Calibration of a frequency-domain reflectometer for determining soil-water content in a clay loam soil

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Abstract

A soil-water frequency domain reflectometry sensor, the ThetaProbe, was evaluated for its ability to measure the apparent soil dielectric constant and subsequent estimation of soil-water content. The soil-water content of a clay-loam soil, determined using factory-supplied parameters for the sensor and soil-estimated parameters, was compared to the soil-water content determined in the laboratory. The range in soil-water content was from 0.20 to 0.42 $m^3 \cdot m^{-3}$. A total of 78 soil samples from the 0 to 600 mm depth of a clay loam soil were used for these comparisons. There was a good correlation between sensor soil-water content determined using the factory-supplied parameters and the gravimetric soil-water content. Use of both the factory-supplied and the soil-estimated parameters resulted in more than 20% overestimation of soil-water content compared to the gravimetric soil-water content. However, using a recalibration process, the adjusted soil-water content was within 0.02 $m^3 \cdot m^{-3}$ for both the factory-supplied and the soil-estimated calibration constants. Soil bulk density, clay content and temperature had negligible influence on sensor soil-water contents.

Keywords: soil-water content, ThetaProbe, frequency domain reflectometer

Introduction

Knowledge of soil-water content is important for water management and hydrological studies and for calibration and validation of soil-water balance models. Monitoring soil-water content for irrigation scheduling, based on a measurement and control system, requires fast, precise, non-destructive and *in situ* measurement techniques (Lukangu et al., 1999; Gebregiorgis and Savage, 2006a, b). The laboratory methods for determining soil-water content gravimetrically and pressure plate soil-water potential fail to satisfy this requirement, although they are still used for calibration purposes. The neutron probe field method has the advantage of allowing measurements of soil-water content for a greater soil volume but radioactive hazard, lack of automated data collection methodology, and high cost restrict its use.

Dielectric-based soil-water content techniques are influenced by factors that affect the dielectric constant of the soil other than water. The time domain reflectometry (TDR) method involves measuring the propagation of an electromagnetic pulse along the transmission lines (wave guides). By measuring the travel time, the velocity and hence the apparent dielectric constant of the soil can be estimated. Usually, the TDR method is not soil-specific (Drnevich et al., 2005), and therefore no soil calibration is required. The frequency-domain reflectometer (FDR) method used in the present study makes use of radio frequencies and the electrical capacitance of a capacitor (formed by using the soil and embedded rods as a dielectric) for determining the dielectric constant and thus the soil water content. The signal reflected by soil combines with the generated signal to form a standing wave with amplitude that is a measure of the soil-water content. In the case of capacitance-type sensors, such as that used by Grooves and Rose (2004), the charge time of a capacitor is used to determine the soil-water content. Profile-probe versions using FDR and capacitance methods are now commercially available (Whalley et al., 2004; Czarnomski et al., 2005; Mwale et al., 2005).

The effect of clay, soil organic matter content and soil bulk density on TDR measurements has been reported by Topp et al. (1980), Roth et al. (1990), and Jacobson and Schjonning (1993a, b). A temperature effect has been reported by Topp et al. (1980) while an iron influence on the dielectric constant has been discussed by Robinson et al. (1994). Evett et al. (2005) found that TDR measurements may be affected by soil salinity, soil temperature, clay type and clay content. The TDR technique may overestimate soil-water content in saline soils because the apparent dielectric constant also depends on the electrical conductivity of the soil (Wyseure et al., 1997). For example, Wyseure et al. (1997) used a dielectric-based technique to estimate the electrical conductivity. Miyamoto and Maruyama (2004) found that by coating the TDR rods, more accurate measurements in a heavily fertilised paddy field was possible. Roots, earthworm channels, cracks and stones can also cause small variations in soil-water content estimated using the dielectric-based technique (Jacobson and Schjonning 1993b). Furthermore, old root channels would affect dielectric measurements if these were within the measurement volume of the sensor.

The objective of this work was firstly to calibrate the FDR sensors, for example, the ThetaProbe, for the site and compare the calibration parameters with those supplied by the manufacturer. A second objective was to evaluate the effect of soil bulk density, clay content and temperature on soil-water content measured with these sensors.

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