By Tim Spann, PhD
Spann Ag Research & Consulting

Irrigation Basics: From the Ground Up

In early June, the California Avocado Commission held a grower field day at Pine Tree Ranch and irrigation was the primary topic of discussion. Irrigation and Water Management Farm Advisors Dr. Ali Montazar and Andre Biscaro discussed work underway to refine the crop coefficient for avocados and how this information is used to calculate irrigation needs. Feedback from some attendees after the meeting was that the information was good but was beyond their current knowledge and understanding of irrigation management. This article is an attempt to define some of the basic terminology used in irrigation management and clarify the underlying principles needed to properly manage avocado irrigation.

Evapotranspiration

Evapotranspiration, commonly abbreviated as ET, is the sum of water lost from the soil by evaporation and transpiration. Evaporative water loss occurs directly from the soil surface and can be reduced by using mulch. Transpiration is water lost through the tree: soil → roots → stems → leaves → atmosphere. The primary drivers of transpiration are air temperature and relative humidity. Higher temperatures and lower humidity increase transpiration and vice versa. There is essentially nothing that can be done to reduce transpiration and doing so by using antitranspirants is not good for the tree since the loss of water by transpiration (essentially evaporation from the leaf surface) is how plants regulate their temperature. When transpiration stops, as happens if the soil becomes too dry, leaves heat up and severe damage, even plant death, can occur.

Reference ET

Directly measuring ET requires the use of expensive analytical equipment and serious number crunching that isn't practical for growers. Fortunately, most states have free tools available that provide growers with reference ET values. Reference ET (abbreviated ETo) is usually calculated using a weather station situated on a grass plot of a specific area and maintained at a certain height. Grass (or sometimes alfalfa) is used as the reference crop because it has been extensively studied and all its biophysical properties needed to calculate ET are well known. In California, ETo values can be obtained from CIMIS (California Irrigation Management Information System), which maintains a network of about 200 weather stations across the state. In addition, there is also Spatial CIMIS data available, which uses satellite data to calculate ETo at a resolution of 2 km (1.25 miles). Spatial CIMIS data is particularly useful for growers who are not close to a physical CIMIS station or for growers who know that the data from their local CIMIS station is not representative of their grove due to their specific microclimate. CIMIS data can be accessed online at https://cimis.water.ca.gov.

Crop ET and Crop Coefficient

CIMIS tells you how much water grass has used in your area for a given period, but you're not growing grass. So, how do you know the actual ET of your avocado trees? The actual ET of your trees is known as the crop ET or ETc. To determine the ETc from ETo, you need what is known as a crop coefficient (Kc). The Kc is a number that adjusts the ETo to ETc. Historically for avocados in California 0.86 has been used as the Kc. This means that if the ETo for a given period is 1.0 inch (i.e., a grass crop used 1.0 inch of water) the ETc for avocados is 1.0 × 0.86 = 0.86. That is, avocados used 0.86 inches of water for the same period that the grass crop used 1.0 inch of water. The problem with the Kc of 0.86 is that it does not account for seasonal variability, aspect of the grove, geographical location (coastal or inland), or other factors that can influence crop water use. The project that Dr. Montazar is conducting is collecting data from 12 different avocado sites in San Diego, Riverside, Orange and Ventura Counties with varying geographic locations and grove aspects. His early data show that the true Kc for avocados ranges from about 0.60 to 0.78 depending on season, grove location and aspect.

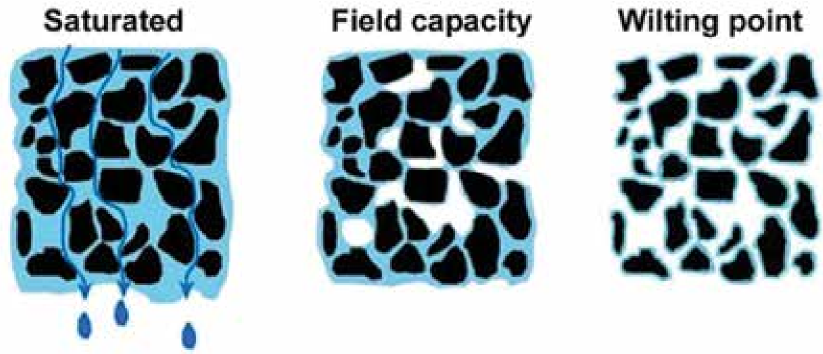

Figure 1. A cartoon showing the three stages of water in a soil. At saturation, all soil pores are filled with water. At field capacity, gravity has drained water from the largest pores. At the wilting point, the remaining water is held very tightly by adhesive forces and the plant cannot extract any more water from the soil. The amount of water in a soil between field capacity and the wilting point is the plant available water.

When To Irrigate

ET only tells you part of the story—how much water your trees are using. But how do you know when to apply water to meet their needs? The answer can be found under your feet, in the soil.

Every soil has a certain water holding capacity, which can be measured using soil moisture sensors. For a comprehensive review of soil moisture sensors please see "Using Soil Moisture Sensors to Improve Irrigation Efficiency" in the Fall 2015 issue of *From the Grove*. Briefly, soil moisture sensors tell you how much water is in the soil. This will either be measured as the percentage of the total volume of water held at saturation (volumetric water content) or as soil tension (a measure of how "difficult" it is for plant roots to extract moisture from the soil).

Course textured soils such as sand, have large pore spaces and have lower water holding capacity than fine textured soils such as clays, which have small pore spaces. However, water holding capacity doesn't tell the whole story. There are three stages of soil moisture that are important to understand: saturation, field capacity and the wilting point. These three stages are illustrated in Figure 1. At saturation, every pore in a soil is filled with water and there is no oxygen in the soil. At field capacity, gravity has pulled the water from the largest pores and the remaining water is held between soil particles by adhesive forces. At field capacity, there is a

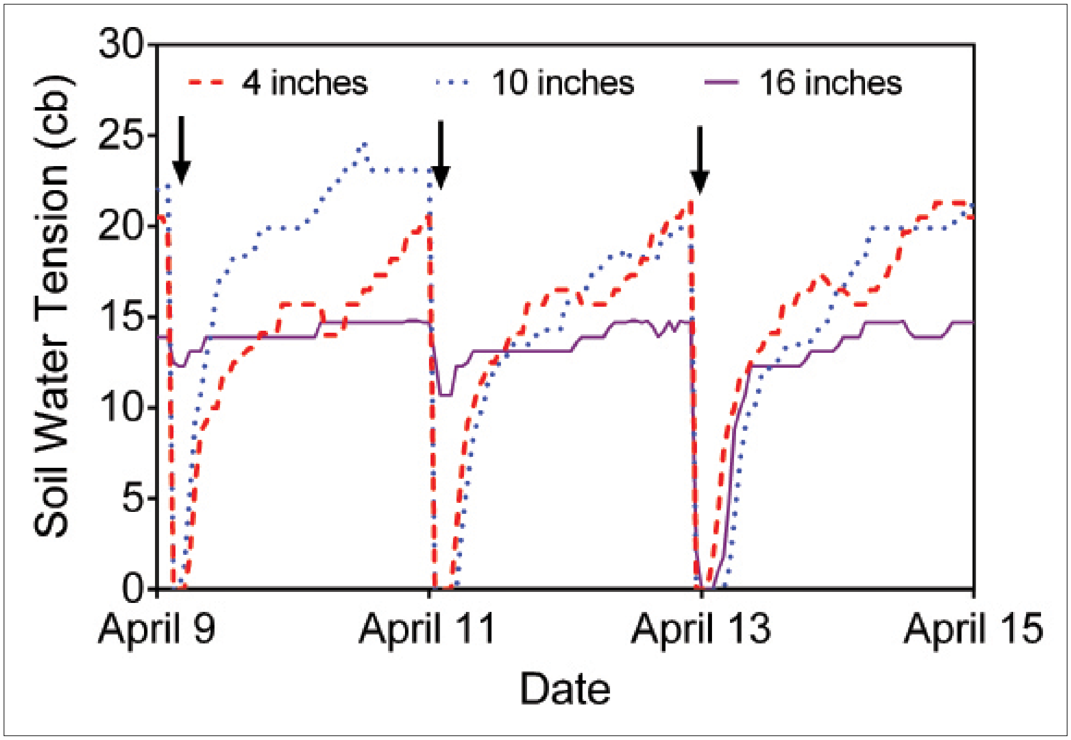

Figure 2. Sample soil moisture data from tensiometers installed at three different depths in a new planting of trees at Pine Tree Ranch.

balance of water and oxygen in the soil and the soil has the most plant available water. At the wilting point the water that remains in the soil, typically in the smallest pores, is held extremely tightly and cannot be extracted by plant roots. Thus, at the wilting point there is no plant available water. The difference in the volume of water between field capacity and the wilting point is the amount of water available in your soil for your trees to use.

In a coarse-textured soil with large pores, there may actually be very little water held at field capacity and, thus, little plant available water. Similarly, a very fine textured soil may hold a lot of water at field capacity, but much of that water can be held so tightly that there is little water available between field capacity and the wilting point. The coarse-textured soil is often called "droughty" because there is so little water available for plant use. Whereas the fine soil would be called "saturated" because managing the fine line between saturation and the wilting point is very hard. This is why monitoring your soil moisture is critical to good crop management.

Soil moisture sensors help you understand how much water your soil can hold so you know how often you need to irrigate. You need to have at least one pair of sensors in each soil type in your grove and in a representative block for each different aspect (north, south, east, west). For groves on hills, it's also a good idea to have sensors at the top and bottom of slopes to be sure your system is not overwatering the downhill trees and underwatering the uphill trees. Lastly, you will want a pair of sensors in blocks of different age trees since young trees have different water requirements than mature trees.

A pair of soil moisture sensors is composed of one sensor placed at a shallow depth (usually about 4 inches) and one near the bottom of the root zone (typically 12-16 inches for avocados). You can add additional sensors in between but they're not critical. The shallow sensor will tell you when to turn on your irrigation. It also lets you know when, during your irrigation set, the water has begun moving into the soil profile. The deeper sensor tells you when you have fully wetted the soil profile. When your deeper sensor reaches your target soil moisture reading you can turn your system off. If you are doing a leaching irrigation to move salts below the root zone, leaching begins when your deeper sensor reaches your target reading.

Figure 2 shows some soil moisture sensor data from tensiometers installed at Pine Tree Ranch on a new planting. Tensiometers measure soil moisture in the form of soil tension—how much force does it take to pull water from the soil, like a root would—and the data are reported in units of centibars (cb). A reading of zero (0) correlates to no tension or soil saturation and numbers increase as the soil becomes drier. For most of our avocado soils, a very dry soil will likely be in the 60 cb range, and it should not be wetter than about 10 cb except following a rain or briefly following a leaching irrigation. In these sample data, the arrows indicate when an irrigation occurred. Note that following the first two irrigations on April 9 and April 11, the 16-inch sensor (solid purple line) did not reach zero, indicating that no leaching took place with these irrigations. Also note the separation between the 4- and 10-inch sensors and the 16-inch sensor prior to irrigation (this is easiest to see at the far-right edge of the graph). This separation is showing the drying of the soil (higher reading) at the shallower depths with more moisture present at the deeper depth (lower reading). Based on CIMIS data, the ETc for April 9-10 was 0.38 inches, April 11-12 was 0.31 inches and April 13-14 was 0.42 inches.

Putting It All Together

You now know how to check CIMIS to determine how much water your trees have used over a certain period. You have also installed some soil moisture sensors to see how much moisture is in your soil. So how do you know when to irrigate? The answer is that you're going to have to do some grunt work. Here's my recommendation on how to figure out when to irrigate.

You will need to record your soil moisture sensor readings on a regular basis. If it's during the summer, you may want to record the readings daily; during the cooler months of spring or fall you may be able to collect the readings every other day or maybe even every third day. Plot the readings so you can see what is happening like is shown in Figure 2. This is relatively easy to do in Microsoft Excel or Google Sheets and you can find excellent tutorials on how to make simple graphs for both programs on YouTube if you don't know how. Along with your soil moisture sensor data, record the ETo and calculate the ETc for the same period. When your soil moisture sensors start to get into the 30 to 40 cb range you probably want to plan an irrigation. You will also want to add up the ETc values you've recorded so you know how much ET it has taken for your sensors to tell you that you need to irrigate.

When you irrigate, watch your soil moisture sensors carefully. How long does it take before you start to see the shallowest sensor reading start to change? When do you see the deepest sensor reading start to change? When your deepest sensor reading begins to change, you can turn the system off. The soil above the deepest sensor will be nearly saturated and that water will drain down past your deepest sensor when you turn your system off.

After a few sessions of recording data like this you will start to see some patterns. What you should see is that the total ETc between irrigations is about the same (assuming you are starting your irrigation at about the same sensor reading each time). This will tell you the water holding capacity of your soil. Maybe you find your ETc totals 1.5 inches between irrigations. Thus, your soil can hold 1.5 inches of water in the root zone. What will change over the season is how long it takes for your trees to use the water your soil can hold. In cooler months maybe you can go 10 days or more between irrigations, but in hot periods maybe you can only go a few days.

Since it is unlikely you will have a set of soil moisture sensors associated with each sprinkler in your grove you will want to make sure your system is in good working order and that each sprinkler is putting out a similar amount of water (system distribution uniformity). But that is another article.