# *Re-evaluating Avocado Water Needs:*

## What is the True Avocado Crop Coefficient?

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Dr. Ali Montazar, UC Irrigation and Water Management Advisor, recently completed a three-year study to develop more accurate crop water use data and crop coefficients for avocados. This project was funded by the California Avocado Commission and the California Department of Food and Agriculture. Before discussing the results of Dr. Montazar's work it is important to understand how crop water needs are calculated and what crop coefficients are.

### *Understanding the Crop Water Cycle*

Any plant grown in soil is part of a water cycle. This cycle includes water coming into the system through rainfall, irrigation and water lost from the system through evapotranspiration. Evapotranspiration, commonly referred to as ET, is the water that leaves a crop system through evaporation from the soil surface and transpiration — the movement of water from the soil, through the plant and out to the atmosphere from the surface of leaves (Figure 1). The primary environmental factors that affect ET are air temperature, humidity and solar radiation (which is affected by slope and aspect). Crop factors that affect ET are canopy density, plant height, row orientation and the physiology of the crop itself.

In an agricultural setting, our goal as managers is to supply enough water to our crops to meet the ET demands of the crop — $ET_c$. This is done by estimating $ET_c$ over a period, e.g. one week, deducting any rainfall that occurred during that period, and supplying enough irrigation to meet the difference between $ET_c$ and rainfall. Sounds simple, right?

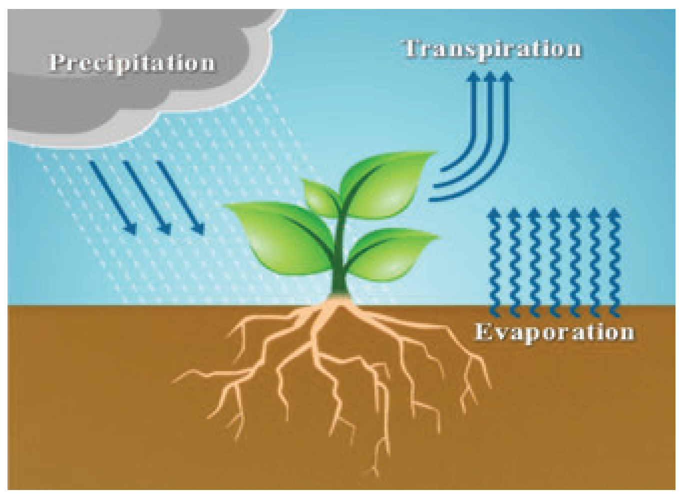


*Figure 1. A graphic showing how water loss from soil evaporation and plant transpiration combine to equal evapotranspiration. Credit: Victor Yee, Oregon State University.*

### *How is $ET_c$ Calculated?*

Direct measurement of $ET_c$ involves expensive equipment and elaborate mathematical equations (Figure 2). To get around this, systems of standardized weather station networks are used to calculate a reference ET ($ET_o$) from which $ET_c$ can then be calculated. In California, this system of weather stations is the California Irrigation Management Information System (CIMIS). CIMIS uses a combination of ground-based weather stations and satellite data to provide more accurate information for areas in between physical stations. But what is this reference ET?

For these weather station networks to provide reliable data, they must be installed within a standardized crop so their data can be reliably compared. In California, this reference crop is irrigated grass or alfalfa of at least  four acres in area and maintained at a specific height. If you maintain a golf course this is good data to have, but for other crops it is essentially useless unless you can calculate how much water your crop uses relative to grass. To do this, we need a crop coefficient.

### *Crop Coefficient*

A crop coefficient, $K_c$, is a value used to calculate your crop's water use relative to the grass reference crop. For example, if your crop has a $K_c$ of 0.50 — that is to say your crop uses 50% of the water of the grass reference crop — and your weather station data says that $ET_o$ for the past week was 1 inch, then your $ET_c$ was 0.5 inches of water in the past week ($ET_o \times K_c = ET_c$). If there was no rainfall during that week then you need to supply 0.5 inches of water through irrigation. How efficient your use of water is, is directly related to the accuracy of the $K_c$ you are using. If your $K_c$ is too low, you will be under irrigating your crop. If your $K_c$ is too high, you will be over irrigating your crop.

For avocados, a detailed study of the actual $K_c$ for Hass has never been undertaken in California, or virtually anywhere else in the world for that matter. Irrigation calculators, like the one available on AvocadoSource.com, provide $K_c$ values that have been developed from grower experience or maybe some limited data sets. For example, in the irrigation calculator tool on AvocadoSource, you can select from "California (new values)" or "California (old values)" for the $K_c$. The California new values are fixed at 0.86 for every month of the year. The California old values are variable from a low of 0.40 in January to a high of 0.65 in July. That's a huge difference. Which one is correct? Is either correct? Given the high cost of water and how critical it is to producing a good crop, we had to do better.

### *Measuring Actual Hass Avocado $K_c$ in California*

Dr. Montazar's project looked to measure the actual water use of Hass avocado trees under a variety of climatic zones that represented the main avocado production areas of Southern California. His project had 12 sites in San Diego, Riverside, Orange and Ventura Counties. These sites represented a diverse range of climates (hot inland valleys to cool coastal areas), planting densities, varying slope and elevation, varying canopy sizes and management practices, as well as different soil types, water sources and irrigation practices.

At each site an elaborate array of sensors was set up from the soil, to within the tree canopy, to above the canopy (Figure 2). These sensors measured parameters such as soil moisture


*Figure 2. Images depicting the equipment set up in avocado orchards to measure actual avocado ET. The images show (a) a tower used to mount sensors, (b) an aerial view of a tower in an avocado orchard, (c) net radiometer and thermocouples mounted above the canopy, (d) a sonic anemometer and temperature and relative humidity sensors, and (e-g) various soil moisture sensors and data loggers. Credit: Dr. Ali Montazar, University of California Cooperative Extension.*

**Table 1. General information about experimental avocado orchard sites.**

| Experimental Site | Age of trees (in 2022) | Tree spacing (ft x ft) | Microsprinkler flow rate (gal/hr) | Elevation (ft above mean sea level) | Row aspect and slope (%) | Water source | Location |
|---|---|---|---|---|---|---|---|
| AV1 | 11-years | 20 x 20 | 25 | 757 | South, 44% | District | San Pasqual Valley |
| AV2 | 8-years | 15 x 18 | 9.5 | 1,490 | Southeast, 20% | District | Temecula |
| AV3 | 5-years | 15 x 19 | 7.5 | 450 | Southwest, 12% | Reclaimed | Irvine |
| AV4 | 5-years | 12 x 14 | 8 | 164 | Southwest, 3% | District and groundwater | West Saticoy |
| AV5 | 18-years | 18 x 18 | 10.5 | 472 | South 4% | Groundwater | Santa Paula |

Table adapted from Montazar, A. et al. 2025. Quantifying evapotranspiration and crop coefficients of California 'Hass' avocado affected by various environmental and plant factors. *Agricultural Water Management* 313:109481.

content, soil temperature, canopy temperature and humidity, air temperature and humidity, solar radiation above and below the canopy to calculate solar energy absorption, wind speed and rainfall. In addition, drones were used to map the canopy of the trees surrounding each sensor station and generate an accurate map of canopy density, volume and tree height.

For simplification, data from five sites that represent the range of site diversity and growing environments will be used for discussing the results of this study. The characteristics of these sites and their general growing region are shown in Table 1. Briefly, these sites represent tree canopy coverage from 44.2% to 88.7%, tree age at the start of the study from 5- to 18-years-old, planting density from 120 to 260 trees per acre, and water sources representing district, ground and reclaimed sources.

Across study sites and years, the actual annual measured $ET_c$ ranged from 28 to 40.5 inches of water. The $K_c$ values varied spatially (from site to site) and temporally (across the seasons). The monthly average $K_c$ was greatest during flower bud development, flowering and fruit set, compared with later fruit development phases, ranging from 0.7 to 0.85 over the year at the site with the highest values (site AV1) and just 0.55 to 0.73 at the site with the lowest values (site AV4). In 2024, this translated to a seasonal difference of 11.5 inches of water requirements between these two sites.

Actual daily $K_c$ values followed a similar pattern across all 12 study sites over the three-year study period with the daily actual $K_c$ being more variable in late fall and winter compared with spring and summer. This makes sense since in fall and winter the weather is more variable with cool, wet periods and warm, dry periods. At site AV1, the actual daily $K_c$ values ranged from 0.61 to 1.10, averaging 0.75 over the entire study period (992 days). In comparison, at site AV3 the actual daily $K_c$ values ranged from 0.43 to 1.06, averaging 0.66 during the study period. This large variability illustrates why using a constant $K_c$ value for the entire season is not a good idea.

Using daily $K_c$ values for irrigation needs calculations isn't practical since most growers are not managing their irrigation daily. Thus, it's more practical to integrate the daily values by month and use monthly average $K_c$ values for calculating irrigation needs. Figure 3 shows the average monthly $K_c$ values for the five representative study sites based on the three

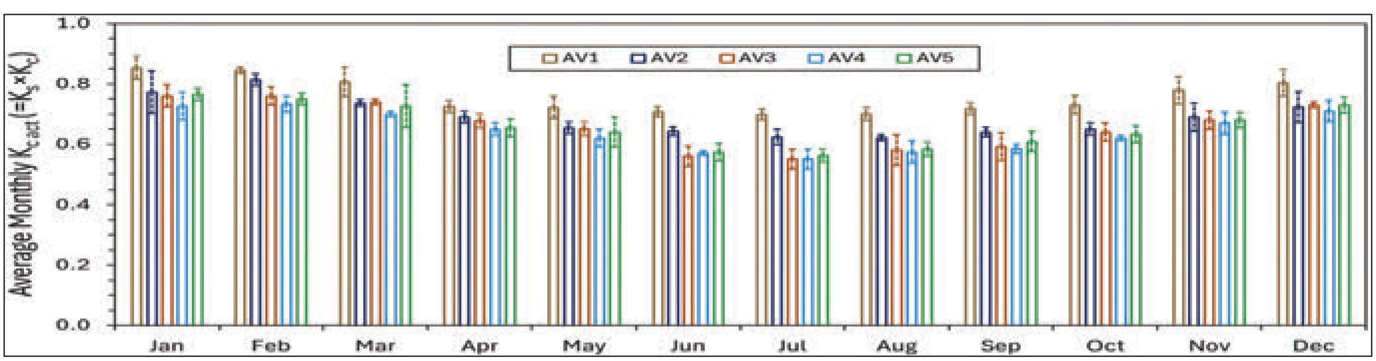


*Figure 3. Mean monthly actual crop coefficient ($K_c$) values at the five study sites presented in this article (see Table 1 for a detailed description of the sites). Credit: Dr. Ali Montazar, University of California Cooperative Extension.*

**Table 2. Mean monthly actual crop coefficients (Kc) for five different 'Hass' avocado orchards that represent the range of growing climates in Southern California.**

| Month | Location | | | | |
|---|---|---|---|---|---|
| | San Pasqual Valley | Temecula | Irvine | West Saticoy | Santa Paula |
| January | 0.85 | 0.77 | 0.75 | 0.72 | 0.76 |
| February | 0.85 | 0.81 | 0.76 | 0.73 | 0.75 |
| March | 0.80 | 0.74 | 0.74 | 0.70 | 0.72 |
| April | 0.73 | 0.69 | 0.68 | 0.65 | 0.66 |
| May | 0.73 | 0.66 | 0.65 | 0.63 | 0.64 |
| June | 0.72 | 0.65 | 0.57 | 0.58 | 0.59 |
| July | 0.70 | 0.63 | 0.55 | 0.55 | 0.57 |
| August | 0.70 | 0.64 | 0.59 | 0.58 | 0.59 |
| September | 0.71 | 0.65 | 0.60 | 0.59 | 0.62 |
| October | 0.73 | 0.66 | 0.65 | 0.62 | 0.64 |
| November | 0.78 | 0.71 | 0.70 | 0.69 | 0.64 |
| December | 0.81 | 0.73 | 0.74 | 0.70 | 0.74 |

Data derived from Figure 3.

years of study data. This is a good visual representation of how the five sites differ from one another within a given month and seasonally during the year. Table 2 shows the approximate values corresponding to the bars in Figure 3. For all sites, $K_c$ is highest from November through March and lowest from July through September.

At first, it doesn't seem right that $K_c$ is higher in winter than summer since we know the trees are using more water during the summer than winter. However, we must remember that $K_c$ values are relative to the grass reference. So, what this tells us is that during the summer grass uses a tremendous amount of water — as much as 1.5 inches per week in Southern California — and avocado trees only use about 60% to 70% of that amount. In contrast, in winter grass uses less water than in summer — about 0.5 inches per week. Avocados also use less water in winter, but as a percentage of the water used by the grass reference crop, they need a higher amount, 70% to 85%. But interestingly it always takes less water to grow an acre of healthy, nutritious avocados than an acre of grass, no matter the time of year.

### *How Can You Use This Information to Improve Your Irrigation?*

One thing that should be abundantly clear from this trial is that every avocado orchard is unique and has a unique $K_c$. However, it's simply not practical to develop $K_c$ values for every orchard. You should be looking at these data and ask yourself which of these study sites is most like my orchard? Chances are, unless you're adjacent to one of the study sites, you're going to be a combination of a couple of sites.

If your orchard is inland with little coastal influence, you probably want to use values like sites AV1 and AV2. If you're more coastal in San Diego County, you're probably more like site AV3. Coastal growing regions in the north are most likely closer to site AV4 and inland areas in the north are probably going to be some combination of sites AV5, AV3 and AV2.

As time goes on, these values will continue to be refined, and more concrete recommendations will be developed. Dr. Montazar is now working on a new project to validate these $K_c$ values developed in this study, and to determine the effectiveness of various irrigation regimes on fruit quality and yield, as well as water use efficiency and water conservation.

*This article is a brief synopsis of the full study conducted by Dr. Montazar. His full research report can be found at https://www.californiaavocadogrowers.com/research-library/developing-tools-and-information-crop-water-use-and-effective-irrigation. Additionally, further details can be found in the publication, "Quantifying evapotranspiration and crop coefficients of California 'Hass' avocado affected by various environmental and plant factors," available at https://www.sciencedirect.com/science/article/pii/S0378377425001957.*