HEALTHY FOOD SYSTEMS • HEALTHY ENVIRONMENTS • HEALTHY COMMUNITIES • HEALTHY CALIFORNIANS
University of California
Agriculture and Natural Resources
Making a Difference for California
UCCE
Kern Soil & Water
July 2018

SCHEDULING IS A NEVER-ENDING JOB! PLANNING THE NEXT STEPS AS SANDEN SAILS OFF INTO RETIREMENT!

Blake Sanden, Irrigation & Agronomy Kern County

That's right folks, Thursday June 28 was my last official day as a UCCE Farm Advisor. But as many of you already know, I am not just sailing off into the sunset and vanishing. (Although, I do plan on doing some sailing!) The UC, like most academic institutions, allows retirees to retain 'Emeritus' status after retirement which allows me a continuing connection to and use of UC facilities, remaining project funding assigned to me, and our statewide network of Advisors and Specialists. I am currently committed to a pistachio ET by salinity and a citrus ET project (refining navel and mandarin crop coefficients, Kc) that are led by Daniele Zaccaria (statewide UCCE Irrigation Specialist from UC Davis). There are a couple other projects pending (almond early/green harvest, almond precision irrigation and developing a certified irrigation education curriculum) and some of you have said you want some of my time for various things. Later this fall, I will also put out a summary of our complicated 5 year almond ET production function trial that ended last year. So … time at the office will be limited (messages on the office phone won't get an immediate answer) but you have my email, which will be good for the foreseeable future.

I share this last newsletter to say a big THANK YOU to an incredible community of growers, water management people and my academic colleagues that have made my 26 years as a UC Farm Advisor the best job in the world. The challenges, connections with all of you, fulfillment (and hours) have been more than I could have imagined. A public relations guy from UC Ag & Natural Resources did a long interview with the idea of summarizing my career. Below are the answers to the last two questions he asked:

1. **What are you going to miss the most about your job?**

The grower interaction in the field and in meetings – seeing the "Ah-Ha" light up in a grower's eyes when he finally grasps the idea and we come up with a reasonable solution. All the better when it makes real money! Finally, in an odd way I will miss the thing that is also my biggest pain – the pressure! Get the presentation done, get the equipment ready for harvest and get the nuts in, summarize the data.

2. **Any advice for the next Blake Sanden?**

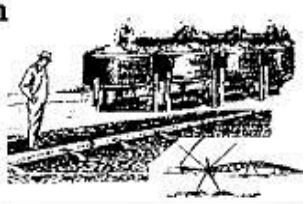
Dig up dirt! Not political, gossip nonsense – the real thing. NEVER leave your house or the office without a soil probe and shovel in your truck. ALWAYS take the probe out of the truck when you make a farm call and use it to help you and the grower understand where the water goes, how it subs

out from the dripper or down the furrow and gets to what depth. How this affects the spread of the roots, the growth and anchoring of the plant and how the plant can pull the water back up along with salts and fertilizers. ALWAYS take pictures for a wealth of visuals for future presentations. ALWAYS be enthusiastic – project energy, be the image of "can do". LISTEN, but do not be shy about stating your opinion/assessment of the problem. **Understand irrigation hardware** and how it works! Much of our extension group does not have a good grasp of this arena – like a lot of growers. This is your 'wrench' for moving water – know how to use it. **Interact** with and be part of technical advisory groups associated with water – irrigation districts, ag coalitions, DWR at the state and local level, understand SGMA. F**inally, find an issue that you can put your stamp on!** For me, I lucked out being part of great team efforts charting the salt tolerance of pistachios early on, and later proving up the water and fertility requirements of high production almonds. This helps to give you a solid foundation, direction and produce a sense of real fulfillment.

CONCLUSION (but not The End): most of you know Brian Hockett, who runs the Irrigation Mobile Lab for system uniformity evaluations as part of the North West Kern Resource Conservation District. He gave a talk at a pistachio ET field meeting we had the end of May and threw in this slide to surprise me at the end of his talk. He said Marvel needed to add a super hero for California water. Wish I still had that much brown hair! I don't know when he took this picture – one of my workshops. The pistachios are Feb 2010.

We all know that super heroes are really only good for movie ticket sales. In the end, what counts is all of you putting out that super-human effort as you make the miracle of growing food happen. So the following pages are a recap of some of the goodies (along with the links to my website) that I have put out over the years and for which have had repeated requests. In fitting fashion, this will start with my old letter head!

University of California Cooperative Extension
KERN SOIL AND WATER



Kern County • 1031 S. Mt. Vernon Ave • Bakersfield CA 93307 • Telephone: (661) 868-6218

SCIENTIFIC IRRIGATION SCHEDULING in PERMANENT CROPS: PROCESS, PLANNING, PROGRAMS & PRESSURE BOMB

Blake Sanden, Irrigation & Agronomy Kern County

2010 UCCE Kern Spring Irrigation Workshop *Bakersfield, CA 4/8/10*

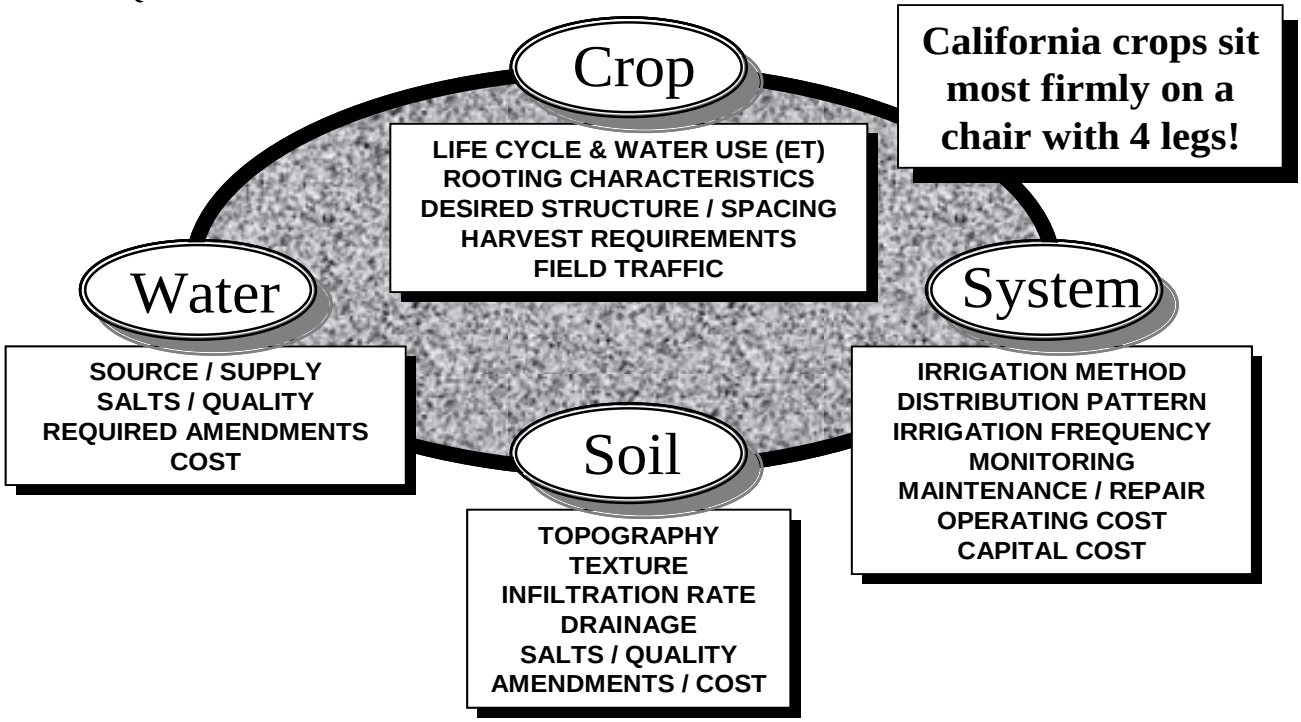
SCIENTIFIC (definition): **"Pertaining to science – systematic knowledge of the physical or material world gained through observation and experimentation."**

PROCESS: Understand the essential water processes and constraints that affect your crop.

1. **SOIL/WATER: Optimizing all factors / knowledge that affect irrigation uniformity, scheduling and water use efficiency.**
2. **CROP: Adjust crop rotation choices to fit water supply / quality.**
3. **TECHNOLOGY: Adopt techniques to track changes in soil/plant water status.**

IRRIGATION FOUNDATION STONES TO OPTIMIZE PRODUCTION & PROFIT

- AVAILABLE WATER / ROOTZONE AERATION (available oxygen)
- SUFFICIENT ROOTED VOLUME FOR ANCHORING AND NUTRIENTS
- AVAILABLE NUTRIENTS – N, P, K, Zinc, Copper, Boron, Iron, proper salt balance
- AVOID SATURATION & HIGH HUMDITY TO DECREASE DISEASE
- CROP STRUCTURE for MAX PHOTOSYNTHESIS & FRUIT DEVELOPMENT
- EQUIPMENT FOR TIMELY OPERATIONS & OPTIMUM CROP WATER USE



PLANNING: QUANTIFYING SOIL WATER CHARACTERISTICS

Determining Plant Available Water by the "Feel Method"

The ability to estimate the soil moisture in the crop rootzone that will be available to the crop is the key to understanding efficient irrigation and producing top yields. Knowing the texture of your soil tells you the maximum amount of water the soil will store between irrigations. Checking the soil moisture of your field every 3 to 4 days will tell you how quickly the crop is using stored water and when you need to irrigate again. Applying irrigation water too early causes water logging, possible disease, loss of fertilizer and decreased yield. Waiting too long between irrigations causes the crop to stress, reducing plant growth, photosynthesis and usually yield.

ESTIMATING AVAILABLE WATER HOLDING CAPACITY (AWHC): The maximum water a soil can hold in the field is called **field capacity (FC).** Following an irrigation it may take 1 to 3 days for excess water to drain out of the large pores, wormholes etc. The remaining water is held against gravity in the smaller pores of the soil. Obviously, a soil with a finer texture (more silt and clay) has a greater number of small pores and can store a greater amount of water in the rootzone. This is now **Field Capacity.** When soil moisture becomes so depleted that a plant wilts and does not recover, this is called the **Permanent Wilting Point (PWP)**. There is still a little water left in the soil, but it is held so tightly that it is unavailable to the plant. The amount of water available between **FC and PWP** is the **Available Water Holding Capacity (AWHC).** AWHC is expressed as a percent of the total soil volume:

$$\textbf{AWHC} = \textbf{\%Volume} = \frac{\textbf{inches depth of water}}{\textbf{12 inch depth of soil}}$$

Thinking of % volumetric water content in terms of **inches of available water per foot depth of rootzone** is the most convenient way to match crop water demand with how much water the soil can store. This is because crop water use (evapotranspiration, ET) is estimated as a depth of water over some period (daily, weekly, monthly, the whole season).

SIMPLIFIED SOIL TEXTURE CATEGORIES: For normal field irrigation scheduling it is usually sufficient for the production farmer to identify his soil by 4 basic types: Coarse, Sandy, Medium and Fine. Table 1 lists the characteristics associated with these types.

Table 1. Simplified soil texture categories, associated USDA soil textures, approximate available water holding capacity (AWHC) and length of soil "ribbon".

Category	Textures	AWHC (in/12 inch soil)	"Ribbon" Length (inches)
Coarse	S / LS	0.6 – 1.2	None. Ball only.
Sandy	LS / SL / L	1.2 – 1.8	0.4 - 1
Medium	L / SCL	1.4 – 2.2	1 - 2
Fine	SiL / SiCL / CL / SiC	1.7 – 2.4	> 2

So the basic rule of thumb (using the length of the soil ribbon you make with your thumb and forefinger) is: **if the wet soil at least makes a ball, but no ribbon your AWHC is about 0.7 to 1 inch/foot depth of soil. Then for all soils that make a ribbon:**

AWHC(in/ft soil) ~ length of ribbon

What this means is a field with sandy loam, (SL) has an AWHC of 1.2 to 1.6 in/ft. If this field is planted to blackeye beans or cotton rooted to a depth of 6 feet the soil can store a 7 to 9.5 inch depth of available water in the rootzone. A fine soil, like a silty clay loam (SiCL), can store 11 to 12 inches of water to 6 feet. For practical field irrigation scheduling you only want to use 50% to 60% of this total storage to avoid crop stress – about 4 inches for the SL and 6 inches for the SiCL. If the summer crop water use runs about 0.31 in/day then the sandy field needs water about every 12 to 15 days and the finer textured field needs water every 18 to 22 days. Soils with infiltration problems require more frequent irrigation. Table 2 shows the total AWHC for soils making different lengths of "ribbon" for coarse to fine soils for different rooting depths.

Table 2. Total available water holding capacity (AWHC) for different rootzone depths and length of soil ribbon.

Soil "Ribbon" Length (in)	AWHC (inches) for Rootzone Depth		
	1.5 ft	3.0 ft	5.0 ft
Ball Only	0.9	1.8	3.0
0.5	0.8	1.5	2.5
1.0	1.5	3.0	5.0
1.5	2.3	4.5	7.5
2.0	3.0	6.0	10.0
2.5	3.8	7.5	12.5

DETERMINING ACTUAL AVAILABLE WATER CONTENT IN THE FIELD USING THE "FEEL" METHOD AND A SOIL PROBE: Table 3 following is the most important table in this publication. The previous discussion was about the maximum amount of water a soil can hold (field capacity as shown for the clay loam soil at the right, making a 2.5 inch ribbon). But the production farmer has to manage fields not only with different soil textures but with crops at different stages of development, often different levels of salinity and with different potentials for maximum yield. So it is critical that the farmer can estimate how much water is still left in the soil and how quickly the crop is using this water so he can irrigate at just the right time. Irrigating too late stresses the crop. Irrigating too early leaches fertilizer, causes water logging and possible disease.

To accurately use this "feel" technique in the field takes some practice, equipment and willingness to do some digging. The top 1 foot of soil for any field crop will always dry out first. If plant roots are well developed then the 1 to 2 foot and later the 2 to 3 foot depths will supply more of the water used by the crop. In a well-drained soil, most fully developed field crop roots can retrieve water to a 6 foot depth. It is essential to have some type of soil probe or auger that allows you to pull up a soil sample from the deeper rootzone – at least to a depth of 3 feet once a week and preferably to a depth of 4 to 6 feet at two to four week intervals.

Table 3. Guide for Estimating Actual Available Field Soil Moisture by the "Feel" Method.

SOIL TEXTURE CLASSIFICATION				
Coarse (loamy sand)	**Sandy (sandy loam)**	**Medium (loam)**	**Fine (clay loam, silty clay loam)**	
Available Water (AW) in the Soil by Appearance (inches/foot soil)				
0.6-1.2 in/ft *AW@FC	**1.2-1.8 in/ft AW@FC**	**1.4-2.2 in/ft AW@FC**	**1.7-2.4 in/ft AW@FC**	
	AW	**AW**	**AW**	Moisture Deficiency
Leaves wet outline On hand when	**1.0**	Appears very dark leaves wet outline **1.6**	Appears very dark leaves wet outline **1.9**	Appears very dark, leaves slight moisture **2.2**	0
squeezed. Appears moist,	**0.7**	on hand, makes a short ribbon (0.5-0.75 inch)	on hand , will ribbon about 1 – 2 inches. **1.7**	on hand when squeezed, will ribbon > 2 inches.	0.2
Makes a weak ball. Appears slightly		Quite dark color makes a hard ball. **1.2**	Dark color, forms a plastic pall, slicks when rubbed. **1.4**	Dark color will feel slick And ribbons easily **1.8**	0.5
moist, sticks together slightly.	**0.4**	Fairly dark color, makes a good ball **1.0**	Quite dark, forms a hard ball **1.2**	Quite dark, will make	0.7
Dry, loose, flows thru fingers. (wilting point)	**0**	Slightly dark color makes a weak ball **0.7**	Fairly dark, forms a **1.0**	thick ribbon may slick when rubbed. **1.4**	1.0
		Lightly colored by moisture, will not **0.4**	a good ball	Fairly dark, makes a good ball. **1.1**	1.2
		ball. Very slight color **0**	Slightly dark, forms weak ball **0.6**	Will ball, small clods will flatten out rather **0.7**	1.4
		due to moisture. (wilting point)	Lightly Colored, small clods crumble **0.2**	Slightly dark, clods **0.4**	1.7
			Fairly easily. Slight color due to	Crumble. Some darkness due to	1.9
			moisture, small colds hard (wilting point). **0**	unavailable moisture, clods are hard, cracked **0**	2.2
				(wilting point)	

* **AW@FC:** Available Water @ Field Capacity = the available water a soil can store against gravity after irrigation and drainage.

Adapted from: Merriam, J.L. 1960. Field method of approximating soil moisture for irrigation. Am. Soc. Agri. Engr. Vol. 3. No.1.

There are many different styles of probes available. In general, an open-faced "push probe" is the quickest to use when the soil is moist, but you are limited to a depth of 3 feet and it doesn't work in rocky soils. Using an auger or screw probe with extension handles every 2 to 3 weeks will allow you to sample to a depth greater than 4 feet. This will tell you if you are losing your deep moisture too quickly (usually because of limiting infiltration that does not refill the rootzone every irrigation) or if the field is too wet.

Before probing, scrape the loose dirt back from the edge of the bed so it doesn't fall down the hole. Then insert the probe near the edge of the wetted area in the furrow and pull out a sample for every 1 foot depth. Use Table 3 to estimate the available water for each depth. **The following guidelines provide a very quick, rough estimate of the % available moisture:**

1. Ribbons easily: 90 – 100% **2. Plastic ball: 70 – 80%**
3. Hard ball: 50 – 60% **4. Crumbly ball: < 50% Crop will begin to stress!**

PLANNING: Using "hand feel soil texture" to estimate irrigation intervals for flood irrigation

Table 4 shows the different irrigation intervals for flood almonds over the season appropriate for a given soil texture and average daily ET by month. This table shows that for most SL to CL soils ***that DO NOT have an infiltration problem*** a traditional 10 to 12 day irrigation interval during June and July is just about right for replacing 50% of the available soil moisture reserve to avoid stress. This is about 3 to 4 inches of water per irrigation. For sealing or saline soils the irrigation must be more frequent.

Table 4. Calculated almond flood irrigation interval (days of moisture reserve) by month and soil texture.

Mature Almonds (S. San Joaquin Valley)		Assume managed rooting depth of 4 feet				
		Apr	May	Jun	Jul	Aug
Soil Texture	Avg Daily ET	0.15	0.23	0.28	0.33	0.25
Available Soil Moisture to 4 feet @ 50% depletion	(in)	Days of Moisture Reserve for Average Daily ET by Month				
Sand	1.4	9	6	5	4	6
Loamy Sand	2.2	15	10	8	7	9
Sandy Loam	2.8	19	12	10	8	11
Loam	3.6	24	16	13	11	14
Silt Loam	3.6	24	16	13	11	14
Sandy Clay Loam	2.6	17	11	9	8	10
Sandy Clay	3.2	21	14	11	10	13
Clay Loam	3.4	23	15	12	10	14
Silty Clay Loam	3.8	25	17	14	12	15
Silty Clay	4.8	32	21	17	15	19
Clay	4.4	29	19	16	13	18

After Ratliff LF, Ritchie JT, Cassel DK. 1983. Field-measured limits of soil water availability as related to laboratory-measured properties. Soil Sci Soc Am. 47:770-5.

PLANNING: Understanding and quantifying the impact of field irrigation distribution uniformity (DU) on applied water and yield (alfalfa example)

DU is defined as the average infiltration depth of water for the "low quarter" (tail end or low pressure 25%) of the field, and is expressed as a percentage:

$$\text{DU (\%)} = 100 * \frac{\text{"low quarter" infiltration}}{\text{Average field infiltration}}$$

Figure 4 illustrates how this plays out in your crop rootzone for a field DU of about 80% with some deficit irrigation on the end. To insure that no more than about 12% of the field gets less than full ET, you divide the expected ET of the crop by the field application DU. So if the alfalfa has a 50 inch requirement for ET and the field has an **80% DU** then the **applied water required = 50/0.8 = 62.5 inches.** That's an extra foot of water! If the **DU is 90%** (which is achievable with quarter mile runs, the right on-flow rate, a tail water return system and proper scheduling) then **applied water = 50/0.9 = 55.5 inches.** So you can save 7 inches of water by improving the uniformity and still adequately water the field.

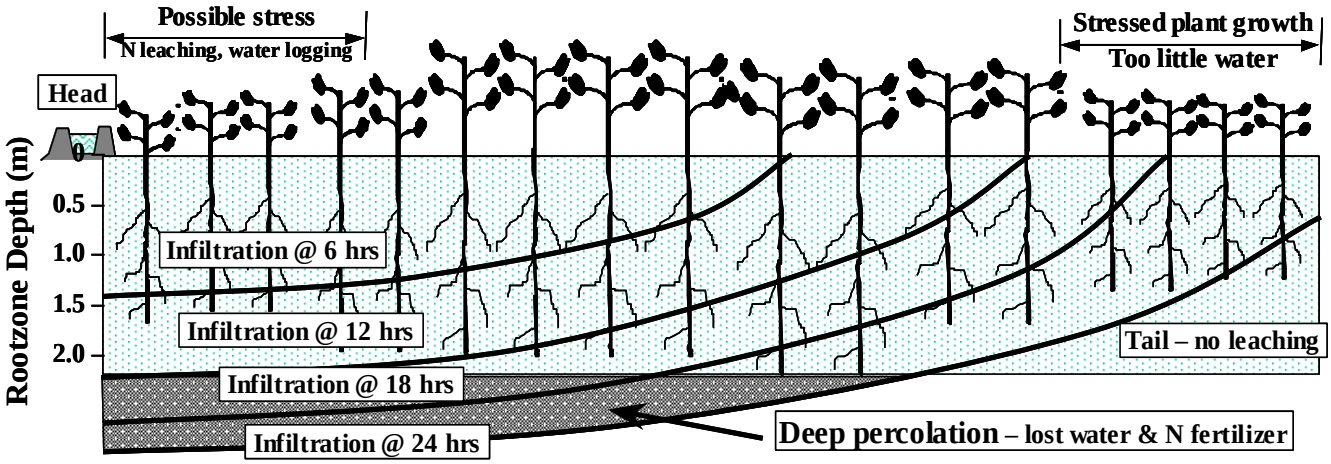


Fig. 4. Cross-section of crop rootzone during a 24 hour furrow irrigation.

Continuing with alfalfa for the moment, 12 ton yields in the SJV usually come from small plots at ag research stations where irrigations were very short and nearly 100% uniform. Actual field DU may range from a low of 65% for a coarse sandy border flood system with no tail water return to 95% for sub-surface drip or new pivots and linear move sprinklers in low wind conditions. In Kern County from 1988 to 2003, the average DU for border systems was 80% (Brian Hockett, unpublished data), ranging from 37 to 100%. (A 100% DU is theoretically possible on a cracking, sealing clay soil.) A total of 27 out of 80 borders evaluated had 90 to 100% DU. The average DU for 40 linear move sprinkler systems tested was only 77%.

So how does this play out in a production field? Figure 5 is a hypothetical alfalfa field that can yield 8.5 ton for the areas in the field where the irrigation schedule is just right. But this field does not drain well and where there is too much water you lose stand and yield to scald and phytophthora (the blocked end of the border and some of the head end in this case). Obviously, where the infiltration is too little (about 900 to 1150 feet from the head) the tonnage also decreases. Table 5 gives 3 scenarios using the production function in Figure 5 for a 70, 80 or 90% DU where the applied water for the season is 42, 48, 54 or 60 inches. Remember that a 55 inch water application is about right for a 50 inch ET requirement and a field with 90% DU.

Field Qtr	Qtr Irrig by Avg Depth (in)				Qtr Yield by Avg Depth (t/ac)			
70% DU	**42**	**48**	**54**	**60**	**42**	**48**	**54**	**60**
Wettest	55	62	70	78	8.5	7.6	6.0	5.0
Wet	46	53	59	66	8.2	8.6	8.1	6.7
Drier	38	43	49	54	6.6	7.8	8.5	8.5
Dry	29	34	38	42	3.6	5.3	6.6	7.6
	Field Average Yield (t/ac):				**6.7**	**7.3**	**7.3**	**7.0**
80% DU	**42**	**48**	**54**	**60**	**42**	**48**	**54**	**60**
Wettest	50	58	65	72	8.5	8.3	7.0	5.9
Wet	45	51	58	64	8.1	8.6	8.3	7.2
Drier	39	45	50	56	7.0	8.1	8.5	8.4
Dry	34	38	43	48	5.3	6.8	7.8	8.4
	Field Average Yield (t/ac):				**7.2**	**7.9**	**7.9**	**7.5**
90% DU	**42**	**48**	**54**	**60**	**42**	**48**	**54**	**60**
Wettest	46	53	59	66	8.2	8.6	8.1	6.7
Wet	43	50	56	62	7.8	8.5	8.4	7.6
Drier	41	46	52	58	7.3	8.3	8.6	8.2
Dry	38	43	49	54	6.6	7.8	8.5	8.5
	Field Average Yield (t/ac):				**7.5**	**8.3**	**8.4**	**7.8**

Table 5. Average seasonal applied water on the wettest to driest areas of an alfalfa field and the resulting yield for those areas for for various irrigation amounts and DU.

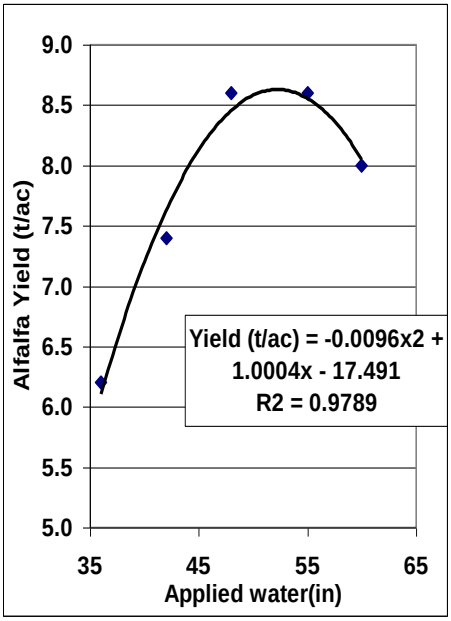


Fig. 5. Alfalfa production function for field sensitive to waterlogging.

If we apply 54 inches of water and we have a DU of 70% then the driest area of the field only gets 38 inches for the season and the wettest gets 70 inches. Looking at the right side of the table (Qtr Yield by Avg Depth) under the 54 inch column you can see that only ¼ of the field gets the right amount of water and hits the 8.5 t/ac. Half of the field yields less than 6.5 t/ac. So the average field yield is 7.3 t/ac. Improve the DU to 90% with tail water return and higher on-flows to reduce infiltration and water-logging you bump the whole field up to 8.4 t/ac with the same 54 inches of water! **Bottom line: improving irrigation DU pays.**

Checking soil moisture for scheduling irrigations: A number of growers have begun using Watermark® electrical resistance sensors in recent years to check the wetting and drying of the soil and improve their irrigation scheduling. This can be very useful in the spring and late summer when you may only need one irrigation between cuttings instead of two. In cooler Intermountain areas and for growers with severe water cutbacks, having some kind of soil moisture sensor can give you the confidence to cut back to one irrigation per cutting all season and still have sufficient moisture for decent tonnage. Table 6 provides approximate soil moisture tension guidelines for scheduling irrigations for coarse to fine

Table 6. Recommended soil moisture tension levels as a trigger for irrigation of tree and field crops.

Applied Irrigation Depth: 0.75 to 1.5"			
	Moisture Reading (cb)		
Soil Type	**12"**	**24"**	**48"**
Sand/loamy sand	70	40	20
Sandy loam	50	30	20
Loam	45	25	20
Clay/Silt Loam	40	25	20
Applied Irrigation Depth: 2 to 4"			
	Moisture Reading (cb)		
Soil Type	**12"**	**24"**	**48"**
Sand/loamy sand	80	50	30
Sandy loam	70	40	25
Loam	65	40	20
Clay/Silt Loam	65	30	20
Applied Irrigation Depth: 4 to 6"			
	Moisture Reading (cb)		
Soil Type	**12"**	**24"**	**48"**
Sand/loamy sand	90	70	60
Sandy loam	90	60	40
Loam	80	50	30
Clay/Silt Loam	70	45	25

Note: Moisture readings in these tables are only a guide. Actual readings for irrigation scheduling will vary for each field. Adjust by watching the 48" depth reading. Too little irrigation will cause this reading to keep increasing over the season. Too much irrigation will push this reading down to 0 to 15 centibars.

soils for various depths of infiltrated water (micro to flood). The numbers in this table are for optimum irrigation efficiency and reasonable tree ET.

PLANNING: Estimating Water Holding Capacity, Subbing, Total Rootzone Water Available Water Storage & Microirrigation Set Times for Orchards

Soil Texture	Field Capacity (in/ft)	Wilting Point (in/ft)	Available Soil Moisture (in/ft)	Avg Drip Subbing Diameter from 1 to 4' Depth (ft)	*Moisture Reserve (gals)
Sand	**1.2**	**0.5**	**0.7**	**2**	**4**
Loamy Sand	**1.9**	**0.8**	**1.1**	**3**	**16**
Sandy Loam	**2.5**	**1.1**	**1.4**	**4**	**35**
Loam	**3.2**	**1.4**	**1.8**	**5**	**70**
Silt Loam	**3.6**	**1.8**	**1.8**	**6**	**102**
Sandy Clay Loam	**3.5**	**2.2**	**1.3**	**7**	**100**
Sandy Clay	**3.4**	**1.8**	**1.6**	**7**	**123**
Clay Loam	**3.8**	**2.2**	**1.7**	**8**	**170**
Silty Clay Loam	**4.3**	**2.4**	**1.9**	**9**	**241**
Silty Clay	**4.8**	**2.4**	**2.4**	**9**	**305**
Clay	**4.8**	**2.6**	**2.2**	**10**	**345**

*This is the maximum gallons of water stored to a 4' depth beneath a single drip emitter. In fine textured soils, the wetted volume of one emitter merges with another on the same hose and final gallons of moisture reserve per emitter will be less than the number shown in the table. Plant stress will usually be seen when about 50% of this reserve has been used.

Ref: Ratliff LF, Ritchie JT, Cassel DK. 1983. Field-measured limits of soil water availability as related to laboratory-measured properties. Soil Sci Soc Am. 47:770-5.

Refill Times for Different Soil Textures and Micro Systems

[1]Irrigation Time to Refill & Moisture Reserve of 4 Foot Wetted Rootzone @ 50% to 100% Available

ALMONDS 0.30 inch/day ET

Soil Texture	Available Soil Moisture (in/ft)	Avg Drip Subbing Diameter from 1 to 4' Depth (ft)	Dble-Line Drip 1-gph, 10 per tree (irrig hrs)	Moisture Reserve @ 0.30"/day (days)	10 gph Fanjet, 1 per tree (irrig hrs)	Moisture Reserve @ 0.30"/day (days)	14 gph Fanjet, 1 per tree (irrig hrs)	Moisture Reserve @ 0.30"/day (days)
Sand	**0.7**	**2**	**2.2**	**0.3**	**11.6**	**1.4**	**12.5**	**2.1**
Loamy Sand	**1.1**	**3**	**7.8**	**0.9**	**19.6**	**2.4**	**20.9**	**3.6**
Sandy Loam	**1.4**	**4**	**17.5**	**2.1**	**26.9**	**3.3**	**28.3**	**4.8**
Loam	**1.8**	**5**	**35.9**	**4.4**	**37.1**	**4.5**	**38.6**	**6.6**
Silt Loam	**1.8**	**6**	**43.1**	**5.3**	**39.7**	**4.8**	**40.8**	**7.0**
Sandy Clay Loam	**1.3**	**6**	**31.1**	**3.8**	**28.6**	**3.5**	**29.5**	**5.0**
Sandy Clay	**1.6**	**7**	**44.7**	**5.4**	**37.6**	**4.6**	**38.3**	**6.5**
Clay Loam	**1.7**	**8**	**54.3**	**6.6**	**42.6**	**5.2**	**42.9**	**7.3**
Silty Clay Loam	**1.9**	**9**	**68.2**	**8.3**	**50.6**	**6.2**	**50.5**	**8.6**
Silty Clay	**2.4**	**9**	**86.2**	**10.5**	**64.0**	**7.8**	**63.8**	**10.9**
Clay	**2.2**	**10**	**87.8**	**10.7**	**62.3**	**7.6**	**61.5**	**10.5**

[1]Based on a tree spacing of 20 x 22'. Drip hoses 6' apart. 10 gph fanjet wets 12' diameter. 14 gph fanjet @ 15' diameter.

Note: Peak water use @ 0.30"/day and 20 x 22' spacing = 82 gallons/day/tree. 0.20"/day = 55 gallons/day/tree.

Table takes into account merging water patterns below soil surface for drip irrigation.

University of California Cooperative Extension
KERN SOIL AND WATER
Kern County □ 1031 S. Mt. Vernon Ave, Bakersfield CA 93307 □ Telephone: (661) 868-6218

PLANNING: Using technology to monitor soil moisture

The best key to unlock efficient irrigation practice is to know exactly how much water your crop uses and replace it in a timely fashion that matches your irrigation system capacity and avoids crop stress and water logging. We have good "normal year" estimates of citrus water use (evapotranspiration, ET) for the San Joaquin Valley, but as any grower knows very few blocks are "normal". The Frost Nucellar on the Cajon loamy sand and fanjets in Edison doesn't behave the same as the Fukumotos planted to double-line drip on an Exeter clay loam.

So what's the trick for hitting optimum water management for a particular block? You have to keep account of your soil moisture reservoir in the crop rootzone. Tracking soil moisture tells you whether you're putting on too much or too little water to meet crop needs. It's also the key to increasing fruit set and quality in many crops such as canning tomatoes, improving flavor in most wine grape varieties and possibly help control puff and crease in citrus.

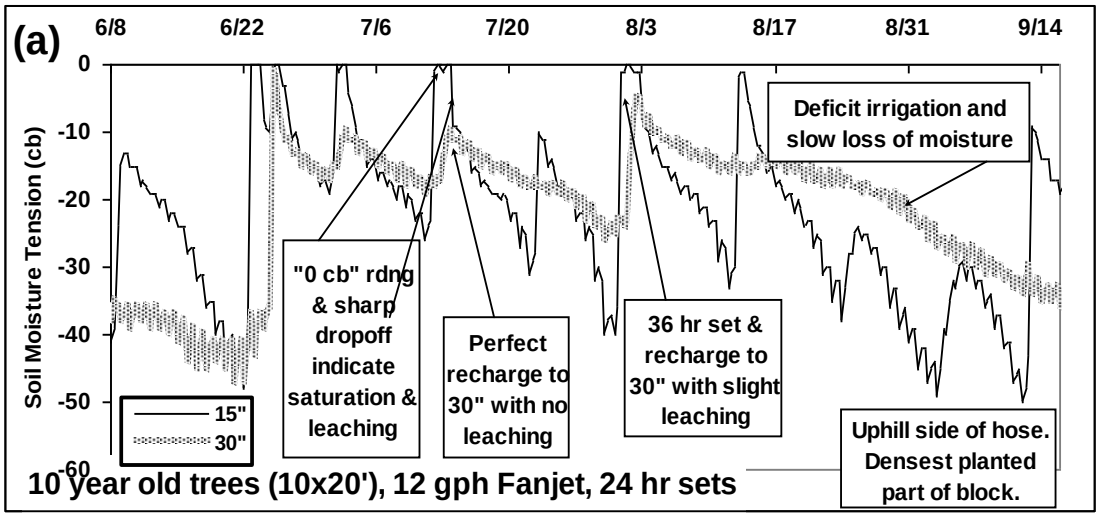
But any farmer and most ag consultants will tell you that checking soil moisture is not for the faint of heart because it requires auguring holes, pounding a soil probe, and/or installing moisture monitoring instruments to depths of 2 to 6 feet depending on the crop. Checking instruments or hand probing needs to be done on at least a weekly basis to be useful.

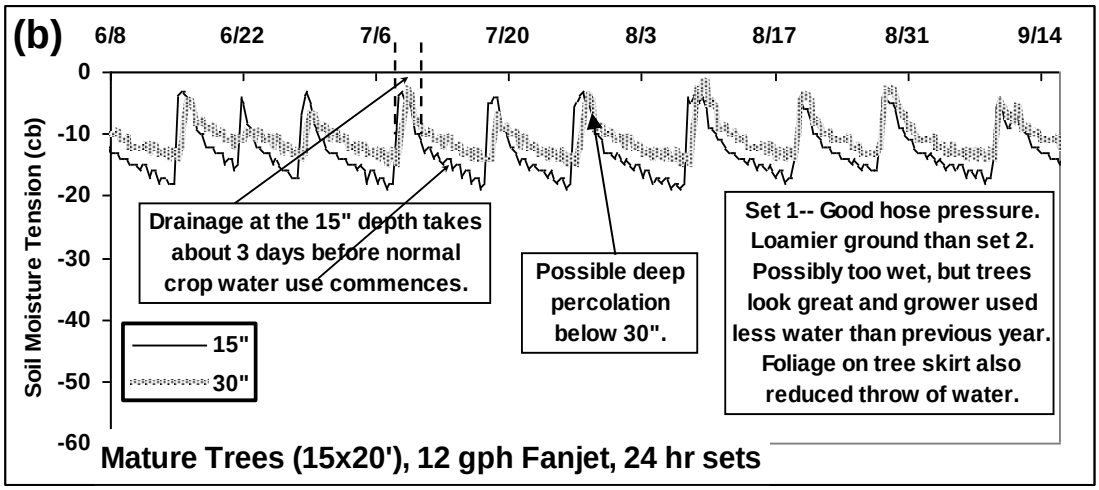
After pushing, twisting, pounding and digging thousands of holes in hundreds of fields around the San Joaquin Valley I can testify to the fact that this is only slightly more fun than shoveling manure, and it's a whole lot harder on your shoulders and wrists. The result is that it's not done very often, if at all, and farmers tend to stick to a traditional irrigation schedule. Given all the other decisions and details growers have to see to on a daily basis it's not surprising this activity gets pushed to the side. At the same time, the years of experience a farmer has with a crop and with a particular field often give him an intuitive sense of how to run the water and end up being 75 to 90% efficient anyway! So if you're already this efficient why check moisture anyway?

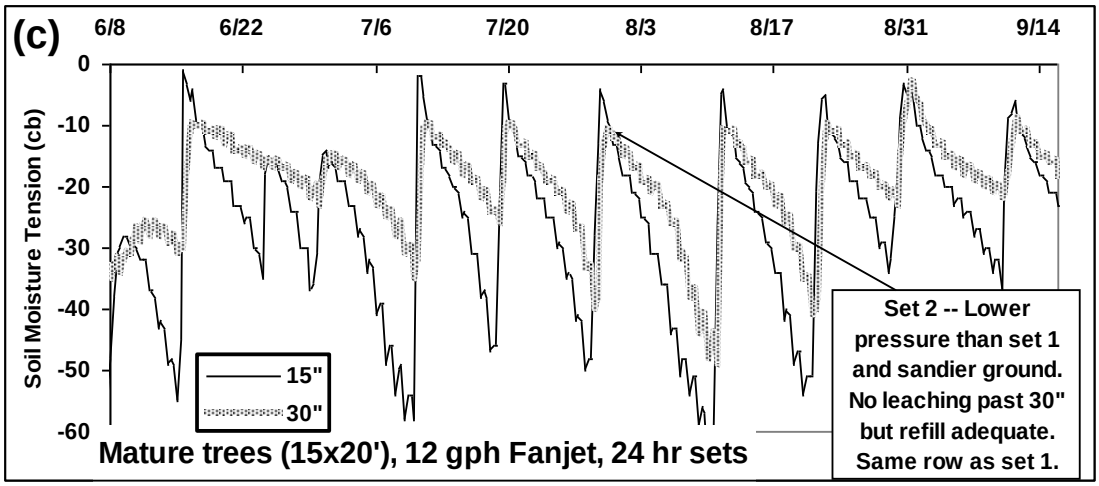
There are two reasons: 1) You're not really sure that you're at the optimum point of the crop water use curve until you check, and 2) The simple math of cost versus benefit. Water monitoring consulting services run around $15/acre/season depending on total acreage and what degree of technology and reporting you want done. If this is the only cost you incur to get the extra 5% out of a 3-bale cotton crop then you've made an extra $22/acre even if cotton is only 50 cents/lb. Even at just $2 net/box, an extra 15 boxes of grapes or extra fancy oranges is a 100% return on your $15 investment.

Many growers have tried tensiometers in the past and usually get fed up with the maintenance. A new generation of medium and high technology sensors are now available to growers and consultants. The huge diversity sensors can be intimidating at first glance but these systems can make this job easier, more accurate and even more affordable. The biggest advantage to the new technology is the use of a continuously recording data logger coupled to responsive soil moisture sensors.

A series of irrigation management/monitoring demonstrations by UC Cooperative Extension over the last 3 years in Kern County has looked at using a combination of 6 granular matrix electrical resistance blocks (Watermark®) coupled to a logger with a graphic display (Hansen AM400®, pictured above) to allow growers a "push button" look at 5 weeks of soil moisture history at any time during the season. The cost of this system is about $600 and should be good for 3 to 5 years. This gives growers a look at the dynamic changes in soil moisture due to actual crop water use and subsequent recharge of the profile during irrigation. The pattern of the peaks and rate of change of these readings is more useful than the actual numbers themselves. Many different sensors and loggers provide this type of information but the AM400/Watermark system is the only combination providing a graphic display in the field without having to download to a computer. Computer downloads can also be done anytime during the season to develop charts such as those shown below.







Charts (a), (b) and (c) show the changes in soil moisture for 2 different blocks of early navels in the Edison area of Kern County for summer 2003. Comments are placed in boxes connected to explain what these patterns mean.

Even though all 3 of these monitoring locations are within 800 feet of each other we see very different changes in soil moisture. The hedgerow block (a) has many skips as the grower has begun pulling trees and he wants to avoid over watering the whole block.

Charts (b) and (c) are for trees in the same row but different sets. Slightly higher hose pressures and loamier ground keep (b) moister than (c), which shows almost a perfectly efficient pattern of crop water use and recharge. To keep the trees in (c) from looking "hot" required an irrigation frequency for this block that resulted in the wetter condition at location (b). But the bottom line for the grower is these trees have never looked better, he used less water in 2003 and had a better packout than in 2002.

Irrometer, Onset and Spectrum companies also make inexpensive loggers (<$400) that can be used with Watermark blocks. The Watermark block is currently the least expensive, fairly reliable sensor. (Note: use of any product names is not intended as a commercial endorsement.)

PLANNING: Using weather data (CIMIS), crop coefficients (Kc) and "normal year" crop evapotranspiration (ET) to estimate water use and schedule irrigations

THE TOOLBOX: 1) Weather records of our very stable climate in the San Joaquin Valley that allow us to estimate the **"historic or normal year" potential evapotranspiration (ETo), 2) Crop coefficients (Kc)** for most of our important crops that relate crop ET to changes in crop development over the season, **3) Statewide CIMIS weather stations** (California Irrigation Management Information Service) that can be accessed through the internet to tell you when current ET is significantly different from "normal", and **4) Soil moisture monitoring technology and consulting services** to optimize the above estimates to a specific orchard site. Using only two or three of these tools is like driving a car without all four wheels – the ride will not be smooth, or efficient.

To Access CIMIS for Potential Evapotranspiration (ETo for tall grass) data follow below steps:
Website Address: http://www.cimis.water.ca.gov/

Non-Members – last 7 days only:

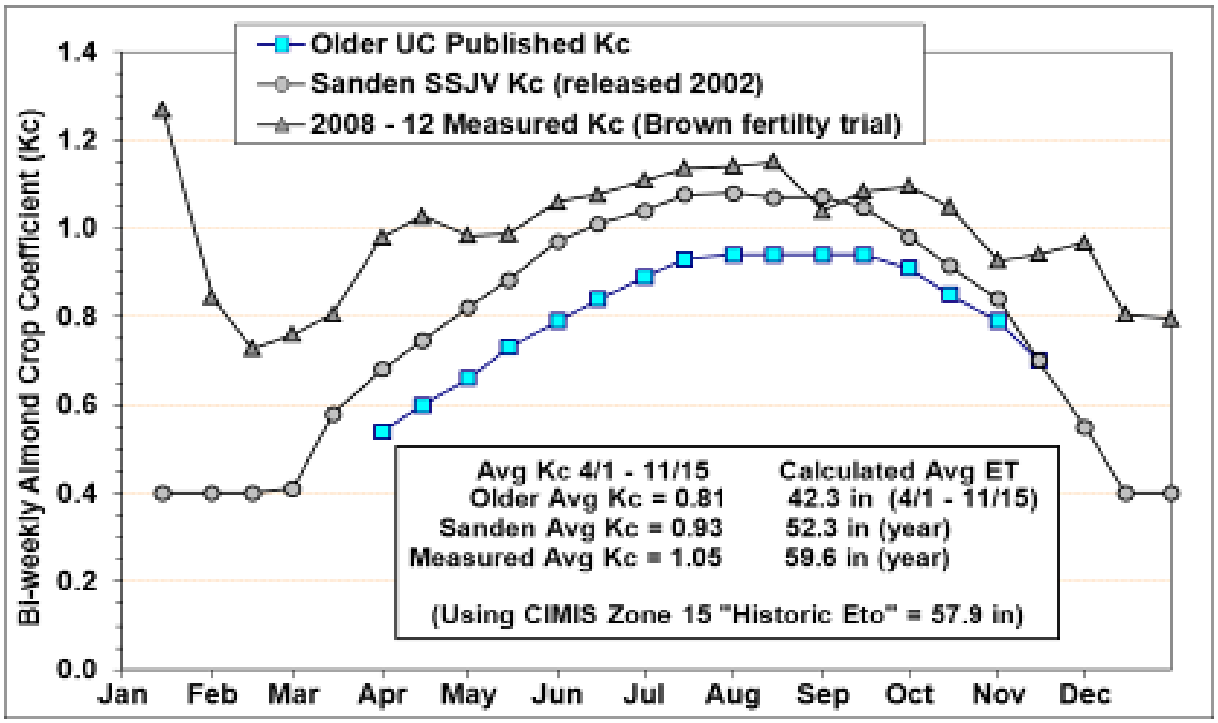
1. Select Data tab on header
2. Sample Daily or Monthly report
3. Select County
3. Submit – gives last 7 days for all stations in county

Signing up for membership is free, can be done on the website and allows many more options for data access.

KERN CIMIS STATIONS	
Shafter	5
Blackwells Corner	54
Arvin-Edison	125
Famoso	138
Belridge	146

CURRENT DEBATE OVER "HISTORIC ETo": The science of crop water/weather monitoring continues to change. Fifteen years ago the "historic ETo" for the San Joaquin Valley was put at 49 inches/year. New calculations using CIMIS data now put this number at 57 inches/year. Wow, 8 inches more … is this global warming? Not really. We now have many more weather stations and some changes in the way ETo is calculated, but which number is right? That's why you need **Tool (4)**, because the "right" number is the one that keeps your trees well-watered without wasting water and you won't know unless you have a way to check the moisture status of the rootzone.

COMPARISON OF VARIOUS CROP COEFFICIENTS FOR MATURE ALMONDS AS MEASURED IN KERN COUNTY



CIMIS Average Almond ET by Age -- Southern San Joaquin Valley							
			Almond ET -- Some Cover Crop, Microsprinkler (S. San Joaquin, inches/week)				
Week	Normal Year Grass ETo (in)	Mature Crop Coefficient (Kc)	1st Leaf @ 40%	2nd Leaf @ 55%	3rd Leaf @ 75%	4th Leaf @ 90%	Mature
1/6	0.21	0.40	0.03	0.05	0.06	0.08	**0.09**
1/13	0.28	0.40	0.03	0.06	0.08	0.10	**0.11**
1/20	0.30	0.40	0.04	0.07	0.09	0.11	**0.12**
1/27	0.36	0.40	0.04	0.08	0.11	0.13	**0.14**
2/3	0.42	0.40	0.05	0.09	0.13	0.15	**0.17**
2/10	0.47	0.40	0.06	0.10	0.14	0.17	**0.19**
2/17	0.54	0.40	0.06	0.12	0.16	0.19	**0.22**
2/24	0.61	0.40	0.07	0.13	0.18	0.22	**0.24**
3/3	0.69	0.42	0.09	0.16	0.22	0.26	**0.29**
3/10	0.79	0.61	0.14	0.27	0.36	0.43	**0.48**
3/17	0.89	0.64	0.17	0.31	0.43	0.51	**0.57**
3/24	0.98	0.67	0.20	0.36	0.49	0.59	**0.65**
3/31	1.09	0.72	0.23	0.43	0.59	0.70	**0.78**
4/7	1.19	0.74	0.26	0.48	0.66	0.79	**0.88**
4/14	1.32	0.75	0.30	0.55	0.74	0.89	**0.99**
4/21	1.41	0.81	0.34	0.63	0.85	1.03	**1.14**
4/28	1.49	0.83	0.37	0.68	0.93	1.12	**1.24**
5/5	1.59	0.86	0.41	0.75	1.03	1.23	**1.37**
5/12	1.66	0.90	0.45	0.83	1.13	1.35	**1.50**
5/19	1.73	0.94	0.49	0.89	1.22	1.46	**1.63**
5/26	1.78	0.96	0.51	0.94	1.29	1.54	**1.72**
6/2	1.85	0.98	0.54	0.99	1.35	1.62	**1.80**
6/9	1.86	0.99	0.55	1.01	1.38	1.65	**1.83**
6/16	1.90	1.02	0.58	1.06	1.45	1.74	**1.93**
6/23	1.93	1.05	0.61	1.11	1.52	1.82	**2.03**
6/30	1.93	1.06	0.62	1.13	1.54	1.85	**2.05**
7/7	1.93	1.08	0.62	1.14	1.56	1.87	**2.07**
7/14	1.93	1.08	0.62	1.14	1.56	1.87	**2.07**
7/21	1.86	1.08	0.60	1.10	1.50	1.80	**2.00**
7/28	1.86	1.08	0.60	1.10	1.50	1.80	**2.00**
8/4	1.78	1.08	0.58	1.06	1.44	1.73	**1.92**
8/11	1.75	1.08	0.57	1.04	1.42	1.70	**1.89**
8/18	1.69	1.08	0.55	1.00	1.36	1.64	**1.82**
8/25	1.62	1.07	0.52	0.96	1.30	1.57	**1.74**
9/1	1.55	1.07	0.50	0.91	1.24	1.49	**1.66**
9/8	1.47	1.06	0.47	0.85	1.17	1.40	**1.55**
9/15	1.40	1.04	0.43	0.80	1.08	1.30	**1.45**
9/22	1.31	1.02	0.40	0.73	1.00	1.19	**1.33**
9/29	1.19	0.97	0.35	0.64	0.87	1.04	**1.16**
10/6	1.10	0.95	0.31	0.57	0.78	0.94	**1.04**
10/13	1.00	0.88	0.26	0.48	0.66	0.79	**0.88**
10/20	0.90	0.88	0.24	0.43	0.59	0.71	**0.79**
10/27	0.77	0.83	0.19	0.35	0.48	0.58	**0.64**
11/3	0.67	0.78	0.16	0.29	0.39	0.47	**0.53**
11/10	0.57	0.71	0.12	0.22	0.31	0.37	**0.41**
11/17	0.48	0.68	0.10	0.18	0.25	0.30	**0.33**
11/24	0.42	0.60	0.07	0.14	0.19	0.22	**0.25**
12/1	0.36	0.50	0.05	0.10	0.13	0.16	**0.18**
12/8	0.31	0.40	0.04	0.07	0.09	0.11	**0.12**
12/15	0.29	0.40	0.03	0.06	0.09	0.10	**0.11**
12/22	0.25	0.40	0.03	0.06	0.08	0.09	**0.10**
12/29	0.21	0.40	0.03	0.05	0.06	0.08	**0.09**
Total	**57.90**		**15.69**	**28.76**	**39.22**	**47.06**	**52.29**

CIMIS Average Citrus ET by Crop Age -- Zone 15 SSJV

Week	Normal Year Grass ETo	Mature Crop Coefficient (Kc)	--Weekly Citrus ET (inches/week)-- Wide Spaced, No Cover Crop, Fanjet 1st Leaf @ 15%	3rd Leaf @ 40%	5th Leaf @ 70%	7th Leaf @ 90%	Mature	20X20 Spacing day / tree
1/7	0.21	0.75	0.02	0.06	0.11	0.14	**0.16**	**6**
1/14	0.28	0.75	0.03	0.08	0.14	0.19	**0.21**	**7**
1/21	0.30	0.75	0.03	0.09	0.16	0.20	**0.22**	**8**
1/28	0.36	0.75	0.04	0.11	0.19	0.24	**0.27**	**10**
2/4	0.42	0.75	0.05	0.13	0.22	0.28	**0.31**	**11**
2/11	0.47	0.74	0.05	0.14	0.24	0.31	**0.35**	**12**
2/18	0.54	0.74	0.06	0.16	0.28	0.36	**0.40**	**14**
2/25	0.61	0.73	0.07	0.18	0.31	0.40	**0.44**	**16**
3/4	0.69	0.73	0.08	0.20	0.35	0.45	**0.50**	**18**
3/11	0.79	0.71	0.08	0.22	0.39	0.50	**0.56**	**20**
3/18	0.87	0.70	0.09	0.24	0.43	0.55	**0.61**	**22**
3/25	0.98	0.70	0.10	0.27	0.48	0.62	**0.69**	**24**
4/1	1.09	0.70	0.11	0.31	0.53	0.69	**0.76**	**27**
4/8	1.19	0.70	0.13	0.33	0.58	0.75	**0.84**	**30**
4/15	1.32	0.70	0.14	0.37	0.64	0.83	**0.92**	**33**
4/22	1.41	0.70	0.15	0.39	0.69	0.89	**0.98**	**35**
4/29	1.49	0.70	0.16	0.42	0.73	0.94	**1.04**	**37**
5/6	1.59	0.70	0.17	0.45	0.78	1.00	**1.11**	**40**
5/13	1.66	0.70	0.17	0.47	0.81	1.05	**1.16**	**41**
5/20	1.73	0.70	0.18	0.49	0.85	1.09	**1.21**	**43**
5/27	1.78	0.69	0.18	0.49	0.86	1.10	**1.23**	**44**
6/3	1.85	0.68	0.19	0.50	0.87	1.12	**1.25**	**44**
6/10	1.88	0.66	0.19	0.50	0.87	1.12	**1.25**	**44**
6/17	1.91	0.65	0.19	0.50	0.87	1.12	**1.24**	**44**
6/24	1.93	0.65	0.19	0.50	0.88	1.13	**1.25**	**45**
7/1	1.94	0.65	0.19	0.50	0.88	1.13	**1.26**	**45**
7/8	1.94	0.65	0.19	0.50	0.88	1.13	**1.26**	**45**
7/15	1.93	0.65	0.19	0.50	0.88	1.13	**1.25**	**45**
7/22	1.89	0.65	0.18	0.49	0.86	1.11	**1.23**	**44**
7/29	1.86	0.65	0.18	0.48	0.84	1.09	**1.21**	**43**
8/5	1.80	0.65	0.18	0.47	0.82	1.05	**1.17**	**42**
8/12	1.75	0.65	0.17	0.46	0.80	1.03	**1.14**	**41**
8/19	1.69	0.65	0.17	0.44	0.77	0.99	**1.10**	**39**
8/26	1.62	0.65	0.16	0.42	0.74	0.95	**1.05**	**38**
9/2	1.55	0.68	0.16	0.42	0.74	0.95	**1.06**	**38**
9/9	1.47	0.73	0.16	0.43	0.75	0.96	**1.07**	**38**
9/16	1.40	0.78	0.16	0.44	0.76	0.98	**1.09**	**39**
9/23	1.31	0.65	0.13	0.34	0.59	0.76	**0.85**	**30**
9/30	1.19	0.66	0.12	0.32	0.55	0.71	**0.79**	**28**
10/7	1.10	0.69	0.11	0.30	0.53	0.68	**0.76**	**27**
10/14	1.00	0.70	0.10	0.28	0.49	0.63	**0.70**	**25**
10/21	0.90	0.70	0.09	0.25	0.44	0.57	**0.63**	**22**
10/28	0.77	0.70	0.08	0.22	0.38	0.49	**0.54**	**19**
11/4	0.67	0.70	0.07	0.19	0.33	0.42	**0.47**	**17**
11/11	0.57	0.70	0.06	0.16	0.28	0.36	**0.40**	**14**
11/18	0.48	0.70	0.05	0.13	0.23	0.30	**0.34**	**12**
11/25	0.40	0.70	0.04	0.11	0.20	0.25	**0.28**	**10**
12/2	0.34	0.70	0.04	0.10	0.17	0.21	**0.24**	**8**
12/9	0.29	0.70	0.03	0.08	0.14	0.18	**0.20**	**7**
12/16	0.26	0.70	0.03	0.07	0.13	0.16	**0.18**	**6**
12/23	0.23	0.70	0.02	0.06	0.11	0.14	**0.16**	**6**
12/30	0.21	0.73	0.02	0.06	0.11	0.14	**0.16**	**6**
Total	**57.90**		**5.93**	**15.82**	**27.68**	**35.59**	**39.54**	

CIMIS "NORMAL YEAR" ETo AND CROP WATER USE (ETc)[1] FOR GRAPES IN THE SSJV (7'x11' spacing, inches/week)

Week	Kern ETo	WINE GRAPES (Irrigated at 50% of ETo starting June 1 to end of September)				SHORT SEASON TABLE FLAME/THOMPSON (DWR Published Values)				[2]LONG SEASON TABLE CRIMSON/RED GLOBE (Full cover trellis, Kc estimate of Larry Williams for gabled trellis, Kearney Ag Center			
		Crop Coeff. (Kc)	Weekly ET (inch)	Gals/wk/ vine (100% Effic)	Gals/wk/ vine (85% Effic)	Crop Coeff. (Kc)	Weekly ET (inch)	Gals/wk/ vine (100% Effic)	Gals/wk/ vine (85% Effic)	Crop Coeff. (Kc)	Weekly ET (inch)	Gals/wk/ vine (100% Effic)	Gals/wk/ vine (85% Effic)
1/7	0.21												
1/14	0.28												
1/21	0.30												
1/28	0.36												
2/4	0.42												
2/11	0.47												
2/18	0.54												
2/25	0.61												
3/4	0.69												
3/11	0.79												
3/18	0.87												
3/25	0.98	0.13	0.12	6	7	0.13	0.12	6	7	0.15	0.15	7	8
4/1	1.09	0.14	0.15	7	8	0.14	0.15	7	8	0.13	0.14	7	8
4/8	1.19	0.16	0.19	9	11	0.16	0.19	9	11	0.20	0.24	12	14
4/15	1.32	0.23	0.30	14	17	0.23	0.30	14	17	0.30	0.39	19	22
4/22	1.41	0.40	0.56	27	32	0.40	0.56	27	32	0.22	0.32	15	18
4/29	1.49	0.50	0.74	36	42	0.50	0.74	36	42	0.51	0.75	36	42
5/6	1.59	0.58	0.91	44	52	0.58	0.91	44	52	0.31	0.49	23	27
5/13	1.66	0.63	1.04	50	59	0.63	1.04	50	59	0.49	0.81	39	46
5/20	1.73	0.68	1.17	56	66	0.68	1.17	56	66	0.56	0.98	47	55
5/27	1.78	0.71	1.27	61	72	0.71	1.27	61	72	0.60	1.08	52	61
6/3	1.85	0.50	0.92	44	52	0.75	1.38	66	78	0.73	1.35	65	76
6/10	1.88	0.50	0.94	45	53	0.79	1.48	71	84	0.87	1.63	78	92
6/17	1.91	0.50	0.96	46	54	0.81	1.55	74	88	0.97	1.85	89	104
6/24	1.93	0.50	0.96	46	54	0.83	1.59	76	90	1.09	2.09	100	118
7/1	1.94	0.50	0.97	47	55	0.83	1.60	77	90	1.17	2.28	109	128
7/8	1.94	0.50	0.97	47	55	0.83	1.60	77	90	1.24	2.41	116	136
7/15	1.93	0.50	0.96	46	54	0.83	1.59	76	90	1.30	2.50	120	141
7/22	1.89	0.50	0.95	45	53	0.83	1.56	75	88	1.33	2.52	121	142
7/29	1.86	0.50	0.93	45	52	0.83	1.53	73	86	1.35	2.51	121	142
8/5	1.80	0.50	0.90	43	51	0.83	1.49	71	84	1.37	2.47	118	139
8/12	1.75	0.50	0.88	42	50	0.83	1.45	69	82	1.38	2.42	116	136
8/19	1.69	0.50	0.85	41	48	0.80	1.35	65	76	1.39	2.35	113	133
8/26	1.62	0.50	0.81	39	46	0.76	1.24	59	70	1.39	2.25	108	127
9/2	1.55	0.50	0.77	37	44	0.66	1.03	49	58	1.40	2.17	104	122
9/9	1.47	0.50	0.73	35	41	0.61	0.90	43	51	1.40	2.05	98	116
9/16	1.40	0.50	0.70	34	39	0.53	0.73	35	41	1.40	1.96	94	110
9/23	1.31	0.50	0.65	31	37	0.45	0.59	28	33	1.40	1.83	88	103
9/30	1.19	0.50	0.60	29	34	0.38	0.45	21	25	1.40	1.67	80	94
10/7	1.10	0.25	0.28	13	16	0.25	0.28	13	16	1.40	1.54	74	87
10/14	1.00	0.25	0.25	12	14	0.25	0.25	12	14	1.40	1.40	67	79
10/21	0.90	0.25	0.22	11	13	0.25	0.22	11	13	1.40	1.25	60	71
10/28	0.77	0.25	0.19	9	11	0.25	0.19	9	11	1.40	1.09	52	61
11/4	0.67	0.25	0.17	8	9	0.25	0.17	8	9	0.50	0.34	16	19
11/11	0.57	0.25	0.14	7	8	0.25	0.14	7	8	0.50	0.29	14	16
11/18	0.48	0.25	0.12	6	7	0.25	0.12	6	7	0.50	0.24	11	14
11/25	0.40	0.25	0.10	5	6	0.25	0.10	5	6	0.50	0.20	10	11
12/2	0.34												
12/9	0.29												
12/16	0.26												
12/23	0.23		TOTALS				TOTALS				TOTALS		
12/30	0.21		(inch)	(gal)	(gal)		(inch)	(gal)	(gal)		(inch)	(gal)	(gal)
TOTAL	**57.90**	**(inch)**	**23.38**	**1122**	**1320**		**31.04**	**1490**	**1753**		**49.97**	**2398**	**2822**

[1]Irrigation studies by UC Specialist Larry Williams found berry size was not reduced as long as table grapes got at least 75% ET.

[2]This total of 49 inches is close to the 45 inches of water use documented in 2003 by Kern UCCE in gabled Crimsons near Arvin.

CIMIS ET Estimates Using Zone 15 Southern SJV "Historic" Eto PISTACHIOS

Week Ending	Normal Year Grass ETo	[1]Pistachio Crop Coefficients	Drip Year 1	Drip Year 2	Drip Year 3	[2]Drip Year 4 & FJ Year 1	Drip Year 5 & FJ Year 3	Drip Year 6 & FJ Year 5	Year 7	Year 8	Year 9 (>65% cover)
	Adjustment Factor		**0.10**	**0.15**	**0.22**	**0.30**	**0.40**	**0.65**	**0.78**	**0.90**	**1.00**
1/7	0.21										
1/14	0.28										
1/21	0.30										
1/28	0.36										
2/4	0.42										
2/11	0.47										
2/18	0.54										
2/25	0.61										
3/3	0.69										
3/10	0.79										
3/17	0.89										
3/24	0.98	0.07	0.01	0.01	0.02	0.02	0.03	0.04	0.05	0.06	0.07
3/31	1.09	0.10	0.01	0.02	0.02	0.03	0.04	0.07	0.09	0.10	0.11
4/7	1.19	0.20	0.02	0.04	0.05	0.07	0.10	0.16	0.19	0.21	0.24
4/14	1.32	0.30	0.04	0.06	0.09	0.12	0.16	0.26	0.31	0.36	0.39
4/21	1.41	0.40	0.06	0.08	0.12	0.17	0.23	0.37	0.44	0.51	0.56
4/28	1.49	0.50	0.07	0.11	0.16	0.22	0.30	0.48	0.58	0.67	0.74
5/5	1.59	0.60	0.10	0.14	0.21	0.29	0.38	0.62	0.74	0.86	0.95
5/12	1.66	0.70	0.12	0.17	0.26	0.35	0.47	0.76	0.91	1.05	1.16
5/19	1.73	0.90	0.16	0.23	0.34	0.47	0.62	1.01	1.22	1.40	1.56
5/26	1.78	1.00	0.18	0.27	0.39	0.54	0.71	1.16	1.39	1.61	1.78
6/2	1.85	1.10	0.20	0.30	0.45	0.61	0.81	1.32	1.58	1.83	2.03
6/9	1.86	1.15	0.21	0.32	0.47	0.64	0.85	1.39	1.66	1.92	2.13
6/16	1.90	1.17	0.22	0.33	0.49	0.67	0.89	1.44	1.73	2.00	2.22
6/23	1.93	1.17	0.23	0.34	0.50	0.68	0.90	1.47	1.76	2.03	2.25
6/30	1.93	1.19	0.23	0.34	0.50	0.69	0.92	1.49	1.79	2.06	2.29
7/7	1.93	1.19	0.23	0.34	0.50	0.69	0.92	1.49	1.79	2.06	2.29
7/14	1.93	1.19	0.23	0.34	0.50	0.69	0.92	1.49	1.79	2.06	2.29
7/21	1.86	1.19	0.22	0.33	0.49	0.66	0.88	1.44	1.72	1.99	2.21
7/28	1.86	1.19	0.22	0.33	0.49	0.66	0.88	1.44	1.72	1.99	2.21
8/4	1.78	1.19	0.21	0.32	0.47	0.64	0.85	1.38	1.66	1.91	2.12
8/11	1.75	1.19	0.21	0.31	0.46	0.63	0.83	1.36	1.63	1.88	2.09
8/18	1.69	1.19	0.20	0.30	0.44	0.60	0.81	1.31	1.57	1.81	2.01
8/25	1.62	1.12	0.18	0.27	0.40	0.54	0.73	1.18	1.42	1.63	1.82
9/1	1.55	1.12	0.17	0.26	0.38	0.52	0.69	1.13	1.35	1.56	1.74
9/8	1.47	1.00	0.15	0.22	0.32	0.44	0.59	0.95	1.15	1.32	1.47
9/15	1.40	0.95	0.13	0.20	0.29	0.40	0.53	0.86	1.04	1.19	1.33
9/22	1.31	0.96	0.13	0.19	0.28	0.38	0.50	0.82	0.98	1.13	1.26
9/29	1.19	0.88	0.10	0.16	0.23	0.31	0.42	0.68	0.82	0.94	1.05
10/6	1.10	0.87	0.10	0.14	0.21	0.29	0.38	0.62	0.74	0.86	0.95
10/13	1.00	0.80	0.08	0.12	0.18	0.24	0.32	0.52	0.62	0.72	0.80
10/20	0.90	0.74	0.07	0.10	0.15	0.20	0.27	0.43	0.52	0.60	0.67
10/27	0.77	0.71	0.05	0.08	0.12	0.16	0.22	0.36	0.43	0.49	0.55
11/3	0.67	0.70	0.05	0.07	0.10	0.14	0.19	0.31	0.37	0.42	0.47
11/10	0.57	0.45	0.03	0.04	0.06	0.08	0.10	0.17	0.20	0.23	0.26
11/17	0.48	0.40	0.02	0.03	0.04	0.06	0.08	0.12	0.15	0.17	0.19
11/24	0.42	0.30	0.01	0.02	0.03	0.04	0.05	0.08	0.10	0.11	0.13
12/1	0.36										
12/8	0.31										
12/15	0.29										
12/22	0.25										
12/29	0.21										
Total	**57.90**		**4.74**	**7.11**	**10.43**	**14.22**	**18.96**	**30.81**	**36.97**	**42.66**	**47.40**

Note: the below numbers are a guide only. There are some areas of Kern County where elevated soil/water salinity reduces pistachio ET by as much as 15 to 25%. There are other locations where adjacent canals and sand layers allow shallow groundwater to move out under fields and be taken up by pistachio roots -- reducing the need for surface applied irrigation water. Augering/probing for current soil moisture levels in the orchard rootzone is the only way to insure that you are not deficit or overirrigating.

4,000 lb/ac pistachios have been grown in Kern County with as little as 30 inches to as much as 52 inches of water.

[1] No weeds, bare middles. Goldhamer crop coefficients.

[2] FJ stands for Fanjet or any microsprinkler spraying a 10 to 15 foot diameter. Higher evaporative losses from this system create a first year water demand equal to a 4th leaf orchard on drip.

PROGRAMS: Putting all the information together – balancing the checkbook

Wow, do I need all this information all at the same time to schedule irrigations? And we haven't even talked about salinity! But in its simplest form, the essential constraints on running your water for a micro system can be boiled down to look very much like the boiler plate on an electric motor. (Table 1 shows how this looks for almond Field 12-2.) You wouldn't never think of buying a booster motor for your pump that didn't have the boiler plate specs on the casing. But after 23 years of tromping the fields of Kern County I am still surprised by the number of growers and fields that don't have this simple yet critical information readily and easily accessible. **For volume balance, or "check book" irrigation scheduling the critical factors all boil down to 6 pieces of information:**

Table 1. Soil and irrigation system charactersitics necessary for scheduling irrigations in mature almonds with 2, A-40 Fanjets per tree.

FIELD NAME:	**12-2**		
SOIL TYPE:	Milham/Panoche sandy clay loam		
FIELD CAPACITY (in/ft):	2.4		
REFILL POINT (in/ft):	0.9	**Total Avail @ 100% (in):**	**9.0**
ROOTING DEPTH (ft):	6	**AREA/TREE (sq ft):**	504
ROW SPACING:	21' x 24'	**DESIGN FLOW (gph/tree):**	21.6
IRRIGATION SYSTEM:	2, 10.7 gph Fanjets		
NORMAL RUN TIME (hrs):	24	**WET AREA APPLIC (in):**	3.30
WETTED VOLUME (%):	50%	**NUMBER of SETS:**	3
		TOTAL AREA APPLIC (in):	1.65

(The first four are from the physical field boiler plate)

1) **Area covered be the crop** (tree spacing x row spacing)
2) **Volume of water stored in the rootzone under this area** (tree spacing x rooting depth x wetted volume x (field capacity – refill point)
3) **Flow of water to this area** (design flow, infiltration rate if flood)
4) **Usual set duration** (normal run time and number of sets to get across the field)

(The last two are basically the estimated budget and account balancing over the season.)

5) **Expected crop water use, ET** (from "normal year" tables or Kc x CIMIS ETo)
6) **Real time feedback on soil moisture and plant stress** ("hand feel" or sensor estimate of soil moisture, plant stem water potential (SWP), canopy temperature, shoot growth, plant color)

FIELD 12-2														
VIGOR FACTOR	SOIL TYPE:	FIELD CAPACITY (in/ft):	REFILL POINT (in/ft):	ROOTING DEPTH (ft):	ROW SPACING:	IRRIG. SYSTEM:	NORMAL RUN TIME (hrs):	WETTED VOLUME (%):	Total Avail @ 100% (in):	AREA/ TREE (sq ft):	DESIGN FLOW (gph/ tree):	WET AREA APPLIC (in):	NUMBER of SETS:	TOTAL AREA APPLIC (in):
105%	Milham/ Panoche sandy clay loam	2.6	0.9	6	21' x 24'	2, 10.7 gph Fanjets	24	50%	10.2	504	21.4	3.27	3	1.63
	Week Ending:	6/15	6/22	6/29	7/6	7/13	7/20	7/27	8/3	8/10	8/17	8/24	8/31	9/7
	"Normal Yr" Almond ET:	1.99	2.09	2.11	2.14	2.14	2.06	2.05	1.97	1.95	1.87	1.79	1.71	1.60
	Block ET (in/week):	2.09	2.19	2.22	2.24	2.24	2.16	2.16	2.07	2.04	1.97	1.88	1.79	1.68
	Run Time to Refill for Week (hrs):	30.7	32.2	32.6	32.9	32.9	31.7	31.6	30.4	30.0	28.9	27.6	26.3	24.7
	Actual Run (hrs):	24	24	48	24	48	48	HARVEST		48	HARVEST		48	24
	Cumulative Deficit or Surplus (hrs):	-6.7	-19.4	-7.0	-16.0	-0.9	8.8	-22.8	-52.8	-30.7	-59.5	-87.2	-42.0	-42.7
	Estimated Soil Moisture Depletion or Excess (in):	-0.91	-2.64	-0.96	-2.17	-0.12	1.20	-3.11	-7.20	-4.18	-8.11	-11.87	-5.72	-5.81
	Estimated Soil Moisture (% available):	91%	74%	91%	79%	99%	112%	70%	29%	59%	20%	-16%	44%	43%
	Actual Soil Moisture (% available):	85%	70%			90%		70%	35%			15%		

So now all 6 pieces of information are contained in the above Excel Table (available at http://cekern.ucanr.edu/Irrigation_Management/Southern_SJV_Irrigation_Checkbook_Scheduler/ click IRRIGATION CHECKBOOK SCHEDULER in the list of files. The file has separate worksheets for mature almonds, citrus, late season table grapes and pistachios.) The budget part of the checkbook simply uses "NORMAL YEAR" ET, multiplies it by a VIGOR FACTOR and using the system characteristics on the top calculates the hours of RUN TIME needed for that week. If you have a well you might just want to irrigate that number of hours/set, but most operations have to work on a 24 hour rotation so the checkbook will forward any deficit to the next week.

You will notice that the entries for ACTUAL SOIL MOISTURE are not entered every week over the season (kind of like what happens on a real farm with otherwise the best of intentions). This checkbook updates for the actual soil moisture number (if one is entered) so that extra irrigation hours will be added to make up the deficit from the previous weeks calculated value. If the calculated %AVAILABLE is consistently higher than the actual value consider increasing the % WETTED VOLUME as it may be larger than you think and therefore require more run time to refill. Alternatively, you can increase the VIGOR FACTOR if it looks like you have a heavy load on and your soil moisture always seems on the dry side. If the block is salt affected you want to stay in the 70% + range to keep water more available to the crop.

One of the deficiencies of the simple checkbook method is it does not accurately account for a slower rate of moisture extraction when you drop below 50% available and will overestimate the actual depletion (look at the week ending 8/24 as an example).

MORE CHECKBOOKS ON THE WEB: There are plenty of irrigation scheduling aids/programs on-line. A Google search of "free irigation scheduling programs" returns more than 80,000 hits. The list will make your head hurt – even before you start to use them. Links to a few of these sites that I have looked at and can recommend as completely free and sponsored by worthy organizations are below:

http://wwwcimis.water.ca.gov/Resources.aspx Concise list of free and pay-for scheduling software. Some tutorials on basic scheduling. State of CA, Sacramento.

http://www.waterright.org/ Checkbook type schedule, all on-line, mostly crop water demand based on CIMIS weather and standard crop coefficients. Cal State Fresno, CATI.

http://biomet.ucdavis.edu/irrigation_scheduling/bis/BIS.htm Multi-worksheet Excel file, completely downloadable, soil moisture estimation but no feedback adjustment. Most comprehensive list of crop coefficients. Calculator for estimating daily crop coefficients. Rick Snyder, UC Davis.

http://cesanjoaquin.ucdavis.edu/files/14724.xls Simple one-page worksheet checkbook for winegrape irrigation scheduling.

Simplified Stem & Leaf Water Potential Guidelines for Almonds, Citrus and Pistachio

(Note: The following guidelines assume that irrigation water is excellent quality and salinity is not accumulating to damaging levels.)

Using the pressure chamber to determine tree stress:

Before we can begin to understand the best times to reduce water and apply stress to a tree we need to have a means to measure the degree of that stress in the tree. The easiest way to measure this water potential is with the pressure chamber. This device, also called a pressure "bomb", is basically an aluminum chamber capable of applying up to 600 psi (40 atmospheres, or bars) of pressure on a leaf. The petiole of the leaf is sealed in a rubber gasket in the top of the chamber with the cut end sticking out. When the pressure applied to the leaf equals the force with which the xylem sap was under when the leaf was cut then the liquid sap oozes out of the end of the stem. The more stress on the tree (which is actually a negative pressure), the more pressure required to reach the "endpoint" to make the sap ooze out. If a bare

leaf is used this is called the leaf water potential (LWP), or if the leaf is first bagged for 15 to 30 minutes or a damp rag placed around the leaf prior to cutting then the leaf reflects more the stem water potential (SWP) of the tree. For almonds the low to no-stress range is around -8 to -10 bars and wilting and some defoliation starts around -18 to -20 bars. A fuller explanation of how to use the pressure bomb, by Allan Fulton, Irrigation Advisor for Tehama County can be found on the web at: http://cetehama.ucdavis.edu/files/37294.pdf.

Table 1, following, lists the various stress levels in bars for almonds, citrus, pistachio and walnut. The ranges are broad as operator method, tree variability and air temperature can vary readings by +/- 1.5 bars. (See below figures, Goldhamer and Fereres (2001). **1 MPa = 10 bars.**)

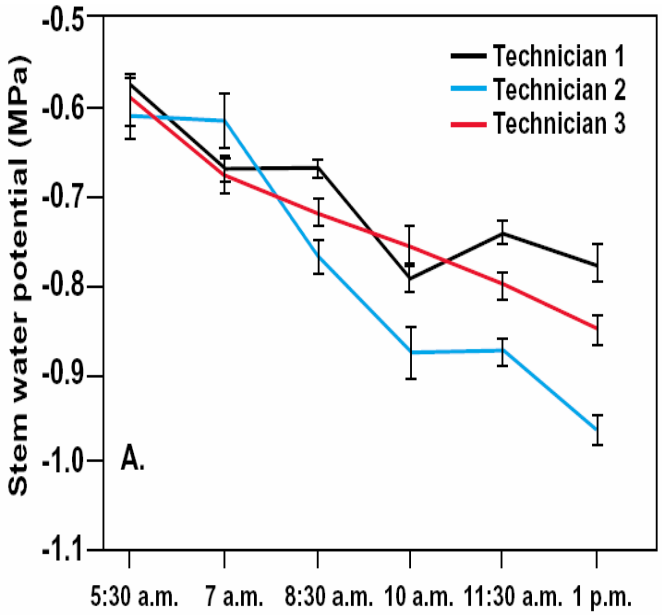


Fig. 1. Diurnal measurements of SWP for the same four trees by technicians using the same sampling technique on Aug. 4, 2000. Each data point is the mean of single measurements on each of 4 trees. Vertical bars represent two standard errors of the mean.

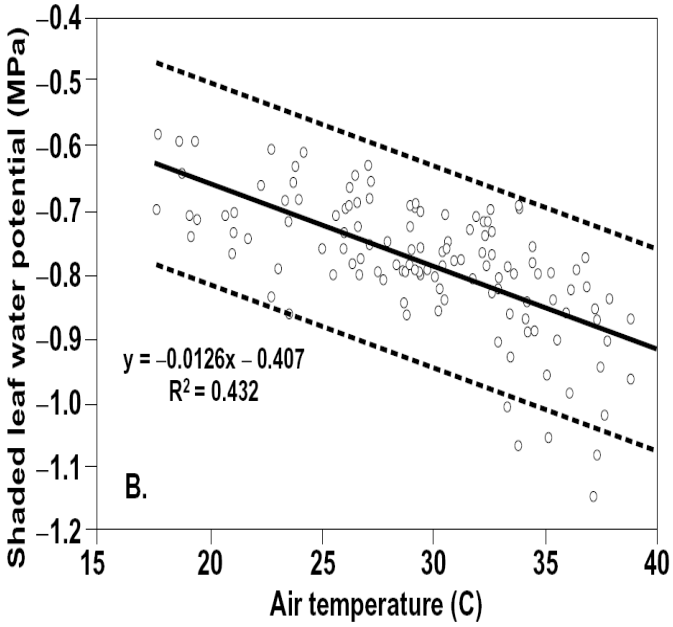


Fig.2. Relationship between shaded LWP using damp cloth and air temperature at the 2 p.m. sampling time for fully irrigated almond trees. Each data point is the mean of four trees. June-October. With 95% confidence limits.

GUIDELINES FOR INTERPRETING PRESSURE CHAMBER READINGS (midday stem water potential (SWP) for almonds, pistahcio and walnuts, and midday shaded leaf water potential (LWP) for citrus)

ALMOND & WALNUT: Allan Fulton/Richard Buchner-UCCE Tehama; Joe Grant-UCCE San Joaquin; Terry Prichard, Bruce Lampinen, Larry Schwankl, Ken Shackel Extension Specialists, UC Davis.

CITRUS & PISTACHIO: Dave Goldhamer-UCCE Kearney Ag Center; Craig Kallsen/Blake Sanden UCCE Kern County

Pressure Chamber Reading (- bars)	ALMOND	CITRUS	PISTACHIO	WALNUT
0 to -2	Not commonly observed	Not commonly observed	Not commonly observed	Not commonly observed
-2 to -4	↓	↓	Fully irrigated, mild spring conditions, rapid shoot expansion. Excellent for early season flush. Avoid saturation on heavy soils.	Fully irrigated using CIMIS ETc estimates, low stress, phytophthora may be a concern, especially on California Black rootstock.
-4 to -6	↓	↓	↓	Low to mild stress, high rate of shoot growth visible, suggested level from leaf-out until mid June when nut sizing is completed.
-6 to -8	Low stress, indicator of fully irrigated conditions, ideal conditions for shoot growth. Suggest maintaining these levels from leaf-out through mid June.	Low stress, indicator of fully irrigated conditions, ideal conditions for shoot growth. Excellent for early season flush.	Low stress, indicator of fully irrigated conditions, ideal conditions for shoot growth.	Mild to moderate stress, shoot growth in non-bearing and bearing trees has been observed to decline. These levels do not appear to affect kernel development.
-8 to -10	↓	↓	Moderate stress, may slightly reduce shoot growth.	Moderate to high stress, shoot growth may stop, nut sizing may be reduced in bearing trees and bud development for next season may be negatively affected.
-10 to -12	Mild to moderate stress, these levels of stress may be appropriate during the phase of growth just before the onset of hull split (late June).	Mild to moderate stress, puff and crease in navels still occurs in this range.	Leaves can "harden" and slightly cup, shell splitting/nut size can be reduced during nutfill (Jul-Aug).	High stress, temporary wilting of leaves has been observed. New shoot growth may be sparse or absent and some defoliation may be evident. Nut size likely to be reduced.
-12 to -14	↓	↓	↓	Relative high levels of stress, moderate to severe defoliation, should be avoided.
-14 to -18	Moderate stress in almond. Suggested stress level during hull split, Help control diseases such as hull rot and alternaria, if present. Hull split occurs more rapidly	Moderate stress, can accelrate color in early Becks (Sep-Oct), control puff and crease/size in Frost Nucellar, Washington (5/16-7/15)	Increasing stress, slight defoliation, may reduce shell hardness/increase splits Stage 2 (May-Jun).	Severe defoliation, trees are likely dying.
-18 to -20	Transitioning from moderate to higher crop stress levels	Stress prominent, leaf cupping obvious and can feel "warm" to the touch. Yield/size loss in early Becks (Sep-Oct). Controlled granulation Lane Late/best packout (Jul-Sep).	Stress prominent, leaf hardening and cupping obvious and can feel "warm" to the touch.	Not observed at these levels in English walnut ↓
-20 to -30	High stress, wilting observed, some defoliation	High stress, severe cupping, some defoliation	High stress, significant defoliation.	↓
Less than -30	Extensive defoliation has been observed	Significant defoliation	↓	↓

CROP HISTORICAL ET/Kc TABLES

- Average SSJV ET and Crop Coefficients
- Almond Drip - Microsprinkler - Flood Weekly ET
- Citrus ET by age
- Forage Crop ET
- Grape ET Estimating vineyard crop coefficients
- Pistachio ET by age
- Regulated Deficit Irrigation of Almond, Citrus & Pistachios

- **Current Real Time Kern UCCE/DWR Weekly Crop Water Use Report**
  - How To Use Weekly Crop Water Use Report
  - Subscribe to Kern ET Update Reports here.
  - Kern ET Update

SALINITY MANAGEMENT

- ANALYTICAL CONVERSIONS AND LEACHING CALCULATIONS
- MANAGING SALINITY, SOIL AND WATER AMENDMENTS
- IMPROVING WATER PENETRATION

SOIL MOISTURE AND IRRIGATION SCHEDULING

- Soil Texture-Sub-Fill Almond
- Soil Texture-Sub-Fill Grape
- Making sense of soil moisture sensors
- Southern SJV Irrigation Checkbook Scheduler
-

UC DROUGHT MANAGEMENT

- http://ucmanagedrought.ucdavis.edu/index.cfm
- http://ciwr.ucanr.edu/California_Drought_Expertise/Insights__Water_and_Drought_Online_Seminar_Series/ (On-line Videos)
- https://anrcatalog.ucanr.edu/Details.aspx?itemNo=21635 "MONITORING SOIL MOISTURE FOR IRRIGATION WATER MANAGEMENT"

Good source of augers and soil probes: Art's Manufacturing **http://www.ams-samplers.com** Part 401.07 7/8 in. x 33 in. Chrome Soil Probe with Cross Handle and Slide Hammer