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The soil moisture sensor trial planting at the end of year one. The row in the foreground is a mulched row and the next two rows are not mulched.

Using Soil Moisture Sensors to Schedule Avocado Irrigation – First Year Trial Report

In April 2017, the California Avocado Commission (CAC) planted a trial at Pine Tree Ranch in Ventura County to look at using soil moisture sensors to manage irrigation in avocados and to determine potential water savings that could be achieved compared with traditional calendar-based irrigation scheduling.

Trial Design

The trial was planted on April 4, 2017, with 'Hass' on 'Toro Canyon' and consists of eight rows of 20 trees planted at a spacing of 10 feet between trees and 15 feet between rows. Four of the eight rows were mulched to look at the potential added benefits of mulch on water savings. The trees were established on drip irrigation using one one-gallon-per-hour dripper per tree.

Each pair of rows — one mulched, one not mulched — serves as a treatment block for a total of four treatments. The treatments originally were planned to be irrigation-based using one of three different types of soil moisture sensors and a calendar-based control. However,

as will be detailed later in this article, some of the sensor types have proven unreliable so the treatments have been modified and are now as follows:

- Irrigate based on soil moisture sensor data to turn on/off at designated soil moisture readings
- Run daily if evapotranspiration (ET) has exceeded a preset cumulative threshold and turn off based on flow meter data
- Run daily if ET has exceeded a preset threshold and turn off based on soil moisture sensor data
- Calendar-based irrigation

These treatments were implemented in the spring of 2018 and results will be discussed in future articles.

The project is irrigated from well water stored in two 5,000-gallon tanks. The tanks fill automatically when the well runs using a float valve. A small electric pump is used to pump the water from the tanks and irrigate each row as needed. This setup allows us to operate this small test block independently from the rest of the ranch.

Soil Moisture Sensors and Flow Meters

Three different types of soil moisture sensors are used in this project. The sensors used are:

- EnviroPro EP100G-04 capacitance probe
- Irrometer Watermark 200SS granular matrix sensor
- Acclima SDI-12 Digital TDT sensor

The pros and cons of each of these sensors, based on our year of experience with them, will be discussed in more detail later.

Within each of the eight rows of the planting, one or two trees were selected to be the data tree(s). Every row has an EnviroPro sensor installed on one tree. The four non-mulched rows also include the Irrometer and Acclima sensors. The EnviroPro sensors are a single 40 cm (approximately 16 inches) probe with temperature, moisture and salinity sensors built in at 10 cm intervals (4, 8, 12 and 16 inches approximately). The Irrometer and Acclima sensors are individual sensors and were installed in sets of three at 4-, 10- and 16-inch depths.

The entire system is equipped with four Netafim M series flow meters. Each meter records the flow for two rows (one mulched, one not mulched) and the data are captured electronically. By comparing the time stamps on the flow data and the valve opening/closing we can determine the exact volume of water applied to every row.

An in-field data logger and radio station used to record and transmit soil moisture sensor data back to the base station.

The water tank, irrigation controller, valves and flow meters used for the soil moisture sensor trial planting.

Control System

Because of the number of sensors we are using in this project and the fact that we are using different types of sensors with varying data outputs, we did not use a traditional control system that growers would be familiar with (e.g., Ranch Systems). The control system used for this project is from ADCON Telemetry, a Vienna-based company with extensive expertise in data collection, radio and cellular communications, and software development. The ADCON system essentially allowed us to create a unique system for this trial and to manage the trial exactly as needed.

Each soil moisture sensor's data is captured by a data logger in the field. That data is transmitted by radio to a base station elsewhere on the property. That base station is connected to a PC that runs the ADCON software and can be programmed to manipulate the irrigation in whatever way we need. The computer is then connected to the Internet, which allows users to access data, make programming changes or simply monitor things from anywhere in the world.

What We've Learned in the First Year

Sensors: The Acclima sensors are a moderately priced sensor option (about $200 each) for those who want to solely monitor soil moisture. These sensors use a technology called time domain transmissometry (TDT) to measure soil volumetric water content (the percentage of soil pore space filled with water). They measure the speed of an electrical pulse through a loop. In principle, the wetter the soil is the slower the pulse moves. One advantage of this technology is that the readings produced are highly stable over a wide range of soil temperature and salinity.

However, the soils we have at Pine Tree Ranch are very gravely and this has proven to be the Achilles heel for the Acclima sensors. The readings they provide are erratic at best and not reliable or consistent enough to be used for turning irrigation on and off. In a finer textured soil or a nursery setting with soilless potting medium this type of sensor can be very reliable, but there are probably very few avocado growers who have the ideal soil type for this type of sensor.

The Irrometer Watermark sensors are very inexpensive — $40 each — and are time tested, reliable technology. Watermark sensors measure soil moisture as tension, which is analogous to how easy or difficult it is for a plant root to extract water from the soil. A soil tension of 0 indicates a saturated soil and the tension increases as the soil dries out. This is the same principle that a tensiometer works on, but the Watermark uses a pair of electrodes in a special matrix to measure changes in electrical resistance due to moisture content. Unlike a tensiometer, the Watermarks are installed permanently and do not need periodic servicing. Like the TDT sensors, they are relatively unaffected by soil temperature and salinity.

The Watermark sensors have proven reliable over the past year. However, that reliability is predicated on a good installation, which can be tricky, especially in gravely soil. If installed

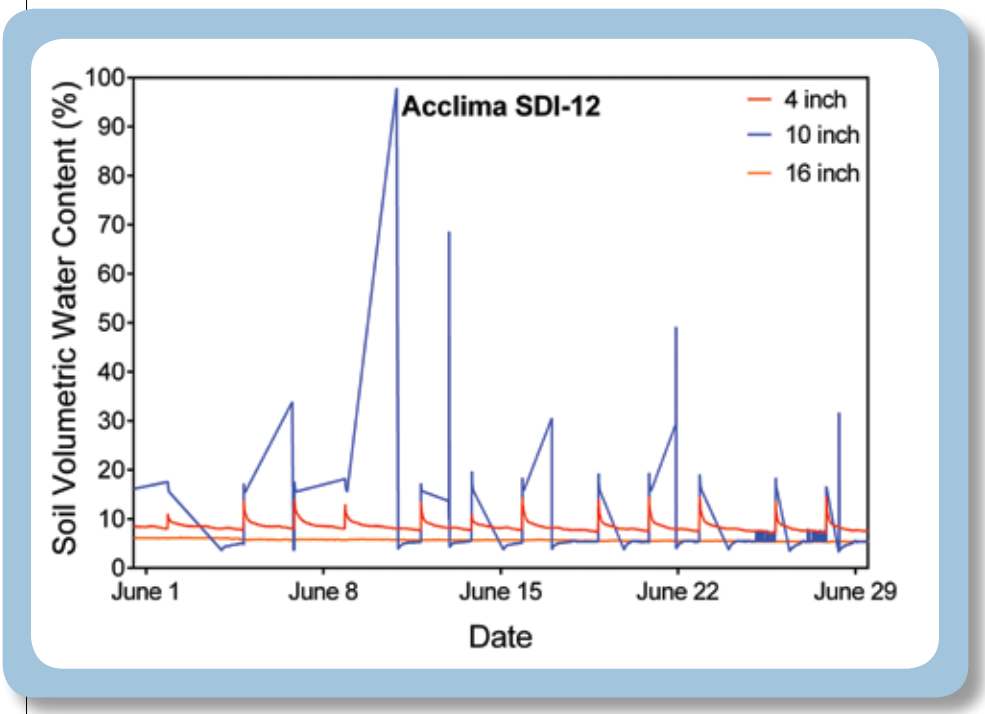
correctly, these sensors should provide years of reliable service. The Watermark sensors provide a lot of flexibility when it comes to reading the data. The sensor leads can be connected to a datalogger and computer system for continuous monitoring, or they can be read manually by periodically connecting a small battery-powered meter to the sensor leads.

The EnviroPro sensors are the Cadillac of sensors with each 40 cm probe costing about $1,000. Although that sounds like a lot, and it is, consider that these probes have 12 sensors built into them — temperature, moisture and salinity at four different depths. If all those sensors were purchased separately the cost would be similar. However, not everyone is going to need or want all that data, but for those who do this type of sensor is a good deal.

The EnviroPros are capacitance probes. That means that, like the previous two types of probes, they use the concept of electrical resistance to determine soil moisture. As soil moisture increases, the capacitance changes, which is directly correlated to water content. The EnviroPro probes have built in technology to correct soil moisture for variation in salinity, and moisture and salinity are both autocorrected for temperature.

Over the past year, the EnviroPros have proven to be the most consistent sensors we have installed. Since they are a straight probe (about 1.5-inch diameter) they can be affected by installation, especially if the soil does not make continuous contact with the length of the probe. Water channeling — i.e., water flowing down the length of the probe between the probe and the soil — also can be an issue and will result in errant readings. Again, this issue can be avoided with careful installation.

Mulch: Agromin generously donated their ES-2 mulch for use in this trial. This is a recycled wood mulch product consisting of 2-inch minus pieces. To date it has been difficult to discern any significant benefit of mulch in terms of soil moisture content. This is likely because the trees are still young, and we did not place the mulch tight against the trees but kept it back about 6 to 8 inches all the way around the tree. Since we have been applying water through a single dripper between the mulch and the tree trunk and the soil moisture sensors are in this same area we may simply be missing the mulch effect at this time. That said, mulch has a myriad of benefits for your trees beyond



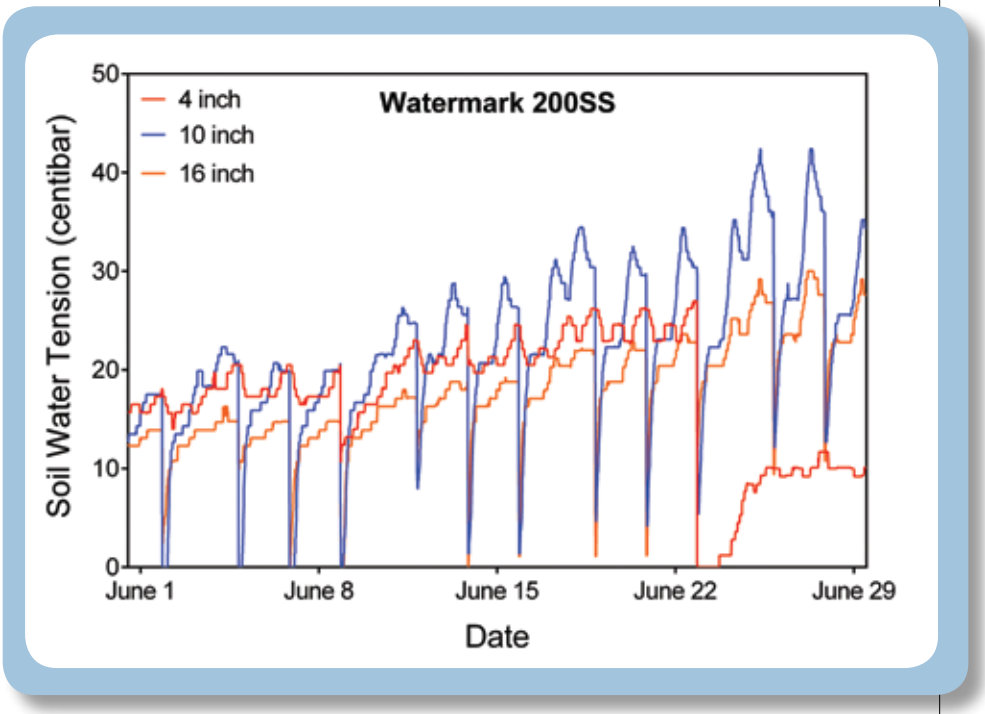
Data from June 2017 for the Acclima SDI-12 soil moisture sensors installed at three different depths at Pine Tree Ranch. Notice the erratic data from the sensor at 10 inches and the lack of movement in the sensor data at 16 inches. This sensor design has proven unsuited to the soil conditions at Pine Tree Ranch.

soil to ensure there are no rocks touching the sensor. However, part of our objective for this project was to find sensors that are user friendly and don't require finicky installation. Making too many modifications to the environment around the sensor — such as sifting out rocks — may give more consistent data, but those data may no longer be indicative of what is happening with the soil the tree is growing in.

One interesting observation that has come from watching the soil moisture conditions over the first year is noting where the trees are using water. The deepest sensors, at 16 inches, showed very little change between irrigations after the soil reached field capacity. This indicates the trees are not taking up much water from these depths. This is well-illustrated in the graph showing the EnviroPro sensor data and also can be seen in the Watermark data. For the simply retaining soil moisture, so it is still a recommended best practice.

One unanticipated side effect of the mulch application was the attraction of coyotes. Within a week of application, we noticed very large volumes of water flowing during irrigation sets. We found several lines chewed, only in the mulched rows. The damage stopped after a couple of weeks once the mulch had aged a bit, but the fresh mulch was apparently very attractive to coyote pups who liked to dig in it and chew on irrigation lines. We have heard of growers having similar experiences, so you should be aware of this potential issue when applying mulch.

Soil Moisture: Samples of the data from all three sensors for June 2017 are shown in the accompanying graphs and demonstrate the inconsistency associated with some of the sensors. Some of this inconsistency could potentially be corrected by removing and reinstalling the sensors, and maybe sifting the



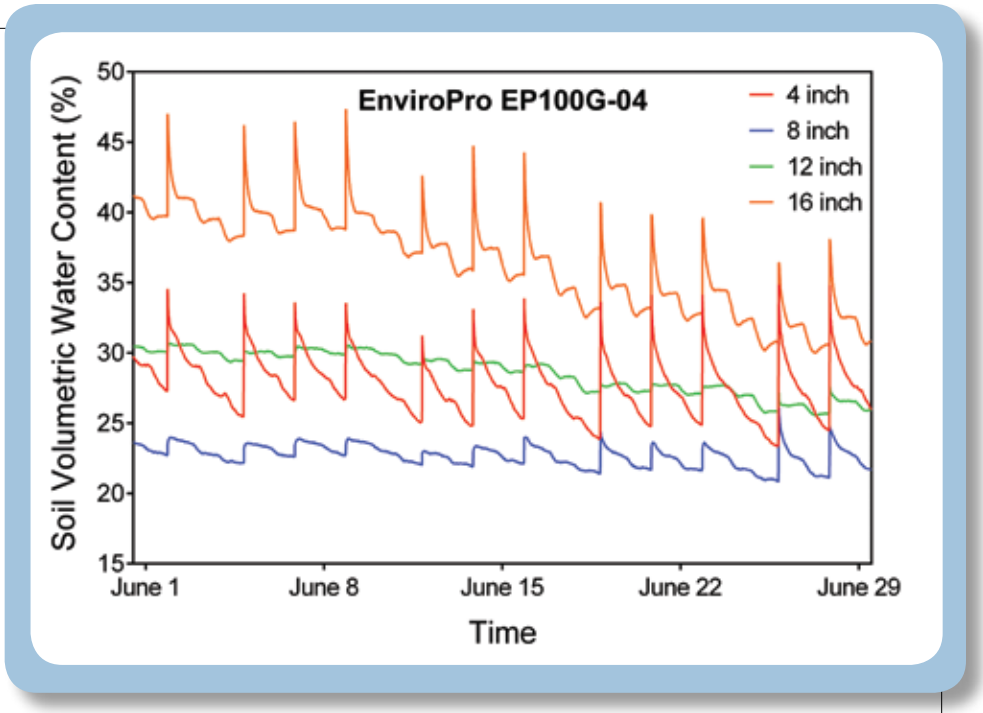
Data from June 2017 for the Watermark 200SS soil moisture sensors installed at three different depths at Pine Tree Ranch. A lower soil water tension value indicates wetter soil. Note the different wet/dry patterns for the sensors at different depths and the changes from early June (cooler temperatures) to later June (warmer temperatures).

EnviroPro data, the higher the volumetric water content percentage, the wetter the soil; whereas for the Watermarks, the lower the soil water tension value, the wetter the soil. The 16-inch depth is clearly the wettest soil in the profile for both of these sensors.

In contrast, sensors at 4 inches showed the greatest fluctuation between irrigations illustrating the influence of solar radiation and wind, as well as tree uptake. This can best be seen in the EnviroPro data where there was about a 10 percent variation in soil moisture between irrigations at 4 inches compared with the other depths that were steadier.

The sweet spot appeared to be in the 8-12-inch range. At these depths, soil moisture tended to be the lowest (lowest volumetric value or highest soil tension), indicating the driest soil. Again, both the EnviroPro and Watermark data demonstrate this. Interestingly, the deepest sensor (16-inches) revealed the water at that depth was available to the tree, but was apparently only accessed during hotter weather, such as occurred in the latter half of June 2017. For the EnviroPro data, the soil volumetric water content begins to drop steadily after about June 15; whereas for the Watermark data the soil tension steadily increases after June 15.

The interesting and important dynamics of soil moisture cannot be observed with the naked eye. Regardless of whether you are in a situation where you can fully automate your irrigation, soil moisture sensors can prove a valuable tool for improving grove management. Soil moisture sensor data allow you to better understand where the water is going when you irrigate, monitor tree water use and know how much water is left in your soil. This information can help you avoid overirrigation, as well as avoid periods of drought stress because of too infrequent irrigation.



Data from June 2017 for the EnviroPro EP100G-04 soil moisture sensors installed at Pine Tree Ranch. This sensor probe has integral sensors at four depths. Higher volumetric water content indicates wetter soil. Note the different wet/dry patterns for the sensors at different depths and the changes from early June (cooler temperatures) to later June (warmer temperatures).

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