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Pavan P
College of Agricultural Engineering, PJTSAU, Sangareddy, Telangana, India

Pranitha M
College of Agricultural Engineering, PJTSAU, Sangareddy, Telangana, India

Shirisha N
College of Agricultural Engineering, PJTSAU, Sangareddy, Telangana, India

Ganga Bhavani R
College of Agricultural Engineering, PJTSAU, Sangareddy, Telangana, India

Samshikha S
College of Agricultural Engineering, PJTSAU, Sangareddy, Telangana, India

Jawaharlal D
College of Agricultural Engineering, PJTSAU, Sangareddy, Telangana, India

Charith Kumar K
College of Agricultural Engineering, PJTSAU, Sangareddy, Telangana, India

Corresponding Author:
Pavan P
College of Agricultural Engineering, PJTSAU, Sangareddy, Telangana, India

Comparative evaluation of soil moisture sensors using Arduino UNO interface and traditional oven dry method

Pavan P, Pranitha M, Shirisha N, Ganga Bhavani R, Samshikha S, Jawaharlal D and Charith Kumar K

Abstract
Soil moisture plays a crucial role in agricultural and environmental studies. This research aimed to assess the performance and reliability of three locally available soil moisture sensors REES52, Capacitive soil moisture sensor V1.2, and V2.0 by comparing their measurements with the oven dry method of soil moisture estimation. A low-cost Arduino Uno microcontroller was utilized to interface the sensors for data acquisition and processing. The sensors were calibrated using traditional methods, and the coefficient of determination (R^2) values obtained were 0.849, 0.826, and 0.833 for the REE S52, Capacitive Soil Moisture Sensor V1.2, and V2.0, respectively. These values indicate a reasonably strong correlation. The calibration process ensured that the sensor's output values were adjusted to accurately represent the actual soil moisture content. To validate the sensors' performance, a field experiment was conducted in representative soil conditions. Soil moisture readings from the sensors were compared with those obtained from the traditional oven dry method. Preliminary results suggest that the locally available soil moisture sensors, when appropriately calibrated, exhibit promising performance in estimating soil moisture content. The Arduino Uno interface provided a cost-effective and efficient solution for integrating the sensors into the data acquisition system. These findings contribute to the development and utilization of low-cost soil moisture sensing technologies, facilitating better water management practices and enhancing agricultural productivity. Further research is recommended to validate these results in diverse soil types and environmental conditions.

Keywords: Soil moisture, sensors, resistance type and capacitive type sensors, Arduino UNO, low cost data acquisition

1. Introduction
Accurate measurement and monitoring of soil moisture content is crucial for effective water management in agricultural and environmental applications (Ali *et al*. 2016 and Prasad *et al*. 2012) [1, 6]. Traditional methods, such as the oven dry method, have long been used as a reference for soil moisture estimation. However, these methods are time-consuming and labor-intensive. To address these limitations, there is a growing interest in the development and utilization of low-cost soil moisture sensors that provide real-time and continuous measurements. This research focuses on comparing the performance of three locally available soil moisture sensors, namely the (REES52 soil moisture sensor, Capacitive Soil Moisture Sensor V1.2, and V2.0), with the traditional oven dry method. A low-cost Arduino Uno microcontroller was used to interface these sensors, providing a cost-effective solution for data acquisition and processing (Prasad *et al.* 2012). The sensors were calibrated using traditional methods, and the coefficient of determination (R2) values were obtained to assess the correlation between the sensor readings and the oven dry method (Mohamed *et al.* 2011) [4]. The objective of this study is to evaluate the reliability and accuracy of these sensors in estimating soil moisture content. The findings will contribute to the advancement of low-cost soil moisture sensing technologies (Neha *et al.* 2014) [5], facilitating improved water management practices and enhancing agricultural productivity.

2. Material and Methods
2.1 Location and Experiment site
The present experiment was carried out at Department of Soil and water engineering, College of Agricultural Engineering Sangareddy which is under Central Telangana zone.

2.2 Hardware requirements
Soil moisture sensors

Three locally available soil moisture sensors were used in this study: the REES52 Soil moisture sensor, Capacitive Soil Moisture Sensor V1.2, and Capacitive Soil Moisture Sensor V2.0. These sensors were selected for their availability and affordability, making them suitable for widespread use.

Arduino Uno Microcontroller

A low-cost Arduino Uno microcontroller was employed to interface the soil moisture sensors and collect data. The Arduino Uno provides analog input ports to connect the sensors and digital output ports for data processing. It offers a cost-effective and user-friendly solution for data acquisition and control.

Calibration of Sensors

The sensors were calibrated using traditional methods to establish a relationship between their output readings and actual soil moisture content (Ginger *et al.* 2008) [2]. Calibration was conducted in a controlled laboratory setting. Soil samples with known moisture content were prepared by combining different proportions of dry and moist soil. The sensors were inserted into the soil samples, and corresponding readings were recorded. Regression analysis was performed to determine the calibration equations for each sensor.

Field Experiment

A field experiment was conducted to validate the performance of the soil moisture sensors (Heidi M *et al.* 2012) [3]. The experiment was carried out in representative soil conditions, and multiple locations within the study area were selected to capture the spatial variability of soil moisture. At each location, soil moisture readings were collected using the sensors and compared with measurements obtained from the traditional oven dry method.

Data Analysis

The collected data were analyzed to evaluate the agreement between the sensor readings and the oven dry method. Statistical techniques, such as regression analysis and correlation coefficients, were employed to assess the accuracy and reliability of the sensors. The coefficient of determination (R^2) values were calculated to determine the strength of the relationship between the sensor measurements and the reference method.

3. Results and Discussions

The results of the comparative evaluation of the three locally available soil moisture sensors (REES52 soil moisture sensor, Capacitive Soil moisture sensor V1.2, and V2.0) with the traditional oven dry method are presented and discussed in this section.

Based on the calibration process as observed from the figure 1 to 3, the coefficient of determination (R^2) values obtained for the sensors were 0.849, 0.826, and 0.833 for the REES52, Capacitive Soil Moisture Sensor V1.2, and V2.0, respectively. These values indicate a reasonably strong correlation between the sensor readings and the reference oven dry method. The calibration process ensured that the sensors' output values were adjusted to accurately represent the actual soil moisture content.

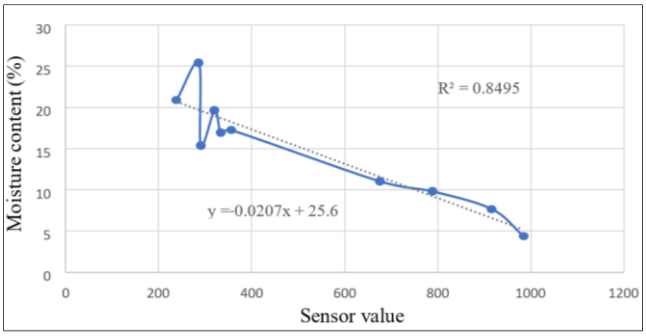

Fig 1: Response of REES52 Soil moisture sensor for various moisture conditions of the soil

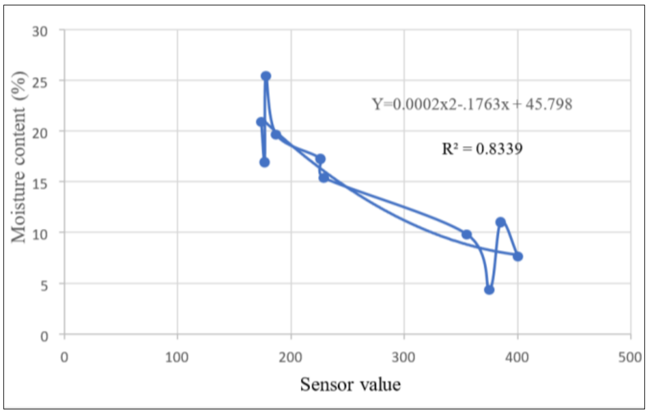

Fig 2: Response of Capacitive soil moisture sensor (V1.2) for various moisture conditions of the soil

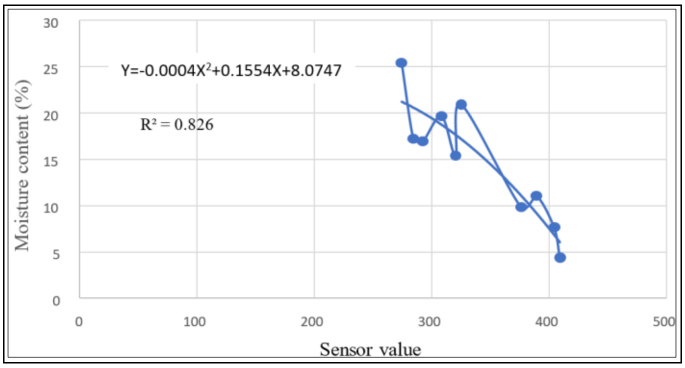

Fig 3: Response of Capacitive soil moisture sensor (V2.0) for various moisture conditions of the soil

During the field experiment, soil moisture readings from the sensors were compared with those obtained from the traditional oven dry method. The results as shown in the Demonstrate that all three sensors exhibited significant correlations with the oven dry method. However, there were variations in the level of agreement among the sensors.

The REES52 sensor demonstrated the highest level of agreement with the oven dry method, The Capacitive Soil Moisture Sensor V1.2 and V2.0 showed slightly lower but still substantial agreement with oven dry method. These results indicate that all three sensors can provide reliable estimations of soil moisture content. However, it is important to note that there may be inherent differences in the sensing mechanisms and calibration techniques among the sensors, which could contribute to the variations in their performance. Factors such as soil type, temperature, and electrical conductivity may also influence the accuracy of the sensor readings.

4. Conclusions

The present research aimed to compare the performance of three locally available soil moisture sensors (REES52 Soil Moisture Sensor, Capacitive Soil Moisture Sensor V1.2, and V2.0) with the traditional oven dry method and assess their suitability for estimating soil moisture content. The sensors were calibrated using traditional methods, and a field experiment was conducted to validate their performance. The data collected from the sensors were compared with measurements obtained from the oven dry method, and statistical analysis was performed to evaluate their accuracy. Three sensors compared in the present study showed good agreement with the traditional method of soil moisture estimation. REES52 was more accurate among all three sensors. Overall, this study contributes to the development and utilization of low-cost soil moisture sensing technologies. The findings emphasize the potential of these locally available sensors and the Arduino Uno interface in improving water management practices, enhancing agricultural productivity, and supporting environmental studies. These advancements in soil moisture monitoring can lead to more efficient use of water resources and contribute to sustainable agricultural practices.

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