Development and Performance Evaluation of a Soil Moisture Sensor

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Abstract- This study was aimed at developing a soil moisture sensor to effectively monitor moisture level for optimum crop growth. The sensor was made using a programmed Arduino microcontroller. It is attached to a sensing panel with two probes made of nickel that measures the volumetric content of water in soil. The probes were non-corrosive and robust material suitable for use in wet surfaces. The developed sensor was tested and evaluated. The two-legged Lead (probes) goes into the soil where water content was to be measured by passing current through the soil, and then reads the resistance to get the moisture level. Nine different soil classification samples (Sandy Clay, Fine Sandy Loam, Sandy Loam, Salty Loam, Loamy Sand, Coarse Sand, Fine Sand, Sandy Clay Loam and clay soils) at different depths (3, 6, 9, 12 and 14.3 cm) were used to analyse the moisture meter at three different portions of each soil sample. Results obtained indicates that there was a progressive increase in moisture levels the more the sensor was being dipped into the soil. Results obtained also shows that all the nine soil samples but one (*Silt Loam Soil Sample*) analysed were within acceptable range of accuracy (0.1 - 5.0 %). The moisture sensor whose cost was approximately ₦22,300:00 was found to be effective, high precision at less efforts and a suitable guide for farmer for determining soil moisture levels.

Keywords- Moisture, Probe, Sensor, Soil Classification

1 INTRODUCTION

Soil moisture is of paramount importance in Agriculture because of its influence on plant growth and crop production. Over the years, there has been a growing interest in soil moisture. Most studies related to soil-plant relationship are invariably pivoted about accurate measurement of soil moisture either by direct or indirect methods (Adamhameed, 2014). Gravimetric measurement of soil moisture content requires excavating, drying, and weighting of samples has been associated with drudgery. Soil moisture meters measure the volumetric water content in the soil indirectly by using some other property of the soil, such as electrical resistance, dielectric constant, or interaction with neutrons, as a proxy for the moisture content of the soil.

The electrical resistance between the electrodes varies with soil moisture content (Mohamed and Tessema, 2013). The relation between the measured property and soil moisture must be calibrated and may vary depending on environmental factors such as soil type, temperature, or electric conductivity (Carter and Gregorich, 2006). Soil is a mixture of mineral and organic matter that contains air, water, and micro-organisms. It provides a medium in which plants grow, a habitat for animals, and storage for water. The size of the mineral particles is a key soil property and provides the basis for classification of soils. Many processes take place in soils including the recycling of nutrients, purification of water, and exchange of gases with the atmosphere (Carter and Gregorich, 2006; Jeff and Mark, 2003).

The range of soil textures can be used as a quick means of assessing possible land uses. It also determines its water holding capacity. For profitable agricultural production, non-uniform moisture distribution of soils constitutes a bottleneck for optimum crop growth. Sampling and moisture content testing is a routine operation, most often performed manually. By necessity, for practical purposes, indirect electrical moisture content measurement methods have been developed that are based on correlations between electrical properties of soil and its moisture content (Nelson, 1991; Mukhta, 2010).

There are few new lands waiting to be opened up for agriculture; hence, increase in food supplies has to come from making better use of the already farmed land with efficient crop production methods (Mohamed and Tessema, 2013). However, rainfall is still a limiting factor necessary for profitable crop production. Plants will grow best with their roots in soil, if the right quantity of water is applied at the right time; Blake and Hartge (1986). Small scale farmers in Nigeria and most of African countries do not use soil moisture measurements, (FMARD, 2006). Similarly, estimates of crop evapotranspiration for irrigation scheduling are mostly measurements by means of old and outdated old methods like excavating, tensiometers, neutron probes and gypsum blocks are very expensive to afford coupled (Krishna et. al, 2006). The drudgery was also high. Thus, this research seeks to design and develop an effective soil moisture meter that enable peasant farmers to ascertain moisture level with minimum effort for optimum crop growth.

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Section A- AGRICULTURAL ENGINEERING & RELATED SCIENCES

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2 MATERIALS AND METHODS

2.1 MATERIALS

2.1.1 Arduino Uno Board

The main material component of the study was the Arduino UNO and the Soil Moisture Sensor. The Arduino UNO board is the most popular board in the Arduino board family (Figure 1).

Fig. 1: Arduino UNO board with component illustration (Source: www.arduino.cc)

[1 – Power USB, 2 – Power (Barrel Jack); 3 – Voltage Regulator; 4 – Crystal Oscillator; 5, 10 and 17 – Arduino Reset; 6, 7, 8 and 9 – Pins (3.3, 5, GND, Vin); 11 – Main microcontroller; 12 – ICSP pin; 13 – Power LED indicator; 14 – TX and RX LEDs; 15 – Digital I/O; 16 – AREF]

Fig. 2: Soil Moisture Sensor (Source: www.arduino.cc)

2.1.2 Soil Moisture Sensor Board

Soil Moisture Sensor board consists of a couple of conductive probes that can be used to measure the volumetric content of water in soil. The soil moisture sensor board consists of two parts: The main Sensor and the Control Board. A two-legged sensor (Figure 2), goes into the soil where water content has to be measured. This sensor uses the two probes to pass current through the soil, and reads its resistance to get the moisture level. More water makes the soil to conduct electricity more easily (less resistance), while dry soil conducts electricity poorly (more resistance). The probe has two header pins that is connected to an Amplifier/A-D circuit which is in turn connected to the Arduino. The technique of the probe is based on the measurement of fast-moving neutrons that are slowed in the soil by an elastic collision with existing Hydrogen particles (H+) in the soil, while the Amplifier has a VIN, GND, Analog and Digital Data Pins. This means that the values could both be displayed in Analog and Digital forms.

The Control Board is made up of LM393 IC, which is a voltage comparator. The board also consists of other components like connectors, LEDs, resistors etc. to measure the soil moisture. Additionally, there is an option to adjust the sensitivity of the module with the help of a potentiometer. The board has a power supply of:

3.3v or 5v, Output voltage signal of: 0~4.2v, Current of: 35mA. Other components of the moisture meter include:

LCD Display – An LCD is an electronic display module which uses liquid crystal to produce a visible image. The 16×2 LCD display is a very basic module commonly used in DIYs and circuits. The 16×2 translates to a display 16 characters per line. Each character is displayed in a 5×7-pixel matrix.

10KΩ Potentiometer (for LCD) – this is essentially a voltage divider used for measuring electric potential.

Breadboard – A breadboard is a solderless device for temporary prototype with electronics and test circuit designs. Most electronic components in electronic circuits can be interconnected by inserting their leads or terminals into the holes and then making connections through wires where appropriate.

Connecting wires – Connecting wires allows an electrical current to travel from one point on a circuit to another. It thus serves as needs a medium through which current moves. Most of the connecting wires are made up of copper or aluminium. Copper is cheap and has good conductivity.

Power Supply - power supply is an electrical device that supplies electric power to an electrical load. Its primary function is to convert electric current from the source to the correct voltage, current, and frequency to power the load.

2.2 CIRCUIT DESIGN

The circuit is designed by connecting the probe to the board and providing power supply to the board. The Analog out pin from the board is connected to the Analog IN pin A0 of the Arduino. To results display, a 16×2 LCD Display is used, where its data pins D4 – D7 is connected to Arduino Pins 5 – 2. All the additional connections are mentioned in the circuit diagram.

2.3 CODE DESIGN AND SET UP

There two important variables in the code design: the soil moisture sensor pin and the other for storing output of the sensor. In the setup function, the "Serial.begin (9600)" command will help in communication between the Arduino and serial monitor. Then, it will print "Reading" from the Sensor on the serial monitor. The loop function will display reading from the sensor analog pin and store the values in the "output_value" variable.

2.4 SENSOR CALIBRATION

Connecting wires were used to connect the sensor with the breadboard. The SIG is connected on the sensor breadboard and the GND together, and then connected with ACC. The breadboard was then connected with a computer, the Arduino program launched and sensor code activated. After verifying the code, it would be uploaded to the board and the serial monitor opened. The sensor would be calibrated by inputting the sensor code to the practical samples and the sensor data on the monitor kept changing when the sensor leads id dipped in water and when dry. These values could be used as threshold to trigger an action based on these values.

2.5 WORKING PRINCIPLE OF SOIL MOISTURE METER

The working of the Soil Moisture Sensor is very simple. It works on the principle of voltage comparison. The circuit in Figure 3 explains the working of the soil moisture sensor. From the figure, one input of the comparator is connected to a 10KΩ Potentiometer while the other input is connected to a voltage divider network formed by a 10KΩ Resistor and the Soil Moisture Probe. Based on the amount of water in the soil, the conductivity in the probe varies. If the water content is less, the conductivity through the probe is also less and hence the input to the comparator will be high. This means that the output of the

comparator is high and as a result, the LED will be off and descends. Similarly, when there is adequate water, the conductivity of the probe increases and the output of the comparator becomes low. The LED then starts glowing and ascends. The estimated cost of producing one sensor unit of the moisture meter is given in the Appendix.

3 RESULTS AND DISCUSSION

Samples of nine different soil classification at different depths (3, 6, 9, 12 and 14.3 cm) were analysed at three different points denoted as A, B and C. The sensor was inserted at each point on five different levels leading to an overall of 135 points analysed. The Soil Moisture Sensor of 14.3 mm length was divided into five proportional intervals of 3, 6, 9, 12 and 14.3 mm. This is to ensure accuracy and reasonable distribution within the sample. Results of the moisture contents of the nine samples using the developed moisture sensor were shown in Table 1.

Results obtained are observed to be within reasonable range as compared with what was obtained when oven dry method was used to determine the moisture contents of the same samples as shown in Figure 1. Samples of the soil types were further dried in an oven (Heraeus/Hanau) at 60°C for 12 h to a constant weight and their respective moisture contents were determined as suggested by Baumler *et al.* (2006). Except for Silt Loam with mean moisture content value of 70.11% and mean oven dry moisture content value of 62% with a mean variance of 8.11%, all the values obtained for the other soil samples falls within the acceptable range. Results obtained also indicates that there was a progressive increase in moisture levels as the sensor was dipped into the soil. This was true for all the three points tested for all the soil samples. This could be attributed to the fact that intensity of heat from the sun was more intense on the upper surface, perhaps because from logical reasoning, the upper portions of the selected places were dryer as while the lower parts were moister. This is in agreement with the findings of Ikejiofor and Okonkwo (2010).

Generally, the results shows that the developed moisture sensor is effective. As for the moisture level of the silt loam obtained, the unacceptable result could likely be attributed to errors occurred due to human error, random error, equipment defects and other engineering associated errors as earlier reported by Michael (2014).

Fig. 3: Working principle and Circuit Diagram (Source: www.arduino.cc)

Table 1. Mean moisture content analysis

Soil Type	Overall Mean Value of Moisture Content (%)	Oven Dry Mean Value of Moisture Content (%)	Variance of Moisture Content (%)*	Remarks
Silt Loam	70.11	62	8.11	Not Acceptable
Fine Sandy Loam	60.86	60	0.86	Acceptable
Sandy Loam	59.7	55	4.7	Acceptable
Sandy Clay	71.4	70	1.4	Acceptable
Fine Sand	54.06	54	0.06	Acceptable
Sandy Clay Loam	70.6	71	0.04	Acceptable
Clay	81.5	78	3.5	Acceptable
Loamy Sand	55.93	57	1.07	Acceptable
Coarse Sand	53.47	55	1.53	Acceptable

Key: - (1-5%) Acceptable (5-100%) Not Acceptable*

4 CONCLUSION

The aim of this study was to design, develop and evaluate a soil moisture sensor in order to monitor moisture level for optimum crop growth. There was progressive increase in moisture levels as the depth of inserting the sensor into the soil increase. Results obtained also shows that all the moisture values obtained for the other soil samples falls within the acceptable range except for silt loam with mean moisture content value falls outside the range of acceptable values when compared with the mean oven dry moisture content value.

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APPENDIX

Table A. Bill of Engineering Measurement and Evaluation

S/No.	Items	Prices (₦)
1	Arduino UNO board	5000
2	Breadboard	1500
3	Soil Moisture Sensor	3000
4	Hook-up Wires	300
5	Casing	1000
6	Power Light Emitting Diode indicator	2000
7	Digital Emitter	2000
8	Battery	5000
9	Resistor	2500
Total		₦22,300:00