Neutron Moisture Meter: A Tool For Effective Soil Moisture Monitoring

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Abstract

The neutron moisture meter when calibrated with a particular mineral soil, accurately measures soil moisture content by employing the neutron scattering technique. A neutron moisture meter was calibrated with a sandy loam soil located in the Faculty of Agriculture Teaching and Research Farm, University of Maiduguri, Borno State. An average calibration curve was obtained for the soil from a linear relationship between probe count ratio and soil moisture content at various depths. The neutron scattering probe can be used to measure soil moisture content with an appreciable degree of accuracy with the aid of the calibration curve. The model equation so obtained could also be useful for other similar soils, elsewhere.

Introduction

In mineral soils where hydrogen atoms originate primarily from the dissociation of water molecules, the neutron moisture meter (neutron probe) when calibrated with a given soil, measures soil water content accurately by employing the neutron scattering technique (Brady and Weil, 1999). The neutron scattering probe which contains a source of fast neutrons and a slow neutron detector is lowered into the soil through a previously installed access tube. The source, which could consist of a combination of radium or americium and beryllium, emits neutrons at a very high speed. When these fast neutrons collide with hydrogen atoms from water, the neutrons loss some energy, slow down and scatter. The probe reading represents the number of slow neutrons counted by the detector, which in turn is proportional to the amount of water in the soil.

Soil water content affects both the behaviour and productivity of the soil. Soil moisture is a major component of soil solution together with the dissolved nutrients. Therefore, soil moisture must be available within the profile in relatively large amounts to first meet evapotranspiration requirements of crops. To ensure that adequate amount of moisture is stored within the soil profile and made available to crops when they need it, regular and accurate profile moisture monitoring by an effective means is very essential.

Soil water can be measured by direct and indirect methods. In some cases, more than one method may be required to cover the entire range of soil moisture conditions as may be desired. The indirect methods include the use of electrical resistance blocks, tensiometers, thermocouple psychrometer and pressure membrane apparatus. The gravimetric, time domain reflectometry and neutron scattering techniques constitute the direct methods of soil water measurement.

The neutron moisture meter is quite expensive and is not effective in soils high in organic matter. The neutrons emitted from the source can possibly activate other materials and render their atoms radioactive. Therefore, a protective shield or covering for the operator and a radiation permit is needed. Also, the operator must be safety- conscious. However, the neutron probe has wide application in agriculture and other areas such as sciences, engineering and industry. The application of the neutron moisture meter is implicated in field water balance studies (Zaongo *et al.*,1994) and could be useful in irrigation scheduling. It is a repeated, non-destructive and rapid technique for monitoring volumetric moisture content and change in moisture storage in a given soil depth over time.

A calibration curve is usually supplied for use along with the neutron moisture meter. However, this calibration curve may not give accurate results for all soils because of differences in properties among soils. Even for a given soil type, it is necessary to recalibrate the equipment after a given period (say every 5 years) to ensure that its accuracy is maintained. Hence, the objective of this work was to calibrate the neutron moisture meter with the soil under study.

Materials and Methods

The work was carried out on a 2m x 2m plot at the Faculty of Agriculture Teaching and Research Farm, University of Maiduguri, Nigeria in February, 2007. Maiduguri is located between latitudes 11°51' and 13°40' N, and longitudes 10°14' and 14°00' E. The dominant soil type in the study area is sandy loam, classified as Typic Ustipsamment (Rayar 1984).

The plot was ponded with water for 7days. On the 5th day, an access tube (3.8cm in diameter and 1.7m long) made from aluminum was installed in the center of the plot with the aid of a bucket auger with a diameter similar to that of the access tube. The access tube was installed to a depth of 120cm. Its bottom was sealed using waterproof polythene material to prevent water entering the access tube from below. Following the installation of the access tube, ponding continued until the 7th day. Thereafter, probe readings or counts commenced.

The neutron moisture meter (Hydroprobe, Model 503) was mounted on the access tube protruding about 50cm above the soil surface. The probe was lowered into the soil through the access tube. Three shield counts were first taken, followed by probe neutron counts at 0 – 10cm, 20 – 40cm, 40 – 60cm, 60 – 80cm, and 80 – 100cm soil depths for about 3 weeks on a daily basis. Along with the duplicate probe readings, soil samples were collected from the various depths for gravimetric moisture content determination (Singh, 1989). Soil samples were also collected at the various depths and analyzed for bulk density (Singh, 1989), particle size distribution, organic matter content (IITA, 1979) and Total porosity (Brady and Weil, 1999).

Regression analysis was done on volumetric moisture content (y - axis) and their corresponding neutron count ratio values (x - axis) at the various soil depths to obtain the calibration curve and the regression (model) equation given in the form, $y = a + bx$. Volumetric moisture content was determined as the product of gravimetric moisture content and bulk density. Count ratio was determined as the ratio of the field test count to the shield count.

Results and Discussion

The results of analysis of soil samples indicate that the selected soil properties are similar at the different depths, except for the 0 – 10cm and 0 – 20cm soil depths where bulk density, % sand, % Silt, and organic matter contents were observed to be slightly higher (Table 1). Also, the % clay content at the 0 – 10cm depth was quite low compared to the other depths. The mean values were 1.36gcm^{-3}, 0.21%, 48.62%, 70.60%, 16.62% and 12.78% for bulk density, organic matter content, total porosity, sand, silt, and clay contents, respectively.

Table 1: Selected soil properties of the experimental site at the University of Maiduguri, Faculty of Agriculture Teaching and Research Farm (2007)

Depth (cm)	Bulk density (gcm^{-3})	Organic matter content (%)	Total porosity (%)	Sand (%)	Silt (%)	Clay (%)
0 – 10	1.49	0.63	43.77	72.85	21.25	5.90
0 – 20	1.36	0.31	48.68	65.15	19.45	15.40
20 – 40	1.36	0.09	48.68	68.90	15.70	15.40
40 – 60	1.28	0.07	51.70	71.40	14.45	14.15
60 – 80	1.32	0.08	50.19	71.40	15.70	12.90
80 – 100	1.36	0.06	48.68	73.90	13.20	12.90
Mean	1.36	0.21	48.62	70.60	16.62	12.78

* estimated assuming particle density of $2.65gcm^{-3}$

Table 2 shows regression equations and correlation coefficients of neutron count ratio with volumetric moisture content at 0 – 10cm, 20 – 40cm, 40 – 60cm, 60 – 80cm, and 80 – 100cm soil depths for the experimental site. The correlation coefficient were generally very low (between 0.003 and 0.302) probably because volumetric moisture content and count ratio remained almost constant, with only a slight change at the various depths over a given period of time. This result could thus, be due to the very slow movement of water in the soil, and the inherent sampling problem associated with gravimetric moisture determination. Babalola (1978) attributed these observations to spatial variability of soil hydraulic properties. It may, therefore, be necessary to extend the sampling interval to once or twice a week rather than on daily basis, so as to observe an appreciable change in soil moisture conditions over a given period of time.

Table 2: Regression equations and correlation coefficients for count ratio and volumetric moisture content at various soil depths

Depth (cm)	No of data points	Regression equations	Correlation coefficients
0 – 10	10	$\theta_v = 0.0004x + 0.0061$	0.249
0 – 20	18	$\theta_v = -0.0002x + 0.0153$	0.017
20 – 40	18	$\theta_v = -0.0121x + 0.5063$	0.110
40 – 60	18	$\theta_v = -0.0056x + 0.5765$	0.025
60 – 80	18	$\theta_v = -0.0024x + 0.5204$	0.006
80 – 100	18	$\theta_v = -0.0017x + 0.5281$	0.003
Average	100	$\theta_v = 0.0666x + 0.0717$	0.302

The average calibration curve for the soil of the experimental site is displayed in figure 1 with count ratio (x) and volumetric moisture content (θ_v) on the x and y – axis respectively. The calibration (model) equation obtained for the site is $\theta_v = 0.0666x + 0.0717$ while 0.30 is the correlation coefficient

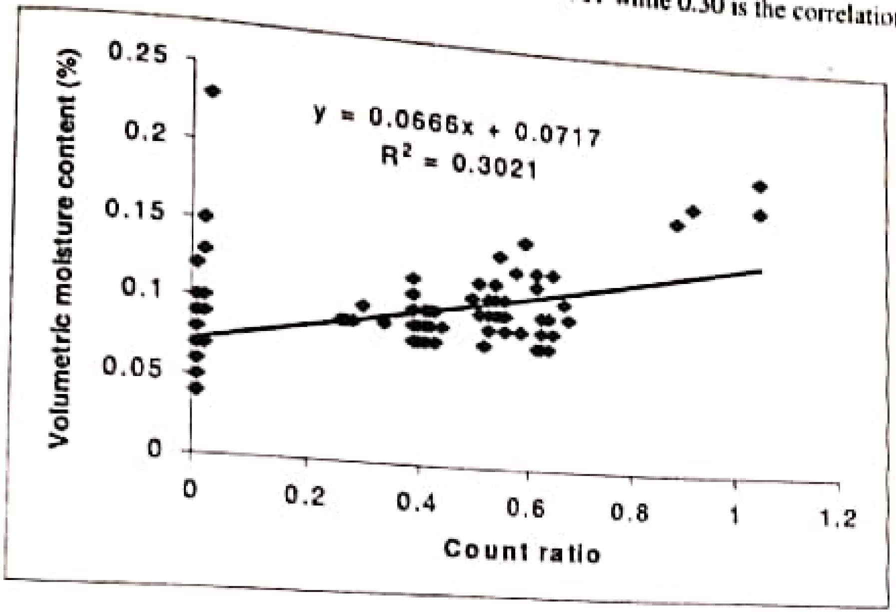

Fig. 1: Average calibration curve for the experimental site

Conclusion and Recommendations

Volumetric moisture content (θ_v) was regressed against count ratio (x) at the various soil depths to obtain a calibration curve and a model equation for the soil of the experimental site. The average model equation is $\theta_v = 0.0666x + 0.0717$ with correlation coefficient of 0.30.

The correlation coefficient obtained for the different depths were generally low. This could be attributed to very slow movement of water in the soil, inherent sampling problem associated with gravimetric moisture determination and spatial variability of soil properties. Despite the low correlation coefficient, the model equation could be useful not only for the soil under study but also for similar soils elsewhere, for water balance studies and irrigation scheduling.

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