University of California
Agriculture and Natural Resources

Irrigation Scheduling Methods & Tools

Advances in Citrus Water Use Workshop
Strathmore, CA – March 26, 2019

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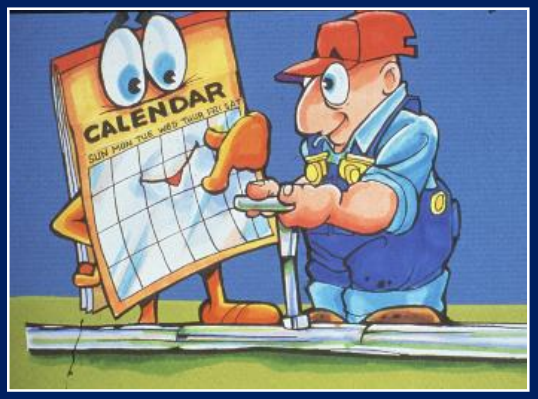
WHAT DRIVES TREE WATER USE (ET)?

- ✓ **Crop ET is driven by the amount of energy intercepted by canopy**
- ✓ **The canopy encounters this energy as direct radiation from the sun, and indirect energy sources** (warm air, wind)
- ✓ **The combined effect of these direct & indirect energy sources on the canopy determine the tree water use or ET when soil moisture is not limited.**

IRRIGATION SCHEDULING



It provides answers to the following questions:

1) When to irrigate our crops? → Before plants face water deficit (or at specific deficit/stress levels beneficial for yield & quality)

2) How much water to apply? → The amount of water used by the crop since the last irrigation or rainfall (or a portion of ET max to maintain a target stress level)

3) How to best apply the necessary amount of water? →

Uniformly or Site-specifically

Frequent-light or Infrequent-deep

Application rate and volume compatible with the soil infiltration and storage capacity, or energy rates

METHODS FOR IRRIGATION SCHEDULING

Weather-based

ESTIMATE OF CROP WATER USE (ET)

VERY COMMON

REQUIRES DATA & CALCULATIONS

Soil-based

ASSESS SOIL WATER STATUS

EQUIPM. INTENSIVE

GOOD FOR PERIODIC CHECK

Plant-based

DETECTS PLANT WATER STATUS

LABOR INTENSIVE

DEVELOPED FOR SOME CROPS, NOT ALL

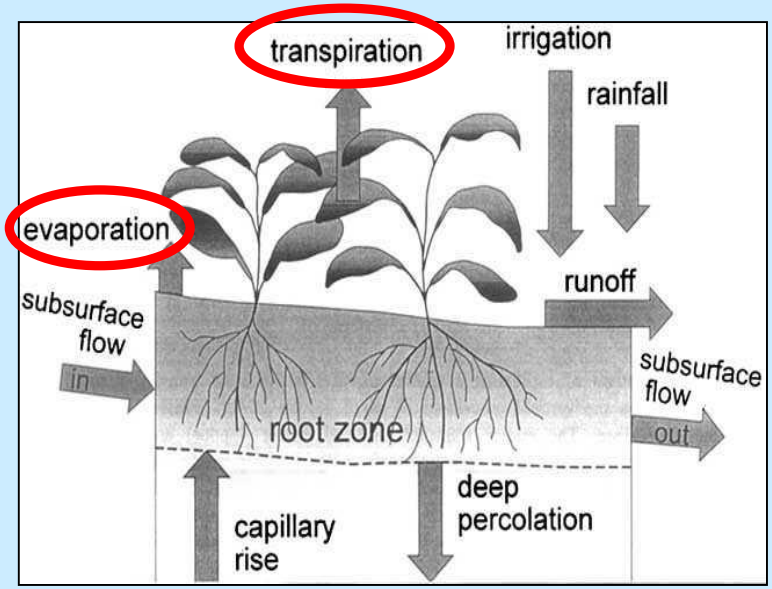
ALL IRRIGATION SCHEDULING METHODS REQUIRE SKILLED ON-FARM PERSONNEL & CAPACITY FOR TROUBLE-SHOOTING

WEATHER OR ET-BASED SCHEDULING

<u>Basic criterion</u>:
replenish the amount of water used by the crop (ET_C) since the last irrigation

Crop ET = Reference ET x Crop Coefficient

$$ET_C = ET_O \times k_C$$



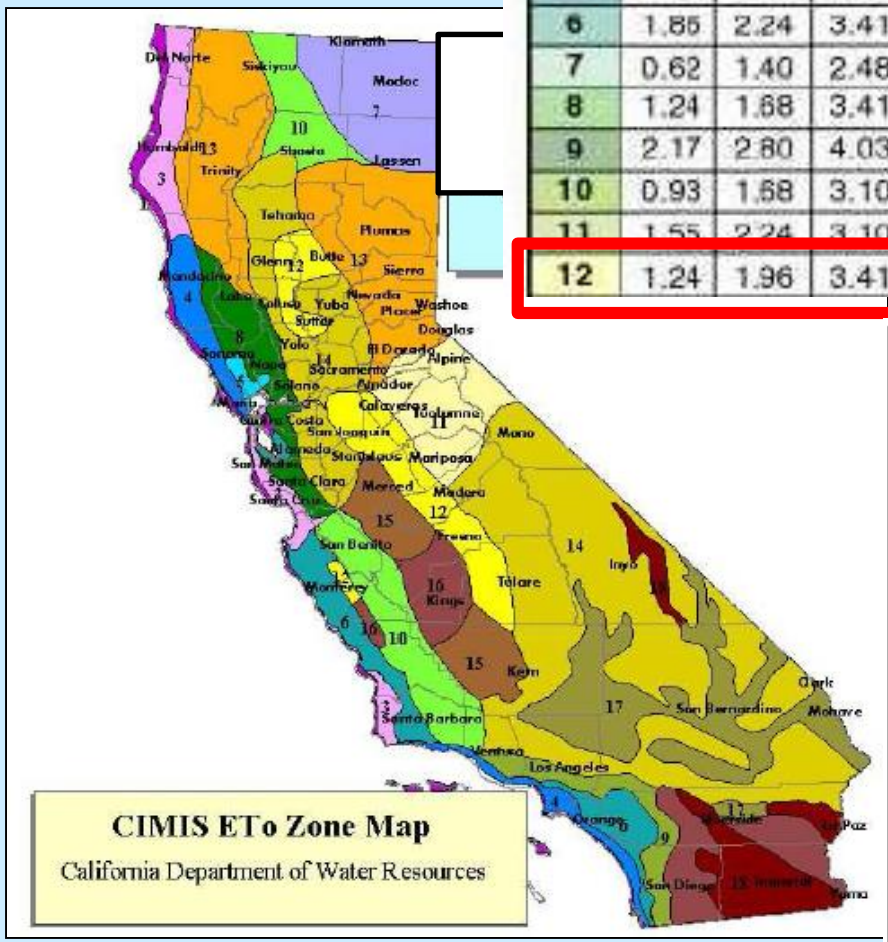
1) Use historical ET averages (ET_O and K_c values)
2) Use real-time ET_O and K_c values
3) Use ETo forecast and K_c values

Historical ET_o average estimates: http://wwwcimis.water.ca.gov/cimis

CIMIS

Monthly Average Reference Evapotranspiration by ETo Zone (inches/month)

Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	0.93	1.40	2.48	3.30	4.03	4.50	4.65	4.03	3.30	2.48	1.20	0.62	33.0
2	1.24	1.68	3.10	3.90	4.65	5.10	4.96	4.65	3.90	2.79	1.80	1.24	39.0
3	1.86	2.24	3.72	4.80	5.27	5.70	5.58	5.27	4.20	3.41	2.40	1.86	46.3
4	1.86	2.24	3.41	4.50	5.27	5.70	5.89	5.58	4.50	3.41	2.40	1.86	46.6
5	0.93	1.68	2.79	4.20	5.58	6.30	6.51	5.89	4.50	3.10	1.50	0.93	43.9
6	1.86	2.24	3.41	4.80	5.58	6.30	6.51	6.20	4.80	3.72	2.40	1.86	49.7
7	0.62	1.40	2.48	3.90	5.27	6.30	7.44	6.51	4.80	2.79	1.20	0.62	43.4
8	1.24	1.68	3.41	4.80	6.20	6.90	7.44	6.51	5.10	3.41	1.80	0.93	49.4
9	2.17	2.80	4.03	5.10	5.89	6.60	7.44	6.82	5.70	4.03	2.70	1.86	55.1
10	0.93	1.68	3.10	4.50	5.89	7.20	8.06	7.13	5.10	3.10	1.50	0.93	49.1
11	1.55	2.24	3.10	4.50	5.89	7.20	8.06	7.44	5.70	3.72	2.10	1.55	53.0
12	1.24	1.96	3.41	5.10	6.82	7.80	8.06	7.13	5.40	3.72	1.80	0.93	53.3



CIMIS ETo Zone Map

California Department of Water Resources

DATE	Almonds	Walnuts	Pistachios	Stone fruit	Prunes	Olives	Citrus	Apples	Pears	W. Grapes
Jan 1-15						0.80	0.65			
Jan 16-31						0.80	0.65			
Feb 1-15						0.80	0.65			
Feb 16-28						0.80	0.65			
Mar 1-15				0.55		0.80	0.65			
Mar 16-31	0.54	0.12		0.62		0.80	0.65			0.32
Apr 1-15	0.60	0.53	0.07	0.67	0.62	0.80	0.65			0.41
Apr 16-30	0.66	0.68	.43	0.73	0.84	0.80	0.65			0.50
May 1-15	0.73	0.79	0.68	0.78	0.96	0.80	0.65	0.59		0.59
May 16-31	0.79	0.86	0.93	0.85	0.96	0.80	0.65	0.67	0.55	0.69
June 1-15	0.84	0.93	1.09	0.87	0.96	0.80	0.65	0.76	0.55	0.78
June 16-30	0.86	1.00	1.17	0.87	0.96	0.80	0.65	0.84	0.78	0.82
July 1-15	0.93	1.14	1.19	0.87	0.96	0.80	0.65	0.92	0.80	0.82
July 16-31	0.94	1.14	1.19	0.87	0.96	0.80	0.65	1.00	0.85	0.82
Aug 1-15	0.94	1.14	1.19	0.87	0.95	0.80	0.65	1.00	0.87	0.82
Aug 14-31	0.94	1.14	1.12	0.87	0.92	0.80	0.65	1.00	0.87	0.77
Sept 1-15	0.94	1.08	0.99	0.87	0.84	0.80	0.65	1.00	0.87	0.66
Sept 16-30	0.91	0.97	0.87	0.82	0.78	0.80	0.65	1.00	0.87	0.55
Oct 1-15	0.85	0.88	0.67	0.75	0.69	0.80	0.65	1.00	0.87	0.44
Oct 16-31	0.79	0.51	0.50	0.68	0.57	0.80	0.65	0.91	0.87	
Nov 1-15	0.70	0.28	0.35			0.80	0.65	0.59	0.87	
Nov 16-30						0.80	0.65		0.75	
Dec 1-15						0.80	0.65		0.70	
Dec 16-31						0.80	0.65		0.65	

ETc = ETo x Kc

CIMIS
CALIFORNIA DEPARTMENT OF WATER RESOURCES

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Nov 1-15	0.70	0.28	0.35			0.80	0.65	0.59	0.87	
Nov 16-30						0.80	0.65		0.75	
Dec 1-15						0.80	0.65		0.70	
Dec 16-31						0.80	0.65		0.65	

NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Custom Weather Forecast Table

	Wed Feb 13				Thu Feb 14				Fri Feb 15				Sat Feb 16				Sun Feb 17				Mo
Weather	Rain	Rain	Rain	Rain	Likely Rain Showers and TStorms	Likely Rain Showers	Likely Rain Showers	Rain Showers	Likely Rain Showers	Chance Rain Showers	Slight Chance Rain Showers	Chance Rain Showers	Likely Rain Showers				Chance Rain Showers				
Daily-Temp	High -998				High 64				High 56				High 56				High 55				H
	Low --				Low 54				Low 48				Low 40				Low 38				L
Chance of Precip	--	85%	90%	90%	95%	95%	70%	60%	70%	80%	70%	30%	15%	50%	70%	65%	55%	60%	50%	30%	10%	10
Precip	0.24"	0.14"	0.09"	0.34"	0.34"	0.02"	0.03"	0.16"	0.36"	0.14"	0.04"	0.02"	0.03"	0.06"	0.02"	0.02"	0.03"	0.01"	0.00"	0.00"	0.0
12-hr Snow Total	--	0"		0"		0"		0"		0"		0"		0"		0"		0"		0"	
FRET	-999"				0.07"				0.05"				0.06"				0.05"				


tule
Evapotranspiration
Sensor

DRAWBACKS OF ET-BASED SCHEDULING

Estimated ET may be quite different from the actual ET in the site-specific conditions of our orchard

RISK OF OVER-IRRIGATION OR UNDER-IRRIGATION

Most of the available Kc information was developed for:

- ✓ Infrequent irrigation methods, such as surface or sprinkler irrigation
- ✓ Well-drained soils, level (flat) grounds
- ✓ Crop varieties, rootstocks, plant densities, and canopy management practices that were quite different from the current

MICRO-IRRIGATION IS A GAME-CHANGER
(SPOON-FEEDS WATER AND NUTRIENTS TO CROPS)

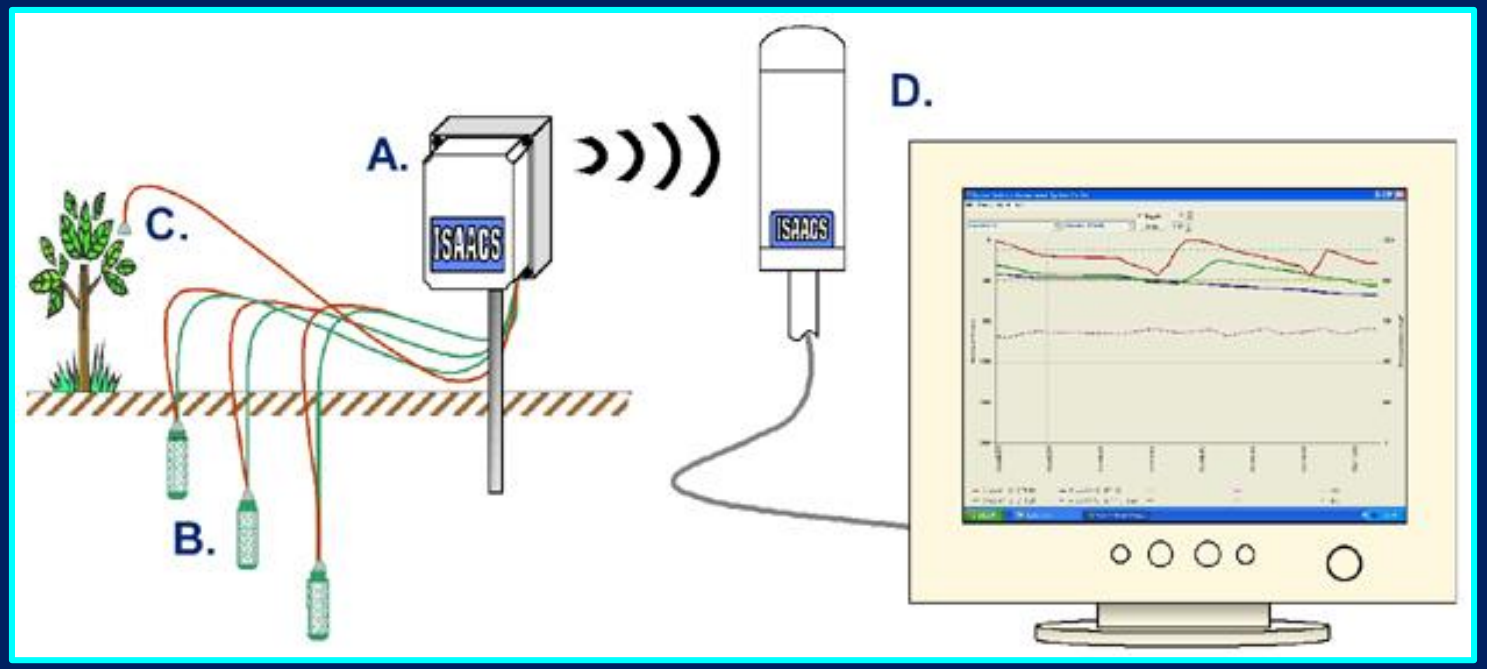
Looking only at ET may be limiting for Fruit Crops

NEED TO LOOK AT THE PLANT-WATER AND SOIL-WATER STATUS

SOIL MOISTURE MONITORING

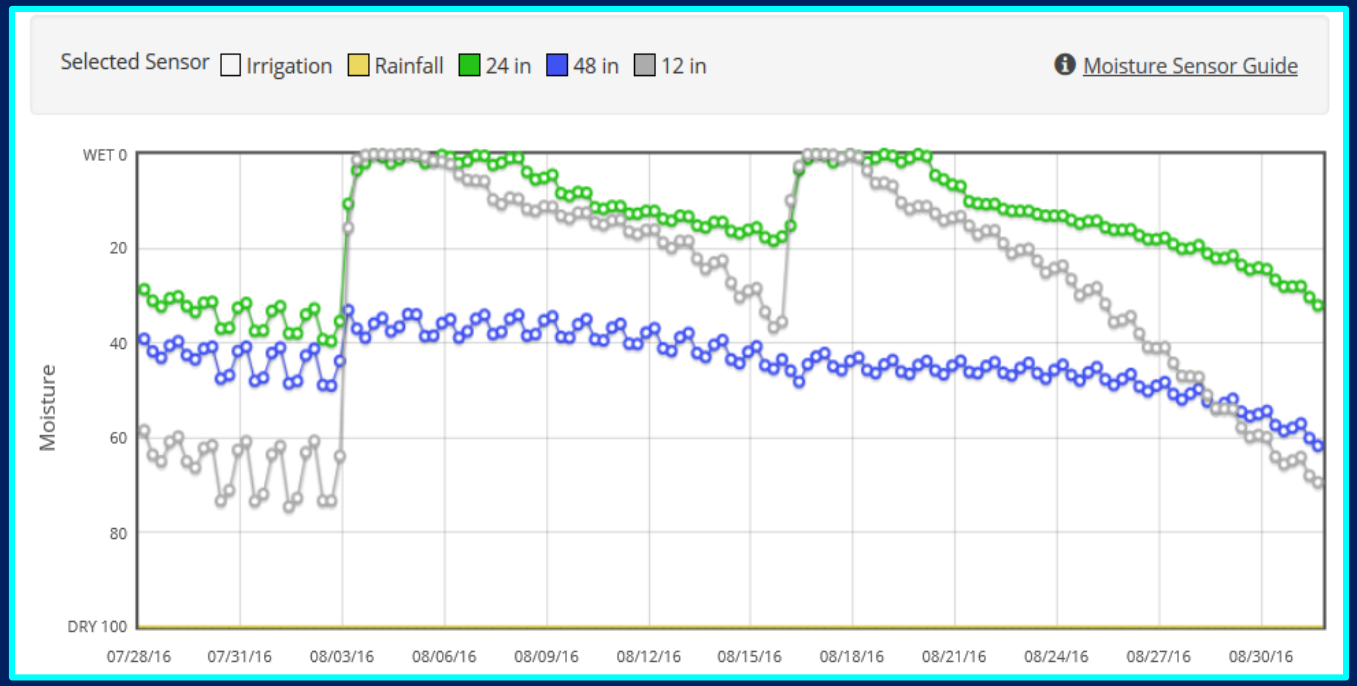
Keeps track of what happens in the root zone with regard to:

1. How much water infiltrates during an irrigation
2. How much water is taken up by plants between irrigations
3. Maintaining good soil water conditions for plants growth & production



SOIL MOISTURE-BASED IRRIGATION SCHEDULING

1. Observe soil moisture frequently
2. Start irrigation at target level of soil moisture (allowable depletion, allowable matric potential or tension)
3. Stop irrigation when soil moisture reaches target levels
4. The next irrigation could also be predicted based on the measured soil moisture depletion rate

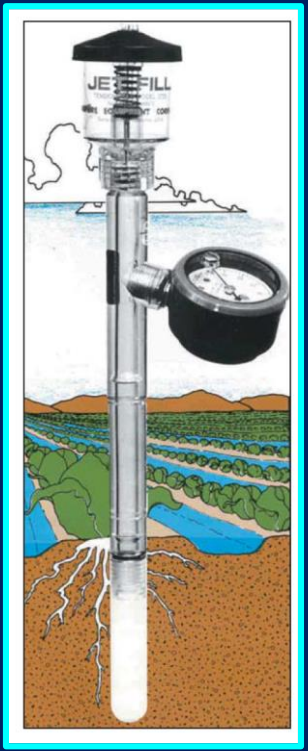


Recommended values of soil moisture tension at which irrigation should occur (50% of PAW)

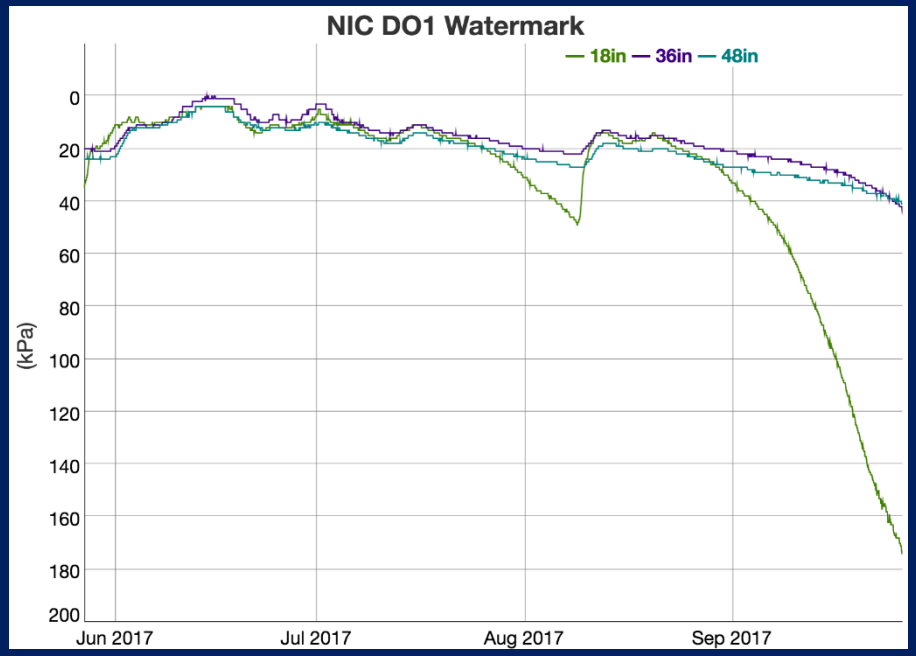
Soil Type	Soil Moisture Tension (centibars)
Sand or loamy sand	40-50
Sandy loam	50-70
Loam	60-90
Clay loam or clay	90-120

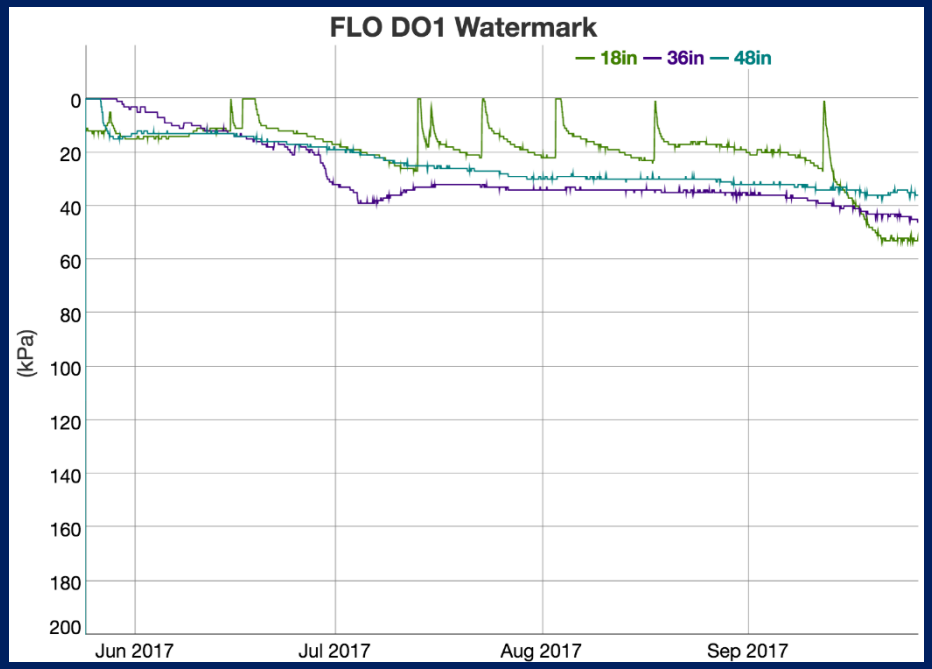
Soil moisture content at which irrigation should occur (@ 50% of PAW depleted)

Soil Texture	Soil Moisture Content (%)
Sand	7
Loamy Sand	12
Sandy Loam	15
Loam	20
Silt Loam	23
Silty Clay Loam	28
Clay Loam	27
Sandy Clay Loam	24
Sandy Clay	22
Silty Clay	30
Clay	31



DRAWBACKS OF SM-BASED SCHEDULING





Plants may face water stress even under well-watered soil conditions (salinity/sodicity, hypoxia, soil-water piling up due to perched water table or compaction layers)

WITH MICRO-IRRIGATION THERE MAY BE SOME PREFERENTIAL FLOW AND NON-HOMOGENEOUS SOIL MOISTURE

NEED TO LOOK AT THE PLANT WATER AND SOIL WATER STATUS

SM CAN BE USED AS FEEDBACK INFORMATION AFTER IRRIGATIONS

Methods to Monitor Plant Water Status (and Stress)

Leaf/Stem Water Potential

Sap Flow

Canopy Temperature

Mid-day Stem Water Potential

- ✓ A popular measure of water potential in trees and vines.
- ✓ Leaf is covered with a bag to block out light during the midday period when a tree is undergoing the most water stress.
- ✓ After 10-15 minutes the stomata of the leaf close and the water potential of the leaf equilibrates with the water potential of the tree.
- ✓ Values of stem water potential have been calibrated to shoot growth, and fruit quality in a few crops (almonds, grapes, etc.).

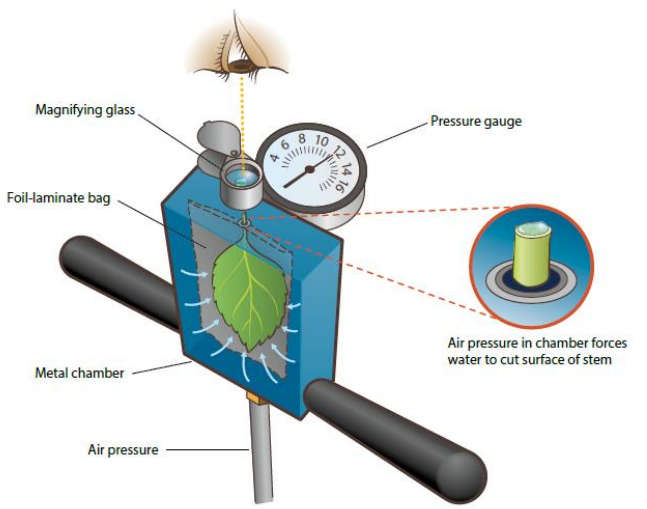
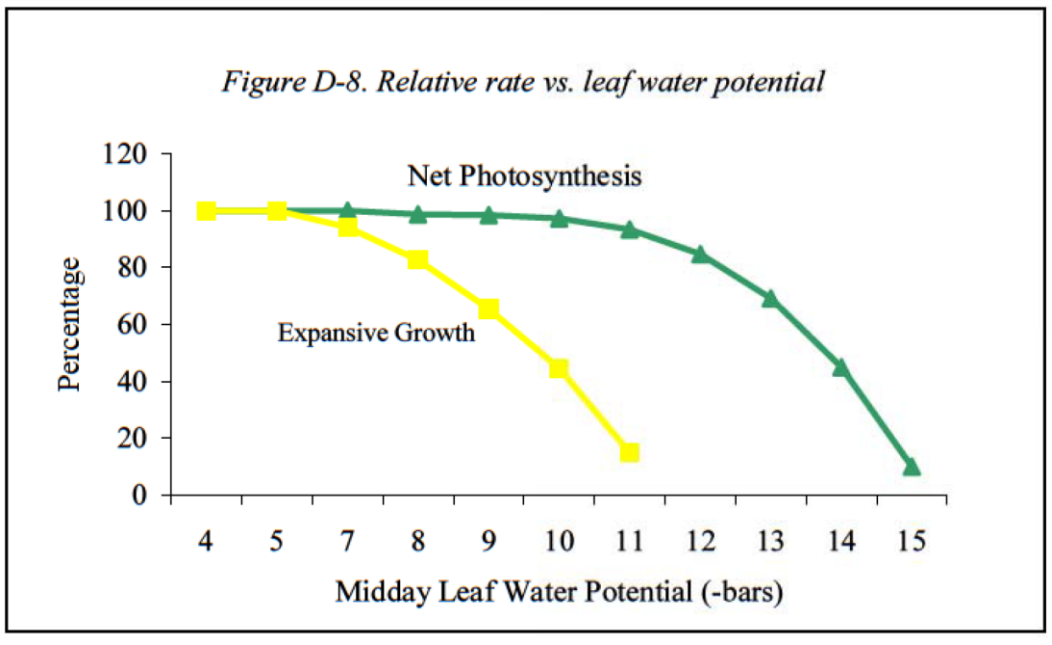


Figure 2. Schematic showing how water potential is measured in a severed leaf and stem (petiole) using a handheld pump-up pressure chamber. *Source:* Adapted from Plant Moisture Stress (PMS) Instrument Company.



Dendrometers and Other Plant Sensors

COMBINATIONS OF DIFFERENT APPROACHES

Plant-based
(Monitoring plant water status)

→ **Proper Irrigation Timing**

↓

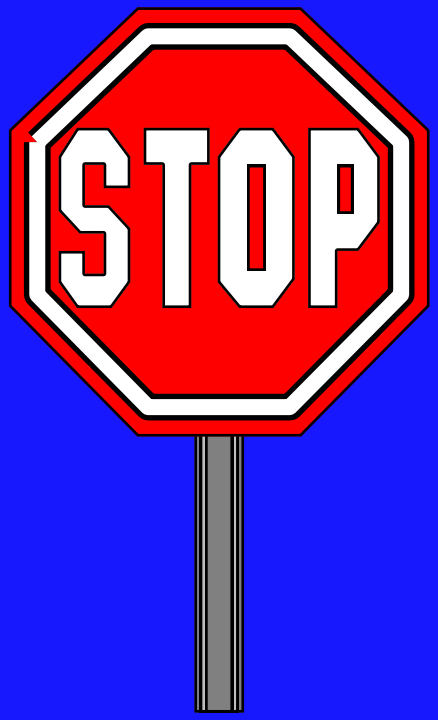
Weather-based
(Estimating the crop water use)

→ **Adequate Irrigation Amount**

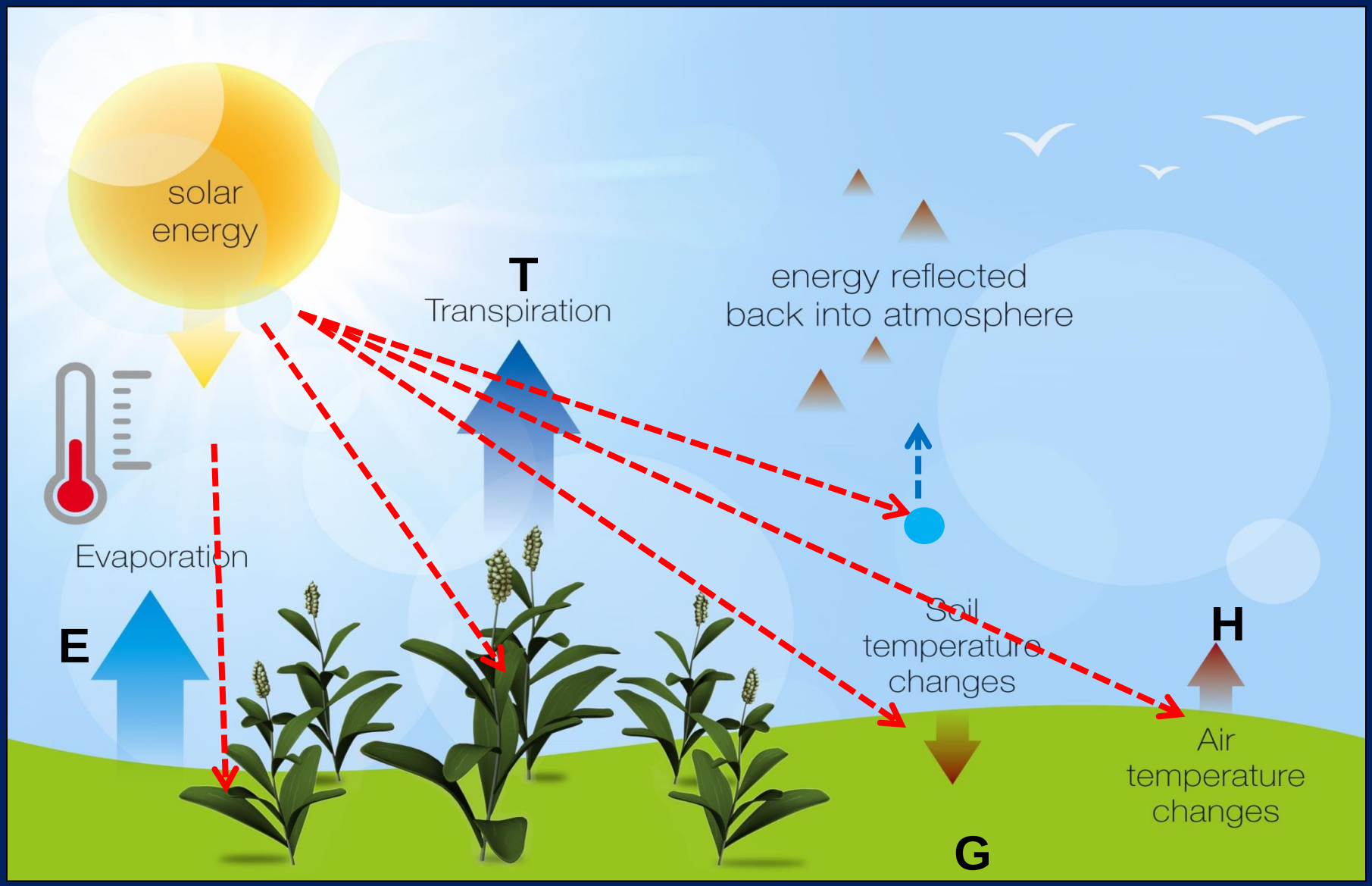
↓

Soil-based
(Monitoring soil moisture)

→ **Check for Feedback**


STOP

WHAT DRIVES CROP WATER USE (Evapotranspiration)?



TAKE-HOME MESSAGES

- **Define your irrigation strategy based on:**
  - ✓ Targets of yield and quality
  - ✓ Economics (water cost, energy cost, labor availability and cost, price rewards for yield or quality, or both)
  - ✓ Site-specific conditions (soil, water supply, slope, aspect, labor etc.)

- **Learn how to implement your strategy - it takes a few crop seasons to learn how to do it**
  - ✓ Select what parameter to monitor over the crop season (ET, Soil, Plant, or a combination of the three)
  - ✓ Schedule irrigation according to your strategy, but get feedback on schedule implementation

- **Do not rely only on your experience & Think beyond the current crop season**
  - ✓ Every year is different and there are things you are not experienced
  - ✓ What happens in this season will have some effects on the next couple of seasons

Pressure Chamber to Measure Leaf/Stem Water Potential

- ✓ Pressure bombs consist of a chamber that can be brought to different pressures using nitrogen gas or air.
- ✓ The petiole of a leaf protrudes from the chamber so that one can see when water bubbles from the end.
- ✓ By slowly stepping up the pressure in the chamber one can determine the water potential in the leaf.
- ✓ The higher pressure, the more the leaf is water stressed.