similar results, requiring physical intervention of the user to verify the actual soil condition. Overall, the results confirm its accuracy and functionality, making it a valuable tool for agricultural and environmental applications. Its successful performance highlights its potential as an efficient and practical solution for soil monitoring.

Recommendations

The researchers recommend further exploration on the different types of soil or material to evaluate the sensor's accuracy in various conditions. Also, utilizing solar energy as a power source instead of batteries for a more sustainable and long-lasting operation can also be considered. Lastly, to integrate a display screen that allows users to directly view the temperature and moisture levels in real time can be done.

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