FIELD CALIBRATION OF ALFISOL SOIL IN GUINEA SAVANNAH OF NORTHERN NIGERIA USING CAPACITANCE PROBE

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(Submitted: 1 August , 2006; Accepted: 12 December, 2006)

Abstract

Soil sampling is the only direct method for measuring soil water content, which is the most accurate method of calibration of other techniques. This method is therefore used for calibration of capacitance probe (Diviner2000) for use in alfisol soil in Northern Guinea Savanna of Nigeria. Changes in the resonant frequency of the circuit depend on changes in the capacitance of the soil-access tube system.

Keywords: *Capacitance probe, Diviner 2000, volumetric water contents, scale frequency.*

Introduction

The only direct method of measuring soil water content is soil sampling, which is the most accurate method used for calibrating other techniques. Other methods of soil calibration include the use of neutron probe, time domain reflectometre, capacitance probe etc. Capacitance Probe (*Diviner 2000*) is a dielectric based sensor, which uses the differences in the dielectric constants of water and soil particles in order to determine the water content of a mixture of soil, water and air (Pedro et al., 2001). Two access tubes are installed in each plot of the three selected sites that represent wet, moist and dry soil of the area. The scale frequency in the soil is measured with *Diviner 2000* in each access tube at 10, 20, 30, 40 and 50 cm. Three sampling core are used to sample at each selected depth and placed very near to the access tube by following strictly the sampling procedure. Samplings are done as quickly as possible to preclude significant changes in volumetric water contents (θ) between determine scale frequency (SF) and taking the samples. Volumetric water contents (θ) and bulk density (ρ) of the sample cores are determined, and calibration equation is thus established.

Theory of Capacitance Probe

The dielectric based sensor uses the differences in the dielectric constants of water and soil particles in order to determine the water content of a mixture of soil, water and air (Dean, *et al.*, 1987; Evett and Stener, 1995 and Evett, 2000; Pedro *et al.*, 2001). The relative large constant of water means that the dielectric constant of bulk soil is higher when the soil contains more water. The dielectric constant of a material arises from its polarization or electric dipole moment per unit volume. The probe inserted in the access tube measures the capacitance of the electrode system with dielectric comprising the in-situ moist soil surrounding the access tube. The probe consists of two electrodes that measure the capacitance of the dielectric comprising the in-situ soil surrounding a vertical PVC access tube (Roald, 1979). Some researchers (Dean, *et al.*, 1987; Evett and Stener, 1995; Evett, 2000) give C (farad), the capacitance of the soil-access tube system:

$$C = g\varepsilon \tag{1}$$

where is the system apparent dielectric constant and g has units of farads and a value dependant on geometry of the system.

Thus, frequency (Hz or s^{-1}) that is a property of the electromagnetic wave (EMW) is a function of the soil dielectric constant (if EMW interacts with soil matter). Also, the soil dielectric constant (ε) is a function of the soil water content (θ). Then, frequency is a function of the volumetric soil moisture (Dim *et. al*, 2005). Therefore, this frequency dependence is influenced by soil composition, soil density, particle size and temperature. Hence calibration is required to establish a measuring protocol for a particular soil type. Thus we can write

$$f = f_{\theta}(\theta) \qquad (2)$$

where f_{θ} is function of θ

The capacitance of the soil is measured by incorporating into an oscillator circuit and the resonant frequency (f) thus

$$f = \frac{1}{2\pi\sqrt{LC}} \qquad (3)$$

where C is the capacitance of the soil access tube system, and L is the inductance (henries) of the coil in the LC circuit. As soil water content increases, C also increase and f decreases (Pedro, *et al.*, 2001).

A resonant LC circuit in the probe includes the ensemble of the soil outside the access tube, the access tube itself, plus the air space between the probe and access tube, as one of the capacitative elements (Evett and Stener, 1995; Evett, 2000). The total capacitative elements of the circuits are both in parallel and series (Kelleners 2004);

The resonant frequency (f) is given by

$$f = \frac{1}{2\pi\sqrt{L\left(C_a + \frac{C_b C_1}{C_b + C_1}\right)}} \cdot \qquad (4)$$

Where C_a and C_b are the electrode capacitance including the capacitances of internal circuit elements to which the electrodes are connected. The capacitance probe gauge is responsive mostly to a soil layer as thin as 8 cm or 12cm vertically, and within 11 cm of the probe centerline (Bell *et al.*, 1987; Dean *et al.*, 1987; Evett, 2000). The electric field induced in the soil by the CP is influenced by boundaries between soil volumes having different permittivities (Bell *et al.*, 1987).

Gravimetric Soil Sampling

The most accurate method for calibration of other techniques is soil sampling which is the only direct method for measuring soil water content. The samples are collected and handled carefully to minimize water loss between the times a sample is collected and processed. The samples are replicated in order to reduce the inherent sampling variability that result from the volumes of soil. The soil samples are taken from the desire depth (root zone) and weighed at the open containers and oven dried under specified time and temperature conditions (104°C for 24 hours). The dried samples are then re-weighed. Percent soil water content on a dry mass or gravimetric basis, P_w, is determined. The difference in the wet and dry weights is the weight of water removed by drying. Soil water content on a volumetric percentage basis is a preferable unit for irrigation management. Comparison of the measured volumetric soil water content with field capacity and wilting point of the soil is used to determine the available soil water and the percent of total available soil water.

Field Calibration

In calibrating the soil a simulated soil similar in nature to the required soil is chosen by taking a representative sample of the area. The three sites (dry, moist and wet) and a representative sample of the area are selected with two access tubes of one to two metres apart installed at each site. The tubes in these sites are destructively sampled. For wet site, wettest time gives a better result of sampling; however this is supplemented by liberal irrigation (ponding). Sampling other tube of each pair for the dry end of the range should be done at end of dry season or by erecting a shelter over each profile of the dry site to prevent wetting by rain.

Experimental Procedure

The scale frequency in the soil is measured with *Diviner 2000* in each access tube at 10, 20, 30, 40 and 50 cm. The three sampling cores are placed closed to the access tube and centered at the selected depth strictly following sampling procedure, which is done by digging a trench and preparing a level surface at each depth. The samplings are done as quickly as possible to preclude significant changes in volumetric water contents (θ) between determine scale frequency (SF) and taking the samples. The sampling cores are usually covered with plastic caps to preclude moisture loss from the samples taken. The scale frequency in the soil is measured with *Diviner 2000* in each access tube at 10, 20, 30, 40 and 50 cm. The three sampling cores are placed closed to the access tube and centered at the selected depth strictly following sampling procedure, which is done by digging a trench and preparing a level surface at each depth. The samplings are done as quickly as possible to preclude significant changes in volumetric water contents (θ) between determine scale frequency (SF) and taking the samples. The sampling cores are usually covered with plastic caps to preclude moisture loss from the samples taken.

Three (3) sites which give a representative sample of the area are selected and two access tubes of one to two metres apart are installed at each site. The three (3) sites are dry, moist and wet site. The measurements are taken by inserting probe in the access tubes, which in the end are destructively sampled. The probe inserted in the access tube measures the capacitance of the electrode system with dielectric comprising the in-situ moist soil surrounding the access tube.

Results and Discussion

The three (3) readings of scale frequency taken from each profile at required depth are not averaged.

$$SF = \frac{f_a - f_s}{f_a - f_w}$$

where, f_s = sensor frequency in soil, f_a = sensor frequency in air, and f_w = sensor frequency in water.

The sensor frequency is scaled, because not all sensors behave exactly the same (Paltineanu and Starr, 1997; Kelleners et al. 2004).

Volumetric water contents (θ) and bulk density (ρ) of the sample cores were determined, and calibration equation was established from Fig. 1 as

$$\theta_v = 0.422' SF'^{1.5781}$$

This is comparable to the factory calibration (Syntek, 2000) that is given as

$$\theta_v = 0.490`SF^{2.1674}$$

Conclusion

Pairing of access tube is strongly recommended as results will be slightly different from that obtained from the same number of randomly distributed single tubes in a uniform fields, but will provide much more information in a non-uniform fields by alternative analysis method. Field calibrations, when analyzed with care for a particular soil are more reliable than factory calibration.

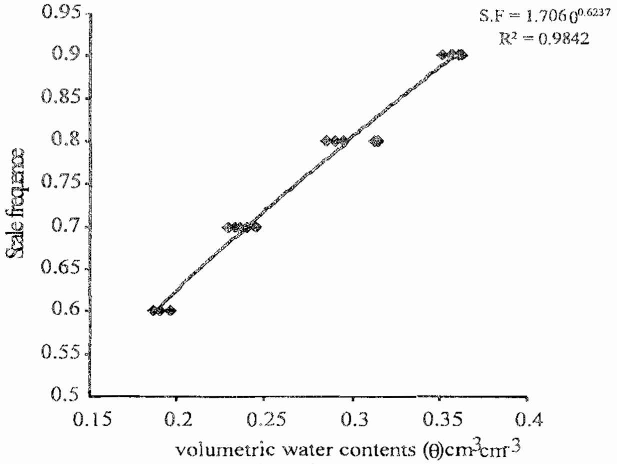

Fig 1 Field Calibration using Diviner 2000

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