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Design and Construction of a Soil Moisture Measuring

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Authors' contributions

This work was carried out in collaboration among all authors. Authors AAI and OWB designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors OOA and JZE managed the analyses of the study, proof read the article and co-type the manuscript. Author ODO managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

A digital soil moisture reader was constructed and tested. It uses a lipo battery of 9v which was regulated to a constant 5v with the help of a voltage regulator 7805. The digital soil moisture reader developed was tested and the result obtained was compared with that obtained using the gravimetric method of determining soil moisture contents. In determining the soil moisture content, a certain quantity of soil was collected and a particular volume of water was added incrementally. The result shows that the soil moisture reader is accurate. The evaluation was carried out using the gravimetric method of soil moisture determination as a basis of comparison. Nine samples of 50g of soli were collected from Federal College of Forestry Mechanization Farm and a certain amount of water was added incrementally during the process of determining the soil moisture content. The soil reader was calibrated using the gravimetric method which shows a regression coefficient R^2 of 0.986 which indicates that the soil reader is accurate, sensitive and reliable.

Keywords: Design; construction; digital; moisture measuring device.

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1. INTRODUCTION

Soil moisture is the water stored in the soil and is affected by precipitation, temperature, soil characteristics, and more. Moisture factor is very important for the soil for the weathering process, because it serves as medium through which organic matters and minerals gets to the root of the plants. However, if it is too humid the movement of air within the soil will be restricted, preventing the roots of the plants from getting oxygen causing death Robock et al. [1]. How suitable a land is for growing of crops depends on the types of biomes present. And how healthy the crop is depends on an adequate provision of moisture and nutrients. The moment there is a reduction in moisture level, the growth of the plant is distorted and the crop yield is affected negatively. The availability of moisture also becomes variable as the climates changes. Soil-moisture content increased during the last several decades in parts of Eurasia Robock et al. [1] and in much of the continental United States during the twentieth century (Andreadis and Lettenmaier, 2006). The increament of the soil moisture content comes with an increase in temperature trend as well, otherwise it would have resulted into a decrease in soil moisture. In this case, increases in precipitation are thought to have been more than compensated for by increased losses due to increases in ET Robock et al. [1].

1.1 Importance of Soil Moisture Content Reader

A good knowledge of the amount of water in the soil is very important in agriculture. In order to design efficient irrigation system, the appropriate crop water requirement and the available water in the soil must be known. The crop water requirement data is usually obtained by monitoring changes in the soil water content or by estimation from environmental variables such as temperature, radiation, relative humidity etc. but even when estimating methods such as penman Evapotranspiration (ET), are used, their accuracy must be verified by measurements made directly in the soil. Asawa [2]. Measuring soil moisture is important in agriculture because farmers can manage their irrigation system effectively by developing irrigation scheduling system than will lead to water conservation. Since the growth of crops depends on the water and agricultural chemicals applied on the soil, this requires better and reliable methods to perform soil water content measurement with minimal soil disturbance. Soil moisture is a key variable in the climate system. By controlling evapotranspiration, soil moisture impacts the partitioning of incoming radiation into sensible and latent heat flux. Furthermore, it represents an important water and energy storage component of the regional climate system. Regional simulations of recent and future climate conditions indicate that a projected increase in summer temperature variability and the occurrence of heat waves in Central and Eastern Europe is mainly due to soil moisture atmosphere interactions Seneviratne et al. [3]. It is easy, simple and economical to design. Because of these benefits, capacitive sensor techniques are applied in the precision agriculture Soltani, M. and Alimardani, [4].

The inability of most soil moisture readers to correctly determine the amount of water in the soil has led to either excess water in the soil for a particular crop or inadequate water for another crop which has hitherto reduce the yield of the crops.

The study therefore seeks to design and build a moisture measuring device that is capable of ascertaining the moisture level of the soil, so that farmers can determine effectively when to irrigate their field to avoid water wastage, or as a part of preliminary test to determine whether a soil is suitable for farming or not. The following steps were therefore taken in the construction of the soil moisture measuring device:

i. Evaluate the performance of the soil moisture content reader.

ii. Calibrate the constructed soil moisture reader using gravimetric method of soil moisture determination.

iii. Construction of a soil moisture content reader.

1.2 Soil Moisture Measurement

The water that fills part or all of the soil pores above the water table is known as the soil moisture. Another dynamic definition says that the soil moisture is the amount of water stored between the pores of the soil. It is caused by evaporation through the soil surface, transpiration and percolation. Soil water content is stated in percent volume i.e. percentage of water volume to soil volume.

The best instrument for soil moisture content determination depends on some factors such as: physical limitations of different techniques; the level of information required (either an absolute or relative moisture measurement); the amount of data needed to objectively decide upon an irrigation regime (with consideration to spatial and temporal problems); the initial cost of the instrument and sampling; the reliability of the instrument and the collected data.

A scientifically accurate moisture measuring instrument must be able to adopt time-tested scientific methods to operate. There are different methods for measuring soil moisture content. One of such is gravimetric method. The removal of water from a soil sample is known as gravimetric measurement of soil water. Sample water is removed by evaporation, leaching or chemical reaction. Once sample water is removed, the amount of water removed from the sample is determined and used to calculate soil moisture content.

In order to design and build a functional moisture device, all of its components must be adequately accounted for. One of such is the soil sensor. A soil sensor operates on the principle of dielectric, and basically consists of a pair of electrodes which form a capacitor with the soil acting as the dielectric in between. The two electrodes and the soil as dielectric material, form a capacitor .The higher the water content, the higher the capacitance. So by measuring the capacitance, inference can be made about the water content in soil.

Changes in soil water content are detected by changes in the operating frequency as the capacitor works with the oscillator to form a tuned circuit.

Capacitance (C) is defined as the amount of charge (Q) required to increase the voltage (V) by one volt between two plates separated by a known distance containing an insulating material and is calculated using

$$C = \frac{Q}{V} \qquad \text{(i)}$$

Where

Capacitance C, is measured in Farads
Voltage V, in volt and
Charge Q, in coulombs.

Dielectric sensor uses capacitance in measuring the permittivity of the surrounding. The arrangement is in the form of a neutron probe installed in the soil. The head of the sensor consist of an oscillator circuit whose frequency is determined by the effect of the capacitor, the dielectric constant of the soil and the electrodes.

1.3 Relative Static Permittivity (Dielectric Constant)

It is sometimes called the dielectric constant. It is that characteristic of a dielectric material that shows how much electrostatic energy can be stored per unit of volume when unit voltage is applied across it, it is of a great importance for capacitors and capacitance calculation.

With the fact that the permittivity of a medium covers the charge that can be held by a medium, it can be seen that the formula to determine it is:

$$\varepsilon = \frac{D}{E} \qquad \text{(ii)}$$

Where:

ε = Permittivity of the substance (farads per metre)
D = Electric flux density
E = Electric field strength

To identify that the soil moisture condition can be measured by applying either soil moisture meter i.e. Soil Tester or manual calculation to know soil moisture referring to American Standard Method (ASM). Suppose MA = mass of water, MTB = mass of wet soil, MTK = mass of dry ground, and KT = soil moisture, the equations which can be used to find soil moisture are showed by (1) and (2) (Stevanus. et al. 2013).

MA = MTB-MTK (iii)

KT = MA / MTK x 100% (iv)

2. MATERIALS AND METHODS

2.1 Soil Moisture Reader Components

The components used in this work include capacitors, resistors, wires, LCD (Liquid Crystal Display), 5v regulator, power switch, 9v battery, Atmega 328p Micro-controler, sensor/probe, crystal oscillator, resistor, capacitor.

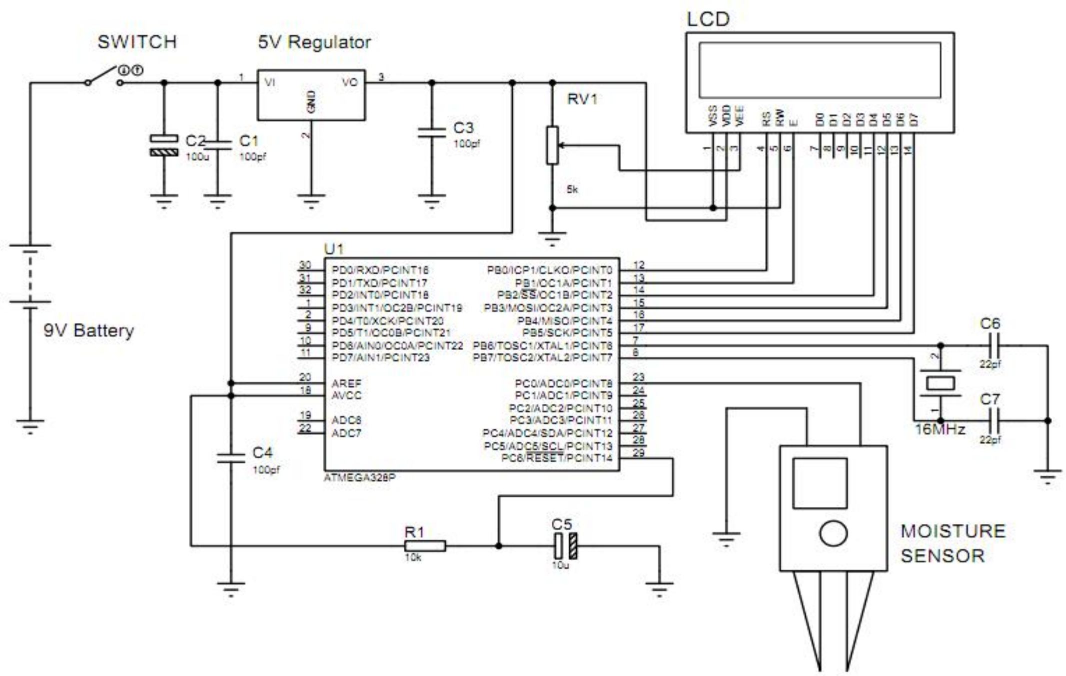

Fig. 1. Circuit diagram of soil moisture measuring devise

3. RESULTS AND DISCUSSION

3.1 Soil Moisture Calibration Using Gravimetric Method

The gravimetric method also known as oven dry method is the standard for the calibration of all other soil moisture determination techniques Schmugge et al. [5].

The moisture content was determined using the equation below:

$$P_{mc} = \frac{W_{ms}-W_{os}}{W_{ms}} \times 100` \quad (v)$$

3.2 Soil Moisture Content Measuring Devise

The Table 1 below shows the calculations for oven dry method of soil moisture determination.

The soil moisture content reader readings and the oven dry moisture content of soil samples was shown on the Table 2.

Table 1. Calculations for oven dry method of soil moisture determination

Samples	A	B	C	D	W_{ms}	W_{os}	P_{mc} (%)
1	0	32.2	82.2	82.2	50.0	50	0.0
2	0.5	31.3	81.5	81.3	50.2	50	0.3
3	1.0	32.0	83.1	82.0	51.1	50	2.2
4	1.5	29.5	81.1	79.5	51.6	50	3.1
5	2.0	32.2	84.4	82.2	52.2	50	4.2
6	2.5	32.4	84.9	82.4	52.5	50	4.7
7	3.0	31.2	84.1	81.2	52.9	50	5.5
8	3.5	30.8	84.2	80.8	53.4	50	6.4
9	4.0	31.7	85.3	81.7	53.6	50	6.7
10	4.5	28.8	82.9	78.8	54.1	50	7.6
11	5.0	29.2	83.7	79.2	54.5	50	8.3

In Table 1, A is the quantity of water added; B is the weight of can; C is the weight of can + weight of wet sample; D is the weight of can + weight of oven dry sample; $W_{ms}$is the weight of wet sample; W_{os} is the weight of oven dry sample

Table 2. Soil moisture content devise readings and oven dry moisture contents of soil samples

S/N	ml of water added	Oven dry moisture content (%)	Soil moisture content reader (%)
1	0	0.0	4
2	0.5	0.3	7
3	1.0	2.2	12
4	1.5	3.1	15
5	2.0	4.2	20
6	2.5	4.7	23
7	3.0	5.5	26
8	3.5	6.4	29
9	4.0	6.7	32
10	4.5	7.6	36
11	5.0	8.3	40

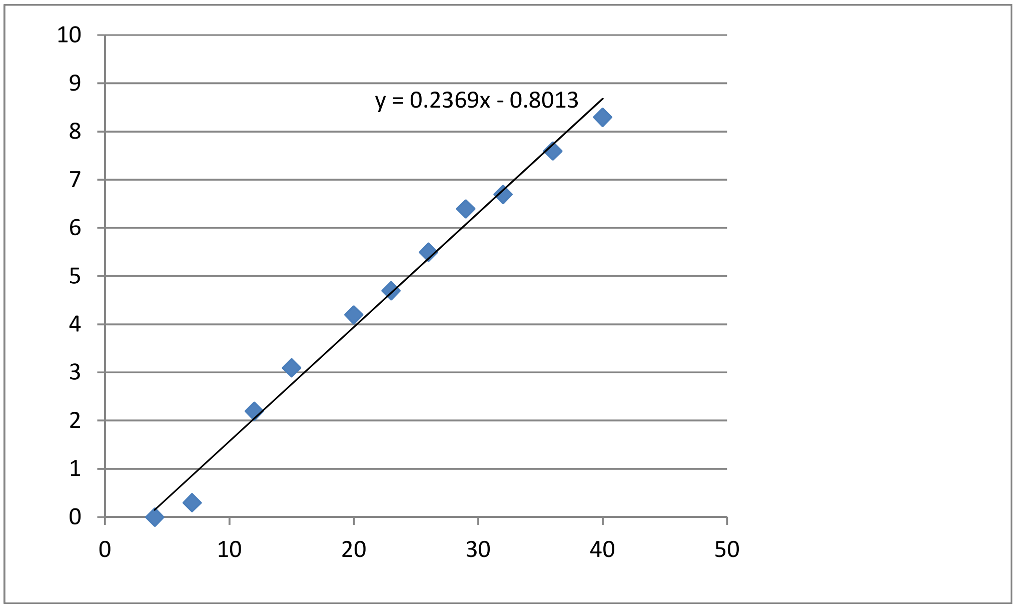

Fig. 2. Calibration graph for the soil moisture content devise

The oven dry moisture content was plotted against the readings obtained from the soil moisture content reader. The regression coefficient of 0.98576 approximately 0.986 was obtained as shown in Fig. 2.

Table 1 shows the eleven soil samples of moisture content at different level of water added incrementally to the soil sample. It consist of weight of moist soil, weight of oven dry soil, percentage of moisture content, weight of can and weight of wet samples. The data were collected to obtain the percentage of moisture content (oven dry moisture content) of the soil.

Table 2 shows the eleven soil samples of moisture content at different level of water added to the soil sample. When the water is added to the soil sample, its moisture content and its weight increases. The moisture content increases by using both the moisture content process and the soil moisture content reader. The data collected was used to calibrate the soil moisture content reader.

Fig. 2 shows the plotted graph of oven dry moisture content against soil moisture content reader readings. The co efficient value for linear regression between the different level of water added was 0.98576 approximately 0.986 which is an acceptable value.

4. CONCLUSION

A soil moisture content measuring device was constructed, tested and the results obtained shows that it is sensitiv e and reliable. The inability of most soil moisture readers to correctly determine the amount of water in the soil has led to either excess water in the soil for a particular crop or inadequate water for another crop which has hitherto reduce the yield of the crops.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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