Estimating Orchard Water Use With CIMIS

CIMIS Station
photo here

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Table of Contents

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Water is a precious natural resource in San Diego County that presents farmers with unique problems. Purchased water has always been expensive because much of the supply is imported from Northern California or the Colorado River. Ground water, when it can be found, is often very poor quality.

Another factor to consider is San Diego County's undulating and often very steep terrain. While pumping water up hillsides is not impossible, it can be very difficult and expensive. Despite this adversity, San Diego County was eighth in total agricultural production in the state for 1998. Gross farm income was calculated to be 1.18 billion dollars. Plant agriculture accounted for 1.08 billion dollars or 92 percent of all gross farm income in the county.

Avocado View Narrow photo here

It is obvious from the above figures that San Diego County is an excellent location for crop production. However, it is also well known that people find San Diego County pleasant as well. New houses and developments are springing up at a rapid pace. As the population of the county swells, more demand will be placed upon an already overburdened water supply system. Even if California receives adequate precipitation in the future, permanent water conservation measures are here to stay. The key to agriculture's survival will be making existing water supplies stretch as far as possible. CIMIS can be a useful tool for stretching this shared water supply.

CIMIS is an acronym for the California Irrigation Management Information System. Development of the system began in 1981 as a cooperative effort among the California De-partment of Water Resources, the University of California, the Soil Conservation Service (now the Natural Resource Conservation Service), local water districts and local Resource Conservation Districts. The purpose of the CIMIS network is to provide daily, real time evapotranspiration data for use in irrigation scheduling. While CIMIS can be an effective and simple irrigation scheduling tool, you need to understand it and use it correctly for it to be effective.

Another consideration is the condition of your irrigation system. If your irrigation system has poor emission uniformity or other problems, CIMIS data will be of little use. By following the steps outlined in this booklet, you will be able to determine basic characteristics about your crop, soil and irrigation system. With this information in hand, you can begin scheduling irrigations with CIMIS.

Where to Start

Before CIMIS data can be used in irrigation scheduling, you should know the following information:

- The potential rooting depth of your crop.
- The available water holding capacity of your soil.
- The size of the area wetted by your emitters.
- The flow rate of your emitters.
- Your irrigation system's emission uni formity percentage.
- The management allowable depletion level preferred by your crop.

These six points will allow you to determine the size of the soil reservoir and the irrigation run times needed to fill the reservoir to various levels.

Potential Rooting Depth

Different crops have different depths at which most of their feeder roots reside. Try to avoid placing water below this depth except for leaching salts from the root zone. If irrigation water is constantly pushed beyond your crop's effective rooting depth, nitrogen, other soil nutrients and pesticides can be lost in the water. Through deep percolation, they eventually end up in the ground water. A large amount of ground water pollution has been caused this way. Expensive and scarce irrigation water will be wasted as well!

Table 1. contains the potential rooting depths of common San Diego County tree crops. While most crops will have some roots below the indicated ranges, the roots that do most of the work are fairly shallow. Actual rooting depths under field conditions could be less than indicated on Table 1. if clay pans, shallow soil depth or other restrictive soil characteristics are present.

Crop Potential Rooting Depth	
Avocados	24 Inches
Citrus	36 Inches
Deciduous	36 Inches

Table 1. Potential Rooting Depths of Common San Diego Tree Crops.

Available Water Holding Capacity (AWC)

A soil's ability to hold water depends on its depth to bedrock, other parent materials or restrictive layers such as hard pans and its combination of sand, silt and clay. In San Diego County, soil depths range from 10 inches to more than 60 inches. Soil depth is easy to determine using a soil probe or soil auger. To determine soil depth, sample several locations within each block or field. As a general rule, deeper soils tend to be found on north and east facing slopes and near the bottom of all slopes. Shallow soils tend to be found on south and west facing slopes and near the top of all slopes.

Soil textures range county-wide from sands (low water holding capacities, high infiltration rates) to clay loams and clays (high water holding capacities, low infiltration rates). Table 2. illustrates the available water holding capacities (AWC) of various soil types. The two columns read in inches of water per inch of soil (In./In.), and inches of water per foot of soil (In./Ft.).

Most of the soils in the county fall into four categories: Coarse sandy loams, sandy loams, fine sandy loams and loams. Soil texture is harder to determine than soil depth. However, with a little practice, you can make a good estimation by rubbing a moistened sample of soil between your thumb and forefinger. Sand particles are gritty. Silt is very smooth and feels like flour or talcum powder. Silt is only moderately plastic and sticky when moist. Clay feels very coherent when moist and will be very plastic and very sticky as well. (Plasticity is the ability of soil to be molded or shaped by moderate pressure.)

Most soils are a combination of sand, silt and clay. A soil that does not exhibit the dominant properties of these three components is termed a loam.

Sands, Loamy Sands — Dry samples are loose, single grained and gritty. Individual grains can be easily felt. Squeezed when dry, the sample will fall apart when pressure is released. Loose sand grains remain on fingers. Squeezed when moist, the sample will form a cast that will fall apart when touched. Moist samples will not be sticky and will therefore, not ribbon. Loose and aggregated sand grains will remain on fingers. Light, uneven staining of the fingers will be evident after handling moist samples.

Sandy Loams — Individual sand grains can be seen and felt. Squeezed when dry, the sample will form a cast that will readily fall apart. Aggregated soil grains will break away from the cast. Squeezed when moist, the sample will form a cast with defined finger marks that can be handled carefully without breaking. Sandy loams will form a short, fragile ribbon. Light soil/water staining will remain on fingers after handling moist samples.

Loams — Aggregates of dry samples are hard to break. Moist samples will feel somewhat gritty, yet fairly smooth and will be slightly sticky and slighly plastic. Loams will form a weak ribbon. When squeezed moist, a moist sample will form a cast that can be handled without breaking. Moist samples will cause light water/soil staining of the hands.

Silt Loams — Aggregates in dry samples will break with some difficulty. Moist samples will form a firm ball and will ribbon fairly well. Both dry and moist samples will form a cast that can be handled without breaking.

Dominant Texture	**In./In.[1]**	**In./Ft.[2]**
Sand, Fine Sand	.05 - .08	0.6 - 1.0
Loamy Coarse Sand	.05 - .07	0.6 - .08
Loamy Sand	.06 - .08	0.7 - 1.0
Loamy Fine Sand	.08 - .11	1.0 - 1.3
Coarse Sandy Loam	.09 -.12	1.1 - 1.4
Sandy Loam	.10 - .13	1.2 - 1.6
Fine Sandy Loam	.13 - .15	1.6 - 1.8
Very Fine Sandy Loam	.14 - .17	1.7 - 2.0
Loam	.14 - .18	1.7 - 2.2
Silt Loam	.15 - .20	1.8 - 2.4
Clay Loam	.17 - .21	2.0 - 2.5
Clay	.14 - .16	1.7 - 2.0

Table 2. Water Holding Capacities of San Diego County Soils. [1] Inches of water per inch of soil depth. [2] Inches of water per foot of soil depth.

Clay Loams — Aggregates separate easily, but are hard to very hard to break. Moist samples will be firm, but will ribbon well and will show a good finger-print. Clay loams will be both sticky and plastic and will form a cast with defined finger marks that will bear a great deal of handling. Light soil/water staining will be apparent on fingers.

Clays — Clays are fine textured soils. When dry, clay soils form very hard to extremely hard blocks or prisms. Moist samples are very plastic and very sticky. A moist sample will ribbon very well and will form a very good fingerprint. Some clays are very firm to extremely firm when moist. Light soil/water staining will be evident on fingers.

Wetted Area

The size of the wetted area (along with the potential rooting depth of the crop and the AWC of the soil) will determine the size of the soil reservoir. It is the size of this reservoir that will help you to determine irrigation frequency.

If your wetted area is small, the size of your soil water reservoir will be reduced as well. Thus, the tree's root system has only a small area from which to draw moisture. During warm weather, the reservoir can be depleted quickly. Frequent irrigations will be required to prevent the crop from going into stress.

On the other hand, if your wetted area is large, the trees will spread their roots out over a larger portion of the available soil area. This expanded root zone provides better mechanical stability and helps to make better use of available soil nutrients and moisture. Irrigations that cover a large wetted area are usually longer and less frequent due to a larger soil reservoir.

To estimate the size of your wetted area, you must judge how far laterally water moves away from the emitter. This lateral movement is a combination of: **1.** How far the emitters throw water. **2.** How far laterally water moves once it enters the soil profile. The throw of emitters varies widely from large nozzle brass spinners to small nozzle micro sprinklers. Drip emitters or drip lines have virtually no throw; they depend on the soil for lateral water movement.

The size of the wetted area is best estimated after a full irrigation during the summer or early fall. By this time, residual moisture caused by rainfall should be depleted. This will provide a more accurate determination of the area wetted by the emitters during each irrigation.

Soon after the irrigation set is complete, observe how much of the soil/ leaf litter surface is wet. Using a soil probe, sample

soil probe here

the soil to a depth of about one foot starting at the edge of the wet surface area. Sample at six inch intervals away from the emitter until the soil samples are unacceptably dry at the one foot level. The distance from the emitter to the point where the samples start to dry up will give you the radius of the wetted area. To find the square footage of a circular wetted area, use the formula: Wetted Area = πr^2. $\pi = 3.14$

Flow Rate

Once the AWC and the wetted area have been calculated, determine the flow rate of your emitters. Flow rate information will determine the amount of time needed to fill the soil reservoir to various levels.

A good place to start is with the emitter's factory specification sheets. (They can be obtained from emittter manufacturer or local irrigation supply stores.) Factory specification sheet provide flow rates and other characteristics of the emitters under controlled, laboratory conditions. However, conditions such as these rarely exist in the field. Factors that affect emitter flow include water pressure differences, mixed emitters or nozzles, poor water quality, nozzle orifice erosion and clogged nozzles. Rather than **assuming** your emitters have a particular flow rate, it is better to **know** the flow rate through simple testing.

Flow Rate/Wetted Area/Precipitation Rate Calculations

1. The catch from a single micro sprinkler is 32 ounces in 30 seconds. Determine the sprinkler's flow rate.

a. Multiply 32 ounces times 2 to get ounces per minute. (32 x 2 = 64)

b. Multiply 64 ounces per minute times 60 (minutes in an hour), to get ounces per hour. (64 x 60 = 3840)

c. Divide 3840 by 128 (ounces in a gallon), to get gallons per hour. (3840/128 = 30 gph)

2. The same micro sprinkler is found to have a wetted area radius of 7.5 feet. What is the square footage of the wetted area?

Wetted Area = πr^2

Wetted Area = $3.14 \times 7.5^2 = 3.14 \times 56.25 = 177$ Square Feet

3. What is the precipitation rate of the micro sprinkler in examples #1 and #2?

$$\text{Precipitation Rate} = \frac{\text{Average Nozzle gpm} \times 96.3}{\text{Wetted Area}} = \frac{0.5 \text{ gpm} \times 96.3}{177} = 0.27 \text{ Inches/Hour}$$

To determine your emitter's flow rate,collect the output from a single emitter for a set amount of time. This provides a flow/time relationship such as gallons per minute (gpm), gallons per hour (gph) or liters per hour (lph). The more flow samples you take, the more accurate your data will be. Collect at least ten flow samples per acre. Older irrigation systems and those on steep terrain will require more samples to obtain accurate results. Flow samples should be taken at the inlet, middle and end of several lateral lines. The average of all flows will give a good representation of how the system is perating. Precipitation rate (PR) is the rate at which an emitter applies water over a given area in a given amount of time. Precipitation rates are often reported in inches per hour.

Emission Uniformity (EU)

Emission uniformity (EU) is a measure of an irrigation system's ability to deliver the same amount of water during each irrigation to each tree. A high EU percentage indicates that water is being evenly applied throughout a given area. A high EU is essential to ensure that all plants receive the same amount when fertilizer or other chemicals are being injected into the water. A poor EU makes management difficult because there can be gross over-irrigation and gross under-irrigation occurring in the same field simultaneously.

Determining your irrigation system's EU is relatively easy. Use the same data that was used to find the system's flow rate. Take an average of all the flows collected. Then, find the lowest 25 percent of all the flows collected. Take an average of these flows. Divide the average of the lowest 25 percent of flows by the average of all flows. Multiply this number by 100 to get the emission uniformity percentage.

Management Allowable Depletion (MAD)

Management allowable depletion, or MAD, is the amount of water that the trees are allowed to use between each irrigation. MAD is usually expressed as a percentage of adjusted soil AWC. For example, avocados do well at a 30 percent MAD level. This indicates when 30 percent of the adjusted soil AWC has been used, it is time to irrigate again. If the adjusted AWC in this example is 1.10 inches, then the MAD level would be .33 inches. (30% of 1.10 = .33) The trees would be allowed to use .33 inches of water before the next irrigation. The MAD is set about 30 percent because avocados have a shallow potential rooting depth and are often planted on shallow soils with low water holding capacities. Citrus and deciduous trees have deeper potential rooting depths and are often planted on deeper soils with moderate to high water holding capacities. MAD levels for citrus and deciduous start about 50% and can be pushed higher if soil condidions permit.

System Basics

The CIMIS system is a network of 80 active weather stations located throughout the state. (The system also includes another 24 inactive or closed stations. Historical data has been keptfor these stations for the time they were open.) The majority of these stations are located in agricultural areas. CIMIS weather stations range in location from the town of Tulelake in Siskiyou County near the Oregon border, to the town of Seeley in Imperial County. Locally, there are six CIMIS stations in Coastal Riverside and all through San Diego. These include #49, Oceanside; #62, Temecula; #66, San Diego; #147 Otay Lake; #150, Miramar; and #153, Escondido/ San Pasqual Valley.

CIMIS automated weather stations have instruments that gather data on air temperature, solar radiation, vapor pressure, wind speed and wind direction. All stations in the network are connected via telephone lines to the Department of Water Resource's central computer in Sacramento. This computer gathers data from each station in the network every 24 hours and summarizes it into hourly and daily formats. The data collected is used to compute a mathematical model that simulates evapotranspiration. (A mathematical model is a lengthy mathematical formula or calculation that requires many steps and several sources of data.) The model used by CIMIS is a form of Penman's equation modified by Pruitt and Doorenbos. This model also uses a wind function developed at U.C. Davis. The result is reference evapotranspiration or ETo. ETo is a measure of how much moisture an actively growing, six to eight inch tall cool season pasture would pull from the soil during a given amoun of time.

Terms and Definitions

Although using CIMIS information is relatively simple, some terms can be confusing. The following are definitions of the most commonly used CIMIS terms.

Evapotranspiration — This is the amount of water used by a particular crop plus the amount of water that has evaporated from the surface of the soil.

ETo — ETo stands for reference evapotranspiration. ETo estimates the evapotranspiration of a cool season grass that is not water stressed. All CIMIS stations use ETo as a standard reporting unit. Remember, ETo is "raw" data. Without proper conversion, ETo data is not an accurate account of your crop's water use.

Kc— Kc represents crop coefficients. These coefficients or conversion factors, account for the difference in the evapotranspiration represented by ETo and the crop you are growing. Crop coefficientsare mainly a function of crop growth, stage of development and location (weather conditions) of the crop. Crop coefficients are very low when a crop is young or the weather is mild. An example would be a Kc of .09 for grain sorghum planted in June in the Imperial Valley. This first Kc indicates that while the crop is small, it would use only 9 percent of the daily ETovalue. As the crop matures and the weather heats up, the Kc increases to a peak of 1.19. This would indicate that the crop is using 119 percent of the reported ETo value.

For perennial crops, such as trees and vines there are usually 12 different Kc values. Each of these values will correspond to a month of the year. Crop coefficients are highly variable from area to area and need to be tailored for each individual situation.

ETc— ETc represents estimate crop evapotranspiration. ETo is determined by performing the following calculation:

ETo x Kc = ETc

ETc is a good estimate of how much water a crop uses daily. Once ETo has been converted into ETc, it is ready for use in irrigation scheduling.

Scheduling Irrigations

Once the EU of the irrigation system has been established and the characteristics of the crop and soil are understood, irrigation scheduling can begin. The fundamental idea of irrigation scheduling is to replace soil moisture that has been used by the crop or has evaporated from the soil surface. There are many methods by which to do this. Two common methods of irrigation scheduling are guessing and using the calendar. These two methods can be arbitrary and are often necessary because of the demands placed on the irrigator. Better methods include the use of tensiometers and judging soil moisture content by its feel and consistency. However, daily weather conditions (along with the stage of crop development) ultimately drive daily evapotranspiration. Using CIMIS data will allow you to correlate daily crop evapotranspiration to daily weather conditions.

Water Budget Method

The method of irrigation scheduling most suited for use with CIMIS data is known as the water budget method. The water budget method is similar to balancing a check book. Deposits (irrigations or rain) are placed into the account(soil reservoir). Withdrawals (evapotranspiration) can be made until the account reaches a zero balance (MAD). At this time, another deposit should be made or an overdraft (crop stress), will occur. As noted earlier, critical data about the performance of the irrigation system and characteristics of the crop and soil must be known so that proper irrigation scheduling can begin. The more accurate this data, the more precise your irrigation scheduling can be. The first water budget example is based on a hypothetical avocado orchard in Fallbrook:

Crop: Hass avocados, Block #1.

Spacing: 20' x 20' (400 sq. ft.).

Crop Location: Fallbrook.

CIMIS Station: #62, Temecula. The Temecula CIMIS station was chosen due to its proximity to Fallbrook.

Date: July 1991.

Monthly KC: .55. This number indicates that an average, healthy and mature avocado tree will evapotranspirate 55 percent of the daily ETo value during July.

Potential Rooting Depth: 2 feet. Over 80 percent of an avocado tree's root system resides within the top 24 inches of the soil profile.

Soil Depth: The soil in Block #1 ranged from 20 to 30 inches deep. Irrigations were scheduled around the 20 inch soil depth areas. Irrigations must always be based on the most limiting soil condition(s) present. Here, the most limiting condition is shallow soil depth which has less water holding capacity than other areas in the block.

Soil AWC: 2.2 inches. This analysis was made at the same time the soil depth was determined. Using the feel method, the grower categorized the soil as a sandy loam with .11 inches of water holding capacity per inch of soil depth. When .11 is multiplied by the most limiting soil depth of 20 inches, the AWC figure of 2.2 inches of water per 20 inches of soil depth is found (.11 inches x 20 inches = 2.2 inches).

Wetted Area: 201 square feet. By watching the throw of the emitters and using a soil probe to check soil moisture, the grower found that an average emitter was spreading water in a full circle with a radius of 8 feet from the riser ($\pi \times 8^2 = 201$ sq.ft.). This is roughly 50 percent of the area occupied by a single tree (201 sq. ft. / 400 sq. ft. = 50%).

Adjusted Soil AWC: 1.10 inches. The AWC of the soil needs to be adjusted because in this example, the wetted area (201 sq. ft.), is less than the area occupied by a single tree (400 sq. ft.). To figure the adjusted soil AWC, multiply the wetted area percent by the soil AWC (50% of 2.20 inches = 1.10 inches). Adjusted soil AWC in gallons can be calculated as follows: Adjusted Soil AWC Inches x .623 x Spacing Sq. Ft. (1.10 inches x .623 x 400 sq. ft. = 274 Gallons).

Emitter Flow Rate: 25 gph. The flows of 20 micro sprinklers in Block #1 were taken and then averaged to find the 25 gph figure.

MAD: 30 percent. When 30% is multiplied by the adjusted AWC, MAD gallons are obtained (30% of 274 gallons = 82 gallons).

EU Percentage: 81 percent. The lowest 25 percent of the flows collected when determining the emitter's flow rate were divided by the average of all flow rates taken to determine this figure.

Normal Irrigation Time: 4.0 Hours. With an emitter flow rate of 25 gph, it took 4 hours of emitter run time to fill the MAD level of 30 percent (82 gallons) with the irrigation system operating at 81 percent emission uniformity.

Normal irrigation time is figured in the following way: Divide MAD gallons by the emitter's flow (82 gallons / 25 gph = 3.3 hours). Then, account for the irrigation system's emission uniformity. Divide the hours figure by the EU percentage (3.3 hours /.81 = 4.0 hours).

Here are a couple of points to remember concerning normal irrigation run time:

1. Thick layers of leaf litter or mulch can slow water penetration into the soil profile. This problem can be compounded when using low volume sprinklers and/or short irrigation run times. Always check the soil profile after an irrigation to see if water penetration is adequate. If it is not, you may have to adjust the irrigation run time or possibly change emitters.

2. Repeated short irrigation sets can lead to a build up of salts close to the root zone. Because of this, it is best not to alter your irrigation run time. Instead, it is better to alter the days between irrigations and keep the irrigation run time constant. This way, water and salts penetrate to the same depth in the soil during each irrigation and helps to keep the concentrated salt zone at a constant depth. Keep in mind however, that periodic leaching of accumulated salts from the root zone will be required for satisfactory crop development.

Keeping Track

Now comes the day-to-day task of recording daily evapotranspiration. The following example is set up to deal in gallons rather than inches. This is the preference of most North County grove operators. ETo is entered daily. ETc is figured by multiplying ETo by the monthly Kc. ETc in gallons is figured as follows: ETc Gallons = ETc Inches x .623 x Tree Spacing Sq. Ft.

Give It a Try!

The following two pages contain blank water budget forms. These blanks can be photocopied or you can set up your own form that suits your needs. The first blank is set up to record water loss and gain in inches (like the citrus example). The second blank is set up to record water loss and gain in gallons (like the avocado example).

Sprinkler Pic photo here

Crop:__***Avocados***___ Location:__***Fallbrook***___ CIMIS Station:***Temecula #66***
Date:***July 1991***___ Monthly Kc:____***0.55***_ Soil AWC: ***2.2" in 20"of soil depth***_
Wetted Area:***201*** $\boldsymbol{ft^2}$ ***(50%)*** Adjust AWC: ***274 gallons*** MAD (30% Ad.AWC): ***83 gal***

Date	ETo	Kc	ETc	ETc Gallons	Net Irrigation Gallons	Effective Rainfall Gallons	Remaining Moisture Gallons
7/7	.20	.55	.11	27	83	0	56
7/8	.21	.55	.12	29	0	0	27
7/9	.18	.55	.10	25	0	0	2
7/10	.18	.55	.11	26	83	0	59
7/11	.17	.55	.09	23	0	0	36
7/12	.21	.55	.12	29	0	0	7
7/13	.21	.55	.12	29	83	0	61

Where do these numbers come from?

- The heading information came from the previous page.
- ETo is obtained by contacting a CIMIS Source (see Appendix C).
- Kc is obtained from Appendix A.
- ETc = ETo x Kc
- ETc Gallons = ETc x 0.623 x Tree Spacing[400 ft^2]
- Net Irrigation Gallons = MAD
- Effective Rainfall Gallons = rain inches (local weather page)x 0.623 x Tree Spacing
- Remaining Moisture Gallons = 83 - 27 = 56

Think of it this way. The water in the soil profile is your *Bank*. The ETc Gallons are the *Withdrawls*. The Net Irrigation Gallons and Effective Rainfall Gallons are *Deposits*. The Remaining Moisture Gallons are *Balances*. When the *Balance* is lower than the *Withdrawls*, you must *Deposit* more!

Crop:__***Valencias***__ Location:_***Valley Center*** CIMIS Station:***#153 Escondido***
Date:***July 1990***___ Monthly Kc:____***0.53***_ Soil AWC: ***5" in 36"of soil depth***_
Wetted Area:***254ft² (85%)*** Adjust AWC: ***4.25"*** MAD (30% Ad.AWC): ***2.1"***

Date	ETo	Kc	ETc	Net Irrigation Inches	Effective Rainfall Inches	Remaining Moisture Inches
7/22	.25	.53	.13	2.1	0	1.97
7/23	.25	.53	.13	0	0	1.84
7/24	.26	.53	.14	0	0	1.70
7/25	.26	.53	.14	0	0	1.56
7/26	.26	.53	.14	0	0	1.42
7/27	.27	.53	.14	0	0	1.28
7/28	.27	.53	.14	0	0	1.14

Citrus in Valley Center

This water budget example is set up around a typical North County citrus operation. Evapotranspiration and irrigations are dealt with in inches rather than gallons.

Crop: Valencia oranges, Block #7.

Spacing: 15' x 20' (300 sq. ft.).

Crop Location: Valley Center.

CIMIS Station: #74, Escondido.

Date: July 1990.

Monthly Kc: .53. This number indicates that an average, healthy and mature Valencia orange tree will evapotranspirate 53 percent of the daily ET_o value during July.

Potential Rooting Depth: 3 feet.

Soil Depth: The irrigator found soil depths in Block #7 to be uniform at 50 inches to decomposed granite.

Soil AWC: 5.0 inches. The soil in Block #7 from 0 inches to 12 inches is a sandy loam having .12 inches of water holding capacity per inch of soil depth. From 12 inches to 24 inches, the soil is a loam with .15 inches of water holding capacity per inch of soil depth. Because the effective rooting depth of the crop is 36 inches, soil AWC is not computed beyond this level.

Wetted Area: 254 square feet. By watching the throw of the emitters and using a soil probe to check soil moisture, the irrigator found that an average emitter was spreading water in a circle with a radius of 9 feet from the riser (π x 81= 254 sq.ft.). This is roughly 85 percent of the area occupied by a single tree (254 sq.ft. / 300 sq. ft. = 85%).

Adjusted Soil AWC: 4.25 inches. To figure the adjusted soil AWC, multiply the wetted area percent by the soil AWC. (85% of 5.0 inches = 4.25 inches)

Emitter Flow Rate: 30 gph - The flows of 30 micro sprinklers in Block #7 were taken and then averaged to find the 30 gph figure.

MAD: 50 percent. When 50% is multiplied by the adjusted AWC, MAD inches are obtained (50% of 4.25 inches = 2.1 inches).

EU Percentage: 75 percent. The lowest 25 percent of the flows collected when determining the emitter's flow rate were divided by the average of all flow rates taken to determine this figure.

Normal Irrigation Time: 17.5 Hours. With an emitter flow rate of 30 gph, it took 17.5 hours of emitter run time to fill the MAD level of 50 percent (2.1 inches) with the irrigation system operating at 75 percent emission uniformity.

Normal irrigation time is figured in the following way: Multiply the tree spacing area square feet by .623. Then, multiply this product by MAD inches (300 sq. ft. x .623 x 2.1 inches = 393 Gallons). Divide 393 gallons by 75 percent to account for the irrigation system's emission uniformity (393 gallons / .75 = 524 gallons). Then divide 524 gallons by the emitter's flow rate of 30 gph to obtain normal irrigation time (524 gallons / 30 gph = 17.5 hours).

Points to Remember

Here are a few points to remember when figuring your soil water balance:

1. **NEVER** draw your soil water balance into a negative (-) state! This is the equivalent of bouncing a check. Extended periods of time at a negative soil water balance can cause severe yield reductions or possible crop failure. (While moisture stress can be used as a yield enhancing technique in some crops, it is normally very undesirable.) The key here is to never draw more water out of the soil than you have put into it.

2. Before starting water budget irrigation scheduling, be sure that your orchard's root zone is fully moist (field capacity), down to the potential rooting depth.

3. Always remember to account for the emission uniformity of your irrigation system when calculating the amount of gross irrigation water to be applied to your crop. Trees require irrigation amounts in terms of net water. However, since no irrigation system operates at 100 percent uniformity, water must be over applied to be sure all trees are receiving the minimum amount. The lower the EU percentage, the greater the irrigation application must be. Gross water is figured by dividing the net water required by the emission uniformity of your irrigation system: 1.50 inches net water/.75 (75% emission uniformity) = 2.0 inches gross water applied.

4. CIMIS is only one of many tools that can aid irrigation scheduling. It is not fool proof. CIMIS should not replace constant visual observations of orchard and soil conditions. Continue monitoring soil moisture conditions with a soil probe, shovel or tensiometers while CIMIS data is being employed.

5. Account for your tree's daily ET_c when figuring your soil water balance after an irrigation or rainfall. Evapotranspiration continues during periods of irrigation and rainfall. Daily ET_c must be subtracted from the net amount of water applied (irrigation or rainfall) before it is added to the remaining moisture column.

6. Rainfall must be adjusted for effectiveness. A good rule of thumb is to include only 50 percent of total rainfall collected in the effective rainfall column: 1.0 inch total rainfall x .50 (50% effectiveness) = .50 inch net rainfall. If the effective rainfall total is greater than the adjusted soil AWC, use the smaller of the two figures. In other words, you cannot draw more water out of a reservoir than its total capacity.

In Conclusion

Why take the time to use CIMIS? The answer is simple. The utilization of CIMIS data in irrigation scheduling can help you to use water more effectively. By helping to eliminate water wasted by deep percolation, surface runoff, subsurface runoff and surface evaporation, you can lower your water bill. Proper irrigation scheduling can also provide other dividends such as cutting energy use (to run pumps, etc.), optimizing fertiizer use and in some cases, increase crop yields. This means more profit and a better bottom line.

Date	ETo	Kc	ETc Inches	Net Irrigation Inches	Effective Rainfall Inches	Remaining Moisture Inches
Date	ETo	Kc	ETc	Net Irrig.	Effective Rain	Remain. Moisture

Date	ETo	Kc	ETc Inches	ETc Gallons	Net Irrigation Gallons	Effective Rainfall Galloms	Remaining Moisture Gallons
Date	ETo	Kc	ETc	ETc Gallons	Net Irrig. Gallons	Effect. Rain	Rem. Moisture

Appendix A: Crop Coefficients (Kc)

Crop coefficients are the "keys" that allow daily ETo information to be converted into a useful form. While these crop coefficients will get you into the ball park, they should not be considered accurate for every circumstance. Factors such as crop condition, slope aspect and varying micro climates may mean that given crop coefficients need to be adjusted up or down to function correctly.

The first set of coefficients comes from a Soil Conservation Service publication entitled "Irrigation Water Requirements." These coefficients cover avocados, citrus and deciduous tree crops (with and without cover crops).

The second set of avocado coefficients comes from UC Cooperative Extension specialist Jewell Meyer. These avocado coefficients are unpublished and are based on data taken at the University's avocado irrigation plot in Corona. These coefficients reflect a 20% increase over the current UC Cooperative Extension avocado coefficients. The higher coefficients are recommended because of higher yields and earlier sizing of fruit.

	Avocados[1]	Citrus[2]	Grazed Pasture[2]	Ungrazed Pasture[2]	Open Water Surfaces[2]
January	.27	.63	.90	1.0	1.1
February	.42	.66	.90	1.0	1.1
March	.58	.68	.90	1.0	1.1
April	.70	.70	.90	1.0	1.1
May	.78	.71	.90	1.0	1.1
June	.81	.71	.90	1.0	1.1
July	.77	.71	.90	1.0	1.1
August	.71	.71	.90	1.0	1.1
September	.63	.70	.90	1.0	1.1
October	.54	.68	.90	1.0	1.1
November	.43	.67	.90	1.0	1.1
December	.30	.64	.90	1.0	1.1

	Deciduous (No Cover Crop)[3]	Deciduous(With Cover Crop)[3]
January	.17	.63
February	.25	.73
March	.40	.86
April	.63	.98
May	.88	1.09
June	.96	1.13
July	.95	1.11
August	.82	1.06
September	.54	.99
October	.30	.90
November	.19	.78
December	.15	.66

	Avocados[4]
January	.40
February	.50
March	.55
April	.55
May	.60
June	.65
July	.65
August	.50
September	.55
October	.55
November	.55
December	.55

1. USDA/Soil Conservation Service. Technical Release #21 - Irrigation Water Requirements. September 1970
2. University of California Cooperative Extension leaflet #21427, 1987.
3. USDA/Soil Conservation Service. Technical Release #21 - Irrigation Water Requirements. September 1970
4. Jewell Meyer, UC Cooperative Extension. Corona Foothills Avocado Irrigation Trial, 1993.

Appendix B: Juvenile/Stumped Trees

Normal crop coefficients assume mature trees and full ground shading conditions. Since juvenile, stumped or newly grafted trees are initially growing under less than fully shaded conditions, adjustment of their ETc is required.

Example: Two year old avocado trees are planted on 15' x 20' centers. The average radius of the tree's canopies are 3 feet. The Temecula CIMIS station reported the ETo for July 19 as 0.26. The July crop coefficient for avocados is 0.55. What is the adjusted ETc for these juvenile trees?

1. Calculate the shaded area of a single tree. (Shaded Area = πr^2) In this case, 3.14 x 3^2 = 28 square feet of shaded area.

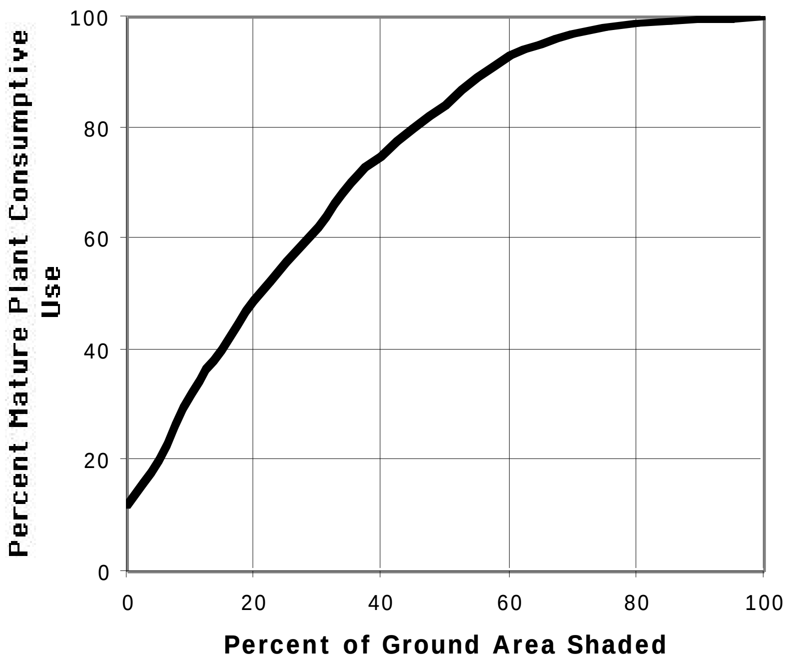
2. Calculate the area occupied by a single tree. This is simply the tree spacing measurement multiplied together: 15 feet x 20 feet = 300 square feet.

3. Percentage of the area occupied by a single tree that is shaded: 28 ft^2 /300 ft^2 = 9 %.

4. Calculate the ETc for mature avocado trees: .26 (ETo) x .55 (Kc) = .14 (ETc).

5. Refer to the following chart. Draw a line straight up from the Percent of Ground Area Shaded range (9 percent), to the point where it intersects with the consumptive use curve. This intersection point corresponds to 31 percent on the Percent Mature Plant Consumptive Use range. This signifies that the juvenile avocado trees in this example are using 31 percent of mature tree ETc. The adjusted July 19 ETc for these juvenile trees would be calculated as follows: .14 (Mature Tree ETc) x .31 (Percent Mature Plant Consumptive Use) = .04 (Adjusted Juvenile Tree ETc).

Note - Juvenile/stumped trees can grow very quickly during warm weather. This growth means more leaves, which in turn means a larger shaded area. You may need adjust crop coefficients several times during one growing season.



Appendix C: CIMIS Sources

California Department of Water Resources

Division of Planning and Local Assistance

1020 Ninth Street, 3rd Floor

Sacramento, CA 95814

(800) 922-4647

http://wwwdla.water.ca.gov/cimis.html

DWR can provide growers with passwords and login identifications that allow access to the CIMIS central computer. With a personal computer and a modem, you can obtain daily ETo data, CIMIS weather station information, CIMIS news and other valuable information.

Mission Resource Conservation District

P. O. Box 1777

990 East Mission Road

Fallbrook, California 92088-1777

(760) 728-1332 Evapotranspiration Line (800) 339-9954

http://www.tfb.com/~missnrcd/cimisweek.html

With funding from the San Diego County Water Authority, Mission Resource Conservation District (MRCD) operates a toll-free evapotranspiration line. ETo data from stations #49, Oceanside; #62, Temecula; #66, San Diego; #147 Otay Lake; #150, Miramar; and #153, Escondido/San Pasqual Valley, are presented daily for the previous seven days. MRCD's evapotranspiration line is updated Monday through Friday. ETo data for Saturday and Sunday are presented on the following Monday.

The Avocado Commission

http://www.avocado.org

The Avocado Commission operates a website that calculates gallons per day requirements, customized to your input data.

North County Times

232 South Main Street

Fallbrook, California 92028-2850

(760) 728-6116

The North County Times newspaper reports CIMIS data from the previous week every Thursday in the Local section. Evapotranspiration data information from station #153 , Escondido/ San Pasqual Valley is reported in the form of ETo. ETc data is also reported for avocados, citrus, deciduous and pasture/turf. Questions regarding this information should be directed to Mission Resource Conservation District at (760) 728-1332.

Appendix D: CIMIS Help

While the aim of this booklet was to be as comprehensive as possible, every situation cannot be accounted for. Thus, you may need assistance with such things as soil type determination, irrigation system performance, etc. The following agencies can provide help to growers with the various aspects CIMIS use.

Mission Resource Conservation District
P.O. Box 1777
990 East Mission Road
Fallbrook, California 92088
(760) 728-1332

Assistance Offered: Help with all aspects of CIMIS irrigation scheduling, irrigation system evaluations, soil and water conservation education.

USDA/Natural Resource Conservation Service
Escondido Office
332 South Juniper St., Suite 110
Escondido, California 92025
(760) 745-2061

Assistance Offered: Soil type determinations, land use capability determinations, soil erosion control and prevention measures.

California Department of Water Resources

P.O. Box 942836		P.O. Box 29068
Sacramento, California 94236-0001	OR	Glendale, California 91209-9068
(916) 322-6820		(818) 543-4600

Assistance Offered: General CIMIS network information.

U.C. Cooperative Extension

Assistance Offered: The University of California Cooperative Extension offers for sale publications that can aid growers in using CIMIS evapotranspiration data. Useful publications include:

#21454 - Irrigation Scheduling: A Guide for Efficient On-Farm Water Management.

#21426 - Determining Daily Reference Evapotranspiration (ETo).

#21427 - Using Reference Evapotranspiration (ETo) and Crop Coefficients to Estimate Crop Evapotranspiration (ETc) for Agronomic Crops, Grasses and Vegetable Crops.

#21428 - Using Reference Evapotranspiration (ETo) and Crop Coefficients to Estimate Crop Evapotranspiration (ETc) for Trees and Vines.

Information regarding publications can be obtained by contacting:

ANR Publications		U.C. Cooperative Extension
University of California	OR	5555 Overland Avenue, Building 4
6701 San Pablo Avenue		San Diego, California 92123
Oakland, California 94608-1239		(858) 694-2849

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San Diego County Water Authority

The information presented in this publication can also be found at
http://www.tfb.com/~missnrcd/cimisinstruct.html

Location is Everything

Deciding which CIMIS station to use is important. Try to use the station nearest to your crop. If your crop is being grown between two stations, take an average of both stations and use accordingly.

Station #	**Station Name**	**MRCD Classification**	**Nearby City/Town**
49	Oceanside	Coastal	Oceanside
County	**Latitude**	**Longitude**	**Elevation**
San Diego	33 deg 15' 22"N	117 deg 19' 11"W	50 ft
Owner		**Start Date**	**Maintenance**
San Diego Gas and Electric		03-11-1986	DWR: Southern District Oceanside Golf Course

Station #	**Station Name**	**MRCD Classification**	**Nearby City/Town**
62	Temecula	Inland	Temecula
County	**Latitude**	**Longitude**	**Elevation**
Riverside	33 deg 29' 25"N	117 deg 13' 20"W	1420 ft
Owner		**Start Date**	**Maintenance**
DWR		11-25-1986	DWR: Southern District

Station #	**Station Name**	**MRCD Classification**	**Nearby City/Town**
66	San Diego	Coastal	San Diego
County	**Latitude**	**Longitude**	**Elevation**
San Diego	32 deg 43' 29"N	117 deg 08' 05"W	370 ft
Owner		**Start Date**	**Maintenance**
DWR		04-27-1989	DWR: Southern District

Station #	**Station Name**	**MRCD Classification**	**Nearby City/Town**
147	Otay Lake	Intermediate	Otay
County	**Latitude**	**Longitude**	**Elevation**
San Diego	32 deg 37' 48"N	116 deg 56' 18"W	580 ft
Owner		**Start Date**	**Maintenance**
Metropolitan Water District		04-15-1999	Otay Water District

Station #	**Station Name**	**MRCD Classification**	**Nearby City/Town**
150	Miramar	Intermediate	Miramar
County	**Latitude**	**Longitude**	**Elevation**
San Diego	32 deg 53' 09"N	117 deg 08' 31"W	445 ft
Owner		**Start Date**	**Maintenance**
DWR		04-23-1999	City of San Diego

Station #	**Station Name**	**MRCD Classification**	**Nearby City/Town**
153	Escondido/SPV	Inland	San Pasqual Valley
County	**Latitude**	**Longitude**	**Elevation**
San Diego	33 deg 04' 52"N	116 deg 58' 33"W	390 ft
Owner		**Start Date**	**Maintenance**
Metropolitan Water District		04-26-1988	City of San Diego

NOTES

Useful Conversions

1 Acre = 43,560 Square Feet
1 Cubic Foot of Water = 7.48 Gallons
1 Gallon of Water = 231 Cubic Inches

1 Acre Foot of Water = 325,829 Gallons
1 Acre Inch = 27,152 Gallons
1 Gallon = 3785 Milliliters

1 gallon of water will cover 1 square foot of open surface to a depth of 1.60 inches.

1 inch of water covering 1 square foot of open surface contains .623 gallons.

Conversion from inches of water used per day (ETc) to gallons of water used per tree per day is as follows:

1. **Measure:** The distance between trees and multiply to calculate the area per tree.

   Example: If your trees are 20 feet apart, 20' x 20' = 400 square feet.

2. **Multiply:** .623 x Daily ETc x area (in square feet).
   Example: .623 x .15 x 400 = 37 gallons\tree\day.

3. **Account:** For the emission uniformity of your irrigation system. Divide the gallons\tree\day figure by the emission uniformity percentage of your system. Most well maintained sys tems operate at or near 75 percent emission uniformity.

   Example: 37/.75 = 49.3 gallons\tree\day adjusted for 75% emission uniformity.

The above method can also be used to calculate the amount of effective rainfall in gallons:

20' x 20' Tree Spacing (400 Square Feet Per Tree)

.50" of Effective Rainfall

.623 = Inches to Gallons Conversion Factor

400 x .50 x .623 = 125 Gallons of Effective Rainfall Per Tree