



Calibration of Soil Moisture Measurement Using Pr2 Moisture Meter and Gravimetric-Based Approaches

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The research study strongly focused on creating strong mechanism for measuring and evaluating soil moisture content comparing PR2 capacitance moisture meter and gravimetric approach. PR2 moisture meter shows a better performance accuracy of $\pm 6\%$; $0.06 \text{ m}^3/\text{m}^3$ and intercept $a_0 = 1.8$; indicating the field is heavy clay. It measures to 1000 mm depth with high precision; while realistic result could not be obtained from gravimetric method at this measuring depth. Therefore, effective soil moisture measuring, monitoring and evaluation can be achieved with PR2 moisture meter.

Keywords: Measurement, Evaluation, Moisture, PR2, Gravimetric, Precision, Monitoring, Soil

1. Introduction.

Soil moisture is a key parameter regulating the flux of energy between the land and atmosphere. It is the water held in pores in the soil in liquid and vapour phases (Scott and Mailtre, 1998). It is the source of water for plant use in particular, in the rainfed agriculture. Measuring soil moisture is very imperative due the heavy changes in energy flux between the land and the atmosphere due to alternation of hydrological variable. Soil moisture content is always evaluated and monitored on agricultural field using the integration of combined concepts such as available water (AW), wilting point (WP) and permanent wilting point (PWP). Moisture availability is related to soil hydraulic properties. Hydraulic conductivity (K) is the rate at which water moves through a porous medium under a unit of potential gradient (Dingman, 1993). Knowledge of hydraulic properties is indispensable for addressing many soil types, hydrological, environmental, ecological and agricultural problems.

The dependency on irrigation in an area requires some analyses of the water balance. Water balance may have three perspectives (Farshad, 1997). The first is the balance of agricultural demands within a watershed. An evaluation at the field

level presumes that this information is available, and it should be generally understood in as much as the limits of on-farm irrigation may be dictated by the magnitude and distribution of the total water supply. (Farshad, 1997) The water balance within the confines of a field is a useful concept for characterizing, evaluating or monitoring any surface irrigation system.

In using this aspect of water balance, an important consideration is the time frame in which the computations are made, i.e. whether the balance will use annual data, seasonal data, or data describing a single irrigation event. This requires precise determination of change in soil moisture storage in order to create robust input data for computing Evapotranspiration (ET) for effective irrigation scheduling and water management system (Lascano,1997). This will also help to management drought on the agricultural field which has become a worrisome situation in northern Nigeria. There numerous methods and instruments used to measure soil moisture such Time Domin Reflectometry (TDR), tensiometer, electrical resistance block (Knight, 1992). Measurement and calibration of soil moisture using PR2 capacitance moisture meter and gravimetric methods will be conducted on the *Plantain field* and the result generated be compared.

2. Material and methods

2.1. Soil moisture measurements

The soil moisture status requires periodic measurements in the field, from which one can project when the next irrigation should occur and what depth of water should be applied. Conversely, such data could indicate how much has been applied and its uniformity over the field. It is therefore important to determine the precise amount of available water on real-time basis. This research was carried out by measuring and calibrating of soil moisture using PR2 capacitance moisture meter and gravimetric methods on the *Plantain field*.

2.1.1. Gravimetric sampling

Gravimetric sampling involved collecting a soil sample from each 15-30 cm of the soil profile to a depth at least that of the root penetration. Typical samplers are shown in Figure 19. The soil sample of approximately 200 g is placed in an air tight container of known weight (tare) and then weighed. The sample was then placed in an oven heated to 105° C for 24 hours with the container cover removed. The temperature range of 105° C was maintained so that the vital nutrient composition of the soil was not destroyed. After drying, the soil and container were again weighed and the weight of water determined as the before and after readings. The dry weight fraction of each sample was calculated using Eq. 1. Knowing the bulk density, one could determine moisture contents from Eq. 2.

$$DWMF = \frac{W_w - D_w}{D_w} \quad (1)$$

Where;

DWMF = Dry Weight Moisture Fraction

W_w = Wet soil weight

D_w = Dry soil weight

The soil bulk density was evaluated as follows:

$$\rho = \frac{w_b}{v} \quad (2)$$

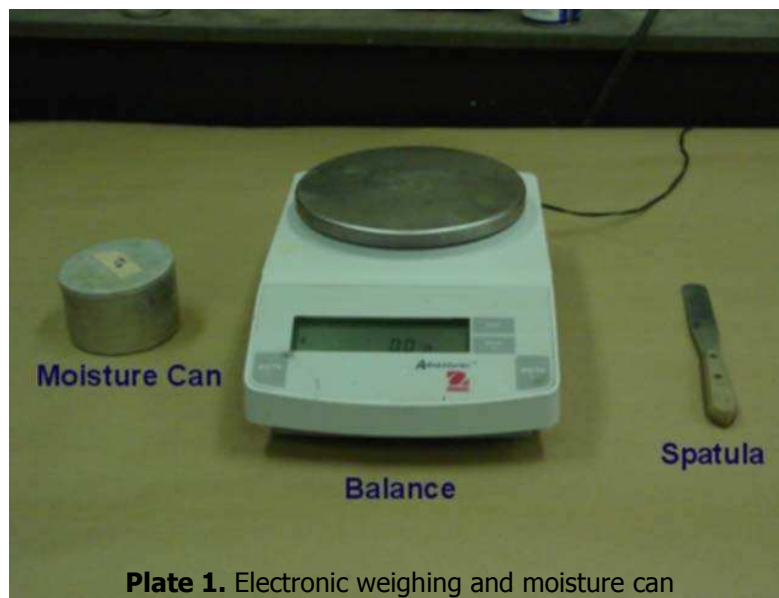
Where; ρ – bulk density

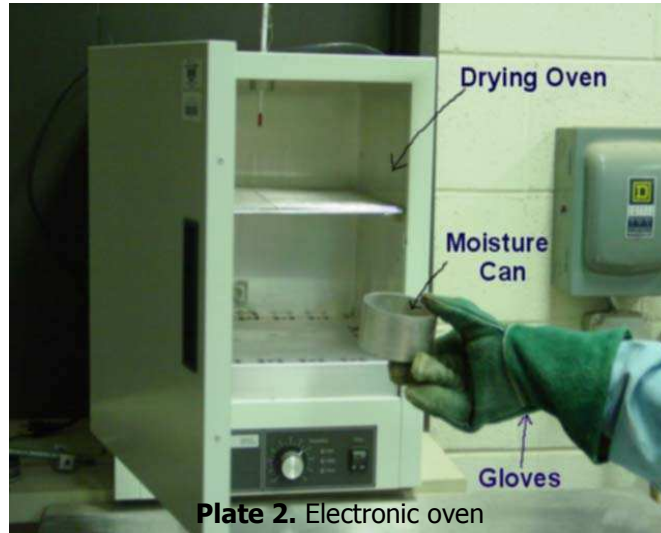
V = Volume of the soil

Water content was evaluated as follows:

$$W = \frac{M_w}{M_s} \cdot 100 \quad (3)$$

The picture in plate (1) and (2) show some the instrument used in determining soil moisture using gravimetric method.





2.1.2. PR2 capacitance moisture meter

i. Description

The *Profile Probe* measures soil moisture content at different depths within the soil profile. It consists of a sealed polycarbonate rod, ~25mm diameter, with electronic sensors (seen as pairs of stainless steel rings) arranged at fixed intervals along its length. When taking a reading, the probe is inserted into an access tube. The access tubes are specially constructed thin-wall tubes, which maximise the penetration of the electromagnetic field into the surrounding soil. The output from each sensor is a simple analogue dc voltage. These outputs are easily converted into soil moisture using the supplied general soil calibrations or the probe can be calibrated for specific soils. The picture in the plate 3 shows the processes of inserting the PR2 probe into the soil for measurement. This equipment was used to determine soil moisture content at depth 20 cm, 30 cm, 40cm, 60cm and 100cm respectively on *plantain field* as shown in the plate 4, 5 and 6 respectively.

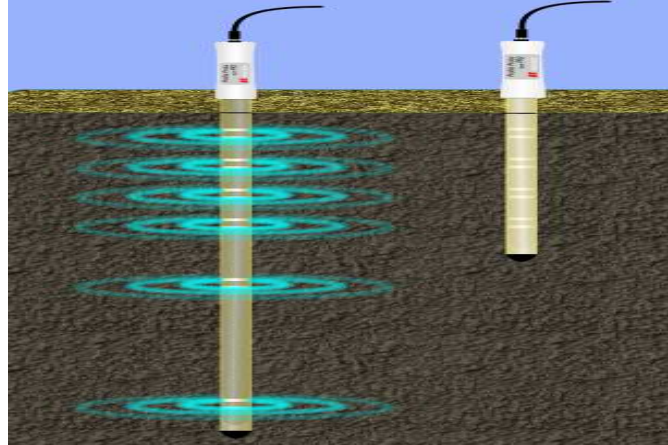


Plate 3. Reaction of soil with PR2 capacitance moisture meter

3. Results and discussion

3.1. Soil moisture reading

Soil moisture measurement is an integral part of any irrigation scheduling program. Soil moisture readings can be used by themselves to schedule irrigations, but they are most valuable when used in combination with other methods of scheduling such as a simple checkbook method or a computer model. Soil moisture readings can determine initial soil moisture balances and update those balances throughout the irrigation season. The reading of the soil moisture obtained with gravimetric and PR2 capacitance moisture meter are shown in the table (1) and (2) respectively.

Table 1. Reading obtained using PR2 capacitance moisture meter

S/N	DEPTH (mm)	MC (M ³ /M ³)	MC (%Vol)	MC (Mv)	MC (v)	refractive index
1	1000	0.037	3.60	347	0.347	1.907
2	600	0.031	3.10	333	0.333	1.845
3	400	0.051	5.10	382	0.382	2.062
4	300	0.097	9.80	491	0.491	2.545
5	200	0.182	18.30	649	0.649	3.245
6	100	0.252	25.20	752	0.752	3.701

Source: Field data, 2015

Where;

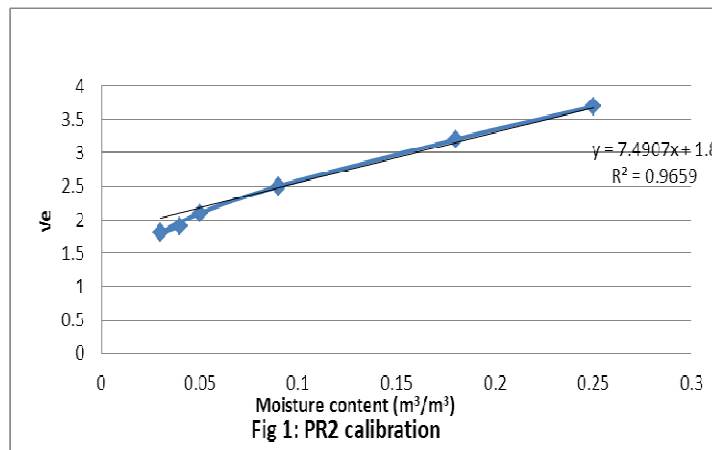
- MC (m³/m³) = Moisture content in volumetric
- MC (%) = Moisture content in percentage
- MC (mV) = Moisture content in millivolt
- MC (V) = Moisture content in Volt

3.1.1. Conversion to soil moisture

Profile Probes gave instantaneous readings of soil moisture using a hand-held meter. In the meter could be configure to convert the profile probe output to soil moisture content. Polynomial conversion was used in this study as shown in equation (5) and (6) respectively for both minerals and organic soil. Combining the soil calibration and profile Probe response steps, the conversion equation becomes:

$$Q_m = -0.057 - 0.66V + 8.00V^2 + 42.46V^3 + 14.47V^4 (m^3 \ m^{-3}) \quad (5)$$

$$Q_{org} = -0.023 - 0.72V + 8.72V^2 + 30.44V^3 + 53.71V^4 (m^3 \ m^{-3}) \quad (6)$$



The intercept $a_o = 1.8$. This indicates that the soil is heavy clay. The soil moisture-measuring readings of PR2 and gravimetric methods are shown in fig 1 and 2 respectively

Table 2. Reading obtained using gravimetric method

S/N	DEPTH (mm)	Wt(g)	Dw(g)	Ww(g)	MC (%)
1	1000	0.058	0.025	0.033	3.3
2	600	0.059	0.024	0.035	3.5
3	400	0.089	0.033	0.056	5.6
4	300	0.143	0.043	0.100	10.0
5	200	0.187	0.052	0.24	24.0
6	100	0.250	0.077	0.17	17.1

Source: Field data, 2015

Where:

Wt = Weight of wet soil

Dw = Weight of wet soil

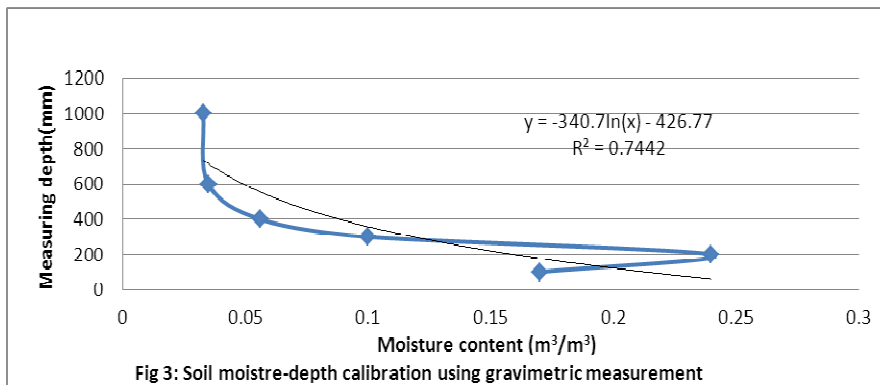
Ww = Weight of water

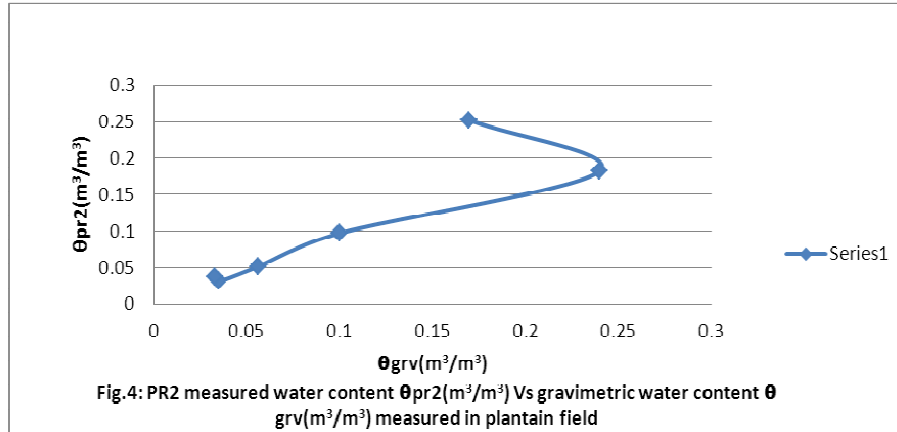
MC(%) = Moisture content in percentage

Volumetric water content was converted to gravimetric water content as follows:

$$\theta = \theta_v \cdot \frac{\rho_w}{\rho_s} \quad (7)$$

Where: ρ_w = the density of water (= 1) and ρ_s = the bulk density of the sample
 (= $\frac{MS}{VS}$)





4. Conclusion

Analytical outputs of the experimental observation using PR2 capacitance moisture meter and gravimetric technique showed high degree of compatibility for soil moisture measurement and evaluation. PR2 showed a better performance accuracy and advantages over the gravimetric method. It measures soil moisture to the depth of 1000 mm with high precision. This in thus is very difficult to achieve with gravimetric method. In addition, instantaneous and automated soil moisture reading could be obtained with PR2 moisture meter. It produces long-time moisture reading which is stored in the in-built device of the instrument for further modelling and simulation analysis. It is easy to operate and also save time.

References

- [1] Dingman S.L., *Physical Hydrology*, Prentice Hall, New Jersey, 1993.
- [2] Farshad A., *Analysis of Integrated Soil and Water Management Practices with different Agricultural System Under Semi-Arid Condition of Iran and Evaluation of their Sustainability*, Published PhD thesis, Fnschede, The Netherland, 1997.
- [3] Knight J.H., *Sensitivity of Time Domain Reflectometry measurement to lateral variation in Soil Water Content* (Water resources. RES, 28, 2340-2353, 1992.
- [4] Lascano R.J., *Soil-Water Relation*, 1997.
- [5] Scott and Maitre, *Interaction between vegetable and groundwater Research proprieties for South Africa*, 1998.

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