RESEARCH ARTICLE Agricultural Reviews, Volume 43 Issue 2: 243-248 (June 2022)

Performance Assessment of Soil Moisture Meter under Sandy Clay Loam Soil

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10.18805/ag.R-2286

ABSTRACT

Background: Irrigation performs a substantial function for the growth of agricultural vegetation. Soil supplies essential nutrients for the growth of plant and provides anchor support to the roots of the crops. Soil moisture permits the requirement for water system to be measured ahead of a yield giving indications of misery. Knowing the soil moisture status empowers exceptionally productive water system, giving the water as and when required and wiping out the inefficient utilization of water when water system isn't required.

Methods: Sandy clay loam soil contains a decent arrangement of plant supplements and supports most sorts of plants and yields. So in the field plentiful accessibility of this soil its texture is discovered by estimating soil moisture.

Result: Within the research we developed a soil moisture meter based on capacitive type sensor the output is analog voltage which is calibrated to soil moisture percentage and its performance is comparatively investigated with different moisture sensor under sandy clay loam soil. The proposed model is highly emphasized on the soil moisture percentage that is the level of water content in the soil. The percentage value is displayed in the LCD. The deployment cost is highly reduced in the proposed model.

Key words: Capacitive soil moisture sensor V2.0, Gravimetric analyzer, Moisture level 3 (ML3), Resistive type soil moisture sensor, Theta probe soil moisture sensor.

INTRODUCTION

Agriculture plays a major role for the contribution of Gross Domestic Product in India. Monitoring of soil moisture results in cost effective and precision agriculture. Soil moisture is assessed both by immediate and aberrant strategy. Direct technique includes the assurance of moisture in the soil and some direct method involves for measuring soil moisture is gravimetric or Thermo-gravimetric analyzer, In direct techniques dampness is assessed thermo-gravimetrically either through broiler drying or by volumetric technique. In indirect method gauge measure of water through the properties of water in the soil some indirect methods are tensiometric, electromagnetic, thermal heat dissipation sensors, thermal heat capacity sensors, radiation neutron scattering, gamma ray attenuation and soil psychrometer. In direct method or traditional method examining the soil moisture is extremely monotonous and tedious. It is hard to decide moisture content at explicit profundities. In indirect method measuring soil moisture is not as precise as immediate strategies and restricted to the top layer of the soil surface. Exceptionally mind boggling hardware typically including satellites. Over the top expensive strategy including the utilization of satellite frameworks by and large.

The proficient utilization of water is turning out to be increasingly significant, all over. Accuracy in agribusiness is likewise important (not just in the utilization of manures). Implementation of good sensors is costly and muddled for ranchers. In addition, they need to work on the administration of flooded yields, planning to a supportable utilization of soils and water. Various sensors are available for measuring the water content in the soil, to utilize the sensors properly and calibrated it is an important task prevails in front of us to get the accurate moisture content of soil.

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How to cite this article: Balaji, K. and Pandiarajan, T. (2022). Performance Assessment of Soil Moisture Meter under Sandy Clay Loam Soil. Agricultural Reviews. 43(2): 243-248. DOI: 10.18805/ag.R-2286.

Submitted: 01-06-2021 **Accepted:** 08-11-2021 **Online:** 15-01-2022

Ling *et al*. (2016) proposed a TDR coaxial test tube calibration plan utilizing a vertical invasion strategy was planned. This plan was then used to concentrate because of dry thickness, pore liquid conductivity and soil/rock proportion on the connection between water content and the dielectric constant of rock-soil combinations. The outcomes show that the experimental alignment condition structures for rock-soil blends can be equivalent to for soil materials. The TDR technique can be utilized to test gravimetric water content advantageously and proficiently without alignment in the field.

Yong-Sheng *et al*. (2016) the guideline of farming reason FDR sensors and the process for implanting this sort of sensors for subgrade designing intentions are presented. In view of field estimated climate information, a mathematical examination model for temperature and moisture content in the subgrade's soil is fabricated. Examinations of the temperature and moisture information got from mathematical simulations and FDR-based estimations are directed.

Aniley *et al*. (2018) an research on soil temperature sensors and in everyday temperature sensors readiness from nanomaterials is introduced. Prologue to soil, the role of nanotechnology in farming, the meaning of soil temperature, the need for soil temperature discovery and strategies for its location is examined. Crafted by certain analysts to recognize the temperature and difficulties of soil temperature estimation are likewise talked about. At last individual proposals and future viewpoints will be given dependent on the current works.

Hazreek *et al*. (2018) this review presents assurance of soil moisture content utilizing research facility trial and field electrical resistivity value (ERV). Field and research center electrical resistivity (ER) test were performed utilizing ABEM SAS4000 and Nilsson400 soil obstruction meter. Soil test utilized for resistivity test was tried for portrayal test explicitly on molecule size conveyance and moisture content test as per BS1377 (1990). Field ER information was prepared utilizing RES2DINV programming while lab ER information was investigated utilizing SPSS and Excel programming.

This paper presents plan and advancement of a soil moisture sensor and a reaction observing framework. Khanna *et al*. (2014). The tests utilized in this sensor are made of nickel which is an enemy of destructive and hearty material for use in agrarian related applications. The reaction checking framework measure the moisture of the soil, contrast it and the ideal qualities given by the client and produce alert if soil moisture goes beneath wanted worth. It helps in issues identified with developing of yields in which water system is needed at unpredictable span. It is additionally useful in checking of soil dampness in golf fields. A resistive soil moisture sensor is used for measuring the water content in the soil with response monitoring system.

Saleh *et al*. (2016) proposed that the resistive sensor isn't that much reliable for measuring the moisture content. Infrequent soil moisture reading is feasible in Resistive sort of sensor. The evaluation of resistive type soil moisture sensor and therefore the result obtained are affected by several sources of error the accuracy and usability isn't reliable.

Machikowa *et al*. (2020) done research and explore the impacts of soil moisture on cassava development and physiological cycles and to decide the basic soil moisture contents. Physiological qualities and plant development boundaries were measured. All physiological attributes diminished altogether when the moisture content was under 40 and 20% of available water holding capacity in sandy clay loam and loamy sand soil. Predawn leaf water potential was utilized to decide the basic place of soil moisture. It was tracked down that the basic soil moisture substance were 39.0 and 15.7% of available water holding capacity (AWHC) in sandy clay loam and loamy sand soil.

Gao *et al*. (2018) the interest of shrewd irrigation system for precise moisture detecting in the soil vertical profile, a soil profile moisture sensor was developed dependent on the rule of high-recurrence capacitance. The sensor comprises of five gatherings of detecting probes, a data processor and some embellishment parts. Low-resistivity copper rings were utilized as parts of the detecting tests. The sensor had the option to recognize ongoing soil moisture at the profundities of 20, 30 and 50 cm and direct internet based reversal of moisture in the sand layer between 0-100 cm.

Objectives

The main aim of this paper is to supply reliable soil moisture meter to the farmers with the following objectives:

- To develop soil moisture meter which is convenient and affordable to farmers.
- To study the performance assessment of soil moisture meter.

Soil moisture sensors

In this study the accuracy of different soil moisture sensors are investigated. The soil moisture sensors are especially used to estimate the volumetric water content. Measuring the soil moisture is essential for improving the irrigation system. Soil moisture sensors are utilized in several applications agricultural sciences and horticultural with irrigation planning.

A. Resistive soil moisture sensor

It consists of two probes that measure the volumetric substances of water. It analyse the relationship between the electrical resistance and therefore the water content to seek out the moisture content in soil. An electrical current which is generated must pass from one probe to another to measure the resistance of the soil between them. Then low resistance reading is obtained in the soil when there's water content in the soil. The soil is dry there exists high resistance no conduction occurs. Selvaperumal *et al*. (2017). The main drawback in resistive type soil moisture is that the corrosion of the probes which results inaccurate measurements.

B. Capacitive soil moisture sensor

Capacitive sensor explores the dielectric contrast between soil and water. Here rather than parallel plate capacitance planar based setup is employed. The dielectric medium *i.e.* the soil is placed above the planar plates or electrodes of the sensor. The capacitive sensor with timer 555 IC is paired to produce the analog voltage as output of the sensor. Bag *et al*. (2015) Results demonstrate that germination principally relies on soil moisture and is a function of soil moisture.

The function of dielectric constant and geometry of the sensor is expressed as:

$$C = € A$$

C- Capacitance; €- Dielectric constant; A- Geometry.
The analog voltage output is expressed as:

$$V = G/C$$

V-Analog Voltage; G-Constant; C-Capacitance.
For solving dielectric constant:

$$€ = G/AV$$

Volumetric water content:
It is the ratio of vol. of liquid to vol. of Soil.

$$\theta_v = (M_w / \rho_w) / (M_d / \rho_d)$$

M_w and M_d = Mass of water and soil.
ρ_w and ρ_d = Density for water and dry soil.
The volumetric content is said to dielectric content.

$$€ = (1- \theta_v) €d + \theta_v €_w$$

Finally, relation between analog voltage and volumetric content is:

$$\theta_v = a /V + b$$

a and b are constants.

C. Gravimetric method for the measurement of soil moisture content

The ratio of the mass of water present to the dry soil to its soil sample weight or by volume as ratio of volume of water to the entire soil sample (Ansari *et al.*, 2017).

Gravimetric analysis method (Sample kept at 105°C for 24 hours)

Wet soil moisture percentage is =

$$\frac{(\text{wt. of wet soil + tare}) - (\text{wt. of dry soil + tare})}{(\text{wt. of dry soil + tare})} \times 100$$

Volumetric basis expressed the water content as:
θ_v = Volume of water/volume of soil
Volume of water = Weight of water/water density
Volume of soil = Weight of dry soil/bulk density
θ_v = Weight of water / weight of dry soil × bulk density/ water density.

$$\theta_v = \theta_d \times db/dw$$

D. ML3 Theta probe soil moisture sensor

Hyunglok *et al*. (2020) proposed a versatile soil water Content (SWC) sensors give valuable data to decide the measure of Soil Water Content in the soil layer for different applications. The soil moisture probe is embedded into the soil and readings are read out using data logger. The values are stored within the data logger. The ML3 includes the thermistor sensor which are used to measure the soil temperature also.

The probes of ML3 are formed through tough stainless steel. Its extends its application in the field of hydrology, civil engineering, pollution monitoring, soil water profiling and forestry. It can also be utilized in non-soil media. The major disadvantage is that the cost it costs around Rs. 100000.

MATERIALS AND METHODS

In this the overall proposed methodology for measuring the capacitive soil moisture content which was designed and developed and field test carried out in Agricultural Engineering College and Research Institute, Kumulur, Trichy, Tamil Nadu on April 2021. This framework through capacitive sensor along with Arduino Nano and I2C with LCD have been shown in Fig 1.

A. Arduino nano board

It is an open source hardware which is compatible, low cost and bread board friendly one which is shown in Fig 2. Its technical specifications are Advance Technology for Memory and Logic (ATMEGA 28/ ATMEL 28) controller as its core then its operating voltage is 5V to 12V, it has a flash memory and Electrically Erasable Programmable Read-Only Memory (EEPROM) of 2 KB 1 KB respectively. It has 8 Analog and 22 Digital I/O pins for sensor interfacing.

B. Capacitive soil moisture sensor

The capacitive soil moisture sensor which is shown in Fig 3 is compatible with all types of controllers. Its operating voltage and current is only 3.3 V and 5 mA respectively It produces analog output with low cost. The IC 555 which is incorporated with this sensor produces the analog voltage for the corresponding capacitance.

C. I_2C with LCD

The I_2C with LCD is shown in Fig 4 is an inter integrated circuit bus protocol which is used to control the LCD with minimal wire, if LCD without I_2C needs more wires to communicate with controller. The 16 × 2 LCD has operating voltage 4.7 V to 5.3 V its current consumption is 1 mA without backlight, Alpha numeric display module, consists of 2 rows and 16 columns for display the characters.

D. Schematic diagram

The monitoring of soil moisture content is done by using capacitive sensor which uses 3.3 V for its operation. The sensor has an on-board voltage regulator. The sensor is connected with the Arduino Nano board the sensor continuously sends the analog voltage values to the controller.

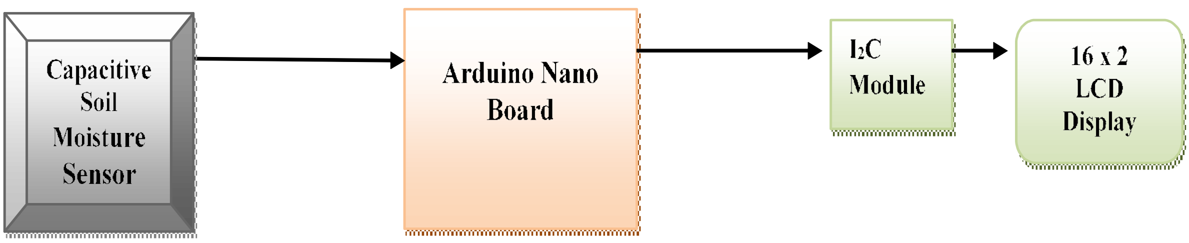

Fig 1: Overall block diagram.

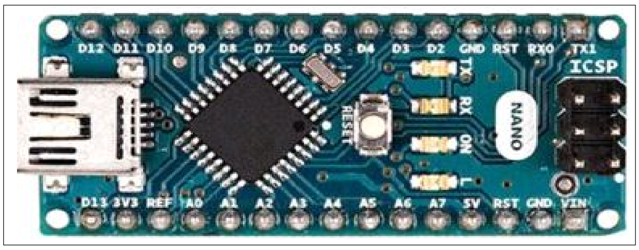

Fig 2: Arduino nano board.

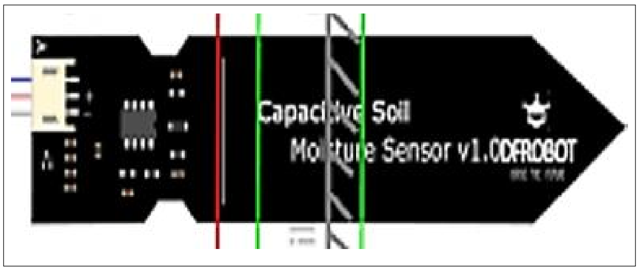

Fig 3: Capacitive soil moisture sensor.

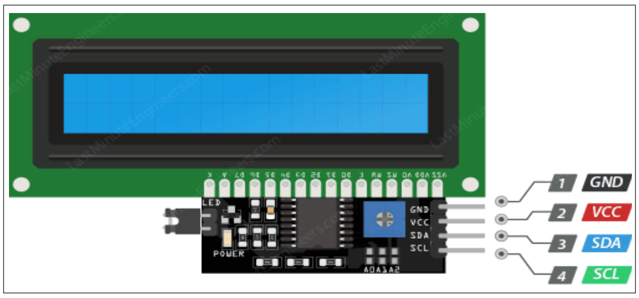

Fig 4: I_2C with 16 × 2 LCD

The sensor continuously sends the analog values to the controller. The obtained analog values are calibrated in the software coding and it is converted into percentage. The percentage is shown in the LCD.

Calibration part in the software coding:

```
void loop()
{
float moisture_percentage;
int sensor_analog;
sensor_analog = analogRead(sensor_pin);
moisture_percentage = (100 - (sensor_analog/730.00) * 100
)/2;
delay(10);
if (sensor_analog < 730 )
{
lcd.setCursor(0,0);
lcd.print ("Percentage=");
lcd.print (moisture_percentage);
lcd.setCursor (15,0);
lcd.print ("%");
lcd.setCursor(1,1);
lcd.print ("AECandRI-KUMULUR");
delay (10);
}
if (sensor_analog < 730 )
{
lcd.setCursor(0,0);
lcd.print ("Percentage=");
lcd.print (moisture_percentage);
lcd.setCursor(15,0);
lcd.print ("%");
lcd.setCursor (1,1);
lcd.print ("AECandRI-KUMULUR");
Serial.print (sensor_analog);
Serial.print (moisture_percentage);
Serial.print ("%\n\n");
delay(10);
}
}
```

In the above coding part the calibration is done and the percentage conversion is carried out as:

Percentage = 100 - (100 - [(sensor_analog/730.00) * 100)]/2;

Here the sensor analog is the analog voltage values form the sensor part whereas the 730 constant value is the threshold analog voltage or the high dry moisture content analog voltage value from the sensor.

The schematic diagram shown in Fig 5 is drawn by using the software circuito.io is an online tool for all electronic circuits design it also develops model code it is an open source tool. The software implementation makes hardware implementation easier.

The circuit connection map of Arduino Nano with Capacitive sensor and 16 × 2 LCD with I2C interface is tabulated in the below Table 1.

RESULTS AND DISCUSSION

Performance assessment of different soil moisture sensor/meter in sandy clay loam soil

In the Table 2 the performance assessment of different sensors and methods in order to find out the soil moisture content are carried out under sandy clay loam soil is performed.

The gravimetric analysis method is performed in order to find out the wet soil moisture percentage this must be taken as basic method or conventional method for the calibration of our proposed model. The wet soil moisture percentage is calculated and found as 27.8%.

Table 1: Connection map of Arduino nano with capacitive sensor and 16 × 2 LCD.

Arduino nano board	Capacitive sensor V2.0	16 × 2 LCD with I2C
5 v	Vin	Vcc
A0	Aout	NC
GND	GND	GND
A4	NC	SDA-Serial data line
A5	NC	SCA-Serial clock line

Note: NC- Not connected; A0, A4 and A5- Analog Inputs.

Table 2: Performance assessment of various sensors and methods.

Gravimetric analysis method (Sample kept at 105°C for 24 hours).

Tare weight is 0.0243 g^{2}.

Wt. of wet soil + Tare = 0.1766 g^{3}.

Wt. of dry soil + Tare = 0.1381 g

Wet soil moisture percentage is = {(Wt. of Wet Soil + Tare) - (Wt. of Dry Soil + Tare)/(Wt. of dry soil + Tare)} * 100

Wet soil moisture percentage is = 27.8%

Dry soil moisture percentgae is = {(Wt. of Wet Soil + Tare) - (Wt. of Dry Soil + Tare)/(Wt. of dry soil + Tare) - Tare} * 100

Equipments	Power consumption	Temperature accuracy	Probe depth	Price of the equipment	Data storage	Sample-dry %	Sample-wet %
Theta probe Soil moisture Sensor	5 to 14 V, 18 mA for 1 s	±0.5°C, to +40°C ±0.75°C, -20 to +60°C	6 cm	Rs. 1,00,000	Yes	2.2% Moisture content	31.5% Moisture content
Soil moisture Meter-resistive type	5 to 12 V 35 mA for 1s	±0.5°C, 15 to +40°C	6 cm	Rs. 600	No	3.1% Moisture content	33% Moisture content
Soil moisture Meter-capacitive type (AEC and RI)	5 to 12 V 19 mA for 1s	±0.5°C, 15 to +40°C	7 cm	Rs. 600	No	2.7% Moisture content	27.6% Moisture content

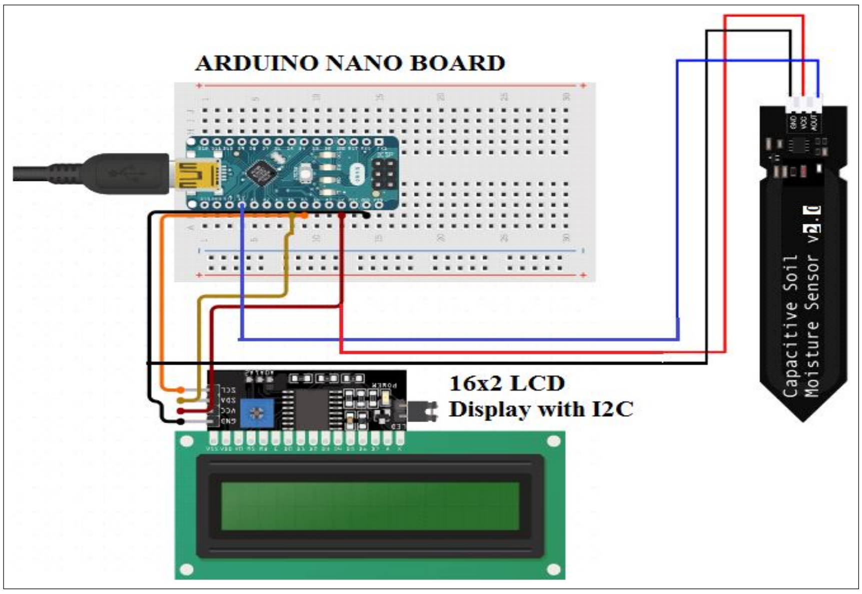

Fig 5: Schematic diagram using Circuito.io software.

The second test of soil moisture is carried out by using Theta Probe soil moisture sensor its consumes 5 to 14 V as operating supply. The probe depth used here is only 6 cm its has the specialty of storing the moisture content percentage. The probe is directly inserted into the soil and the readings are seen in the LCD. The dry moisture and wet moisture percentage found by using this sensor is 2.2% and 31.5% respectively.

The third test in order to found out the soil moisture content percentage in the soil is done by using resistive type soil moisture sensor. It works based on the relationship between the electrical resistance and water content to analysis the soil moisture percentage. The resistance type sensor probe length is 7 cm and it is directly inserted into the soil sample and the obtained readings are dry moisture and wet moisture percentage is 3.1% and 33% respectively.

The fourth test is our proposed model which is shown in the below Fig 6 where the soil moisture content is measured by using capacitive type sensor. It works based on the changes in the capacitance value the soil sample acts as a dielectric medium its capacitance changes based on that. The dry and wet soil moisture percentage after calibration based on the reference from gravimetric analyzer it is 2.7% and 27.6% respectively.

Fig 6: Screenshot of proposed model.

CONCLUSION

In this paper three soil moisture sensors that is resistive type, moisture level (ML3) Theta Probe, capacitive type compares with the conventional method (gravimetric analysis) of measuring soil moisture content. Based on soil moisture percentage obtained through various sensors it is concluded that the capacitive type soil moisture meter model shows the reliable soil moisture percentage with conventional method and further the corrosion problem is overcome in capacitive type. Capacitive soil moisture helps in overseeing water system frameworks more successfully and productively. It assists farmers to save water, to build yields and to expand nature of the harvest. Capacity to peruse volumetric water content straight forwardly. No special maintenance required. Moreover, the cost is also affordable one.

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