Determination of Soil Moisture using Various Sensors forIrrigation Water Management

Praveen Barapatre, Jayantilal N. Patel

Abstract:*This research examination analyzes prototyping an organized calibration and working of various soil moisture sensors. Itprovides recommendationson how to upgrade Internet of Things (IoT) based soil moisture identification system for irrigation frameworks. The observational examination used two sensors to distinguish the soil moisture fronts which are Resistive Soil Moisture and Capacitive Soil Moisture.The results of this study indicate IoT based soil moisture detectionis an effective method that provides reliable front data that can be used to adapt and improve irrigation and precision farming methods. Confirmation ofthe positive impact of this prototyping ispresented in this study.*

Keywords: Agriculture, Irrigation, Sensor, Soil Moisture.

I. INTRODUCTION

Capable and efficientuse of water resources for irrigation is of high importance in agricultural nations. The environmental change criteria affect the farming area;farmers are forced to change and adapt practices to account for environmental changes and pressure from governments and other interested parties. The Internet of Things (IoT) is an innovation that is connectedto numerous fields;itcentres on associating every related gadget (Things) to the Internet.Utilising low essential resources that is installed with sensors, the pattern of Internet and communication network has been as of recently adapted as the improvement of a keen agriculture framework. It is similar for agriculture, where the exactitude of farming winds up modernised in the type of brilliant agriculture. Precision agriculture involves remotely watching, assessing, and observing harvests and equipment, whereascontinually referring to data on climate, soil, air quality, and other variables. This practice helps produce systematic models that aid farmers to improve their practices and makeevidencebased decisions. Water is the fundamental asset of farming, and correct irrigationmanagement isa crucial aspect related to atmosphere change criteria. The capacity for agribusiness to remain strong amidst catastrophic events, and to access data pertaining toirrigation is exceptionally significant. The utilisation of sensors is expanding in numerous spaces ofsociety. The effect and capability of installed sensors in precision agriculture and ecological applications are noteworthy.Precision Agriculture (PA) is related to the capacity to amplify the economic return of a field whereaslessening the use of assets.

The things required to accomplish these objectives are digital information, documentation,and data for key farm qualities. Soil moisture isa significant factor in determining yield, and for understanding the behaviour of water content conduct. Obtaining accurate soil moisture measurementsare viewed as challenging because of the number of variants that can affect the quality.For examplesalinity, temperature, soil structure and saturation. Soil moisture sensors are used predominantly to assist agriculturists with irrigation scheduling and additional fresh water use.The measurement of soil moisture given electrical resistivity is preferred by agriculturists because it is easy to achieve and requires minimal effort. For assessing the execution of minimal effort, resistive soil moisture sensors under greenhouse conditionsare used. Sensors were the subject adjustments and assessment tests[1]. The need to use water efficiently is becoming ever increasingly crucial for agriculturalists.Soil-moisture sensors offer a way to improve efficiency. However,it is difficult to implement such strategies because ofthehigh costs and the absence of soil-particular calibration equations. Precision irrigation is pivotal in reducing the amount of water needed for irrigated agriculture. One benefit of precision agriculture is the information provided on soil moisture content in the root zone of irrigated crops. Dielectric soil moisture sensors can provide this data atminimal cost compared with other techniques.One restriction is that precision cannot be guaranteed in all soils without site-particular calibration, a requirement that has limited the widespread adoption of the sensors [2].

II. IMPORTANCE OF SOIL MOISTURE IN IRRIGATION

Plants are living organisms and require air and water for survival. A plant`swater requirements differ byspecies, with some plants requiring high levels of water, whereas others can survive with practically none.In regions that flood for large parts of the year, the flood water that is absorbed by the land can compensate for the lack of rain during dryer months. This practice relies on nature and in some caseswhen there is not sufficient rain, crops are affected, and it can lead to drought.To avoid the negative consequences of drought, farmers implement different techniques to store water so that it can be used during dry periods. Irrigation can be defined in this manner be characterized as the study of counterfeit utilization of water to the land as per the crop prerequisites all through the product time frame for the undeniable sustenance of the crop.

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III. SOIL MOISTURE SENSORS

Considering that soil moisture is a critical factor in irrigation control, this study investigates the accuracy of resistive soil moisture sensors. The procedure offers fresh insight into resistivity based soil moisture sensors,whereas most commercially available cheap sensors are restricted to category detection (Dry-Humid) of soil state and do not provide real-time moisture data. The investigation details construct recommendations related to use thesensors and data about the wellsprings of blunder influencing execution.An alternative sensor developed to estimate the water substance of soil uses an impedance measurement with a capacitive sensor of a fork-like geometry. The impedance is calculated with a twin T-bridge to cover the considerable scope of the permittivity of soil [3]. Vegetables, for example, require high amounts offertiliser and irrigation to assess the association between N-fertilizer rates and irrigation scheduling utilising soil moisture sensor irrigation controllers (SMS) on yield, irrigation water utilizes proficiency IWUE of bell pepper developed under plastic mulch and drip irrigation [4]. Some recently created sensors rearrange the continuous assurance of soil water content byconsidering aspects of capacitance and frequency. The 10HS sensor is the standout amongst the latest capacitance sensors.Information is lacking related to the accuracy of the sensor`s measurements on soil type and ecological variables. The performance of the 10HS sensor is exploredbyusing liquids with known dielectric properties and experiments that identify avariety of features[5]. Soil moisture sensor(SMSs) designed for landscape irrigation can save water. However,SMSs have not been tested with reclaimed wastewater. The two salts contained in irrigation water and the temperature may change the soil water content (SWC) detected by SMSs [6]. Advances in electromagnetic sensors have made mechanised irrigation planning a reality. The number of access rules for sensors wasdetermined from the site and crop-specific trials. Sensor precision may be a crucial factor that influences irrigation proficiency [7]. A direct measurement technique was used tofulfil the requirement for modest sensors with a wide variety of capacitance change. A consolidated wired and wireless network transmits information to a server, anddifferent battery viewpoints are contrastedwith their use in farming [8]. Another study presents the outline, manufacture and calibration of an inactive UHF RFID tag based soil moisture and environment temperature sensor. The inter-digital advanced twofold sided capacitive sensoradjusts its capacityas the soil moisture changes and changes to the soil permittivity. The smart tag incorporates an external sensor front-end that usesanalogue sensors toprovide digitised measurements [9]. Additionally, frequency domain analysis can be used to identify the moisture and substances in soils. At least two techniques must be used,the first measure the weakening of a fixed frequency signal to measure soil capacitance as an aspect of a low pass filter. The second uses soil capacitance as the controlling component in a variable frequency oscillator. Whereas the two strategies exhibit contrasting sensitivities, they show an acceptably stable relationship in comparison to other soil moisture conditions. When using insulated probes, it is possible that they may become damaged due to excess moisture.Excess moisture can cause the soil capacitor to 'leak' and provide a lower electrically resistive path in comparison with the actual soil capacitance [10]. Another study investigates a bordering field capacitive soil moisture sensor that uses a printed circuit board. It compares an inter-digital sensor for measuring soil moisture with two existing designs. The enhanced outlines were re-enactedwith a 3-D finite element method and created by using a copper clad board[11]. In another study, the bordering electric field istested by using a four distinctive moulded poly methyl methacrylate-coated capacitive sensor[12].

A. Comparison of Soil Moisture Sensors

The capacitive sensor is significantly more accurate than the conventional resistive soil moisture measuring sensor. A comparison was made to identify how both sensors perform at identifying moisture content in the soil.

B. Resistive Soil Moisture Sensor

The sensor comprises two probes that measure the volumetric substance of water. The two probes send an electrical current into the ground,and the level of moisture is established by examining the resistance encountered by the current. When there is high moisture,the soil is more conductive and less resistant.Dry soil does not conduct electricity well, so when there is less moisture, the earth is more resistant and less conductive. The real issue with a resistive soil moisture sensor is corrosion of the probesbecause it causes inaccurate measurementsdue to electrolysis of the sensors.

C. Capacitive Soil Moisture Sensor

The capacitive moisture sensor estimates the soil moisture level with a capacitive sensing technique rather than a resistive one, and it is less susceptible to corrosion because it is made of more resistant material. The sensor incorporates a voltage controller that provides a working voltage scope of 3.3 ~ 5.5V. It is good with low-voltage MCUs (both 3.3V and 5V logic). For optimal performance with Raspberry Pi, an ADC converter is required. Capacitive probes are becoming increasingly popular, and they have several benefits. They do not corrode and provide more reliable results than resistance estimating. It doesn't quantify moisture (as water is a bad conductor of current), instead it quantifies the ion that is broken down in the moisture,i.e.addingfertiliser diminishes the resistance of the soil, even though no water is present. Capacitive sensing effectively measures the dielectric that is framed by the soil,and water is the most influential factor that structures that dielectric.

D. Conventional Oven Method of Measuring Soil Moisture

A wet soil sample is kept in a suitable container,and its mass is measured. It is then dried in an oven,and its new mass is measured. This method is rehashed to the point until the mass becomes constant at determined cut-off points. The difference between the soil samples and the dried samples is used to calculate the mass of waterin the sample. The water content (in percentage) is determined by isolating the mass of water from the dry mass of soil, multiplied by 100. For any soil type,an opportunity to accomplish a constant dry mass can beused to establish a drying time for similar soil types. The moisture inthe soilischaracterised as the ratio of thewater massper unit of soil, to the mass of dry soilper unit of soil, and is expressed in percentage form as:

$$water\ content = \frac{w_2 - w_3}{w_3 - w_1} \times 100 \qquad (1)$$

Where,
w_1 - Weight of empty container
w_2 - Weight of sample (wet soil + container)
w_3 - Weight of sample after 24 hours inthe oven (dry soil + container)

The standard technique for moisture content measurement performed in laboratories is the conventional oven method. It involves weighing a sample of wet soil, drying the soil by dissipating its water content, and reweighing the remained dry soil. Even though the conventional oven method is accurate, it can be tedious and intrusive to implement.

IV. METHODOLOGY

Thisstudy examines the reliability of two soil moisture sensors. Twelve samples for both types of potentiometer settings (high and low) were used.Resulting in a total oftwentyfourtotal samples. After taking readings, the mass of all the wet soil samples was measured using the weighing machine,and the samples were placed in an oven for 24 hours at 105˚ Centigrade.The mass of the dried samples was then measured to identify moisture content.

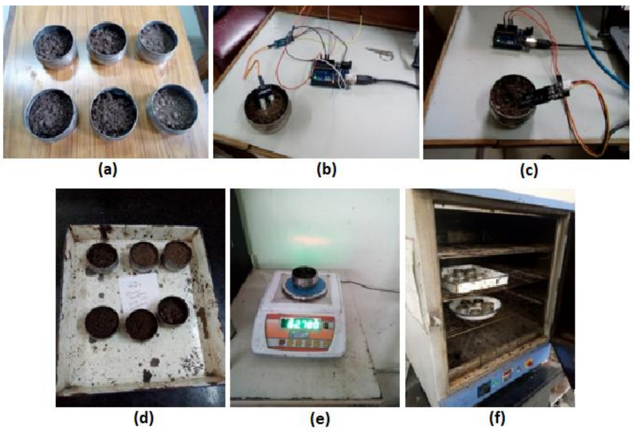

Fig. 1 (a) Soil samples for resistive soil moisture sensor. (b) Arduino setup for resistive soil moisture sensor. (c) Arduino setup for capacitive soil moisture sensor. (d) Soil samples after dried in oven. (e) Weighing of soil samples. (f) Soil samples kept in oven.

Table I. Linear equation table and for slope and R^2 value

Sr. No.	Equation for	Equation	R^2 value
1.	Equation of line for resistive soil moisture sample data on low potentiometer values.	y = 0.3567x + 12.577	R^2 = 0.9057
2.	Equation of line for resistive soil moisture sample data on high potentiometer values.	y = 0.3459x + 10.842	R^2 = 0.8171
3.	Equation of line for capacitive soil moisture sample data values.	y = 0.3582x + 6.7376	R^2 = 0.9491

For the capacitive soil moisture sensor, another twelve soil samples were used. There is no potentiometer present in capacitive soil moisture sensors. Therefore no changes were needed totheregulator settings.Table. I shows the equation for determining slopes in various sensors. In which x value shows the soil moisture content in percentage, whereas y value is calculated from the equation. Fig. 1(a) shows the soil samples used for resistive soil moisture sensors.Fig.1 (b) shows the Arduino setup for the resistive soil moisture sensor. Fig.1 (c) shows the Arduino setup for the capacitive soil moisture sensor. Fig.1 (d) shows the dried soil samples that were put in theoven for 24 hours at 105˚ Centigrade. Fig.1 (e) shows the weight of the soil samples before and after being dried in the oven.Fig.1 (f) shows the soil samples kept in the oven. After taking readings from thecapacitive soil moisture sensors, themass of all the wet soil samples was measured,and the samples were placed in anoven for 24 hours at 105˚ Centigrade. Thesame process was done with the samples from theresistive soil moisture sensor.

V. RESULTS AND DISCUSSION

All three experiments used twelve samples that were moistened with different quantities of water. Sensor value, moisture content measured by the sensor, the mass of container, soil weight (wet and dry) were all assessed to calculate soil moisture content using oven method, soil moisture content using equations, discrepancy ratio, RMSE value, coefficients of correlation and coefficients of determination.

A. Resistive Soil Moisture Sensor Comparison with Oven Method (Low Potentiometer Values)

Table II. Shows the resistive soil moisture sensor data, in which the samples were measured with resistive soil moisture sensor at low potentiometer values and compared to data from the oven-dried samples and the value determined from theequation of slope. Discrepancy ratio, RMSE value, the coefficient of correlation and coefficient of determination are included in the table to understand the differences between the methods better. Fig.2 resistive sensor graph shows the line of slope for low potentiometer values compared with the oven method. Fig.3 shows the bar graph comparison of resistive soil moisture sensor data at low potentiometer values with the oven method data and equation data.

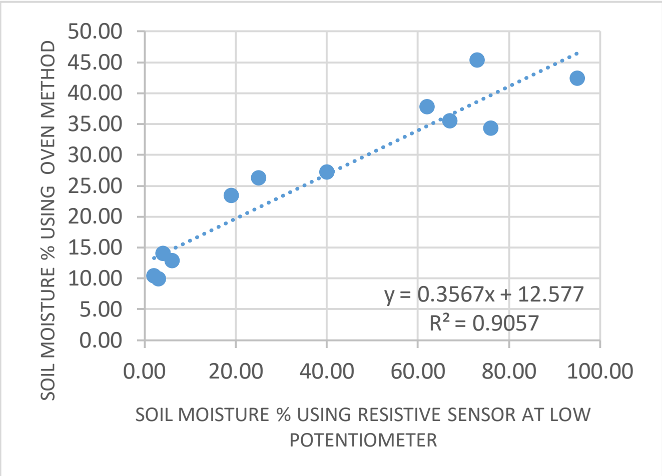

Fig. 2. Resistive Sensor graph at low values.

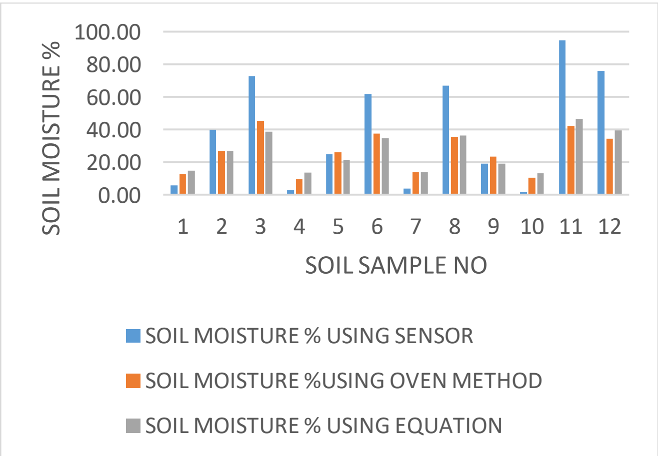

Fig. 3. Resistive Sensor bar graph comparision(lowvalues).

B. Resistive Soil Moisture Sensor Comparison with Oven Method High Potentiometer Values

Table III. Demonstrates the Resistive soil moisture sensor data, in which twelve samples soil moisture content in percentage was measured with resistive soil moisture sensor at high potentiometer values and contrasted these data and soil moisture content compared from oven method and also with value decided from the equation of slope. Discrepancy ratio, RMSE value, Coefficient of Correlation and Coefficient of Determination are additionally added to the table for better understanding the distinction from various methods. Fig.4 Resistive sensor graph demonstrates the line of slope for high potentiometer values contrasted with oven method. Fig.5 illustrates the bar graph comparison of resistive soil moisture sensor data at high potentiometer values with oven method data and equation data.

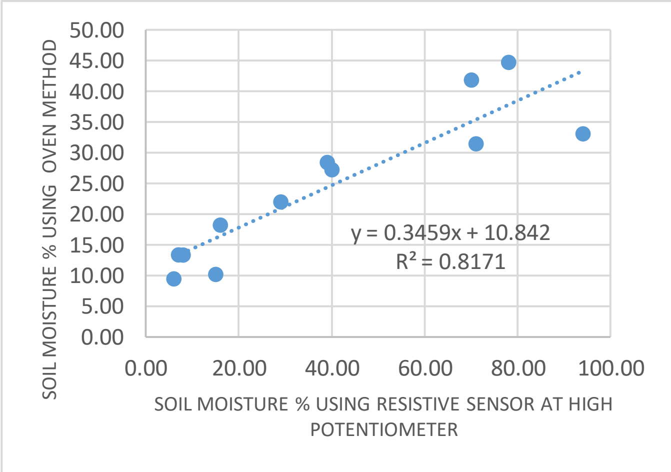

Fig. 4. Resistive Sensor graph at high values.

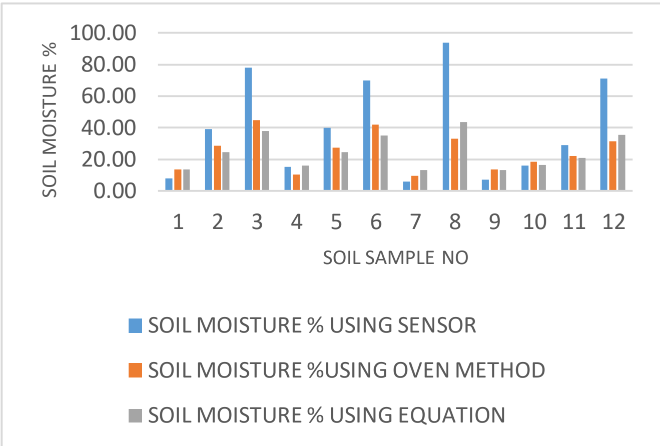

Fig. 5. Resistive Sensor bar graph comparision(high values)

C. Capacitive Soil Moisture Sensor comparison with the oven method

Table IV. Demonstrates the capacitive soil moisture sensor data of the 12 samples comparedwith the samples from the oven method and with values determined from the equation of slope. Discrepancy ratio, RMSE value, the coefficient of correlation and coefficient of determination are included in the table for a better understanding of the differences between themethods. Fig.6 capacitive sensor graph demonstrates the line of slope values contrasted and oven method. Fig.7 shows the bar graph comparison of capacitive soil moisture sensor data with the conventional oven method data and equation data.

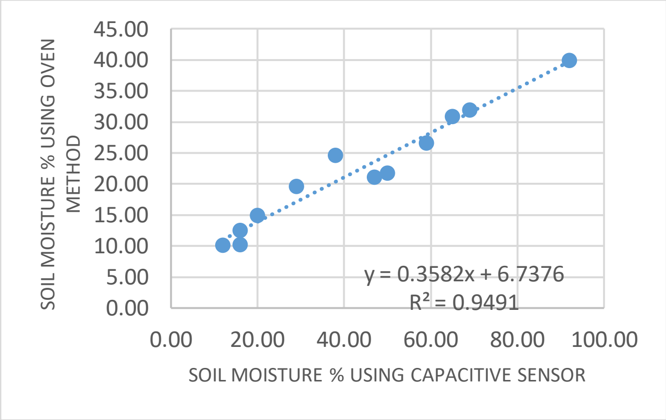

Fig. 6. Capacitive sensor value graph.

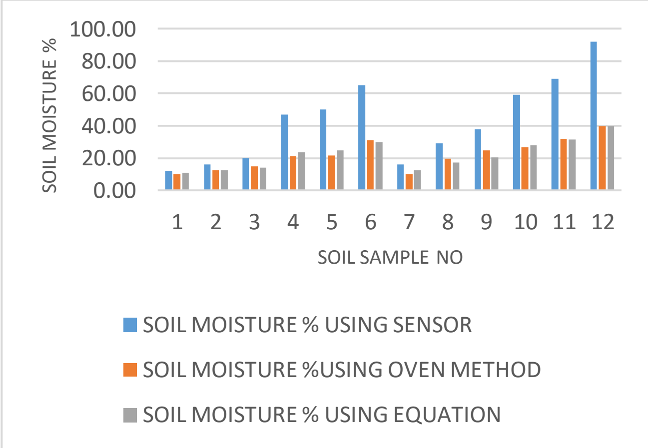

Fig. 7. Capacitive sensor bar graph comparision.

Table II. Resistive soil moisture sensor data at low potentiometer.

CONTAINER NO	SENSOR VALUE	SOIL MOISTURE % USING SENSOR	CONTAINER WEIGHT (in gms)	CONTAINER WEIGHT WITH SOIL (in gms)	SOIL WEIGHT (in gms)	DRY WEIGHT OF SOIL WITH CONTAINER (in gms)	SOIL MOISTURE %USING OVEN METHOD	SOIL MOISTURE % USING EQUATION	DISCREPANCY RATIO	RMSE	COEFFICIENT OF CORRELATION	COEFFICIENT OF DETERMINATION
33	961	6.00	16.63	64.33	47.70	58.90	12.85	14.72	0.87			
36	610	40.00	15.72	53.65	37.93	45.54	27.20	26.85	1.01			
44	271	73.00	20.10	64.92	44.82	50.94	45.33	38.62	1.17			
40	990	3.00	19.69	93.38	73.69	86.74	9.90	13.65	0.73			
28	764	25.00	17.95	67.10	49.15	56.88	26.25	21.49	1.22			
27	383	62.00	18.73	76.36	57.63	60.56	37.77	34.69	1.09	0.000129	0.95	0.91
1	992	4.00	18.07	73.63	55.56	66.80	14.02	14.00	1.00			
2	508	67.00	19.61	65.27	45.66	53.31	35.49	36.48	0.97			
3	867	19.00	19.05	62.87	43.82	54.56	23.40	19.35	1.21			
4	1003	2.00	19.08	78.78	59.70	73.16	10.39	13.29	0.78			
5	297	95.00	20.75	99.19	78.44	75.84	42.39	46.46	0.91			
6	446	76.00	18.46	59.18	40.72	48.78	34.30	39.69	0.86			
						TOTAL	319.29	319.29				

Table III. Resistive soil moisture sensor data at high poentiometer.

CONTAINER NO	SENSOR VALUE	SOIL MOISTURE % USING SENSOR	CONTAINER WEIGHT (in gms)	CONTAINER WEIGHT WITH SOIL (in gms)	SOIL WEIGHT (in gms)	DRY WEIGHT OF SOIL WITH CONTAINER (in gms)	SOIL MOISTURE %USING OVEN METHOD	SOIL MOISTURE % USING EQUATION	DISCREPANCY RATIO	RMSE	COEFFICIENT OF CORELATION	COEFFICIENT OF DETERMINATION
20	936	8.00	19.93	63.95	44.02	58.76	13.37	13.61	0.98			
34	622	39.00	19.06	59.51	40.45	50.55	28.45	24.33	1.17			
30	223	78.00	18.52	62.79	44.27	49.10	44.77	37.82	1.18			
41	861	15.00	18.35	84.13	65.78	78.04	10.20	16.03	0.64	0.006446	0.90	0.82
26	607	40.00	17.72	63.93	46.21	54.03	27.27	24.68	1.10			
35	300	70.00	15.19	69.32	54.13	53.34	41.89	35.06	1.19			
27	970	6.00	18.45	94.57	76.12	87.98	9.48	12.92	0.73			

28	303	94.00	17.62	109.38	91.76	86.55	33.12	43.36	0.76			
33	963	7.00	16.64	92.76	76.12	83.77	13.39	13.26	1.01			
35	898	16.00	15.33	78.32	62.99	68.60	18.25	16.38	1.11			
43	798	29.00	19.38	81.44	62.06	70.24	22.02	20.87	1.06			
44	481	71.00	20.13	80.34	60.21	65.92	31.49	35.40	0.89			
						TOTAL	293.69	293.71				

Table IV. Capacitive soil moisture sensor data.

CONTAINER NO	SENSOR VALUE	SOIL MOISTURE % USING SENSOR	CONTAINER WEIGHT (in gms)	CONTAINER WEIGHT WITH SOIL (in gms)	SOIL WEIGHT (in gms)	DRY WEIGHT OF SOIL WITH CONTAINER (in gms)	SOIL MOISTURE %USING OVEN METHOD	SOIL MOISTURE % USING EQUATION	DISCREPANCY RATIO	RMSE	COEFFICIENT OF CORELATION	COEFFICIENT OF DETERMINATION
33	609	12.00	16.64	95.90	79.26	88.59	10.16	11.04	0.92			
28	597	16.00	17.62	92.88	75.26	84.49	12.55	12.47	1.01			
43	576	20.00	19.38	89.91	70.53	80.73	14.96	13.90	1.08			
27	468	47.00	18.45	75.89	57.44	65.87	21.13	23.57	0.90			
44	458	50.00	20.13	81.50	61.37	70.52	21.79	24.65	0.88			
35	394	65.00	15.33	77.15	61.82	62.55	30.92	30.02	1.03	0.003360	0.97	0.95
1	594	16.00	18.06	68.38	50.32	63.70	10.25	12.47	0.82			
2	543	29.00	19.60	66.50	46.90	58.80	19.64	17.13	1.15			
3	509	38.00	19.30	65.36	46.06	56.25	24.65	20.35	1.21			
4	425	59.00	19.06	64.70	45.64	55.10	26.64	27.87	0.96			
5	387	69.00	20.68	72.74	52.06	60.13	31.96	31.45	1.02			
6	296	92.00	20.10	78.07	57.97	61.52	39.96	39.69	1.01			
						TOTAL	264.62	264.61				

VI. CONCLUSION

This study compares two types of soil moisture sensors,(i.e.resistive soil moisture sensors and capacitive soil moisture sensors) withconventional methods of measuring soil moisture. Both sensors provided analogue values which were converted into a percentage of water content in soil,some of the samples were kept in the oven for 24 hours to identify the soil moisture content. All testing was done on the Arduino UNO board,and programs were run on Arduino 1.8.4 IDE.

In a reflection of the results, the capacitive soil moisture sensor is shown to be more reliable than resistive soil moisture sensor. The sensors have similar calibrationprocesses, butone limitation oftheresistive sensor is that it cancorrodequite easily.All equation used forestablishing slope was developed by determining the R^2 value.

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