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Laboratory Calibration of the Spectrum Field Scout TDR 300

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Summary

Soil moisture sensors (SMSs) are a useful tool that aid in data-driven water management decisions. However, default factory calibrations can be inaccurate and soil-specific calibrations are often required to obtain higher accuracy in the determination of soil water storage and plant available water. In this study, we conducted a lab calibration for the Field Scout TDR 300, which is a popular SMS used in the turfgrass industry. Five soils of different soil textural classes were packed in containers with known soil moisture for the laboratory calibration. The logarithmic model best fit the data for the course- and fine-textured soils, with a root mean square error (RMSE) value of 0.027 and 0.035 cm^3 cm^{-3}, respectively. These two calibration curves help to estimate volumetric water content more accurately for native and sand-based soils.

Introduction

Soil moisture sensors enable water managers and golf course superintendents to monitor soil water storage objectively, rather than to evaluate soil moisture content subjectively with touch and sight. Measurements of volumetric water content using SMSs provide a quantitative observation method that can lead to improved water use efficiency, conservation of water resources, and healthier plant conditions (Serena et al., 2020). Soil moisture sensors are effective tools that offer cost-effective and real-time measurements for data-driven water management decisions. The Field Scout TDR 300 (Spectrum Technologies Inc., Aurora, IL) is a popular hand-held instrument used in the turfgrass industry, most notably by golf course superintendents and athletic field managers. This handheld instrument allows turfgrass managers to guide irrigation decisions by identifying parts of the field that exhibit soil water deficits and by providing a surrogate soil water storage to determine the amount of irrigation water needed. In return, turfgrass managers have been able to cut down on cost, water inputs, and create more consistent playing conditions (O'Brien, 2014). However, a non-calibrated SMS may not accurately represent the soil water storage and soil moisture availability to plant roots, and this inaccuracy can lead to under- or over-watering irrigation events. Our objective was to develop a calibration curve for the Field Scout TDR 300 to help turfgrass managers to accurately estimate soil moisture content on native fine-textured soils often found in fairways, tees, and rough areas, and on engineered sand-based soils used on golf greens and many athletic field complexes.

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Procedures

The Field Scout TDR 300 uses the principle of time domain reflectometry, in which the travel time that it takes for an electromagnetic signal to return to the sensor logger is directly related to the moisture content of the soil. In each measurement, the sensor sends an electric signal through a waveguide consisting of two parallel rods with a 7.6 cm (3.0 in.) length (Figure 1C) that are fully inserted into the soil.

The first step of the calibration process consisted of collecting soils of varying textural classes from different Kansas State University Research Experiment Station sites near Manhattan, KS. Each soil was dried at 105°C (221°F) for 48 hours, and then ground to pass through a 2 mm sieve. Ground soil was then packed into one-gallon plastic containers to a target bulk density of 1.4 g/cm^3 for fine-textured soils and a target bulk density of 1.7 g/cm^3 for the coarse-textured soil (Figure 1B). Each container was brought to a known volumetric water content spanning the range from air-dryness to saturated conditions. Then, each container was sealed with a plastic lid and left for 24 hours to allow for soil water redistribution within the soil in the container.

In each container, two measurements were made with the Field Scout TDR300 by inserting the sensor rods vertically. The two measurements were made at 90-degree angles from each other. For the two measurements we recorded the period average to be used for the curve fitting exercise. At the end of the experiment, all soils from the containers were placed in a drying-oven at 105°C (221°F) for 48 hours and then weighed to obtain the dry mass. The observed volumetric water content was calculated from the observed gravimetric water content and bulk density of each sample. The calibration consisted of a curve-fitting exercise using the observed volumetric water content as a function of the period average for each soil type. The fraction of sand, silt, and clay for each soil was determined using the hydrometer method using a solution of 50 g/L of sodium hexametaphosphate as a dispersing solution (Gavlak et al., 2005).

Results and Discussion

Five textural classes were identified from four sites (Table 1), which provided a wide range of conditions for the calibration of the sensor. The commercial sand had the highest sand content of 100%, while the silty clay-textured soil had the highest clay content of 45.9%.

Calibration curves for fine-textured and coarse-textured soils were considered separately. The results for calibration (Figure 2) show a logarithmic model fit the data well for both sand ($r^2 = 0.93$, RMSE = 0.027) and the fine-textured soils ($r^2 = 0.95$, RMSE = 0.035). These two generated calibration curves help to estimate volumetric water content more accurately for native and sand-based turfgrass systems. Although the factory default calibration can be used and the sensor does not necessarily need to have site-specific calibration, absolute values can be greatly inaccurate if the sensor is left uncalibrated. Calibrated sensors increase the accuracy of the estimated soil water storage and can help end users make more-informed irrigation decisions. In this study, improvements of up to 0.02 cm^3 cm^{-3} were obtained by considering a custom calibration curve for the coarse-textured soil solely. These improvements can be valuable on sand-based turfgrass systems where soil water deficits need to be closely monitored. Value is also added for research purposes where accurately calibrated sensors should always be used.

References

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Table 1. Soil texture characterized by clay, silt, and sand

Soil sampling depth	Clay	Silt	Sand	Bulk density	Textural class
cm	-------------------------	%	-------------------------	g/cm^3	
Site 1:					
0–15	28.3	52.1	19.6	1.32	Silty clay loam
20–40	45.9	40.9	13.2	1.24	Silty clay
Site 2:					
0–15	20.7	59.1	20.2	1.39	Silt loam
Site 3:					
0–25	23.2	30.7	46.1	1.39	Loam
Site 4:					
Unknown	0	0	100	1.62	Sand

Figure 1. (A) Lab setup depicting the hydrometer method used for determining particle size analysis; (B) packed soil containers varying in moisture contents for sensor calibration (note that some containers show the marks of the two measurements at 90-degree angle); and (C) Field Scout TDR 300 depicted with 7.6-cm length rods attached.

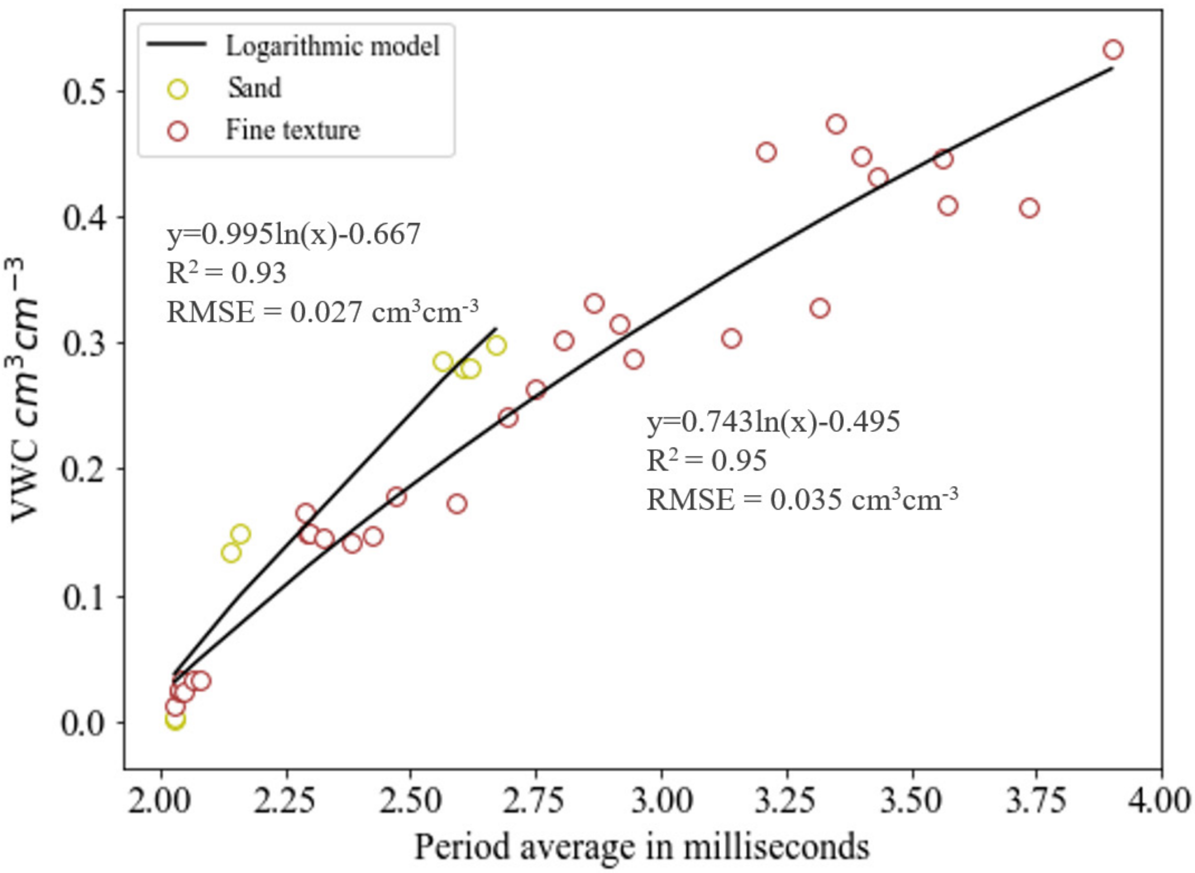

Figure 2. Volumetric water content as a function of period average using two calibration curves, grouped by sand and fine-textured soils. A logarithmic model was used to fit the data. VWC = volumetric water content.