SOIL MOISTURE SENSORS BOOST IRRIGATION EFFECTIVENESS

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Have you felt confused when looking at plants trying to determine whether or not they require water?

Do you know how long to irrigate and how much water to apply?

The soil serves as a plant's water reservoir. Sensors that measure actual soil moisture can help anticipate water needs before plants suffer from overwatering or drought stress. They can help determine when to irrigate and how much water to apply to maintain the optimal target moisture range for the soil in which the crop is growing.

How do you determine target moisture ranges, since they vary with different soil types and crop/plants? Understanding basic terms associated with the soil water reservoir (Figure 1) is important to help you set target moisture ranges.

Soil water – Water that is generally held in the empty spaces in the soil called pore spaces.

Saturated – When water fills all the pore space.

Field capacity – When any excess water has drained out of the soil (because of gravity) but the pores are still full of water.

Permanent wilting point – Soil dried to a point it cannot supply sufficient water to keep plants from dying.

Available water holding capacity (AWC) – Difference between field capacity and permanent wilting point.

Refill point – Sufficient water content to keep plants alive, but they are stressed as the quantity decreases toward the permanent wilting point.

Different soil types have different AWC. For example, sand cannot hold

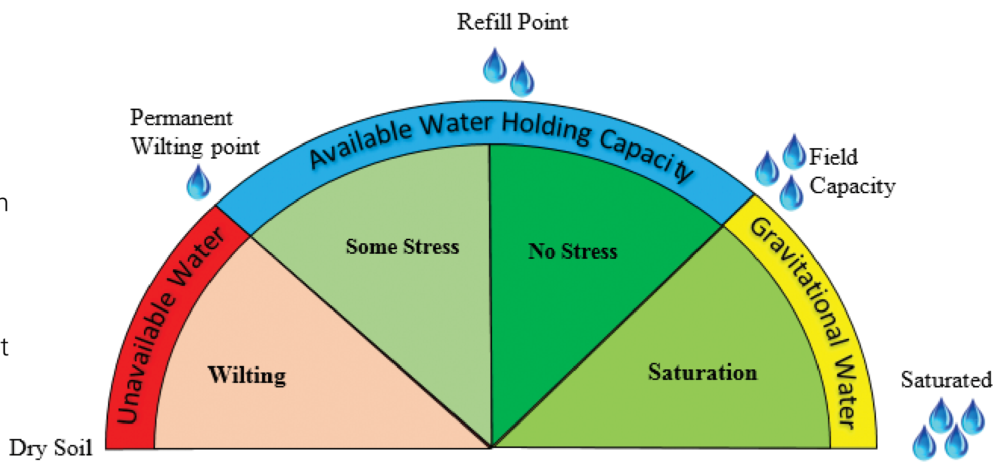

Figure 1. Various levels of the soil water content.

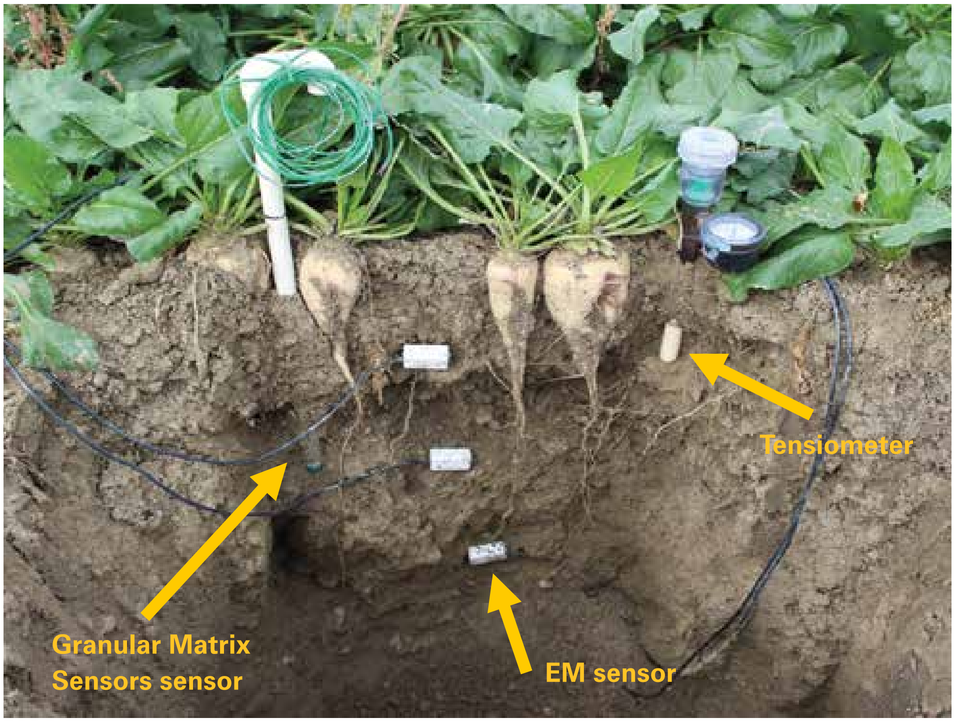

Figure 2. Electrical resistance (granular matrix), tensiometer, and electromagnetic sensors installed in a sugarbeet field at the Powell Research and Extension Center.

very much water compared to silt and clay soil.

Knowing how much available water the soil contains is important. If the soil water reservoir is not replenished by irrigation or rain, the water content will decrease until a point is reached a plant can no longer recover even if water is added.

Soil Moisture Sensors

Soil moisture sensors can be categorized into those that measure the soil water content and those that measure the soil water tension.

Soil water content is the actual amount of water in the soil profile – percentage of water by volume or in inches of water per foot of soil depth.

Soil water tension is a direct indication of the energy required for plant roots to obtain water from the soil – how hard a dry soil is pulling (sucking) on soil water. It is measured using vacuum or pressure units such as pounds per square inch (psi) or centibars (cbar).

Various factors such as soil physical and chemical properties, soil temperature, and others can affect performance and sensor accuracy. Depending on the sensor's technology (response time, sensing volume, operational range), different soil moisture monitoring devices respond differently in different environments.

The following describes three different soil moisture sensors used extensively in agricultural and horticultural settings.

Tensiometer

A tensiometer measures the soil water suction or soil water tension. It consists of an airtight, water-filled cylindrical tube with a porous cup attached to one end (lower end) and a vacuum gauge to other end (top end) (Figure 2). The tension measured is equivalent to the force or energy a plant must exert to extract water from the soil (the drier the soil, the more force needed).

Tensiometers must be installed at the desired depth so the porous cup is in good contact with the soil so water is pulled out of and into the porous cup as the soil dries and wets, respectively. This process creates and releases the suction force in the cup, which is then transmitted through the water column inside the plastic tube and causes a tension reading on a vacuum gauge (recorded manually or automatically using a pressure transducer connected to a data logger).

Electrical Resistance Sensors

Two electrodes are enclosed in a block of porous material, surrounded by a synthetic membrane and perforated stainless steel casing or shell for protection against damage. This sensor is designed to respond quicker to soil wetting and drying. As the soil moisture changes, the water content in the porous block also changes, which affects electrical resistance between the two electrodes.

Readings can be recorded with a handheld meter, watermark monitor data logger, and/or a wireless network. Sensors are relatively inexpensive compared to other soil moisture sensors with costs ranging from $25 to $35 per sensor, with an additional cost associated with a portable handheld meter ($185 to $250) and data loggers ($350-$400) for continuous monitoring (Table1).

Electromagnetic Sensors

Common types of commercially available electromagnetic (EM) sensors include:

(a) Frequency Domain Reflectometry (FDR) or capacitance,

(b) Time Domain Reflectometry (TDR),

(c) Amplitude Domain Reflectometry (ADR) / Impedance, and

(d) Time Domain Transmission (TDT).

These sensors indirectly measure volumetric soil moisture content based on the dielectric (poor conducting) and electric properties of the soil that determines the storage and dissipation of the magnetic and electric energy of the soil components, which is related to soil moisture content.

EM sensors generally consist of two or three parallel rods inserted into the soil or a pair of metal rings attached along the length of a PVC pipe (Figure 2). Different methods can be used to install EM sensors and depend on the sensor design. For example, capacitance or TDR sensors with stainless steel rods can be simply pushed into the soil to the desired depth. Multi-depth capacitance sensors are inserted into a PVC pipe (usually provided by the manufacturer). A soil auger or sampling probe can make a borehole that accommodates the length of the tube.

Care must be taken when drilling the hole. It is important not to install the sensor in an oversized hole as it may cause voids and air gaps. Follow the manufacturers' recommendations for installation. The operational cost of TDR sensors is relatively high (see Table 1) Some examples of EM sensors includes Decagon 5TE, Sentek TriSCAN, Acclima TDR-315L.

All above-mentioned moisture sensors can work together with an irrigation system by signaling the need for water and turning on/off the system.

In general, low-cost sensors tend to be read manually compared to automated sensors that include the cost of a data-logger for continuous data monitoring. The cost further depends on whether moisture sensors are connected to an irrigation controller via direct connection (wired) or remotely (wireless). Many manufacturers now offer technical support, which includes installation, maintenance, and data interpretation.

Table1. Advantages and disadvantages of each soil moisture monitoring technique and associated cost.

Monitoring technique	Advantages	Disadvantages	Cost
Tensiometer	• Inexpensive • Widely used and accepted • Not affected by salinity • Continuous reading possible using transducer • High-frequency sampling • Minimal skill required • Easy to install	• Small operative range (0 to 85 cbar) • Slow response time • Need good contact between sensor and soil • Require frequent maintenance (refilling) to keep the tube full of water • The operating range works for sandy soils but not for fine-textured soils	\$60-\$80 per sensor (require 3-4 sensors) plus \$140-\$155 if installed with transducer
Electrical Resistance	• Large sample area • Can be used in moderately saline soils • Simple and inexpensive • Easy to install	• Not recommended for sandy soils because of slow response time as water moves quickly in sandy soil • Perform poorly in soils that shrink and swell • Affected by soil temperature fluctuation	\$30 per sensor (3-4 required per location) plus \$200 for hand manual reader and \$500 for data logger
Electromagnetic sensors	• Accurate (±1%) • Fast response time • Soil-specific field calibration is usually not required • Not easily influenced by moderate soil salinity • Remote access capability	• Small sensing area • Need good contact between sensor and soil • Expensive • Careful installation is required to avoid air gaps	\$250-\$300 per sensor (require 3-4 sensors per site) plus \$1,000-\$3,000 for data logger

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