Dielectric Soil Moisture Sensors

Dielectric soil moisture sensors determine the soil moisture by measuring the dielectric constant of the soil, an electrical property that is highly dependent on the moisture content. The constant for a dry soil is between 3 and 5; about one for air; and is about 80 for water. Thus, changes in the moisture content cause a substantial change in the dielectric constant of the soil. Calibration equations correlate the dielectric constant with soil moisture content. The most common dielectric devices are capacitance sensors and time-domain-reflectometry (TDR) sensors although other types of dielectric sensors exist. Virtually all of the sensors listed below can be attached to data loggers for a continuous record of soil moisture content. Many of these systems have the option of radio or cell phone telemetry that can link the sensors directly to an office computer or be viewed through a web-based server.

Capacitance Sensors

The capacitance sensor (Fig. 1) consists of two electrodes separated by a material called the dielectric, a material that does not readily conduct an electrical current. Normally, cylindrical-shaped electrodes are used. Inserting the sensor into the soil results in the soil becoming part of the dielectric. An oscillator applies a frequency between 50 and 150 Mhz (depending on the manufacturer) to the electrodes, which, in turn, results in a resonant frequency, the magnitude of which depends on the dielectric constant of the soil. The greater the soil moisture content, the smaller the frequency. The frequency is then used with a calibration equation to estimate volumetric soil moisture content.

Fig. 1. Capacitance instrument

Time-Domain-Reflectometry (TDR)

Time-domain-reflectometry involves installing two or three steel rods, called waveguides, into the soil parallel to each other (Fig. 2). Components of a TDR system are a voltage pulse generator, a signal analyzer, the waveguides, and a cable connecting the waveguides to the instrumentation. An electrical pulse applied to the waveguides travels their length, and then is reflected back when it reaches the end of the waveguides. The travel time required for the pulse to reach the end of the waveguides and back depends on the dielectric constant of the soil. The larger the dielectric constant, the longer the pulse travel time.

Fig. 2. TDR probe

Calibration

Calibration equations relating the dielectric constant to the soil moisture content are necessary. These equations generally are provided by the manufacturer; however, in some cases, site-specific calibration may be needed. Some manufacturers provide a universal calibration, while others provide calibrations based on soil texture. Some calibration curves provide the volumetric soil moisture content. Others may display the percent of available soil moisture remaining in the soil.

Field calibration may be necessary in fine-textured soils of California even though a manufacturer calibration curve is provided. Field experience has shown that unrealistically high readings can occur in these soils. If the sensor reading just after an irrigation (when the soil is at field capacity) exceeds 50% (6 inches/foot), then the sensor should be calibrated for the site-specific conditions. To determine if the dielectric sensor reading is realistic, compare the field capacity volumetric soil moisture content with the sensor value. If the values differ greatly, then a site-specific calibration is needed. Also, in some cases, very low sensor readings (approaching zero) have been found just before irrigation, indicating a need for calibration.

Developing a calibration curve involves collecting soil samples very close to the sensor and determining their volumetric soil moisture content and making a sensor reading at that depth at the same time.

Installation

All dielectric soil moisture sensors must be carefully installed to prevent air gaps between sensor and soil. Air gaps cause errors in their readings. Some sensors require specialized equipment for installation, while others are installed by placing the sensor into a pilot hole. In some cases, slurry is used to obtain a tight seal between sensor and soil.

Zone of Influence

The zone of influence is very small compared to the neutron moisture meter. The zone of influence is about 4 inches from the sensor for capacitance instruments and about 1 inch for TDR sensors.

Advantages/Disadvantages

Advantages of dielectric soil moisture sensors include the ability to be left in place to continuously log soil moisture content; repeatability of measurements; sensitivity to small changes in soil moisture content; and their precise resolution with depth because of the narrow vertical zone of influence. Disadvantages include the need for a calibration equation; the difficulty in developing the equation; the relatively small zone of influence; possible influence of soil salinity on probe reading; and sensitivity to air gaps surrounding the sensor.

Types of Instruments

Many types of dielectic soil moisture sensors exist. A comprehensive list of dielectric instruments can be found at http://www.sowacs.com. An technical report, *Soil Water Monitoring: An Information Package*, written by P. Charlesworth (CSIRO/CRC Irrigation Futures, Australia) can also be downloaded at http://www.irrigationfutures.org.au/, which describes many of the dielectric sensors used world-wide.

Field Studies

Several studies have compared the readings of some dielectric soil moisture sensor with the soil moisture content measured with a neutron moisture meter, calibrated for a specific site. Default calibration curves of the dielectric instruments were used.

Results showed that most of the dielectric sensors generally followed the trends in soil moisture content; however, one instrument tracked moisture content changes very poorly. In general, these sensors perform best in the coarser-textured, non-saline soils. These results also showed that the readings of the dielectric sensors can differ considerably from those of calibrated neutron moisture meter data, indicating the need for soil specific calibration.

References

Hanson, Blaine, Schwankl, Larry, and Allan Fulton, 1999. Scheduling Irrigations: When and How Much Water to Apply. UC ANR Publication 3396.
http://anrcatalog.ucdavis.edu/Irrigation/3396.aspx

Hanson B.R. , Peters, D.W. 2000. Soil types affects accuracy of dielectric moisture sensors. *California Agriculture* **54**(3):43-47.

Hanson, B.R., Orloff, S. 2007. Monitoring Soil Moisture for Irrigation Water Management. UC ANR Pub 21635.
http://anrcatalog.ucdavis.edu/Irrigation/21635.aspx