Soil Water Sensors Use in Irrigation

Soil moisture monitoring can provide valuable information to help evaluate irrigation management for a field crop and maintain the yield potential.

What to Consider

Irrigation should be applied when soil moisture measurements and crop growth stage warrant water inputs with a method that limits waste or excess.

Basic irrigation scheduling, the "Checkbook Method", keeps a soil water balance by measuring rainfall and then measuring or estimating water lost from crop use and evaporation.[1,2] This is based on water availability, soil water holding capacity, water intake rate, and crop water needs. Soil moisture sensors help measure directly, or estimate indirectly, soil water content.

Figure 1. Symptoms of drought stress in corn are leaf rolling and wilting with slow silk emergence and elongation during pollination.

Soil Moisture Sensors

Evapotranspiration (ET) soil water estimations should be periodically validated using soil moisture sensors. Comparing predicted soil moisture with actual soil moisture measurements every couple of weeks is a good strategy to confirm the ET-based scheduling method is accurate. Soil moisture sensors can be placed at differing depths in the crop root zone to provide a direct measure of changes in soil water content. This can help determine when irrigation might be needed. Examples of some common soil moisture sensing instruments include (Table 1):

- **Tensiometers** measure soil water tension. As soil dries, water is pulled from the porous cup at the lower end of tube inserted in the soil, creating a vacuum and causing the vacuum gauge on the top of the tube to move.
- **Electrical resistance blocks** or gypsum blocks, measure electrical resistance changes during wetting and drying cycles of the soil. Depending on the soil moisture content, water moves into or out of the soil-buried blocks. This creates changes in resistance between the two electrodes embedded in the gypsum block.
- **Capacitance probes and frequency domain reflectometry (FDR)** measure the soil dielectric constant using two or more plates or rods, which are embedded into the soil.
- **Time domain reflectometry (TDR) and time domain transmissometry (TDT)** soil moisture sensors measure a soil's dielectric constant.

Accurate Measurements

Measurements should be taken from representative soil types within active crop root zones, and away from high spots, depressions, and slope changes. Variable soil water content means multiple measurements throughout fields and at

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Table 1. Advantages and disadvantages of different methods for measuring soil moisture.		
Method	Advantages	Disadvantages
Gravimetric (oven drying)	**High accuracy with increased sampling, direct measure**	**Very labor intensive, delays to obtain data**
Tensiometers (soil water tension)	**Instantaneous, approximates soil moisture content**	**High maintenance, tension breaks, freezing temperatures**
Electrical Resistance	**Instantaneous, increased range, approximates soil moisture content**	**Slower response, less sensitive at low moisture, affected by soil salinity**
Capacitance and FDR (frequency domain)	**High accuracy, volumetric water content and salinity**	**Highly influenced by adjacent moisture/voids**
TDR and TDT (time domain)	**High accuracy, volumetric water content and salinity, robust calibration**	**High installation cost, highly influenced by adjacent moisture/voids**
Table modified from Crookston, M.A. 2011. Utilizing soil moisture readings in irrigation scheduling. Proceedings of the 2011 Central Plains Irrigation Conference. Burlington, Colorado.		

appropriate depths reduce errors. Additional readings are needed with soil moisture sensors measuring smaller volumes of soil, such as with capacitance probes.[1] Measurements taken in areas where soil and plant properties are most representative of fields may be more cost effective and efficient.

Ideally, for irrigation scheduling, soil water should be measured well below the maximum depth of root water extraction. Conventional TDR is one method that allows the flexibility of deeper measurements.

Typical installations include one or more sensors for each foot of active rooting depth. The variability among soil samples increases as soils dry, indicating that more measurements are needed for accuracy as soil water content reaches the Management Allowable Depletion (MAD) - water amount to be depleted from the root zone before scheduling irrigation.[3] The MAD is usually given as a percentage of maximum water holding capacity of the soil. At the time of irrigation, the soil water deficit should be less than or equal to the MAD.

Sensor Installation and Calibration

Accurate readings come from soil water sensors in direct contact with undisturbed soil. During installation, avoid-

- damage to roots and soil structure,
- air voids,
- large roots,
- rocks, and
- other obstructions.

All soil moisture sensors should be calibrated in the field for the specific soil type, even if manufacturers suggest otherwise. Laboratory calibrations of the devises are often made on re-packed soils, where tight soil-access tube contact is ensured and variability in the soil is minimized. These laboratory measurements may not be transferrable to your field, particularly for the Capacitance or other FDR sensors. Field calibration can provide more accurate readings because the sensor is placed in the actual soil to be measured.

In summary, adequate soil moisture is essential during critical crop growth stages to help achieve maximum yield potential. Soil-moisture measurements should be used with ET-based irrigation scheduling. Soil-water sensors should be calibrated in-field to help provide accurate readings.

Sources: [1] Melvin, S.R. and Yonts, C.D. 2009. Irrigation scheduling: checkbook method. Publication EC709. University of Nebraska-Lincoln Extension.
[2] Sui, Ruixiu. 2017. Use of soil moisture sensors for irrigation scheduling. Irrigation Today. United States Department of Agriculture. p. 16-17.
[3] Evett, S.R., Schwartz, R.C., Mazahrih, N.T., Jitan, M.A., Shaqir, I.M. 2011. Soil water sensors for irrigation scheduling: can they deliver a management allowed depletion? Acta Horticulturae. Vol. 888 p. 231-238.