On-farm Assessment of AquaSpy Soil Mositure Sensors for Irrigation Scheduling

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Summary

The aim of this study was to compare a commercially-available radio-frequency (RF) spectroscopy soil moisture sensor with an array of calibrated research-grade soil water reflectometers in a no-till irrigated corn field during 2020. The RF probe consisted of 12 sensors spaced at 4-inch intervals across 48 inches in length, while the array of soil water reflectometers consisted of four sensors deployed along the soil profile at 4, 12, 20, and 28 in depth. Soil moisture sensors were installed at about 30 ft apart in two different regions within the same field characterized by contrasting soil textural classes. Hourly soil moisture and soil temperature were collected by both sensors and compared across the study period. The RF probe closely followed the soil moisture dynamics captured by the research-grade sensors. Preliminary results reveal that the tested RF sensor is useful for irrigation scheduling as long as end users feel comfortable with relative soil moisture values. Field-specific calibrations are required to translate the relative nature of soil moisture measurements into soil water storage in terms of volumetric water content or inches of water in the soil profile.

Introduction

In-situ soil moisture sensors provide farmers and water managers with field-specific and timely information to guide irrigation scheduling. Accurate observations of rootzone soil water are essential to quantify the amount of plant available water in the soil profile and determine the amount of irrigation needed to prevent plant water stress and the consequent decline in crop yield and/or quality (Evett et al., 2011). Previous research studies have shown that point-level soil moisture sensors can result in up to 50% irrigation water savings compared to fields without sensors (Hassanli et al., 2009), while still maintaining crop yield and profitability (Evans et al., 2013; Kukal et al., 2020). Several commercially-available point-level soil moisture sensors work based on the principles of time domain reflectometry (TDR), frequency domain reflectometry (FDR), and capacitance. All these methods rely on the radically different dielectric permittivity of water (about 80) compared to that of the dry mineral soil (about 2-3). Among these three technologies, capacitance is well-known for being affected by bulk electrical conductivity and soil temperature, to the extent that capacitance sensors may not provide the accuracy required for irrigation scheduling (Evett et al., 2011). A new sensor widely used by producers in the region based on radio-frequency spectroscopy called AquaSpy (AquaSpy Inc. San Diego, CA) has the potential to accurately measure rootzone soil moisture without being affected by the soil bulk electrical conductivity. The goal of this study was to compare the AquaSpy profile-level soil moisture sensor against an array of calibrated research-grade soil water reflectometers.

Material and Methods

The study was conducted in an irrigated no-till corn field of 54 acres located within the Flickner Innovation Farm near Moundridge, KS from June to September 2020. Co-located sensors were installed in two different portions of the field, a set of CS655 and AquaSpy sensors were installed in a region characterized by well-drained silt clay loam soils mapped as Crete soil series with <1% slopes, and the second pair of co-located sensors was installed in a region of the field characterized by sandy loam soils (sand 46% with fine gravel) mapped as Farnum soil series with slopes ranging from 1 to 3% (Figure 1A).

In this on-farm study we conducted a preliminary study of AquaSpy probes featuring 12 sensors spaced at 4-inch intervals across 48 inches in length that was specifically designed to cover the rootzone of common agricultural crops (Figure 1B). This sensor works based on radio-frequency spectroscopy attenuation to measure soil moisture. The AquaSpy sensor also provides soil temperature and bulk electrical conductivity every 15 minutes. To test the ability of the AquaSpy sensor to capture the soil moisture dynamics in the irrigated field, observations obtained with the AquaSpy probe were compared with an array of four calibrated soil moisture sensors (CS655, Campbell Scientific, Logan, UT) deployed along the soil profile at 4, 12, 20, and 28 in depth (Figure 1B). AquaSpy sensing depths beyond this point were not considered in the study. The CS655 sensors were deployed at about 30 ft from the capacitance sensor and recorded hourly soil moisture, soil temperature, and bulk soil electrical conductivity. Because the AquaSpy probe provides relative soil moisture measurements following proprietary algorithms, the comparison of soil moisture dynamics between these two sensors was only performed in relative terms by scaling the average soil moisture in the top 28 inches of the soil profile by the minimum and maximum reading of each sensor during the period of study.

Results

The AquaSpy probes effectively captured changes in profile soil moisture as a consequence of irrigation and precipitation events, and rootzone soil moisture readings resulted comparable to that of the array of research-grade soil moisture sensors (Figure 2). In relative terms, the time series of profile-level soil moisture between the sensors was relatively good for the management zone characterized by fine-textured soil (r^2=0.53) and excellent (r^2=0.83) in the management zone dominated by coarse-textured soils (Figure 2). In both field management zones, the relative soil moisture dynamics exhibited little bias between sensing technologies. Minor discrepancies in the time series could be attributed to errors in either sensing technology, sensing volume, soil spatial variability, and even slight differences in sensor depths introduced during the installation process. A more rigorous analysis in controlled and standardized conditions would be required to accurately test the actual discrepancy between sensors.

To verify that the sensors were deployed at comparable depths we examined the soil temperature observations for both sensing technologies. As expected, soil temperature observations were not greatly affected by the type of sensor, with an average discrepancy of only

1.6 F in both fine- and coarse-textured soils (Figure 3). Further investigation across the different sensors along the soil profile showed an increase discrepancy in soil temperature at deeper layers in the coarse texture soil, with differences as large as 4.2 F at 28-inch depth (Table 1). This difference in temperature at depth could be attributed to small offsets during the installation of either sensor and to normal variations in the spatial distribution of soil moisture.

Our preliminary analysis suggests that the AquaSpy sensors closely followed the soil moisture dynamics of an array of research-grade soil moisture sensors in terms of relative soil moisture. Relative soil moisture trends can be useful for irrigation scheduling when supported by field observations of crop stress conditions and expert guidance from the manufacturing company to better interpret sensor readings. Producers that make in-season irrigation decisions based on the actual amount of soil water storage expressed in terms of volumetric water content or inches of water in the soil profile would require a site-specific calibration to translate relative soil moisture readings into actual soil water storage.

References

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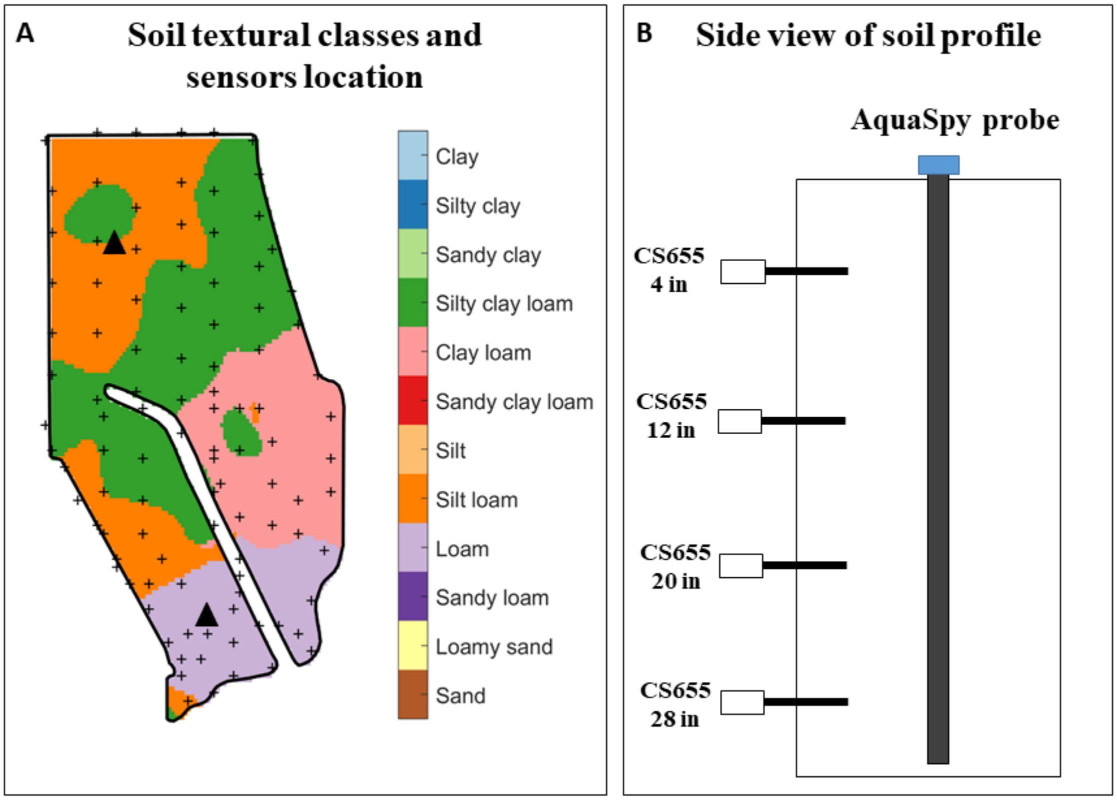

Figure 1. A) Soil textural class of the top 4 inches of the soil profile. Black crosses (+) represent soil sampling locations in which soil texture was determined in the laboratory using the hydrometer method. Solid black triangles represent the locations of the two collocated installations of the AquaSpy and soil water reflectometer sensors. **B)** Layout of the soil moisture sensors location across the soil profile. At each location the two different sensors were deployed about 30 ft from each other.

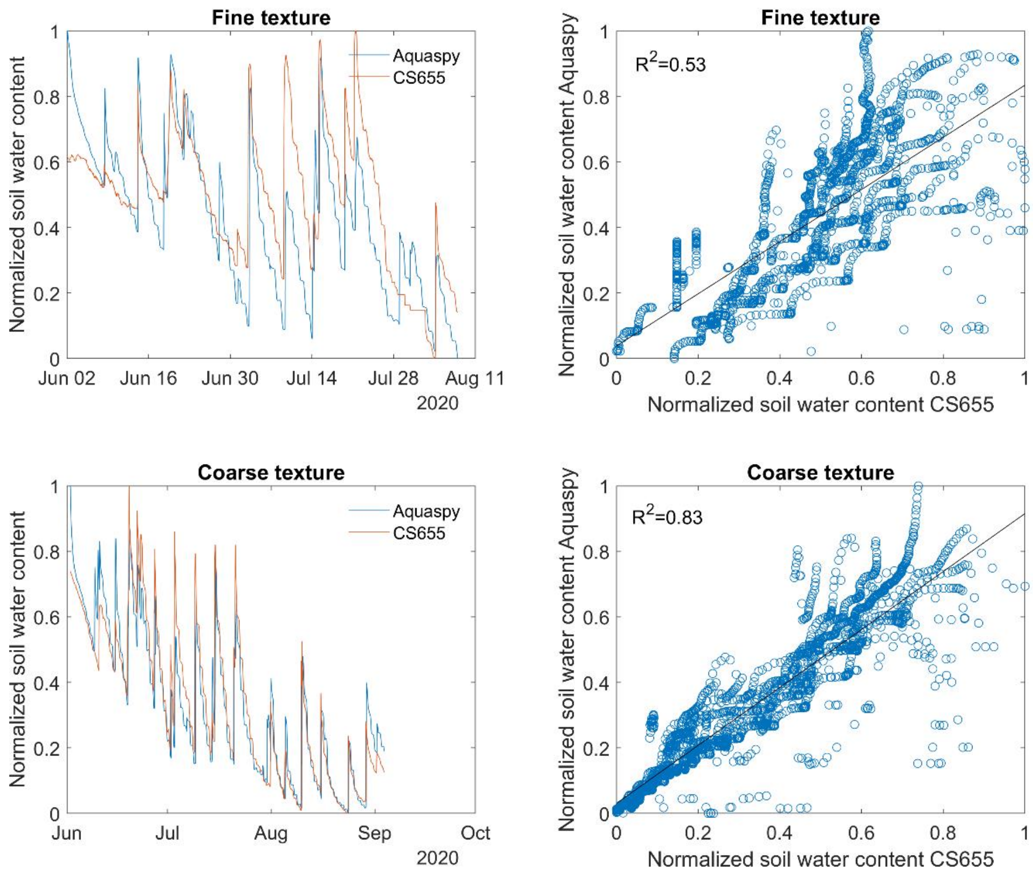

Figure 2. Profile (0 to 28 inches) soil water storage determined using the capacitance probe (red line) and an array of four calibrated CS655 soil water reflectometers (black line). Profile soil moisture of sensors located in the A) fine texture (Silty clay loam) soil and B) coarse texture (Loam, 46% Sand) soil. Dash horizontal lines represents the average profile soil moisture for each sensor over the entire time series.

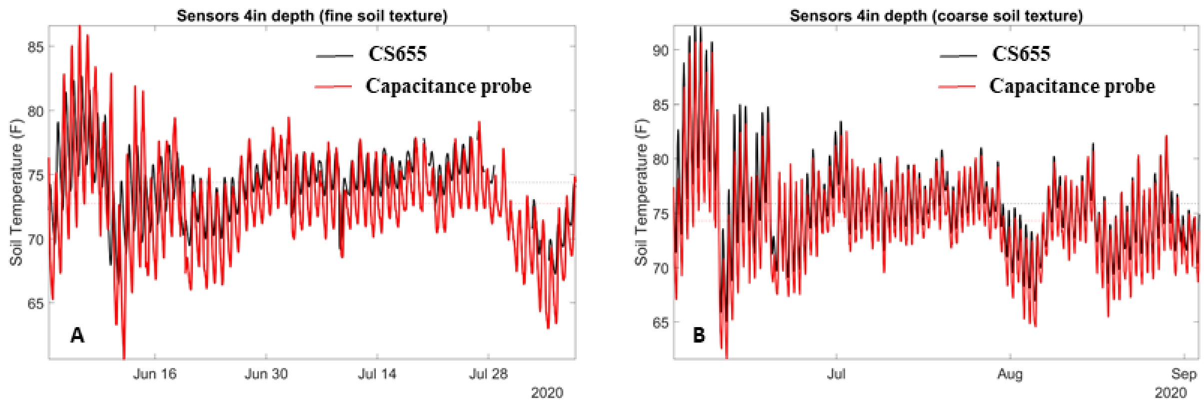

Figure 2. Surface soil temperature at 4-inch depth determined using the AquaSpy probe (red line) and an array of four calibrated CS655 soil water reflectometers (black line). Soil temperature from the sensors located in the A) fine texture soil and B) coarse texture soil. Dash horizontal lines represents the average profile soil moisture for each sensor over the entire time series.