COMMENTS & LETTERS TO THE EDITOR

Comments on "Field calibration of a capacitance water content probe in fine sand soils"

The paper presented by Morgan et al. (1999) deals with the question of obtaining an accurate calibration between a dielectric sensor and soil volumetric water content. Since the pioneering work presented by Hoekstra and Delany (1974) and Topp et al. (1980) with time domain reflectometry, the use of dielectric sensors to estimate water content in field studies has become a common method. Broadly instruments can be split into transmission line techniques such as time domain reflectometry (TDR) and probes which measure capacitance. Basic to these techniques is the measurement of soil relative permittivity (dielectric constant) which is then related to volumetric water content.

Calibration can be seen as a single- or two-stage process. One can either calibrate between sensor output and soil volumetric water content, or the sensor output can be converted to permittivity and permittivity then related to the volumetric water content. The advantage of using a two stage approach being that once the instrument output has been converted to relative permittivity, one of the many calibrations relating soil relative permittivity to volumetric water content can be used (Topp et al., 1980; Dirksen and Dasberg, 1993; Robinson et al., 1999). The use of a single step calibration for capacitance probes has generally been used by workers interested in monitoring changes in water content using a specific instrument calibrated to a specific access tube and soil. The major disadvantage is that one cannot separate errors due to the instrument from errors due to the calibration between capacitance and soil water content. Even though capacitance probes are now manufactured to a high level of quality, calibrations between frequency and capacitance (permittivity) tend to be sensor specific because of the electrode geometry and the tolerance of components used in instrument construction (Robinson et al., 1998). These differences between instruments can be overcome by calibrating each instrument in terms of permittivity.

Morgan et al. (1999) suggest that the oscillation frequency is proportional to the soil capacitance, implying that as capacitance increases so the oscillation frequency also increases. This is not the case; frequency decreases with increased capacitance and the relationship is nonlinear as demonstrated by the equation governing the resonant frequency response (F) of a tuned circuit:

$$F = \frac{1}{2\pi\sqrt{LC}} \quad [1]$$

where, the circuit inductance and capacitance are L (H) and C (F) respectively (Dean 1994; Robinson et al. 1998). This nonlinear response is very sensitive to materials with low capacitance values, i.e., low permittivities. It is this attribute which makes this method ideal for the type of monitoring described in Morgan et al. (1999).

Field calibration is very difficult in the best of conditions, it is often hard to obtain the desired range of water content, and volumetric sampling has its own difficulties. Though this approach has merit, it would have been better if the field calibration was used for comparison with existing permittivity–water content calibrations. Alternatively the field calibration could have been compared with a carefully obtained laboratory calibration in controlled conditions. A calibration for each soil could then have been obtained and the results compared, rather than using their approach of lumping the soils together for calibration. This may or may not be justified depending on soil bulk density, mineralogy and clay content, soil temperature, and organic matter content, none of which appear to be considered. The use of either an established calibration or a good laboratory calibration would, I'm sure, improve their estimates of water content, which is the desired result of the work.

In order to be of benefit to both users and the wider scientific community the scaled count should be replaced by relative permittivity. The authors can then compare their calibration results with previously published work, the estimated error of which is generally smaller than Morgan et al. (1999) obtained with their work. Topp et al. (1980, Fig. 5) presented a calibration for Rubicon (sandy, mixed, frigid Entic Haplorthods) sandy loam with an error for the 0 to 0.4 water content range of 0.0089 showing that a 9% change in bulk density had no measurable effect on the measurement of permittivity. More recently, Robinson et al. (1999) published calibrations specifically for sandy soils for both TDR and an I.H. capacitance probe (Dean, 1994). The square root of the measured permittivity was related to the soil water content and bulk density of four soils with r^2 values of 0.990 for the former and 0.984 for the latter instruments. The findings of most authors who have presented work on calibration in sandy soils (Topp et al., 1980; Zegelin et al., 1989; Drungil and Gish, 1989; Whalley, 1993; Gregory et al., 1995; Robinson et al., 1999) suggests there is little difference between soils. It would be interesting and constructive to determine if the calibration presented in Morgan et al. (1999) differs from these in any considerable way.

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Robinson, D.A., C.M.K. Gardner, J. Evans, J.D. Cooper, M.G. Hod-

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Abbreviations: TDR, time domain reflectometry.

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Response to "Comments on 'Field Calibration of a Capacitance Water Content Probe in Fine Sand Soils' "

The authors thank the writer for his time, effort, and constructive comments. Permittivity is the preferred method of developing a universal calibration for a wide range of capacitance sensors involving changes in frequency. The manufacturer of the sensors used in this study uses a calibration based on scaled counts. Buss (1993) and Paltineanu and Starr (1997) developed calibrations for these sensors on several soil types based on scaled counts.

It was our experience that the calibration supplied by the manufacturer resulted in readings of soil water content ~0.02 cm^3 cm^{-3} lower than gravimetric sampling. Likewise, the Paltineanu and Starr calibration was 0.005 to 0.01 cm^3 cm^{-3} higher. The soils in this study have field capacities of 0.05 to 0.09 cm^3 cm^{-3}, making an error of 0.005 to 0.02 cm^3 cm^{-3} highly significant.

The goal of this paper was to perform a single stage calibration under field conditions for the sensors used in our studies. The soil types used are all fine sand soils, very homogeneous in nature, and similar in most characteristics. The calibration resulting from this study provides soil water content values which are more representative of gravimetric content values in low water-holding sandy soils.

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Comments on "Artifacts Caused by Collection of Soil Solution with Passive Capillary Samplers"

The paper by Goyne et al. (2000) focuses on artifacts caused by the collection of soil solution with passive capillary samplers (PCAPS). They conclude that using PCAPS is not suitable for aqueous geochemical studies of dilute soil solutions, mainly because acid-washed PCAPS reduced Al concentrations and increased pH and concentrations of Ca, Na, and Si relative to zero-tension samplers. We believe that the authors cannot attribute unequivocally these differences in solution chemistry to leaching and weathering of PCAPS fiberglass wicks because they sampled two different categories of soil solutions, one at zero tension and the other one at 5.4 kPa (PCAPS). The two samplers collected different fractions of soil solution with different residence times in the soil and thus chemical composition (Marquès et al., 1996). We believe also that the concluding statements by Goyne et al. (2000) cannot be extrapolated for all soil geochemical studies. The PCAPS technique can be valid to collect soil solutions, as reported by us in forest acid soils on loess in Belgium (Brahy et al., 2000; Brahy, 2000). In our study (1995–1998), all samples from the two first sampling dates were discarded because some of them presented large pH values (6.1–8.3) and large Na$^+$ concentrations (1.1–8.2 mmol$_c$ L^{-1}). These values rapidly decreased in the subsequent samples and reached values similar to the ones presented in Table 2 (in Brahy et al., 2000). After 4 mo in our forest soils, the PCAPS seemed to interfere very little with the pH, the organic compounds, and the major cations and anions of the solution. The following observations support this assessment; (i) Although we can not compare the composition of the soil solutions extracted with distinct sampling techniques, the concentrations we measured were quite similar to those measured in other European loessic soils under forest (Bredemeier et al., 1990; Van der Salm and De Vries, 2000). (ii) In our soil solutions, the concentration of Si, Al, and the sum of the concentrations of alkali and alkali-earth cations (Na$^+$+ K$^+$+ Ca^{2+}+ Mg^{2+} mmol$_c$ L^{-1}) were positively and strongly correlated with the concentration of NO$_3^-$ ($R = 0.66$, 0.92, and 0.78, respectively; $n = 100$). It is well known that in acid brown forest soils, the production of nitric acid has a major impact on the dissolution of aluminosilicates and the mobilization of Al, alkali, and alkali-earth cations (Berthelin et al., 1990). The fiberglass wicks do not adsorb or desorb NO$_3^-$ (Holder et al., 1991). Therefore, the correlations we measured support the fact that PCAPS interfered very little with Al, Si, Na, Ca, K, and Mg. (iii) In addition to soil solution samplers, we used cation-exchange resin and test-vermiculite inserted in situ to study soil weathering processes. The ion accumulation on the resin and the transformation of the test-vermiculite are both in excellent agreement with the composition of the soil solutions (Brahy et al., 2000; Brahy, 2000). For example, the relatively large Mg amount sorbed by the resin in the AB horizon of the podzolized Cambisol is consistent with the large Mg concentration in the solution (Fig. 1). This large Mg concentration has been related to the weathering of Mg-bearing phyllosilicates depleted of Al interlayers in complexing environments (Brahy et al., 2000). We believe that the major discrepancies between our results and the results presented by Goyne et al. (2000) could be because of both the kind and the duration of the fiberglass wicks pretreatment. Goyne et al. soaked the wicking material in 0.01 M HNO$_3$ and changed the solution every 24 h for 10 d until the pH stabilized at pH 2. In our study, we did not use strong acids. We washed the wicks with deionized water and we changed the rinsing water every day until its electrical conductivity reached very small values (<2 μS). The whole procedure took ~2 mo. Goyne et al. (2000) postulated that their acid treatment did not destroy the integrity of the fiberglass rope. This might not be the case as they noted that harsh cleaning treatments with more concentrated acid solutions resulted in complete wick dissolution. Most probably, a strong acid pretreatment of the fiberglass wicks

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Abbreviations: PCAPS, passive capillary samplers.