Accuracy of Moisture Sensors in Saline Soils

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Summary

A study was conducted at New Mexico State University to investigate the accuracy of five soil moisture sensors at several salinity levels in two soil types (loamy sand and silty loam). Two of the probes included in the study (Irrolis and Watermark) measure moisture tension to determine water availability and three probes (SDI-12, Turfguard, and S.Sense System) estimate the soil's dielectric constant to determine moisture content. Linear regression analysis between volumetric soil moisture (VWC) and sensor readings was performed on 2 replicates of each sensor. All sensors measured soil moisture accurately at all salinity levels in both soil types. Regression coefficients ranged from 0.79 (S.Sense) to 0.99 (SDI-12) in loamy sand and from 0.85 (Irrolis) to 0.98 (Turfguard) in silty loam. With the exception of Watermark, readings from sensor replicates did not differ significantly from one another.

Introduction

One of the most challenging problems facing turfgrass managers in arid and semi-arid climate zones is the accumulation of salts in rootzones as a result of irrigation with low quality saline water combined with insufficient leaching through rainfall. In order to maintain adequate turf quality, continuous monitoring of soil moisture and salinity in the rootzone is necessary. Automated soil sensing devices have been developed and promise to accurately and reliably measure soil water. However it is unknown whether these devices also work accurately in rootzones that are affected by salinity. If it can be shown that these technologies provide accurate moisture measurements in the plants' rootzone, they could become powerful tools to maintain high turf quality.
A study was conducted at New Mexico State University to compare the accuracy of five soil moisture sensors at a wide range of salinity in 2 soil types.

Objectives

1. Determine if salinity affects moisture readings of five soil sensors in 2 soil types
2. If salinity affects soil moisture measurements, determine the salinity threshold at which sensors fail to measure moisture accurately

Materials and Method

Moisture Sensors
Sensors that measure the soil's dielectric constant to determine moisture content:
1) SDI-12 Soil Moisture Transducer (Acclima): Digital Time Domain Transmissometer that measures the permittivity of soils

2) Turfguard (Toro): Turfguard soil moisture sensor is a Frequency Domain Reflectometry (FDR) sensor with a wireless configuration to monitor soil temperature, moisture and electrical conductivity simultaneously at 2 depths through 2 sets of probes (upper and lower)
3) S.Sense System (Digital Sun). S. Sense system applies moisture measurement based on determining the capacitance of the soil

Probes derived from the classical tensiometer technology that uses soil tension to determine water availability:
4) Watermark Soil Moisture Sensor (Campbell Scientific): The watermark soil moisture block is estimates water potential based on electrical resistance
5) Irrolis ^{TM} Sense Tx (Hortau): Irrolis probes apply technology that measure moisture tension.

Measurements

Several salinity levels were created in 2 soils (loamy sand and silty loam) by mixing the soils with $MgCl_2$ and NaCl. After salinity was measured in the saturated paste, a container with soil and moisture sensors was placed in a pressure plate extractor (Figure 1). Pressures of 0, 0.3, 0.5, 1.0, 1.5, 2.0, 2.5, and 3.0 bars were applied to each container. Volumetric water content in the soil was determined by subtracting the amount of water removed from the total pore space of the soil. Two replicates of each sensor were tested from salinity ranges of 3 to 27 dS/m for the sandy soil and from 3 to 27 dS/m for the silty soil. A linear regression analysis between VWC and sensor moisture readings (sensor output) was performed using the software package GraphPad Prism. A regression analysis was performed separately for each replicate sensor at each salinity level. The regressions from each sensor type were subsequently compared to one another across all salinity but separately for each soil. Figures 2 to11 show sensor output values plotted against the measured values of soil VWC (%). Separate regression lines indicate significantly different sensor output values for different salinity treatments.


Figure 1 Soil water extractor, model 1600

Results and Discussion

SDI-12 Soil Moisture Transducer (Acclima)

Linear regression analysis suggests that sensors should be calibrated separately for each salinity level higher than 6 dS/m. In silty loam a universal calibration could be applied for all salinity levels (Figure 3).

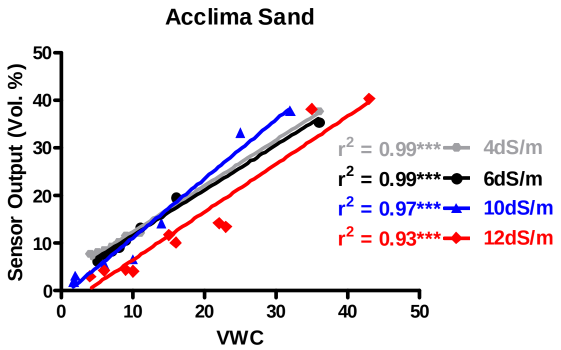


Figure 2

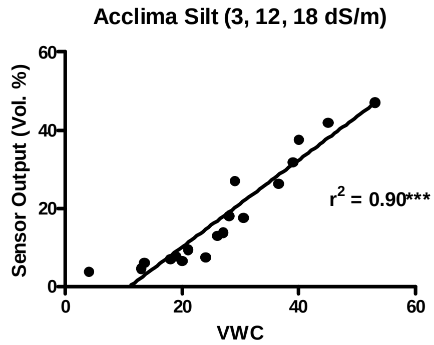


Figure 3

S. Sense System (Digital Sun)

In sandy soil, regression analysis suggests that sensors should be calibrated separately for each salinity level (Figure 4). A universal calibration to measure soil moisture across all salinities could be applied in silty loam (Figure 5).

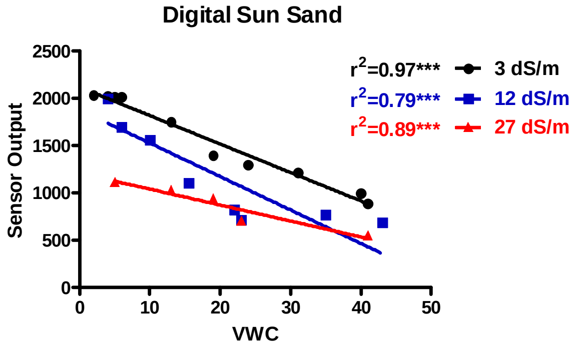


Figure 4

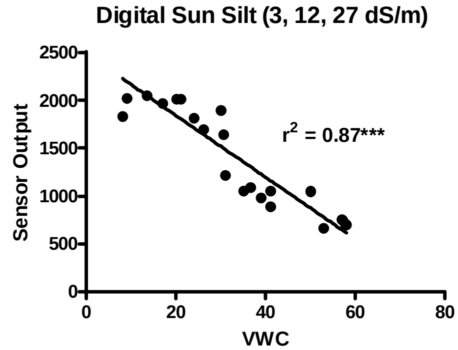
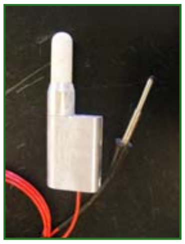


Figure 5

Irrolis ™ Sense Tx



In order to predict soil moisture accurately, sensor output values were log transformed for both soils. In loamy sand, the linear regression suggests that Irrolis sensors should be calibrated separately for each salinity level to measure moisture accurately (Figure 6). In silty loam however, a universal calibration could be applied to correlate sensor output values with soil moisture (Figure 7).

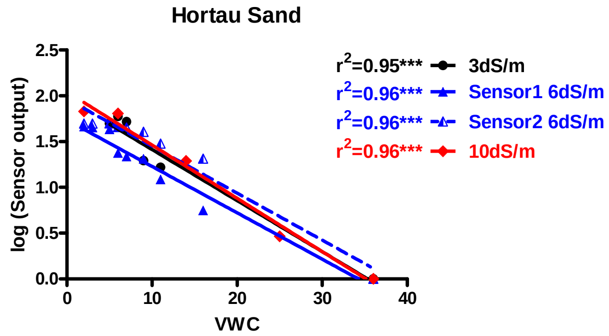


Figure 6

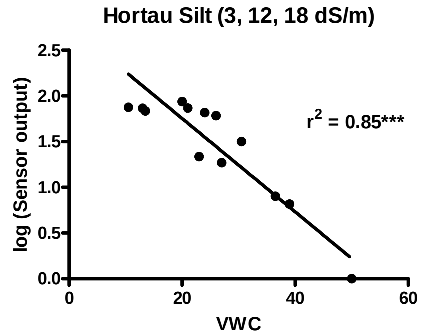


Figure 7

Watermark soil moisture sensor (Campbell Scientific)

In order to predict soil moisture accurately, Volumetric Moisture Content (VMC) had to be log transformed. For both soils and all levels of salinity, sensors must be calibrated separately to measure moisture (Figures 8 and 9). Sensor replicates also differed from one another at the low and the high salinity level in sand (Figure 8) and at the low salinity level in silt (Figure 9), which suggests separate calibration for every sensor.

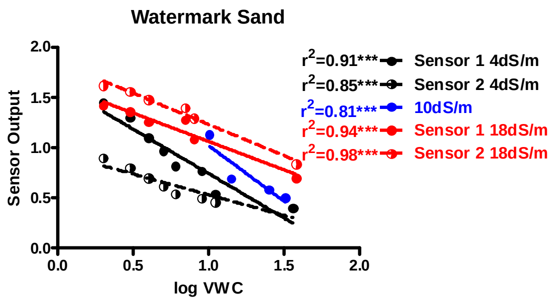


Figure 8

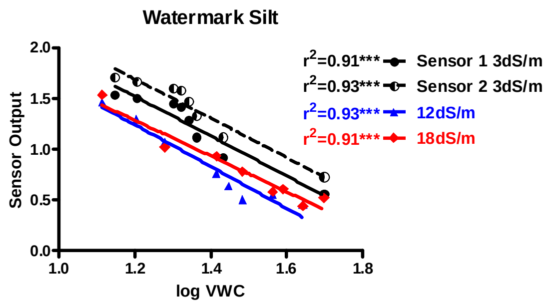


Figure 9

Turfguard soil moisture sensor (Toro)

In sand, salinity did not affect moisture readings and a universal linear calibration function could be applied (Figure 10). In silty loam, a separate calibration for the upper and lower sensor at 3dS/m was required. However, probes measured moisture with equal accuracy at salinities higher than 12 dS/m but required separate calibration for each salinity level (Figure 11).

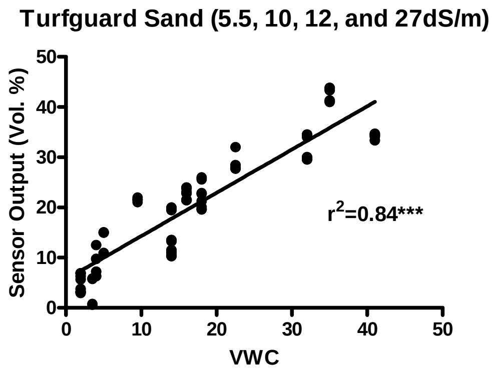


Figure 10

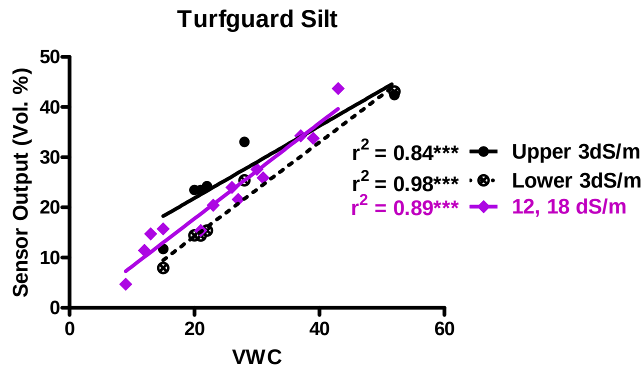


Figure 11

Conclusions

Soil sensors accurately measured moisture in sandy and loamy soil at salinity levels ranging between 3 and 24 dS/m. However, salinity specific calibration in at least one of the 2 tested soils was necessary for all sensors. Some sensors, such as SDI-12 and Turfguard, can also be used to determine soil bulk electrical conductivity. Additional testing is necessary to determine if these sensors accurately measure salinity at varying moisture levels and other soil types.

Acknowledgment.
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