Practical Use of Soil Moisture Sensors for Irrigation Scheduling

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Good irrigation water management will increase yields, improve crop quality, conserve water, save energy, decrease fertilizer requirements, and reduce non-point source pollution. Using soil moisture measurements is one of the best and simplest ways to get feedback to help make improved water management decisions. However, the installation, calibration, and interpretation of the data from these instruments is often overwhelming for most busy growers. Here's an attempt to provide *practical* recommendations for using these sensors to improve your operation.

The major types of soil moisture sensors are listed in Table 1 and grouped according to the technology used to measure soil moisture. Research continues to show that these sensors are not always accurate. However, they all give trend lines that can be usable for irrigation scheduling. Although the technologies used by each sensor type are quite different, these sensors can be roughly categorized into two groups: those that give the soil water *content*, and those that give the soil water *tension*.

Table 1. Major types of soil moisture sensors and their relative advantages and disadvantages.

	Sensor Type	**Advantages**	**Disadvantages**
Soil Water Content	**Neutron Probe** (Campbell Pacific Nuclear; CPN)	Accurate. Repeatable. Samples a relatively large area. One sensor for all sites & depths.	Government required paperwork and regulations. Can't leave in field. Relatively expensive (about $4,500).
	Time Domain Transmissivity (Acclima, Gro-Point)	Less expensive ($110/sensor). Easy to log data.	Samples small area.
	Capacitance Sensors (Enviroscan, Echo Probes, Acclima, Vernier, etc..)	Easy to set up to log and/or transmit data.	Highly affected by soil conditions immediately next to the sensor. High variability. More expensive ($300 - $1,200/system).
Soil Water Tension	**Tensiometers**	Less expensive ($80/sensor)	Maintenance issues.
	Granular Matrix Sensors (Watermark)	Inexpensive ($40/sensor)	Highly variable output. Less accurate. Sensitive to temperature and soil salinity.

Soil Water Content-based soil moisture sensors: (Capacitance, Neutron Probe, gravimetric)

Soil water content measurements are much more meaningful for irrigation scheduling when they are compared to the maximum amount of water that the soil can hold long term, or *field capacity*. The simplest way to determine your soil's field capacity is to use the sensor to take a soil water content measurement at a time when you are confident that the soil is full of water, yet free water has had time to drain through. Good times to take these measurements are in the spring as soon as soil thaws (assuming adequate soil moisture recharge over the winter), or 12 to 24 hours after a heavy irrigation. Remember that the soil content measurement must be multiplied by the depth of soil in the root zone that it represents to give the total water content in that soil depth.

It also helps greatly to have an estimate of the soil water content at which the plants begin to experience water stress. This can be estimated from the previously measured field capacity and the soil's available water capacity (AWC). A range of AWCs by soil texture is given in Table 2 (see http://websoilsurvey.nrcs.usda.gov for a more accurate estimate). This AWC number is then multiplied by a 3.5 ft root depth for most fruit trees and vines (second column of numbers in Table 2) to get the inches of water that is held between field capacity and wilting point. It may be necessary to use a different root depth beside 3.5 ft if the soil is shallow. To manage fruit trees and vines for no stress it is a good idea to limit the soil water depletion to only 50% (half) of the AWC in the root zone. This is given as the last column of numbers in Table 2. Now, for example, if the total water held in the root zone at field capacity is measured in the spring after a wet winter to be 7.0 inches of water in a sandy loam soil (maximum of 2.5 inches depletion for no stress from Table 2), we set the maximum depletion point to 4.5 inches (7.0 - 2.5 in). Plant and soil observations should also be used as feedback to refine these estimates over time. For instance, if in the above example I saw the first signs of vine water stress at a measured 5 inches of water in the root zone instead of 4.5 inches, I would be sure to irrigate before the soil got to 5 inches of water in the future.

Table 2. Ranges of available water by soil texture.

Soil Texture	**Avail. Water Capacity (AWC) in/ft**	**Total Water in 3.5 ft Root Zone (in)**	**Max. Depletion at 50% of AWC (in)**
Coarse Sand	0.2 - 0.8	0.7 - 2.8	0.4 - 1.4
Fine Sand	0.7 - 1.0	2.5 - 3.5	1.2 - 1.8
Loamy Sand	0.8 - 1.3	2.8 - 4.6	1.4 - 2.3
Sandy Loam	1.1 - 1.6	3.9 - 5.6	1.9 - 2.8
Fine Sandy Loam	1.2 - 2.0	4.2 - 7.0	2.1 - 3.5
Silt Loam	1.8 - 2.5	6.3 - 8.8	3.2 - 4.4
Silty Clay Loam	1.6 - 1.9	5.6 - 6.7	2.8 - 3.3
Silty Clay	1.5 - 2.0	5.3 - 7.0	2.6 - 3.5
Clay	1.3 - 1.8	4.6 - 6.3	2.3 - 3.2
Peat Mucks	1.9 - 2.9	6.7 - 10.2	3.3 - 5.1

Using this method the absolute accuracy of the sensor is less important because we are just comparing it to itself. Also the periodic measurements throughout the season now take on meaning as we can determine the soil water deficit (field capacity – the current reading) and the amount of water that can be depleted before water stress occurs. Good irrigation managers will maintain the water content well between field capacity and this stress point.

Tension-based soil moisture sensors: (GMS, Tensiometers)

When using tension-based soil moisture sensors, the soil's field capacity, wilting point, and the maximum depletion point are mostly irrelevant. A soil that is full of water will have a measured soil water tension near zero. Fruit trees and vines should be irrigated before they reach 40-50 centibars. For regulated deficit irrigation, this could be increased to 80 centibars. Again, since these measurements can be inaccurate and soil specific, refine your limits using crop observations over time. For example, note the measured soil water tension at the earliest indications of water stress (this will appear first in sandy, or shallow soil areas), and be sure to irrigate before you reach that point in the future. Also take some readings right after an irrigation. If the bottom sensor goes to zero, then it's possible you put too much water on. If it shows no movement at all, apply more water next time to push water a bit deeper.

Additional Recommendations:

- Avoid preferential flow of water to the sensor due to installation process.
- Flag the sensor well so that it can be easily found.
- Graphical representation of the data greatly helps with data interpretation.
- Use soil water measurements with irrigation scheduling tools such as Kansched and daily water use data from AgWeatherNet or AgriMet for much better water management (all three of these will be the top search return on Google).
- Keep records. Correlate readings with observations.
- Stay away from both the field capacity, and water stress points if possible.
- Realize that soil and sensors have a lot of variability.
- Be patient and stick with it. It may take a year or two before you are good at interpreting your sensor readings.