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Soil Moisture — An Important Part of Irrigation Water Management (Part 2)

In Part 1 of this series, we reviewed basic concepts of soil moisture, including soil water content and soil water potential. We discussed how to measure soil moisture by the gravimetric and feel methods, and where in the field to sample soil moisture. In this article, we discuss soil moisture measurement methods and devices and their application to irrigation water management.

Soil water *content* is the amount of water per unit weight or volume of soil and is a measure of the total amount of water present in a soil or available for crop use. Soil water *potential* is a measure of the energy status of the water in the soil, or how hard the plants must work to extract water from the soil. The relationship between soil water content and soil water potential is called the soil water retention curve, which is shown for three North Dakota soils in Figure 1. Coarse-textured soils such as sands tend to have lower soil water content than fine-textured soils, such as loams and clays, at the same soil water potential. For irrigation scheduling purposes, this means coarse-textured soils run out of crop-available water sooner than fine-textured soils.

Some soil moisture devices measure soil water content, while others measure soil water potential. We will review a few types of devices available today and discuss their advantages and disadvantages. Some example devices are shown in Figure 2.

Soil water content methods and devices

The "feel method" for estimating soil moisture was reviewed in Part 1 of this series. To obtain a sample from below the surface of the soil, a soil probe or shovel is required. A probe is useful because the soil core that is

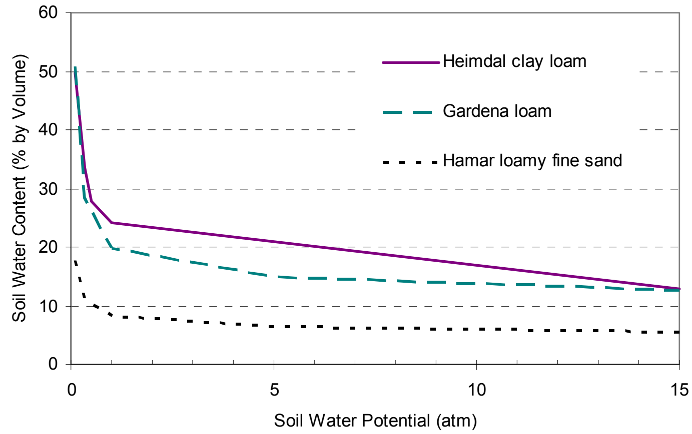

Figure 1. Soil water retention curves for three soils (from Cassel & Sweeney, 1976).

retrieved may indicate the depth to which irrigation or rain water moves into the soil. This boundary between wet soil on top and dry soil beneath it is called the wetting front.

In addition to oven drying used in the gravimetric method, the literature also indicates that a household microwave oven can be used to "cook" soil samples until their weight becomes constant, indicating that all of the unbound water has been driven off. This may take approximately 20 minutes for a 25-gram (approximately 1 oz.) sample and users of this method should be aware that organic matter and bound water may produce erroneously high readings of soil water content compared to gravimetric methods.

In addition to *direct* measurements of soil water content such as gravimetric sampling, there are *indirect* measurements based on various physical properties of the soil-air-water mixture in which we grow crops. An example is measurement of capacitance, an electrical property, by time domain reflectometry (TDR) or frequency domain reflectometry. The capacitances of soil, air and water all differ, enabling calibration of capacitance readings against gravimetric methods. An example sensor consists of two parallel eight-inch-long stainless steel rods that are inserted into the soil. An electrical signal is sent into the rods or waveguides and reflected back into a sensing unit that measures the transmission time. This is converted into a soil water content value, either through a calibration provided by the manufacturer or developed by the user. Research-grade measurements with the TDR method can be quite accurate, but the equipment is expensive, typically costing several thousand dollars.

A handheld sensor with a readout meter is a portable approach to capacitance measurements. This type of unit typically has stainless steel rods as part of the sensing unit, as described above. The rods are inserted into the soil and a reading is obtained from the meter. Cost is in the hundreds of dollars and the units are easy to move from one location to another. A disadvantage is that while the manufacturer may provide a built-in calibration for direct readout of soil water content, the sensors may require a calibration for each soil type on which they are used. Another disadvantage is the need to dig a hole in the soil to measure water content at deeper depths.

Some capacitance-based soil moisture devices are stationary because they are inserted and left in the soil at a single location. For example, a four-foot plastic pipe may be used as a vertical access tube in the soil. A cylindrically-shaped sensor is inserted in the tube and left in place for continuous measurement of soil water content at multiple depths throughout the growing season. This type of device may be used in a portable fashion, by inserting it into an access tube for readings at one location, then moving it to other access tubes for readings at other locations. An advantage of this type of device is that measurements deeper in the soil profile can be made without coring or digging every time you want to make a measurement. Cost may range from several hundred to a few thousand dollars.

Neutron scattering is a soil water content measurement method commonly used in research, and, to a limited extent, for very high-value crops. It is considered by many to be the best indirect method of soil moisture measurement. It involves installation of a vertical access tube — typically steel — in the soil, into which is placed a sensor-detector with a radioactive source of fast neutrons that are slowed down or thermalized by hydrogen in the soil and detected by the unit. Since water contains hydrogen, a readout device can be calibrated against gravimetric methods to indicate soil water content. Multiple access tubes are typically installed, as described above. Cost is a few thousand dollars and use is regulated by the Nuclear Regulatory Commission.

Heat capacity is another physical property of soils used to indirectly estimate soil water content. In this method, a small electrical heating element heats the soil for a short time and the soil water content can be inferred from the rate of cooling that occurs. These sensors are typically referred to as heat dissipation sensors. Costs for sensors and readout devices are in the hundreds of dollars.

Soil water potential methods and devices

Tensiometers consist of a ceramic tip attached to the lower end of a tube which is inserted vertically into the soil. The top has a reservoir and cap that can be removed to fill the unit with water. A vacuum gauge is attached

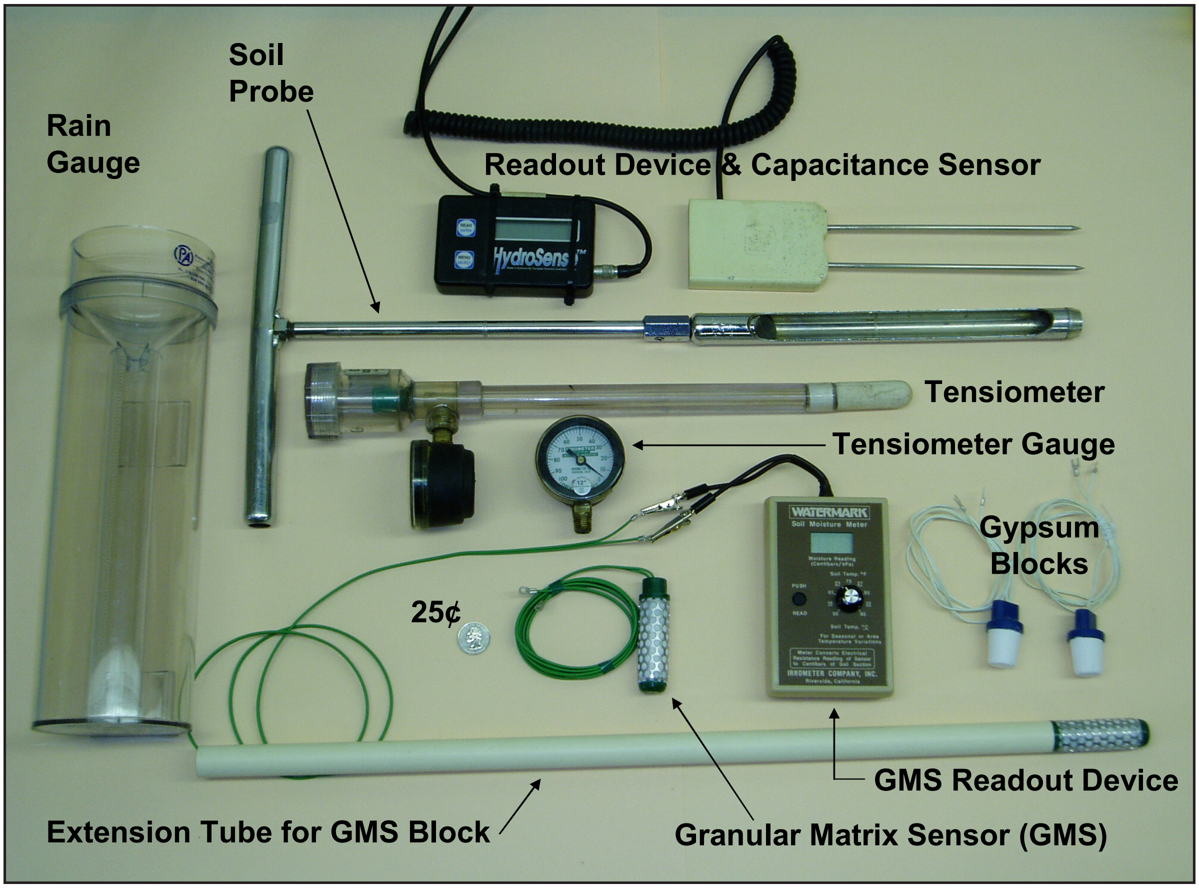

Figure 2. Examples of soil moisture sensors. The U.S. quarter indicates size.

and when the soil dries, it pulls water out of the tensiometer. This "pull" is registered on the vacuum gauge and is a direct indication of how hard the plant must work to extract water from the soil. Cost is typically under $100. An advantage of tensiometers is that they directly measure soil water potential, while disadvantages include maintenance requirements and limited operating range.

Gypsum blocks and granular matrix sensors use the principle of electrical resistance to indirectly measure soil water potential. Two electrodes are embedded in gypsum or a granular material in the sensor head, which is buried in the soil at the desired depth. As the soil becomes wetter or drier, the electrical resistance of the material surrounding the electrodes changes. Lead wires to the surface are hooked up to a readout device for measurement. Advantages include relatively low cost for sensors (on the order of $25-50), simplicity and low maintenance. Limitations include sensitivity to temperature — which may be accounted for in readout devices — and possible sensor degradation over time.

Additional considerations

Most of the devices described above can be automated for recording of sensor measurements at sub daily intervals. Many companies have data logging units that can be dedicated to measuring and recording soil water content or soil water potential data and provide features for transfer of the data to computers. The sensors and data loggers often have very low power requirements, which may enable the use of only a few "AA" size batteries for a season's use. Users may also want to consider monitoring and logging of rainfall, irrigation and soil temperature, which can be done at a relatively low cost.

Users of soil water sensors must consider both location within a field and depth of installation when installing sensors. Location within a field was discussed in Part 1 of this series. The user should recognize that the devices mentioned here apply only to specific locations within the field rather than to large areas, so it is important to select representative locations. Sensors are typically placed between plants and in the crop row to avoid damage by wheel traffic and cultural operations. Regarding depth, the sensors should be installed in the active rooting zone of the crop. For row crops, small grains and alfalfa, a sensor depth of 12 inches is common. A smaller depth may be used for drought-sensitive crops such as potatoes and for shallow-rooted crops such as onions. If additional sensors are used, you may want to place one at 9 to 12 inches depth and another at 18 to

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24 inches depth. The top sensor will tend to change the most in response to crop water use and can be used to indicate when to irrigate, while the deeper sensor will help indicate whether irrigations and rainfall are sufficient to meet the needs of the crop.

It is important to recognize the distinction between absolute measurements and relative changes in soil water content or soil water potential. The devices described here may not provide a research-grade measurement of soil moisture without calibration, but with built-in memory, display screens or the ability to transfer data to a computer, they allow the user to easily see the last week's or month's worth of data. The ability of sensors and loggers to monitor trends in soil moisture is perhaps their most important feature for irrigation scheduling purposes. For example, if soil moisture readings indicate a drying trend, then recent irrigation and rainfall events have not been sufficient to meet the needs of the crop. If under- or over-irrigation are indicated by soil moisture measurements, then adjustments can be made to irrigation scheduling decisions or to procedures such as the approach outlined in NDSU Extension Service publication AE-792, "Irrigation Scheduling by the Checkbook Method."

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