Calibration and Characterization of an Improved Low-Cost Water Content Sensor

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Introduction

Inexpensive, accurate, and reliable soil moisture measurements are necessary in countless applications from research to hydroponics. Many have dreamed of these types of sensors being so inexpensive that they could be spread over a wide area to monitor water status at numerous locations in a watershed, greenhouse, or golf course to name a few. However, measurements of this sort are only as valuable as their ability to truly portray conditions in which they measure. Cheap moisture measurement devices have been available for years, but could only give rough, relative moisture information. Likewise, accurate volumetric water content (VWC) sensors have been available for a long time, but were much too expensive for extensive placement. New, less expensive sensors show considerable promise to maintain or even exceed the measurement quality of higher priced sensors.

Researchers familiar with commercial VWC sensors will often ask three questions when approached with a newly developed dielectric sensor: what is the accuracy of the instrument, how does it react to different soil texture and electrical conductivity (EC), and how much does it cost? Our goal with this application note is to address these three questions with regard to the new EC-5 soil moisture sensors. Our objectives within this study are to:

- compare VWC readings from the EC-5 to the actual VWC obtained through gravimetric methods through the creation of calibration curves
- determine the effects of substrate (soil and soil-less media) texture on EC-5 sensor readings
- determine the effects of electrical conductivity on EC-5 sensor readings

Materials and Methods

The sensor was calibrated in the laboratory in a series of soils and soil-less media to correlate EC-5 probe output to dielectric and VWC. Four soils with differing textures were collected and allowed to dry in air for several weeks. Soil textures included sand, sandy loam, silt-loam, and clay. Soil-less media types included Sunshine Potting Mix, a nursery blend potting mix, Miracle Grow Potting Mix, and rockwool. To test the EC-5 response to changing water contents, deionized water was mixed with soil to make at least four different water contents for each soil and soil-less media types. The substrate was then packed around the dielectric probe in a 30 cm x 15 cm x 15 cm container. Care was taken to standardize packing densities. Voltage outputs of probes packed in soil and soil-less media were recorded at each measured water content. A saturation extract of each soil was taken to determine a baseline EC within the soil.

The above steps were repeated on similar soils at various EC values to test the effects of EC on the sensor output. A regression analysis was performed on all of the data to determine if sensor output could be correlated with soil and soil-less media volumetric water content with varying texture and electrical conductivity.

Results Mineral Soil Calibration

Figure 1 shows the calibration of five EC-5 sensors in a variety of mineral soils at varying electrical conductivities. The probe output is correlated linearly with the gravimetrically obtained volumetric water content with an R^2 value of 0.98. Sensor data show very little dependence on soil type or electrical conductivity (EC) and no sensor-to-sensor variation. Results indicate there is no need for soil specific calibration.

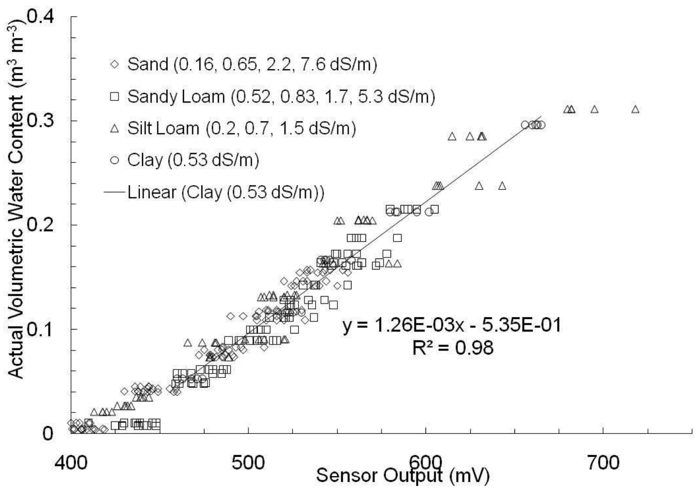

Figure 1. Calibration of five EC-5 sensors in various mineral soils at different ECs. Saturation extract EC values are shown in parenthesis.

Potting Soil Calibration

Figure 2 shows the same five EC-5 sensors calibrated in three types of potting soil. Again, the sensor output is correlated linearly with the gravimetrically-obtained volumetric water content with an R^2 value of 0.977. The data show that the same calibration equation can be used for any of the potting soils tested, regardless of potting soil mixture or electrical conductivity.

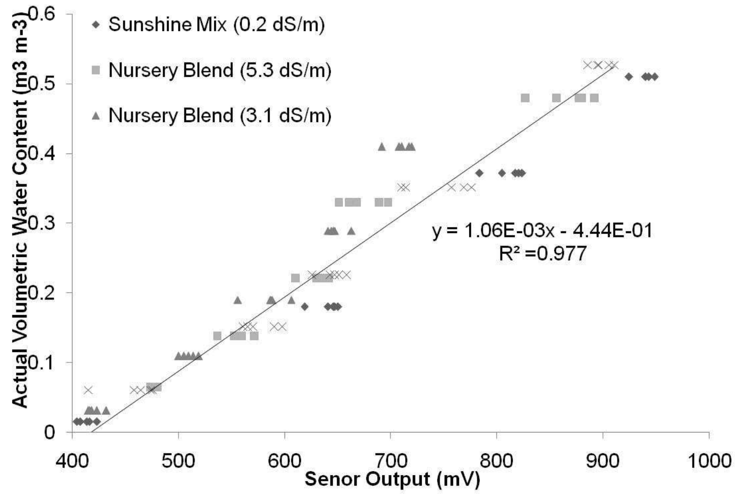

Figure 2. Calibration of five EC-5 sensors in various mixtures of potting soil. Saturation extract EC values are shown in parenthesis.

Rockwool Calibration

Figure 3 shows a similar calibration in Rockwool (Master, Grodan BV), a green fibrous mat visually similar to fiberglass insulation, used to grow greenhouse crops in hydroponics. The relationship between sensor output in rockwool and gravimetrically obtained volumetric water content is quadratic with an R^2 value of 0.982. The EC-5 has good sensitivity over the range of rockwool VWC (0 to ~ 97%, rockwool has a porosity of 97%) and has a low sensitivity to changes in solution EC.

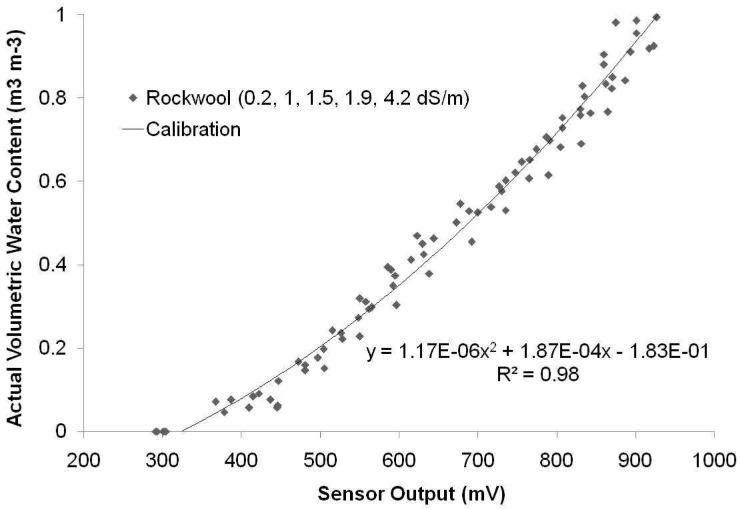

Figure 3. Calibration of five EC-5 sensors in rockwool. Saturation extract EC values are shown in parenthesis.

Conclusions

Although inexpensive, the new EC-5 soil moisture sensor calibrated well over a variety of soil types and electrical conductivities, showing very little sensitivity to the EC and soil type variations that have caused problems for inexpensive probes in the past. The results indicate that one calibration equation can adequately describe all mineral soils regardless of soil EC. Likewise, and single calibration function can be used for all potting soil mixes, and a single function can be used for all EC solutions in rockwool.

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