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Development and Evaluation of a Digital MPF5-Moisture Meter

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Abstract*. An important advantage for applying the right amount of water to the fields is provided by the effective irrigation management tech-niques based on soil moisture monitoring. With a calibrated and exact resolution of* $0.03 m^3/m^3$ *and 36 mV, the developed MPF5 moisture meter monitors soil moisture from a depth of 10 cm to 80 cm using a set of sensors, transducers, capacitors, resistors, and variable micro-switch. The response monitoring system compares the soil moisture to the user-specified target values and generates an alert if the soil moisture falls below the required level for particular crops. There were many similar-ities between the instrument's output and that of other automated soil moisture meters like the REOTEMP-MM17 moisture meter and the PR2 capacitance moisture meter. The device works very well for both mineral and organic soils to monitor soil moisture for reliable irrigation sched-uling.*

Keywords: *Soil moisture, MPF5 moisture meter, Irrigation scheduling, Crop, Mineral and organic soil*

1. Introduction

The level of soil moisture is crucial to the survival of the plant. Through the process of transpiration, water is also necessary to control plant temperature (Gunneet, 2014). For agricultural applications, measuring soil moisture is crucial for better irrigation system management by farmers. Farmers are able to use less water overall by knowing the precise soil moisture conditions on their fields, but they are also able to boost crop yields and quality by better managing soil moisture during crucial plant growth stages. One important factor controlling the flow of energy between the ground and the atmosphere is soil moisture. The volumetric water content of the soil is measured by soil moisture sensors (Gunneet, 2014). Soil moisture sensors measure the volumetric water content directly by using some other characteristic of the soil, such as electrical resistance, dielectric constant, or interaction with neutrons, as a proxy for the moisture content. Direct gravimetric measurement of free soil moisture requires the removal, drying, and weighting of a sample. It is necessary to calibrate the relationship between the measured property and soil moisture because it can change depending on the soil type, temperature, or electric conductivity (Bianca, 2014; Pulkit, 2013). Sensors that assess the volumetric water content are commonly referred to as soil moisture sensors. Water potential is a different type of soil moisture attribute that is measured by another class of sensors. Tensiometers and gypsum blocks are among the sensors, which are typically referred to as soil water potential sensors (Rishi, 2015; Zheng, 2011).

Soil moisture content is an essential component of the water balance equation. Hence, precise computation of changes in soil moisture storage is useful in estimating evapotranspiration (ET) for effective water management and irrigation scheduling. Additionally, this would aid in controlling the agricultural drought in northern Nigeria, which has grown to be a serious problem. To measure soil moisture, a variety of techniques and tools are employed, including Time Domin Reflectometry (TDR), tensiometers, and electrical resistance blocks (Rangem, 2010; Zheng *et al.,* 2010). At measurement depths of 10, 20, 30, 40, and 50 cm, the digital MPF5 moisture meter is anticipated to produce continuous and instantaneous moisture data in the form of m^3/m^3, %vol, mm, and volts, respectively. The main objective of the study is to develop a simple, effective, and user-friendly digital moisture meter that measures soil moisture content in a range of climate change situations.

2. Materials and Methods

2.1. Development of a digital sensor for the MPF5 soil moisture meter

The soil between the probe wires was employed as a voltage divider along with a single sensor read wire (Arduino analog in) and a resistor. Depending on the chosen sensor and soil, various values for 57-100K resistors were used. The primary distinction is the usage of 100 logic pins to control the sensor (Arduino digital out). The 100 digital pins from the Arduino were used in this design to flip-flop the voltage (running the current forward, then reverse). Electrolysis is counteracted by this alternating current. But that doesn't mean that electrolysis does not happen. Simply put, the electrolysis-produced crust is disintegrated when the current is reversed. This would allow the soil moisture sensor to function efficiently for a longer duration. In this new configuration, the sensor reading differs slightly. Since the soil moisture sensor is simply a voltage divider, the relative voltage is switched when the current is reversed (Dingman, 1993; Farshad, 1997). This indicates that depending on the sensor's direction, the sensor now provides two different readings. A two-probe pure nickel sensor was used to create the moisture sensor. Nickel was chosen because it has average conductivity and the durability to last a long time buried in the ground. In the earth, it would not easily corrode. Nickel probes measure 10.5 cm in length and 0.9 cm in breadth. The two probes are separated by 0.6 cm (d). Sensor probes include triangle-shaped tips that make it simple to bury them in the ground. Figures 1-3 depict the soil moisture sensor probes. The circuit diagrams for the instrument are shown in Figs. 4-6.

Figure 1. Setting of 100 cm probe sensors.

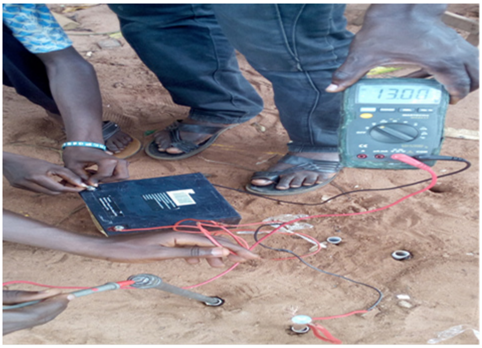

Figure 2. Testing of probe sensor electromagnetic flux at preset soil depth

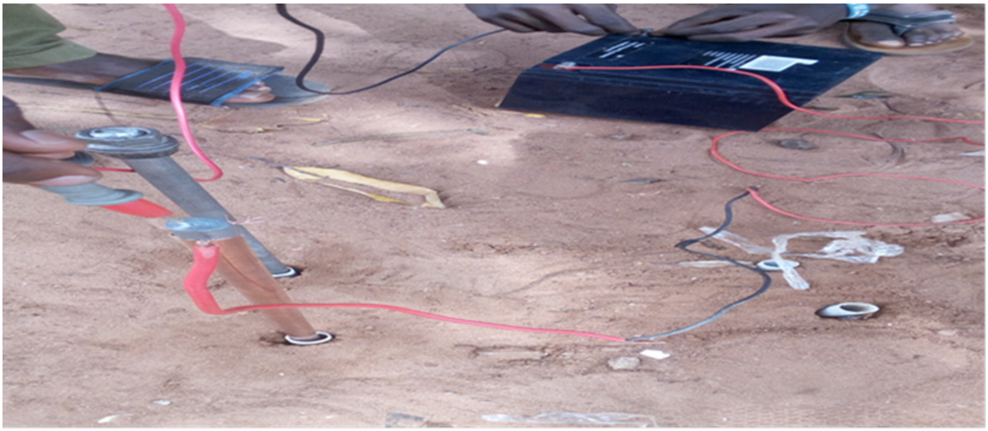

Figure 3. Probe sensor inserted in access tube for elecrtomagnatic flux measurement at preset soil depth.

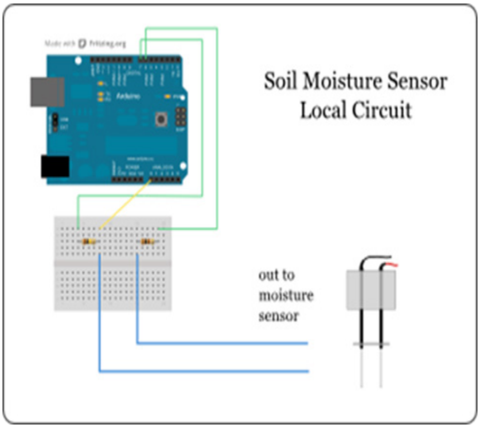

Figure 4. Local circuit breadboard

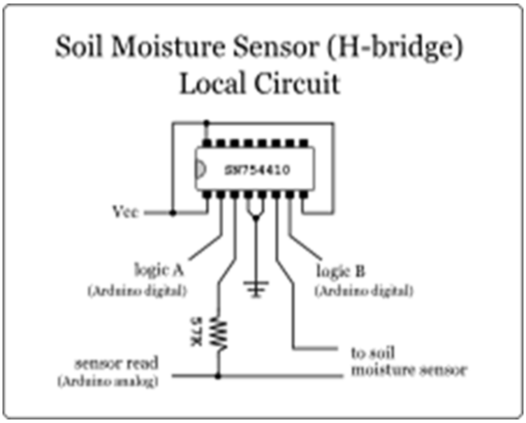

Figure 5. Local circuit – H-bridge, voltage sensor

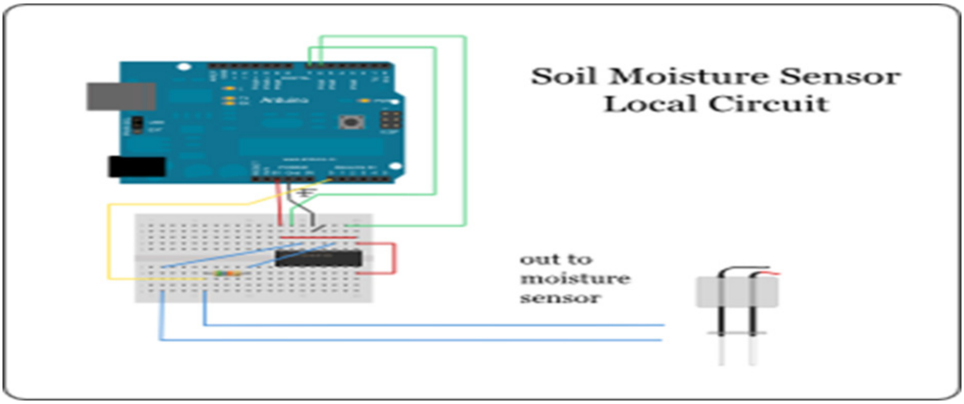

Figure 6. Local circuit - basic sensor (prone to electrolysis)

3. Results and Discussion

3.1. Calibration of MPF5 moisture meter

Using characteristics of the soil, such as the dielectric constant, electrical resistance, and electromagnetic induction, soil moisture transducers and sensors calculate the volumetric water content of the soil. Because using the gravimetric measuring strategy requires a lot of time and harms the soil layer, it is crucial to transition to integrated soil moisture solutions. The outcomes of the trial-testing on mineral and organic soils at varied measuring depths are shown in Tables 1 and 2. The soil moisture content was measured using the sensing probe at every depth at angles of

0°, 180°, and 360°, with corresponding voltage outputs of V_1, V_2, and V_3, accordingly. The volumetric water content values at each measuring depth as determined by the gravimetric method were used to calibrate the findings of the measured soil parameters. The voltage values at each MP were measured with two replicates for the trial testing as described by Knight (1992) and Scott and Maitre (1998). The statistical metrics to analyze the results of duplicated trial tests are therefore shown in Tables 3 and 4.

Table 1. Calibration of MPF5 moisture meter using mineral soil

N/S	MD (cm)	V_1 (volt)	V_2 (volt)	V_3 (volt)	Wet Weg (g)	Dry Weg. (g)	SMC (%)
1	20	6.0	6.2	6.3	3.2	2.8	14.3
2	40	5.5	5.6	5.7	5.1	4.1	23.0
3	60	6.3	6.4	6.5	5.5	5.0	10.0
4	80	7.5	7.3	7.2	3.0	2.9	8.4
5	100	8.2	8.3	8.4	3.4	3.3	3.2

The results in Table 3 show that there is a 10% (0.100) variation from the mean voltage value of 5.6 volts at the MP of 40 cm and 23% soil moisture content, whereas at MP of 60 cm and 100 cm, there is a 0.010 (1%) variation from the mean voltage values of 7.3 volts and 8.3 volts for 8.4% and 3.25% of SMC for mineral soil. It follows that it is evident that the deviation from the mean value rose significantly with high soil moisture content and fell with low SMC (Table 3).

Table 2. Calibration of MPF5 moisture meter using organic soil

N/S	MD (cm)	V_1 (Volt)	V_2 (volt)	V_3 (volt)	Wet Weg, (g)	Dry Weg. (g)	SMC (%)
1	20	12.3	12.1	12.0	5.0	4.0	22.7
2	40	14.5	14.2	14.4	4.6	3.9	18.9
3	60	16.4	16.0	16.2	3.5	3.1	12.9
4	80	20.4	19.8	20.0	3.0	2.9	3.4
5	100	24.5	22.5	21.8	6.0	5.9	1.7

Table 3. Statistical metrics for voltage measurement for mineral soil

MD (cm)	Sta. dev	Mean	Variance (S^2)
20	0.150	6.170	0.020
40	0.100	5.600	0.100
60	0.100	6.400	0.010
80	0.150	7.330	0.020
100	0.100	8.300	0.010

Table 4. Statistical metrics for voltage measurement for organic soil

MD (cm)	Sta. dev	Mean	Variance (S^2)
20	0.150	12.300	0.020
40	0.150	12.130	0.020
60	0.200	16.200	0.040
80	0.310	20.700	0.190
100	1.400	22.900	1.960

The outputs from organic soil, on the other hand, did not resemble those from mineral soil in terms of the relationship between the mean obtained voltage values and computed variance (S^2). According to the measurements made by the MPF5 probe sensors, the variance value (S^2) was found to be 2% (0.002) at 20 cm and 40 cm, 4% (0.04) at 60 cm, and 19.0% (0.190) and 196% (1.96) at MD of 80 cm and 100 cm (Table 4). In general, the sensor can accurately measure the volumetric water content of mineral soil when the soil moisture content is below 40%, however for organic soil, the instrument's performance can be deemed to be around average at the MD of 20 cm, 40 cm, and 60 cm. According to Munzon-Carpena (2021), the link holds true for the majority of mineral soils, but for moisture levels below 50%, it suggests that a particular recalibration is necessary. However, this depends on the instrument's input of the electromagnetic wave frequency (Munzon-Carpena, 2011).

Figures. 4 and 5 present the outputs of the voltage of the sensor against the soil moisture content (SMC) for mineral and organic soils. However, the two plots are very similar to each other. From the plots, it is shown that at higher SMC, the recorded voltage outputs are reduced. This may be due to the repelling of penetration of the voltage as a result of the dissolved salt contained in the soil moisture within the soil layers.

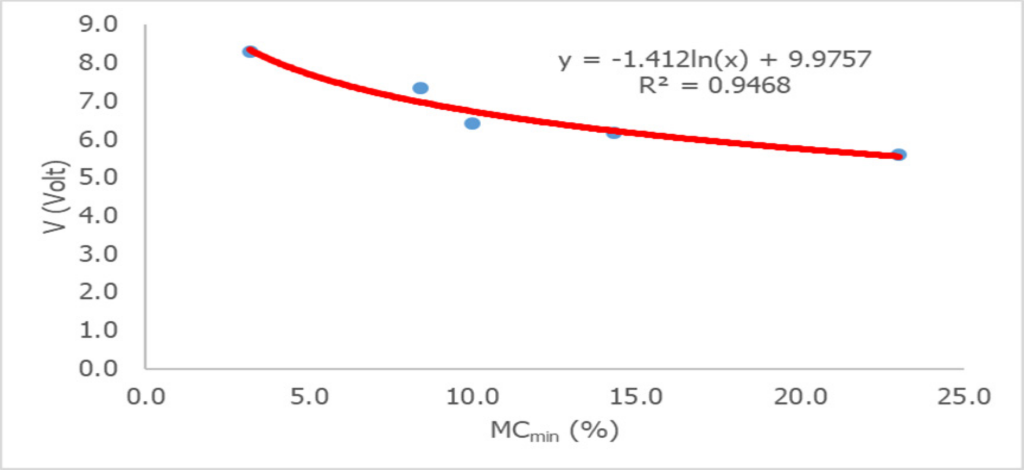

Figure 4. Voltage verse soil moisture of the mineral soil

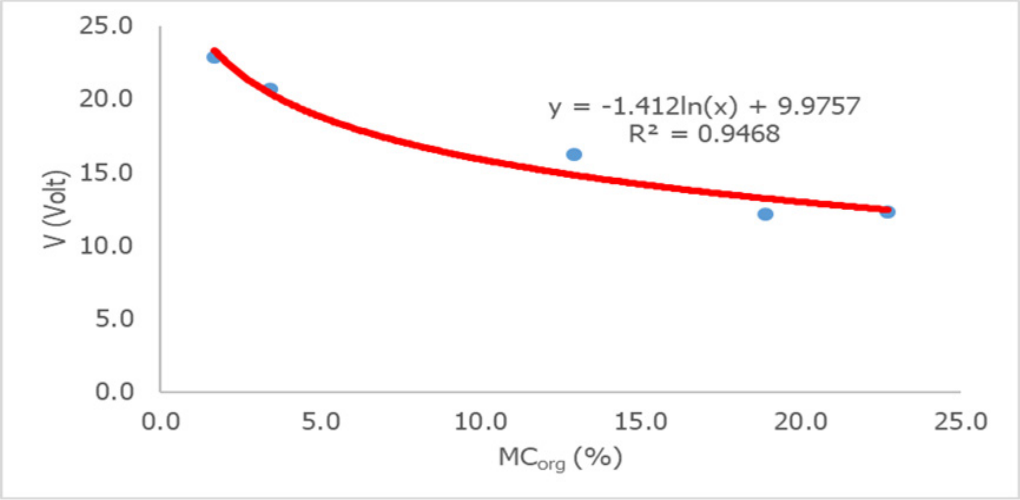

Figure 5. Voltage verse soil moisture of the organic soil

4. Conclusion

In this study, the performance of an integrated soil moisture meter called the MPF 5 was evaluated on both mineral and organic soils, with measurements being made from 20 cm to 100 cm below the surface. In order to facilitate signal reception, a pair of sensing probes (MPF5a and MPF5b) were used. By detecting changes in

SMC and transmitting the results in voltage format, the device operates on the electromagnetic induction principle. At each measuring depth, the device's output voltage was calibrated in response to the volumetric water content determined by the gravimetric method.

Therefore, at increasing SMC, the voltage gradually decreases for both soils, which may be caused by dissolved salt interfering with the electromagnetic process. In contrast, the voltage levels rose when the moisture content was low. The total results demonstrated that the device accurately measures soil moisture content between the MD of 20 cm and 100 cm beneath mineral soil at 40% SMC, while a realistic measurement could be achieved between the MD of 20 cm and 60 cm beneath organic soil at 30% SMC. Future research is required to increase the accuracy of quantifying organic soil.

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