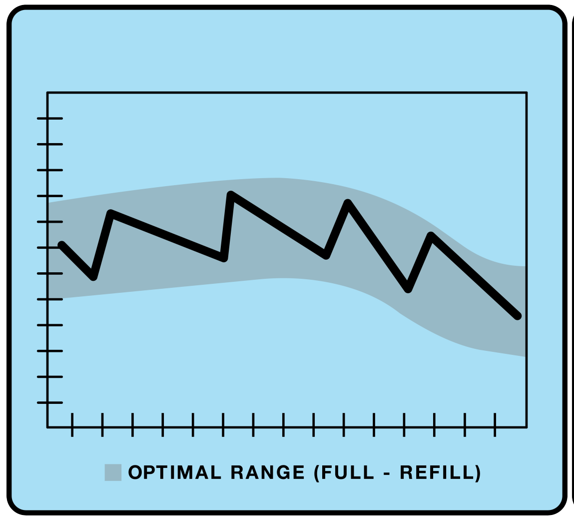

1	07/24/19	07:00	92.37	12	07/24/19	18:00	42.84
2	07/24/19	08:00	88.81	13	07/24/19	19:00	40.37
3	07/24/19	09:00	84.25	14	07/24/19	20:00	38.94
4	07/24/19	10:00	80.67	15	07/24/19	21:00	67.45
5	07/24/19	11:00	77.11	16	07/24/19	22:00	78.36
6	07/24/19	12:00	74.93	17	07/24/19	23:00	90.88
7	07/24/19	13:00	70.52	18	07/24/19	24:00	97.29
8	07/24/19	14:00	62.18	19	07/25/19	01:00	94.71
9	07/24/19	15:00	55.06	20	07/25/19	02:00	87.54
10	07/24/19	16:00	50.49	21	07/25/19	03:00	80.73
11	07/24/19	17:00	47.22	22	07/25/19	04:00	74.61

Figure 6. Data presentation and interpretation options. Graphical presentation of soil moisture data along with full and refill thresholds (left) can be more easily converted to irrigation decisions compared to tabular presentation (right).

through thick and tall canopies. In these cases, extended antennas may be needed. For some sensors and locations, even the extended antennas may not be able to send the wireless signal, resulting in need for additional signal relay capabilities (and associated equipment and costs).

From Data to Decision

The raw data collected and transmitted by soil moisture-sensing systems are usually difficult to be used directly in irrigation scheduling. This is mainly because information on current soil water status must be accompanied with information on two soil moisture benchmarks: the full point and the refill point. Comparing estimated soil moisture against these thresholds determines when irrigation events should be started and stopped. If moisture goes above the full point, water percolates to deeper layers and eventually below the root zone. This drained water becomes unavailable to crops, along with any dissolved nutrients carried with it. The refill point identifies the soil moisture limit at which irrigation must be applied to avoid water stress and potential yield loss. The difference between the full and refill points (optimal range) is largest for drought-tolerant crops in medium textured soils and smallest for drought-sensitive crops in coarse soils.

Some sensor packages in the market only provide an estimate of the current soil moisture status, and sometimes in less useful formats such as lists and tables. Other systems offer estimates of the full and refill points too (or allow the user to define them) and present sensor readings in user-friendly graphical representations that can be easily converted to irrigation scheduling decisions. In addition, some sensing systems provide a short-term (5 to 7 days) forecast of soil moisture status based on predicted weather condition and crop growth stage. This forecast could be extremely useful for producers who need to make irrigation decisions a few days ahead of the intended irrigation application.

Summary

Soil moisture sensors provide insight into water availability in the crop root zone, thus enabling users to avoid under-irrigation or over-irrigation, both of which negatively impact farm profitability and sustainability. Several key factors should be considered when including soil moisture-sensing systems in irrigation decision making:

- Deciding between point sensors versus probes. Probes are typically easier to install and provide a more comprehensive picture of water availability along their length.
- Sensor accuracy, especially if the intended field has high levels of clay content or salinity.
- Installation quality and location, which should be gap-free, at a representative spot and out of the way of farm machinery and irrigation systems.
- Method of accessing collected soil moisture data (wireless vs. manual) and the cost and convenience associated with each option.
- Ability to easily and quickly convert collected data to irrigation decisions.

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OSU EXTENSION

Soil Moisture-Sensing Systems for Improving Irrigation Scheduling

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As the demand for freshwater resources from variable sectors continues to grow, it is critical to improve irrigation scheduling to produce more crop per drop and reduce potential water losses. Several methods of improving irrigation scheduling have been developed and implemented in the past based on monitoring variables such as crop water use, soil moisture status and crop canopy temperature. Among these methods, monitoring soil moisture has been researched and practiced for several decades. Despite this long history, the use of soil moisture sensors in implementing precision irrigation scheduling has remained somewhat limited. The most recent survey conducted by the U.S. Department of Agriculture shows that across the U.S., soil moisture sensors are utilized in only 12% of farms.

It is likely this limited adoption is in part due to technical challenges users face in selecting soil moisture sensors and in translating sensor readings to practical irrigation decisions. The goal of this fact sheet is to assist producers with selecting the right type of soil moisture-monitoring device to ensure their investment results in useful information for their irrigation scheduling. The topics discussed here also can assist sensor manufacturers in developing new devices and improving existing ones to better serve the needs of producers and crop consultants.

Point Sensors vs. Probes

Many available sensors provide data for a single point in the soil immediately around the sensing component of the device (one point in the soil profile). Hence, a separate sensor must be installed for each layer (depth) of the soil intended to be monitored along the soil profile. This could significantly increase the time and labor requirements of sensor installation. Other sensors stack several sensing devices on a column or a probe (Figure 1). This design allows for one probe to provide soil moisture data at several soil layers. The installation and removal of probes usually take less time and labor, when compared to point sensors. Soil moisture probes available in the market vary in type, length and the number and spacing of sensing devices on the probe. One brand, for example, offers 3- and 4-foot long probes with sensors at every 4 inches. The cost of a probe is usually a function of the probe length (longer probes are more expensive).

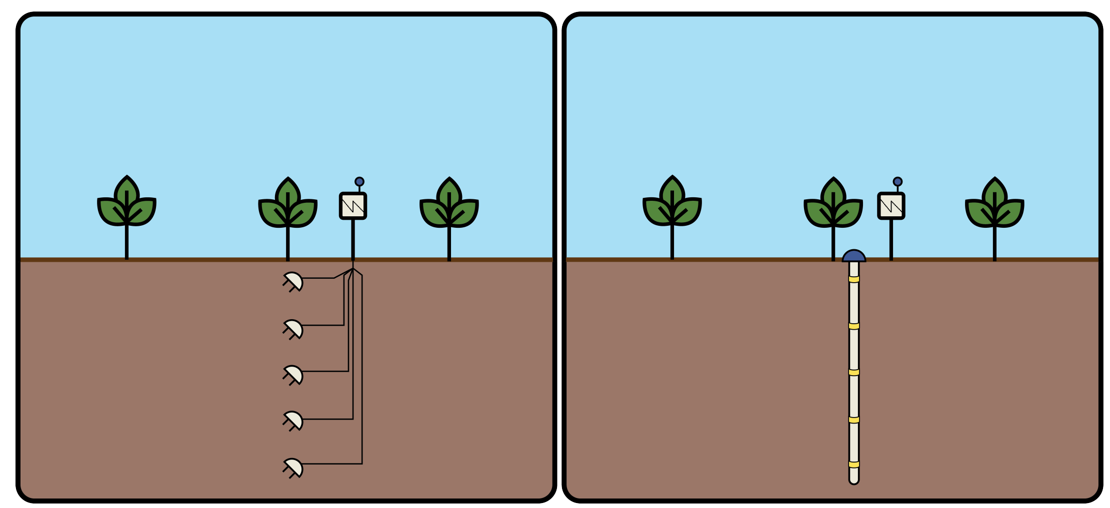

Figure 1. Point sensors (left) versus probes (right).

Sensor Accuracy

Different types of soil moisture sensors have different accuracies, depending on the sensing technology used in them and properties of the soil in which they are installed. The readings of electromagnetic sensors, for instance, tend to have larger errors in soil with higher clay content. The salinity of soil and/or irrigation water is another factor that can increase sensor error. The results of field studies conducted in Oklahoma revealed the combined impact of elevated clay content and salinity on reading accuracy was significant. However, different sensors responded differently to the same level of clay content and salinity. Before selecting soil moisture sensors, it is important for users to consider the physical and chemical properties of the soil in their fields so the most suitable sensor can be chosen.

Sensor Installation

Once the right type of sensor is selected, it must be installed properly. First, the installation location within the field should be identified. This largely depends on the intended use of sensor readings and the number of sensors to be installed. Many producers start with one location to evaluate sensor performance and usefulness before investing in additional sensors. In this case, they may pick a location that represents most of the field in terms of soil type and/or yield potential. In other cases, the producer may want to monitor the most challenging location in terms of irrigation management to boost yield for that zone. If the selected sensor is found reliable and useful, it is recommended to increase the number of sensors installed in each field to better represent variable soil and crop conditions across large fields.

When choosing the location, the integrity of the sensor and above-ground hardware (e.g. antenna and solar panel) must be considered in relation to the succeeding farm operations and irrigation system structure. If the aboveground components are too tall, they can be in the way of irrigation systems and farm machinery, increasing the risk of accidents and damages (Figure 3). Devices can be hit and knocked down by spray rigs and center pivot drop hoses and nozzles.

After identifying the installation location(s), the sensor must be installed properly in the soil. The greatest risks in sensor installation are causing too much disturbance in the soil, or even worse, failing to achieve a tight contact between the sensor and the soil. Gaps between sensor and soil can develop during or after installation and can cause erroneous

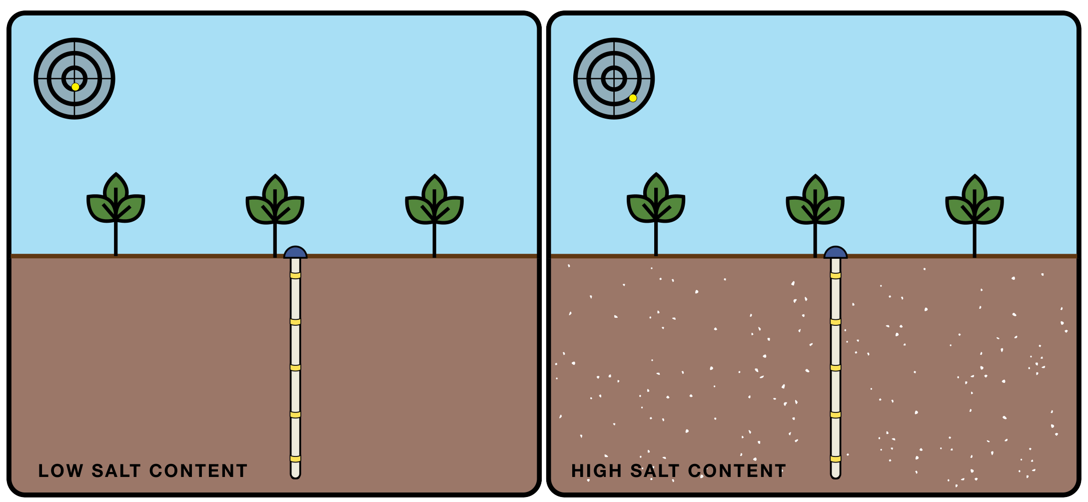

Figure 2. Soil moisture sensor accuracy can be negatively impacted by soil salinity. In a more saline soil, water content is usually overestimated.

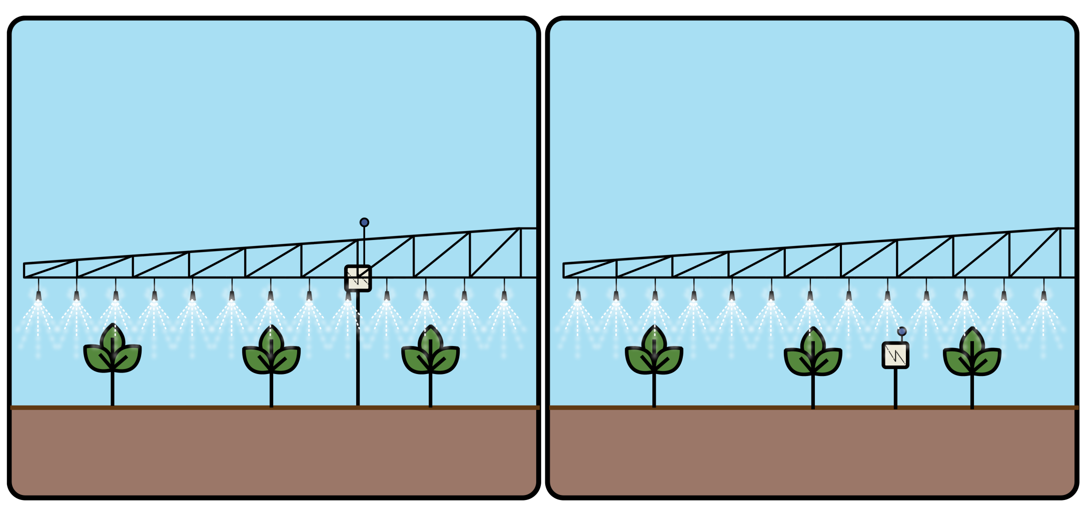

Figure 3. The installation location and height of soil moisture antennas and solar panels must allow for reasonable operation and movement of irrigation systems and farm machinery (e.g. spray rigs).

readings as they fill with water quickly and drain quickly. Sensor readings during the few days after installation should be monitored to identify possible issues with installation. In some cases, local dealers can perform sensor installation and removal, especially if the sensors are leased and not purchased. If available and affordable, this option may save time and prevent frustration caused by improper sensor installation.

Data Access

Selecting the right type of sensor and installing it properly improve the accuracy and reliability of acquired data. However, the data must be accessible to be useful in making informed and timely irrigation decisions. There are two main options for accessing data collected by soil moisture sensors: manual and automatic. Manual access requires the user to visit the sensor site and read the data using built-in gauges and screens or download data by connecting a reader, laptop computer or other portable device. The manual access is usually cheaper than automatic access due to lack of data transmission units and data access (subscription) fees but requires time and trained personnel. In addition, the data may be retrieved too late to be used for timely irrigation decisions. The manual data access may be adequate for some applications, such as when the irrigated area is small, the number of deployed sensors is limited and the irrigation events are infrequent.

Automated data access relies on wireless transfer of data to servers, which allows users to access the collected data at any time using websites and mobile applications. The databases are usually updated every 5 minutes to 30 minutes, providing near real-time monitoring capabilities. The wireless data transfer may take place at the location of the sensor through a communication tower or at a base station that communicates with several nodes where sensors are installed. Some manufacturers of drip and sprinkler irrigation systems also offer the capability of wiring soil moisture sensors to the control panel of irrigation system and then sending data wirelessly to servers along with other information, such as system pressure and flow rate.

One point to consider when choosing wireless data transfer option is that the antennas may not be able to send the signal

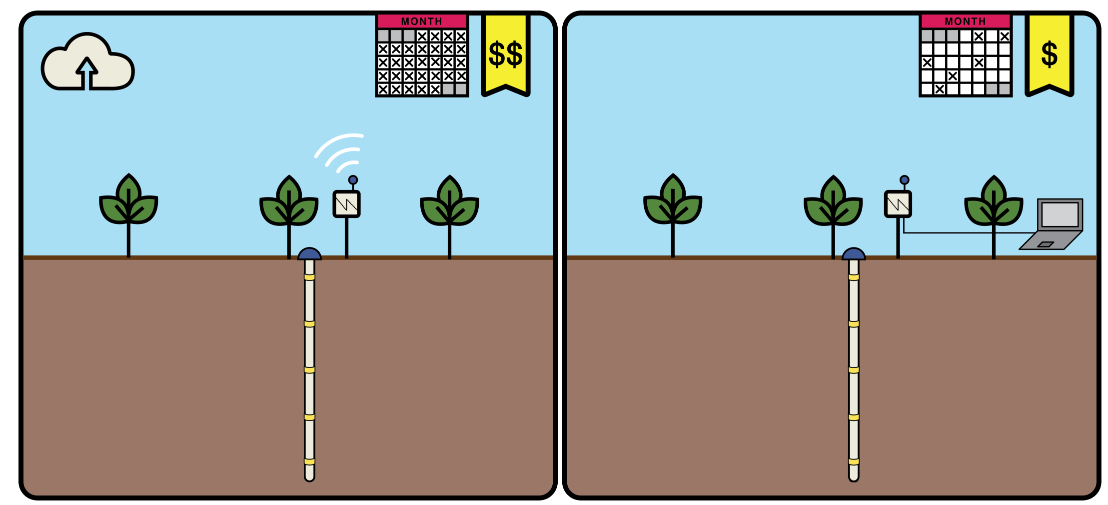

Figure 4. Methods of accessing soil moisture data. Wireless transmission (left) is usually more expensive but provides access to data on a daily or shorter basis. Manual download (right) is less expensive but data is available only when the sensor is visited.

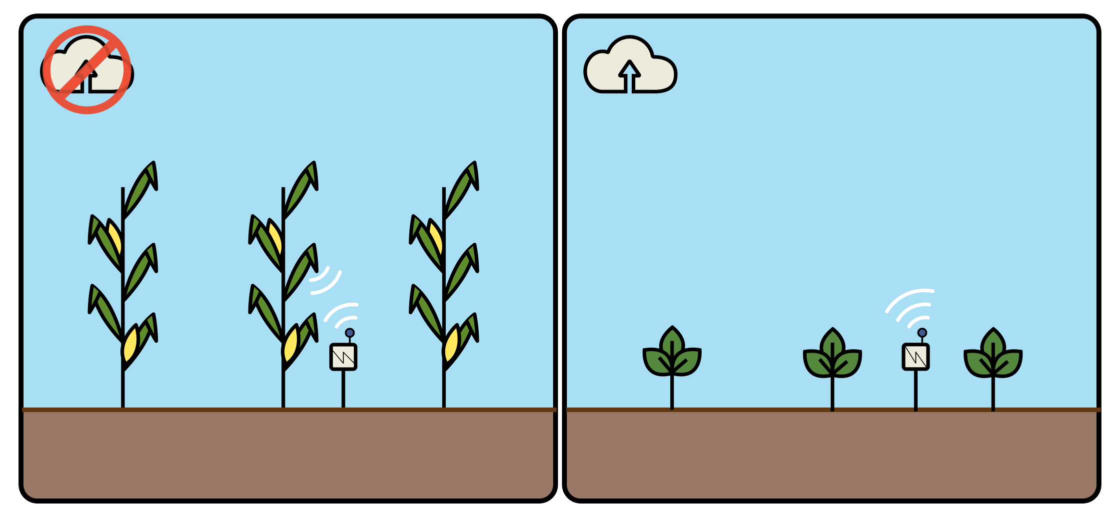

Figure 5. Tall vegetation may block transfer of wireless signal (left). Extending the antenna may be a solution in this case. With shorter vegetation, signals can be transferred more easily (right).