Methods and Tools for Irrigation Scheduling

UC ANR Wine Grape Irrigation Short Course
May 22, 2019 – Napa, CA

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PRESENTATION OUTLINE

1) Review some Basics of Crop Water Use

2) Methods and Tools for Scheduling Irrigation

3) Discuss Advantages and Drawbacks of these Methods

WHAT DRIVES GRAPEVINE WATER USE (ET)?

- ✓ **Water use 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, advection)
- ✓ **The combined effect of these direct & indirect energy sources on the plants' canopy determine vine water use when soil moisture is not limited.**


05/31/2013

07/22/2014



08


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? →

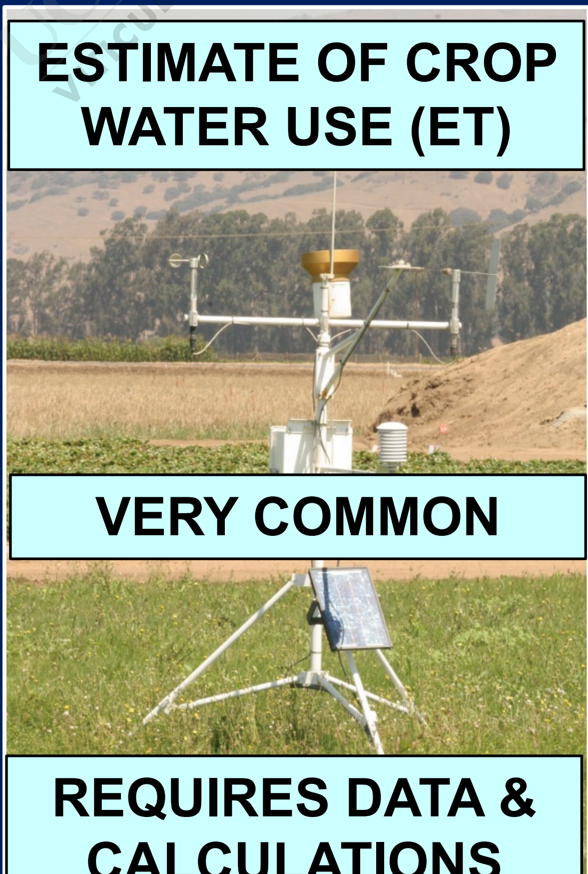
Uniformly or Site-specifically

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

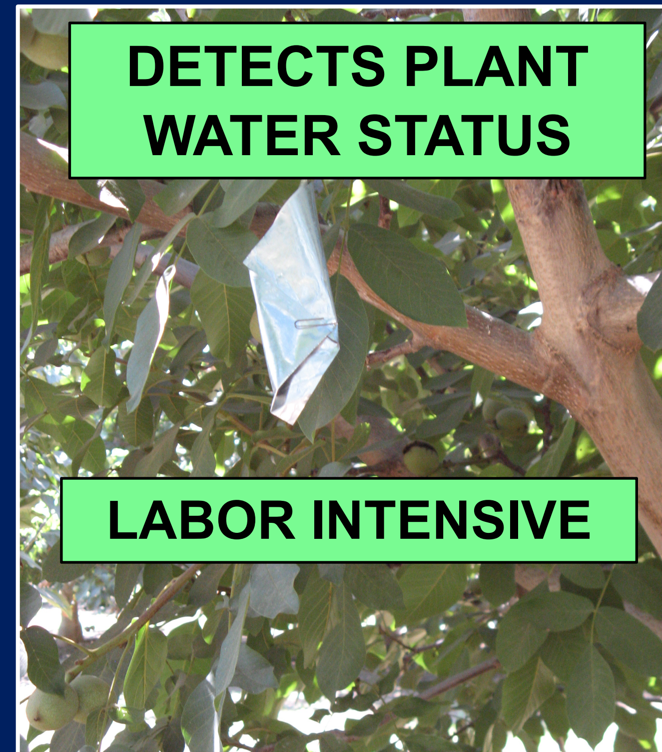
Soil-based

ASSESS SOIL WATER STATUS

EQUIPM. INTENSIVE

GOOD FOR PERIODIC CHECK

Plant-based



DETECTS PLANT WATER STATUS

LABOR INTENSIVE

WELL-DEVELOPED FOR SOME CROPS, NOT ALL

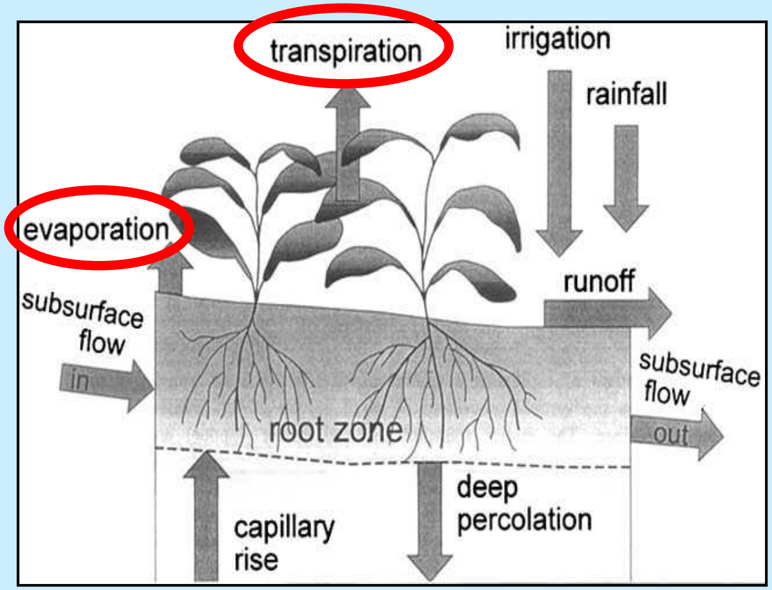
ALL IRRIGATION SCHEDULING METHODS REQUIRE SKILLED ON-FARM PERSONNEL & CAPACITY FOR TROUBLE-SHOOTING

WEATHER OR ET-BASED SCHEDULING

Basic criterion:
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_C, or 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_C average estimates

http://www.itrc.org/projects/cacrop.htm

ZONE 10 ET_C - drip & micro-spray – DRY YEAR

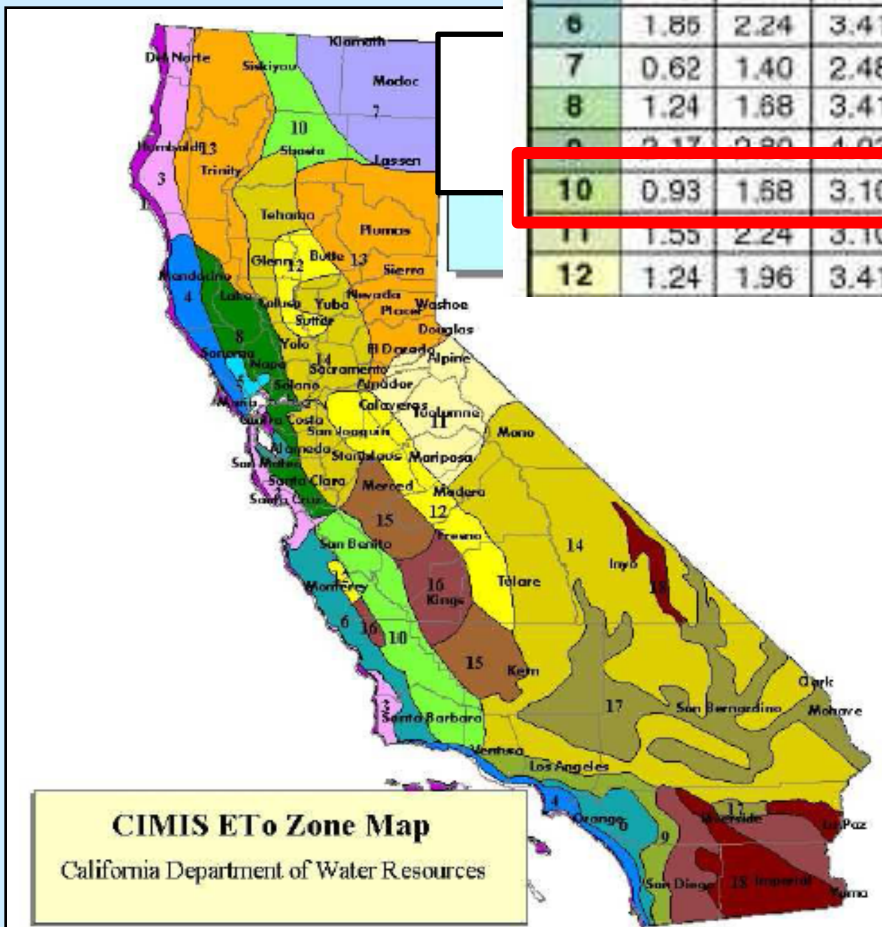
ETc Zone 10- drip & micro-spr - dry year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	YEAR
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
Precipitation	1,8	1,8	3,3	1,5	0,3	0,0	0,0	0,0	0,0	0,0	0,9	0,1	9,9
Grass Reference ETo	1,8	2,2	3,2	4,6	5,7	6,1	6,6	5,8	4,2	3,9	2,1	2,2	48,3
Apple, Pear, Cherry, Plum and Prune	0,8	1,7	2,2	3,2	5,1	5,8	6,2	5,5	3,7	2,1	0,8	0,2	37,3
Apples, Plums, Cherries etc w/covercrop	1,7	2,6	3,5	5,0	6,2	7,3	7,8	6,7	4,7	3,4	2,0	1,5	52,3
Peach, Nectarine and Apricots	0,8	1,7	2,2	3,1	4,7	5,4	5,9	5,2	3,5	2,0	0,8	0,2	35,4
Immature Peaches, Nectarines, etc	0,8	1,7	2,1	2,2	2,8	3,1	3,3	3,0	2,0	1,0	0,8	0,2	22,9
Almonds	0,8	1,7	2,4	3,7	5,1	5,5	5,9	5,2	3,5	1,9	0,8	0,2	36,6
Almonds w/covercrop	1,6	2,5	3,4	5,0	6,0	6,5	6,8	6,0	4,1	2,7	1,8	1,3	47,6
Immature Almonds	0,8	1,7	2,3	2,6	3,3	3,2	3,5	3,1	2,1	1,0	0,8	0,2	24,4
Walnuts	0,8	1,7	2,3	2,7	4,6	6,7	7,1	6,3	4,0	2,4	0,9	0,2	39,5
Pistachio	0,8	1,7	2,0	2,2	2,2	4,7	7,0	6,2	4,2	2,5	0,9	0,2	34,5
Pistachio w/ covercrop	1,6	2,5	3,3	4,1	4,2	5,8	7,4	6,5	4,5	3,4	1,8	1,3	46,3
Immature Pistachio	0,8	1,7	2,0	1,8	1,3	2,8	4,1	3,7	2,5	1,4	0,8	0,2	23,1
Misc. Deciduous	0,8	1,7	2,2	3,2	4,9	5,5	5,9	5,1	3,6	2,0	0,8	0,2	35,8
Small Vegetables	1,7	2,1	3,2	4,8	1,0	0,0	0,0	1,0	1,2	0,8	1,7	2,1	19,6
Tomatoes and Peppers	0,8	1,7	2,4	1,9	3,0	6,4	5,8	0,6	0,0	0,0	0,8	0,2	23,5
Potatoes, Sugar beets, Turnip etc..	1,5	1,9	2,7	5,0	6,0	6,5	5,9	0,1	0,0	0,0	0,8	0,2	30,7
Melons, Squash, and Cucumbers	0,8	1,7	2,1	1,4	1,1	0,7	3,3	4,0	1,3	0,0	0,8	0,2	17,3
Onions and Garlic	1,0	2,4	3,4	4,3	4,0	0,9	0,0	0,0	0,0	0,0	1,6	0,5	18,1
Strawberries	0,8	1,7	3,1	1,8	2,2	5,8	6,2	2,4	0,0	0,0	0,8	0,2	24,9
Flowers, Nursery and Christmas Tree	0,8	1,7	2,2	3,2	4,9	5,5	5,9	5,1	3,6	2,0	0,8	0,2	35,8
Citrus (no ground cover)	1,7	2,6	3,3	4,2	4,0	3,9	4,1	3,6	2,7	2,6	1,9	1,7	36,4
Immature Citrus	1,1	2,2	2,7	3,0	2,5	2,3	2,5	2,2	1,6	1,5	1,4	1,0	24,0
Avocado	0,8	1,7	2,2	3,2	4,9	5,5	5,9	5,1	3,6	2,0	0,8	0,2	35,8

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

CIMIS

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

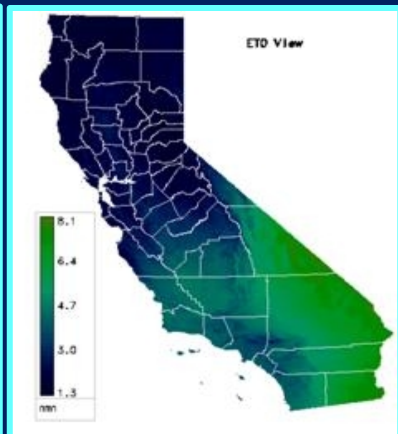
Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	0.93	1.40	2.48	3.30	4.03	4.50	4.65	4.03	3.30	2.48	1.20	0.62	33.0
2	1.24	1.68	3.10	3.90	4.65	5.10	4.96	4.65	3.90	2.79	1.80	1.24	39.0
3	1.86	2.24	3.72	4.80	5.27	5.70	5.58	5.27	4.20	3.41	2.40	1.86	46.3
4	1.86	2.24	3.41	4.50	5.27	5.70	5.89	5.58	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
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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

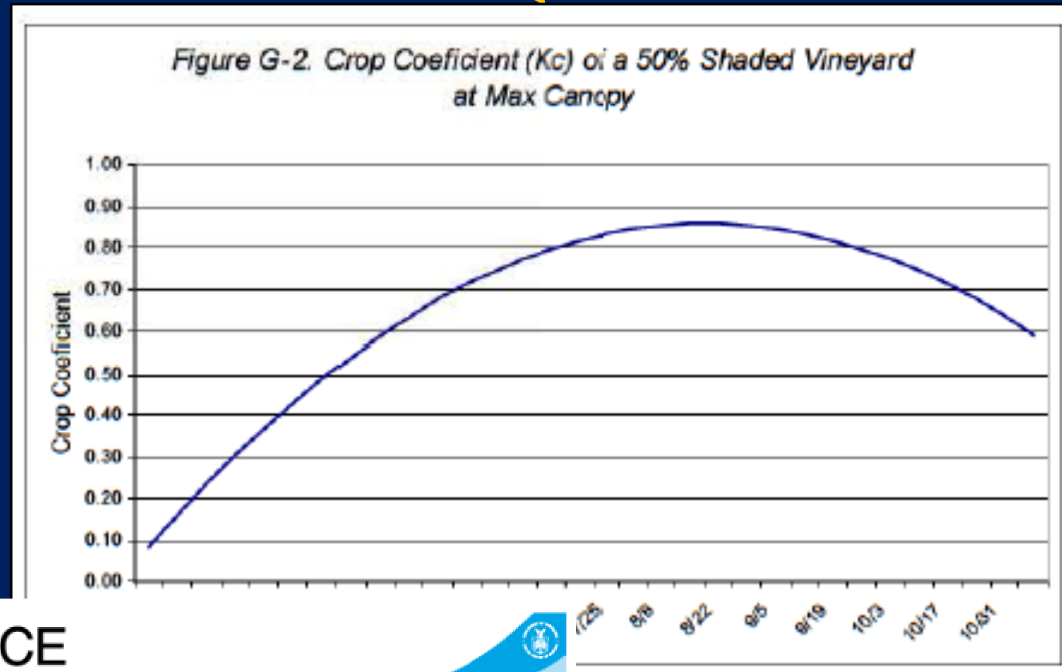


DATE	Almonds	Walnuts	Pistachios	Stone fruit	Prunes	Olives	Citrus	Apples	Pears	W. Grapes
Jan 1-15						0.80	0.65			
Jan 16-31						0.80	0.65			
Feb 1-15						0.80	0.65			
Feb 16-28						0.80	0.65			
Mar 1-15				0.55		0.80	0.65			
Mar 16-31	0.54	0.12		0.62		0.80	0.65			0.32
Apr 1-15	0.60	0.53	0.07	0.67	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





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 Low --				High 64 Low 54			High 56 Low 48				High 56 Low 40				High 55 Low 38				H 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"				

DRAWBACKS OF ET-BASED SCHEDULING

ET estimated with generalized Kc values may be quite different from the actual ET in the site-specific conditions of our vineyard

RISK OF OVER-IRRIGATION OR UNDER-IRRIGATION

Most of the available Kc information was developed for:

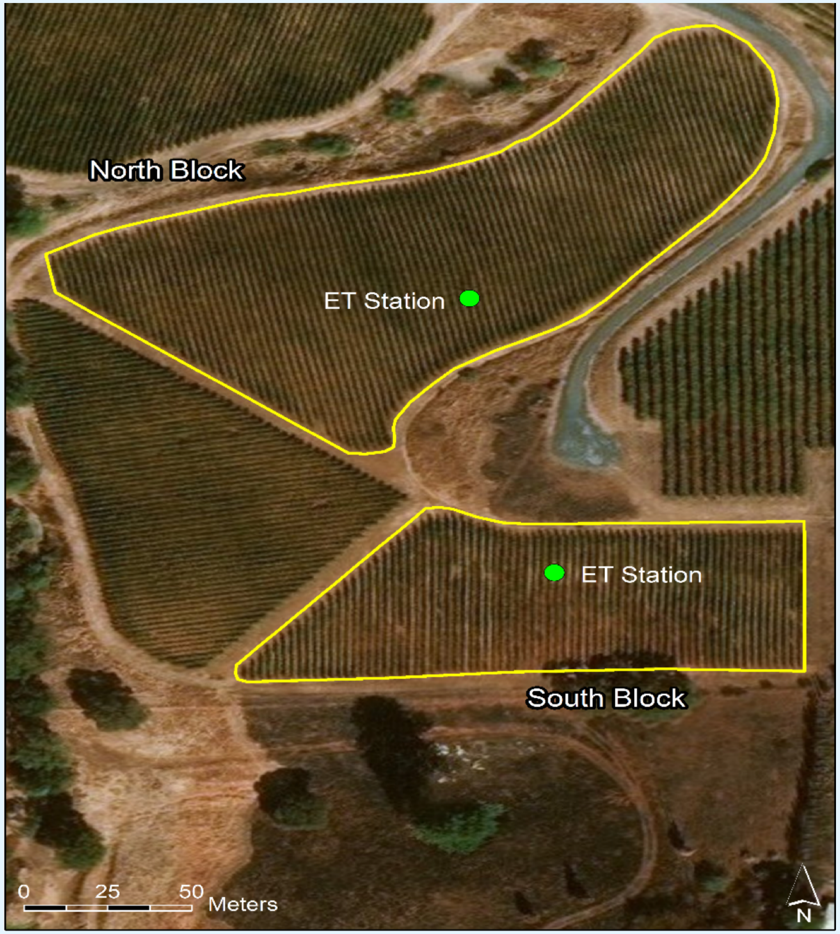
- ✓ Infrequent irrigation methods, such as surface or sprinkler irrigation
- ✓ Well-drained soils, and level (flat) grounds
- ✓ Crop varieties, rootstocks, plant densities, and canopy management practices that were quite different from the current

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

Looking only at ET may be limiting for Fruit and Nut Crops

NEED TO LOOK AT THE PLANT WATER AND SOIL WATER STATUS


tule
Evapotranspiration Sensor



✓ Cabernet sauvignon (clone 15)

✓ Planted in 2000 - density of 3,703 vines ha^{-1} (spacing 1.8 x 1.5 m.)

✓ Vine rows oriented in a north-south direction.

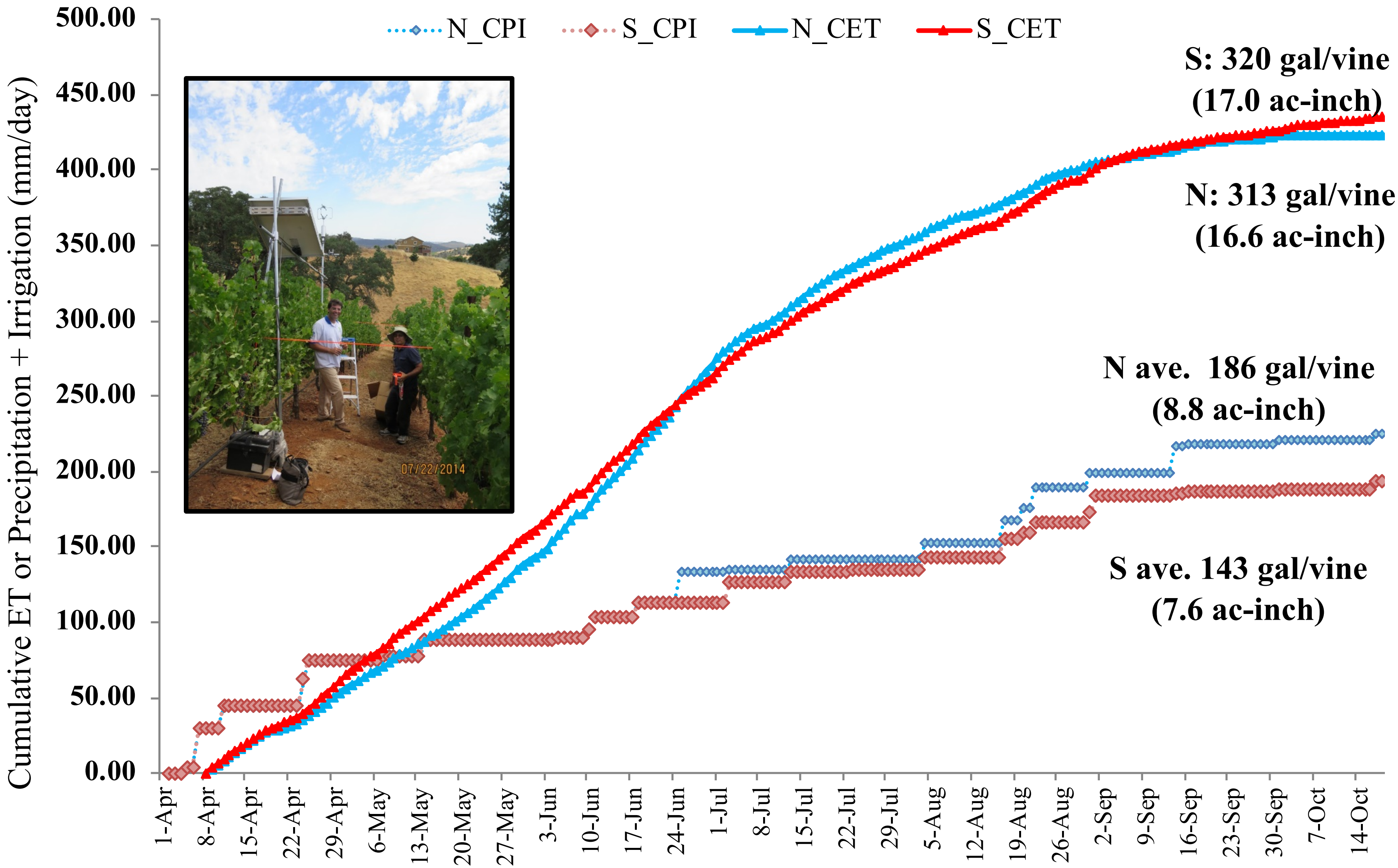
✓ Vines were trained as (VSP) and pruned to 14, 2-bud spurs per vine.

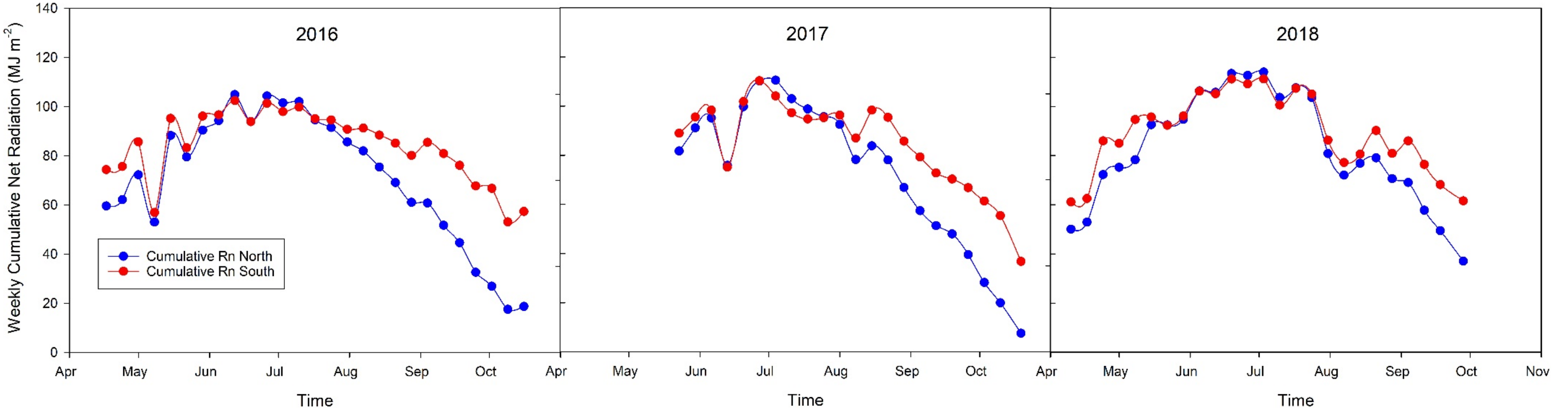
✓ Loam soil with a typical depth to 60 cm (SSURGO).

✓ The slope (RTK GPS) 24.4% N and 25.4% S

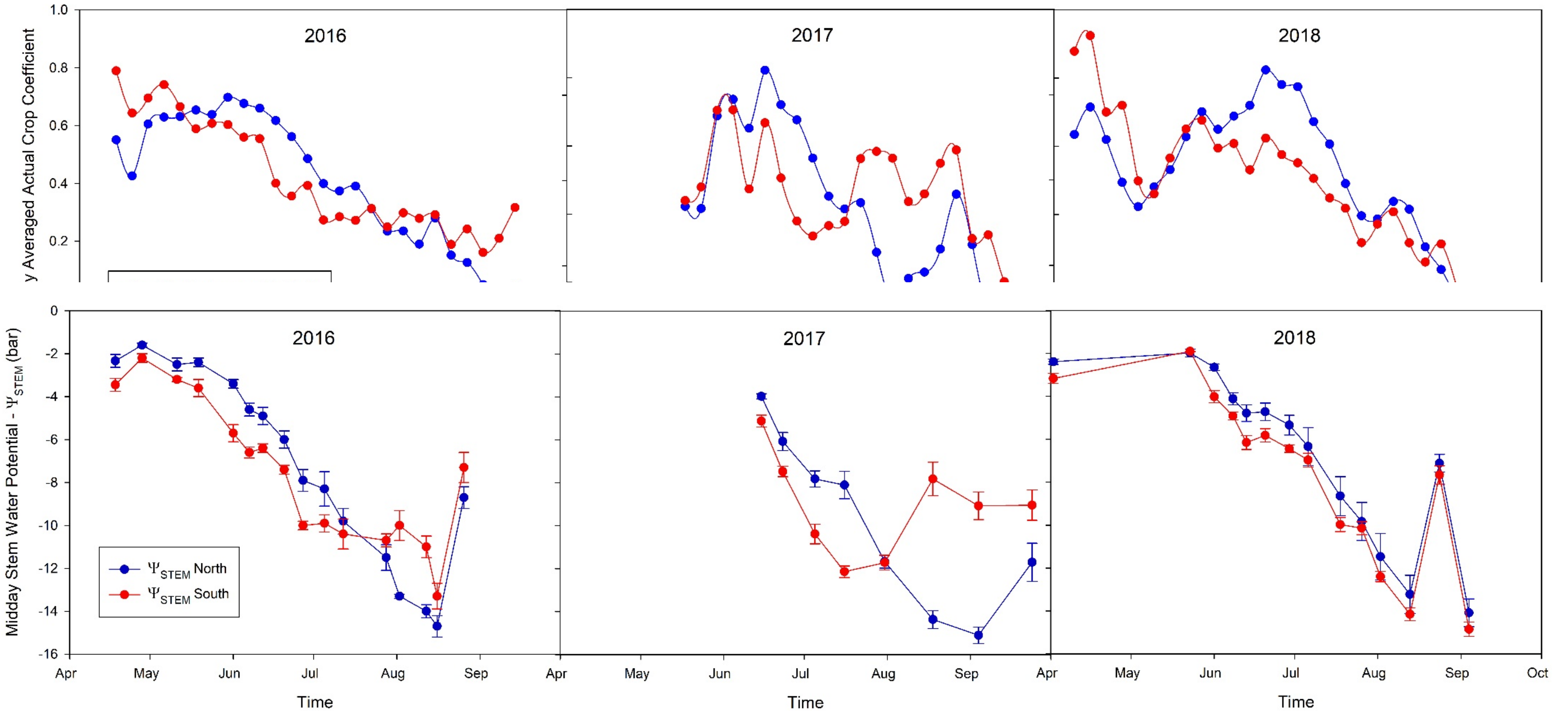
Cumulative ET (mm/day) and cumulative precipitation + irrigation (mm/day) on North and South facing slopes at Safari Vineyards (April 8-Oct 18, 2016)

(D. Zaccaria, L. Wunderlich, R. Snyder, K. Shackel)



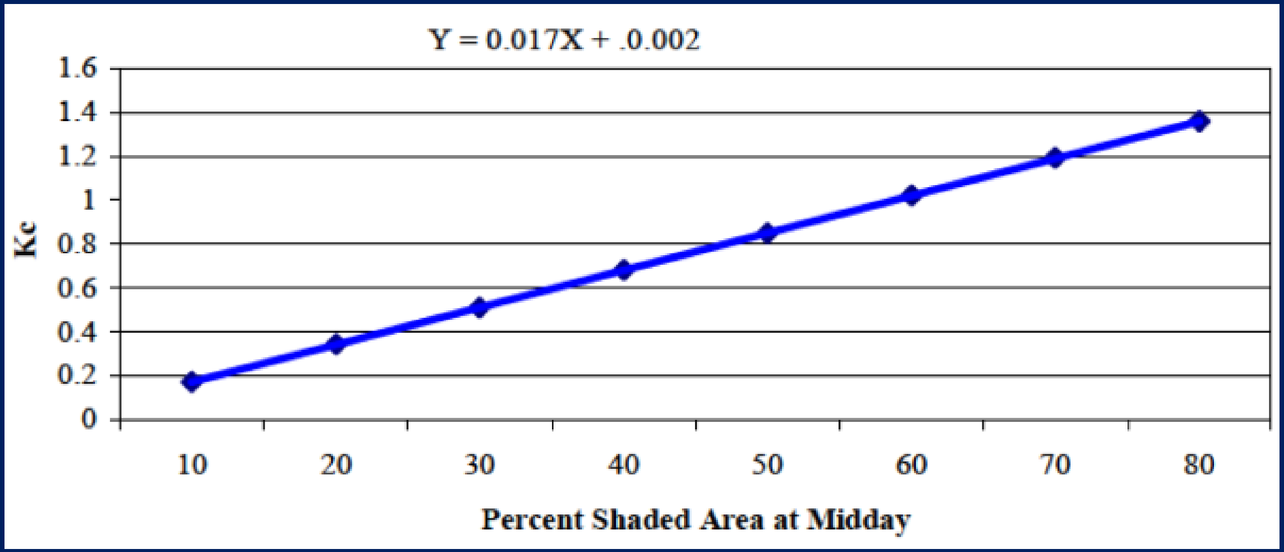


2016
2017
2018
Weekly Cumulative Net Radiation (MJ m^{-2})
Cumulative Rn North
Cumulative Rn South
Time
Apr May Jun Jul Aug Sep Oct Nov



2016
2017
2018
y Averaged Actual Crop Coefficient
Midday Stem Water Potential - Ψ_{STEM} (bar)
Ψ_{STEM} North
Ψ_{STEM} South
Time
Apr May Jun Jul Aug Sep Oct

VINE WATER USE (ET) INCREASE LINEARLY WITH THE % OF GROUND SURFACE SHADED BY THE VINES' CANOPY (L. Williams, 2002)



Kc = 0.002 + 0.017 x % Shaded Area

Simplified formula: Kc = 1.7 x % Shaded Area

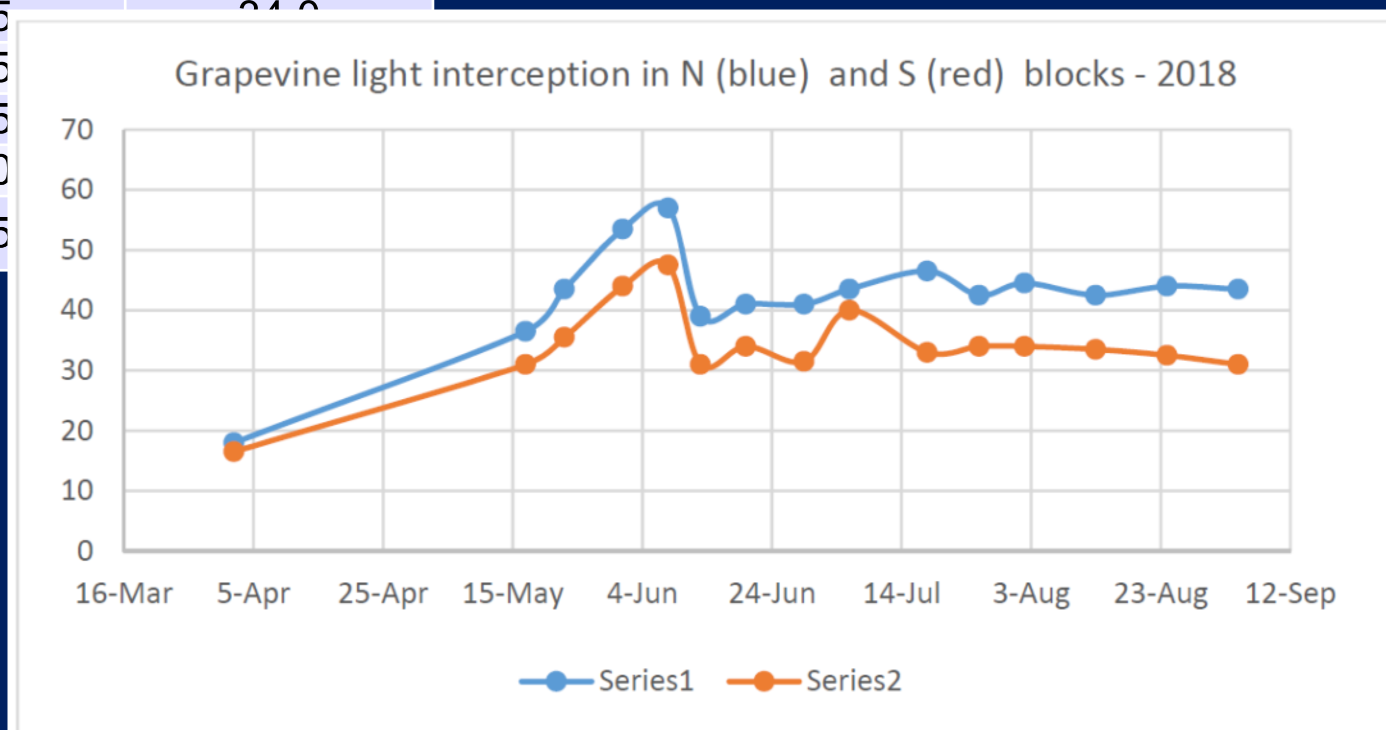
<u>Calculation example</u>

7-foot vine spacing x 11-foot row spacing = 77 sq-ft. x vine

Shaded area: 31 sq-ft./77 sq-ft. = 40%

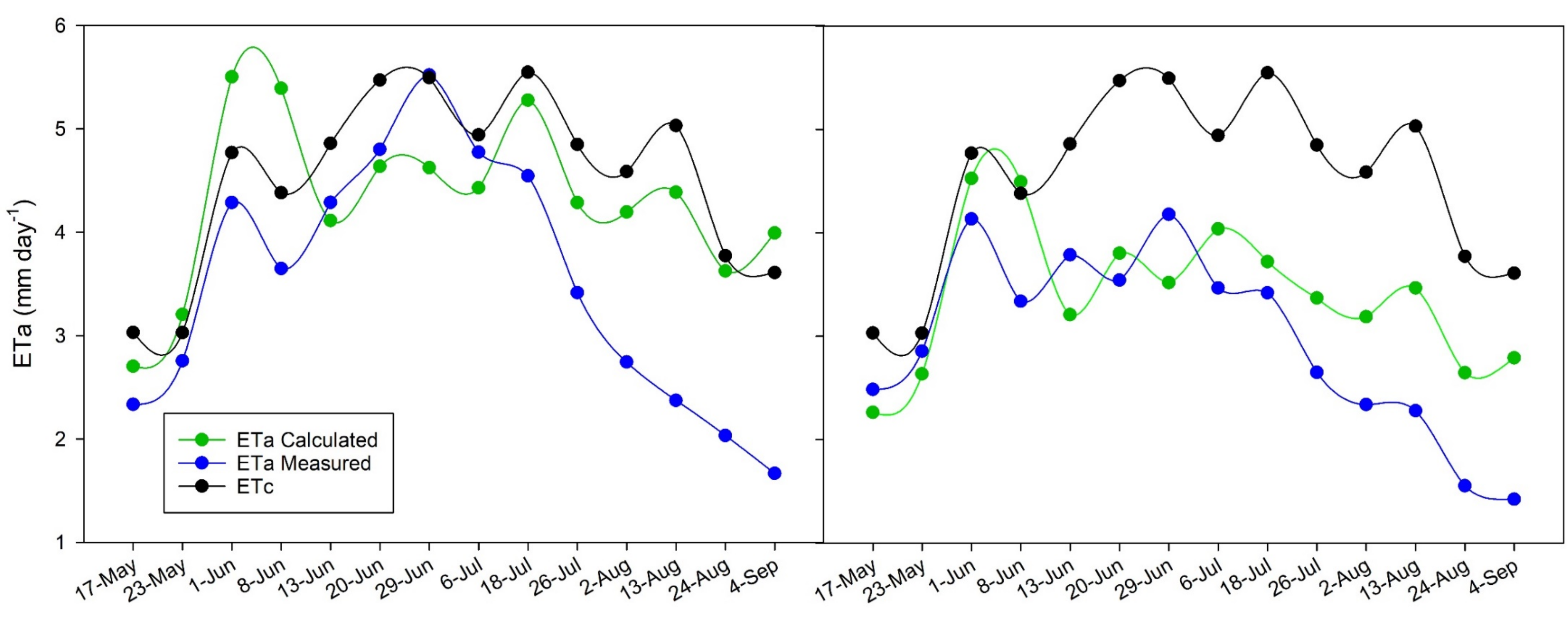
Kc = 1.7 x 0.40 = 0.68

Date	Light interception N block (%)	Light interception S block (%)
April 2	18.0	16.5
May 17	36.5	31.0
May 23	43.5	35.5
June 1	53.5	44.0
June 8	57.0	47.5
June 13	39.0	31.0
June 20	41.0	34.0
June 29	41.0	31.5
July 6	43.5	40.0
July 18	46.5	33.0
July 26	42.5	[illegible]
August 2	44.5	[illegible]
August 13	42.5	[illegible]
August 24	[illegible]	[illegible]
September 4	43.5	[illegible]



NORTH

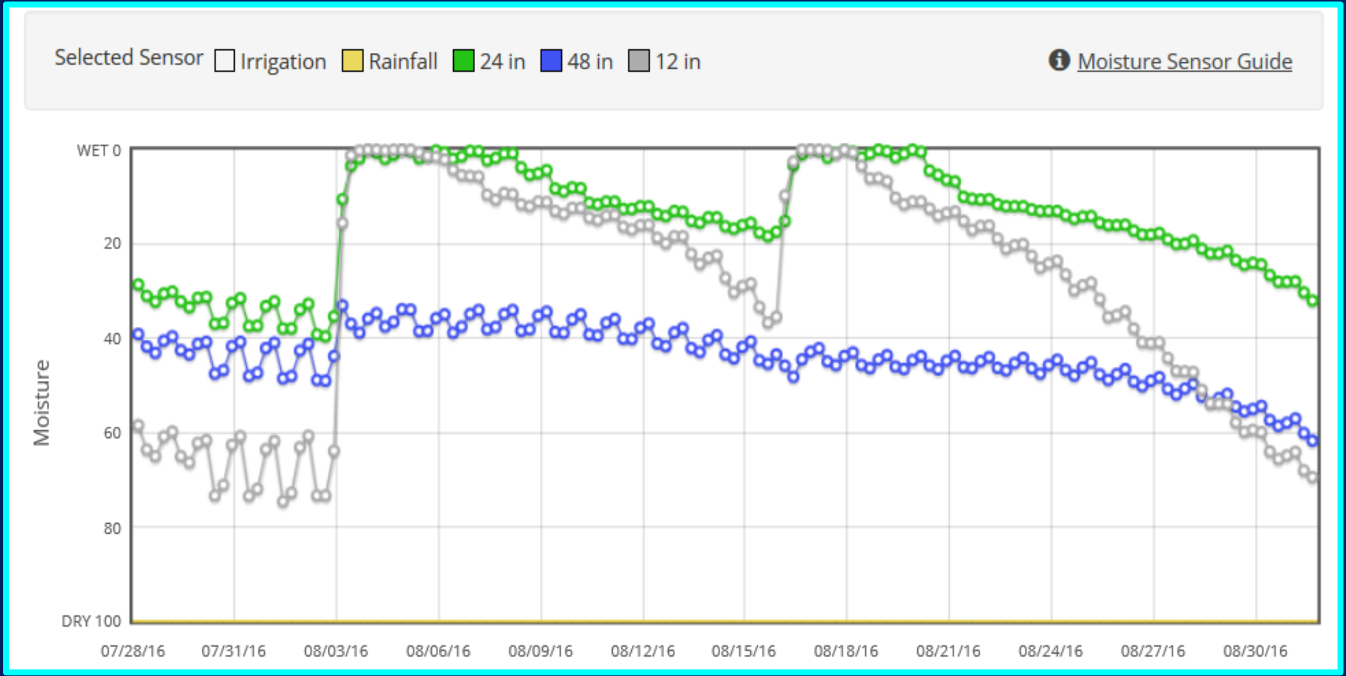
SOUTH



ETa (mm day-1)
6
5
4
3
2
1
ETa Calculated
ETa Measured
ETc
17-May
23-May
1-Jun
8-Jun
13-Jun
20-Jun
29-Jun
6-Jul
18-Jul
26-Jul
2-Aug
13-Aug
24-Aug
4-Sep

SOIL MOISTURE-BASED IRRIGATION SCHEDULING

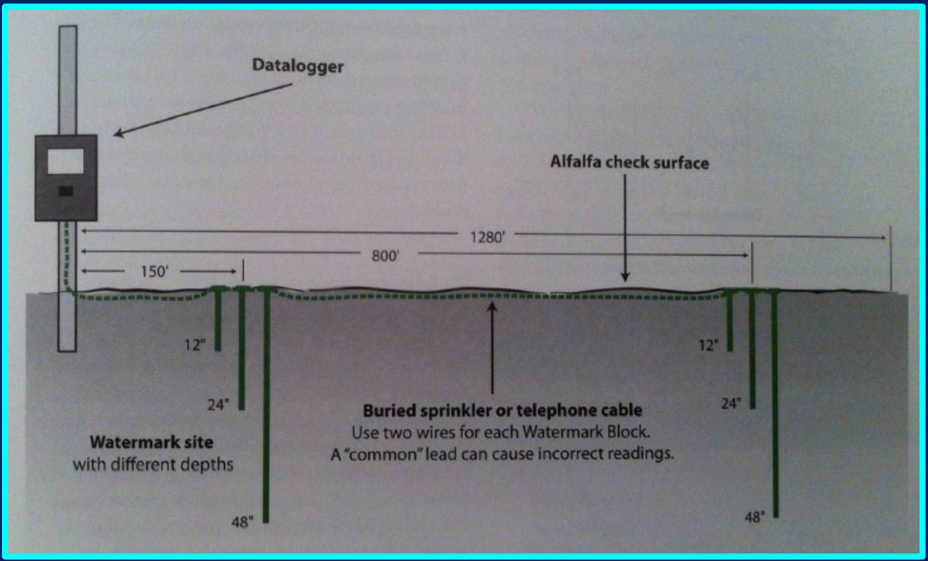
1. Observe soil moisture frequently
2. Start irrigation at target level of soil moisture (allowable depletion, allowable matric potential or tension)
3. Stop irrigation when soil moisture reaches target levels

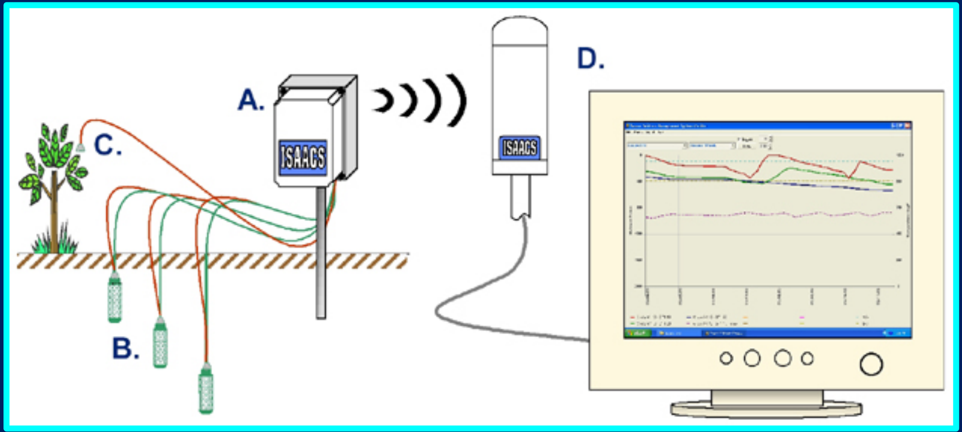


SOIL MOISTURE MONITORING

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





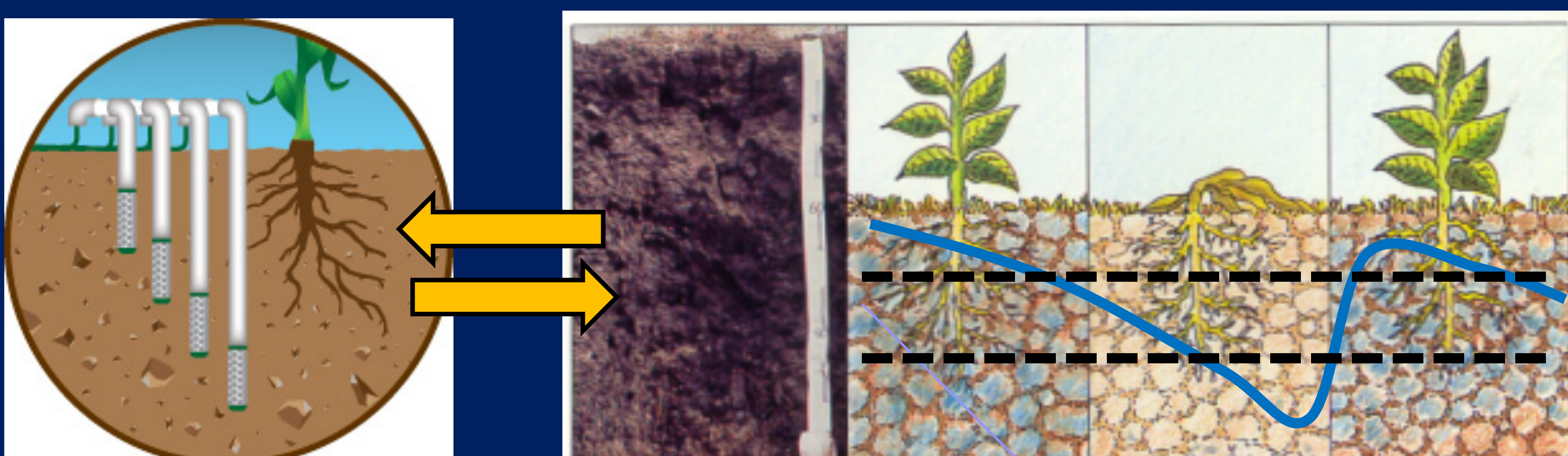
S.M.M. HELPS ANSWERING THE FOLLOWING QUESTIONS

✓When to start irrigation (and when to stop it)?

✓Has enough water infiltrated the root zone during an irrigation?

✓Are we applying enough, insufficient, or excessive water?

✓Is there any deep soil water reserve for crop water uptake during periods of no irrigation, or at bud-break/green-up/harvest?



HOW IS SOIL MOISTURE MEASURED?

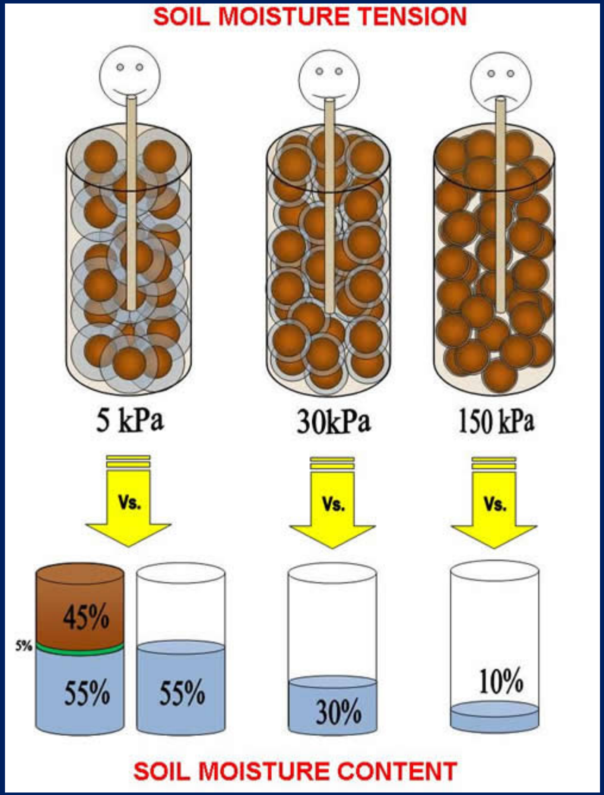
SOIL MOISTURE CONTENT (%, in/ft, mm/m)

How much water is available per unit of soil?

% weight = (weight of water/weight of dry soil) x 100

% volume = (volume of water/volume of soil) x 100

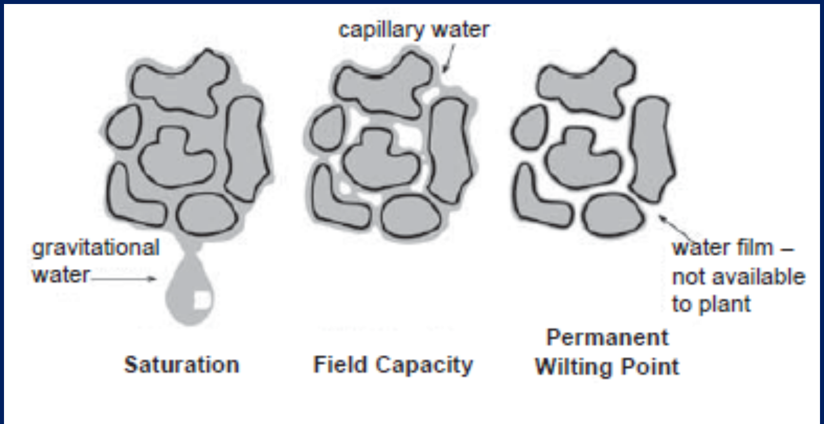
Depth = (inch of water/foot of soil) => MOST COMMON AND PRACTICAL



SOIL MOISTURE TENSION (centibars, kPa)

How strongly water is held by soil particles

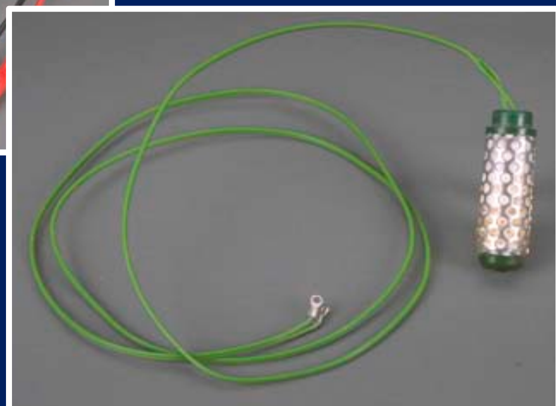
The higher the tension, the drier the soil and the more difficult is for plant to extract water



Some sensors measure soil water content and others measure soil water tension

In reality all sensors measure some properties/parameters that are related to soil moisture content or soil moisture tension through a specific calibration

SOIL WATER TENSION



GYPSUM BLOCKS (tension)

✓Very cheap & Maintenance free

✓Can last 1-5 years (soil moisture)

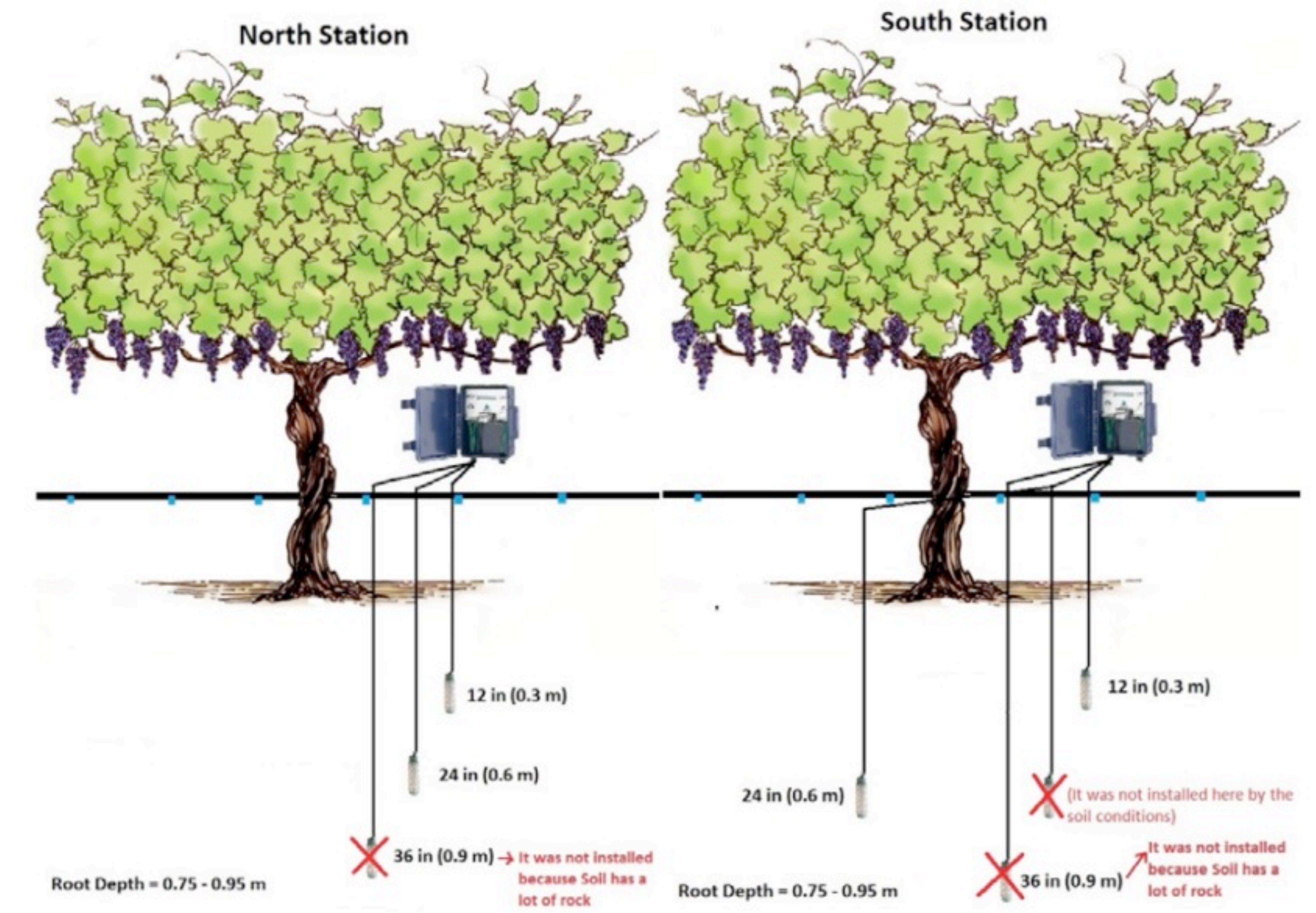
✓Sensitive to soil temperature

✓Corrosion of electrodes

WATERMARK (tension)

- Read from 0 to 200 centibars
  - Low soil moisture tension indicates moist soil
  - High soil moisture tension indicates dry soil
- Saturated soil after irrigation or rainfall
  - Reading < 5-10

- Don't need further calculations; easy to interpret
- Robust and reliable in field conditions
- Buffers against salinity
- Can be hooked up with data loggers and telemetry and monitor in continuous mode

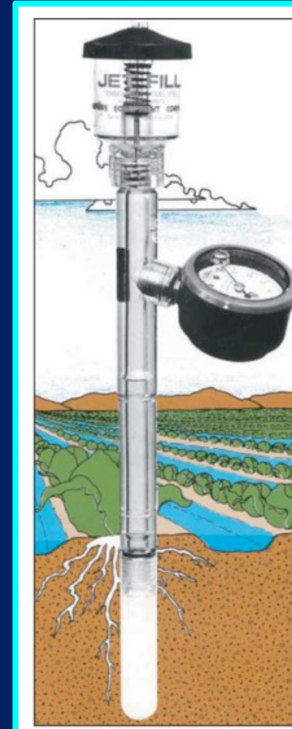

North Station
South Station
12 in (0.3 m)
24 in (0.6 m)
36 in (0.9 m)
It was not installed because Soil has a lot of rock
Root Depth = 0.75 - 0.95 m
12 in (0.3 m)
24 in (0.6 m)
(It was not installed here by the soil conditions)
36 in (0.9 m)
It was not installed because Soil has a lot of rock
Root Depth = 0.75 - 0.95 m

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

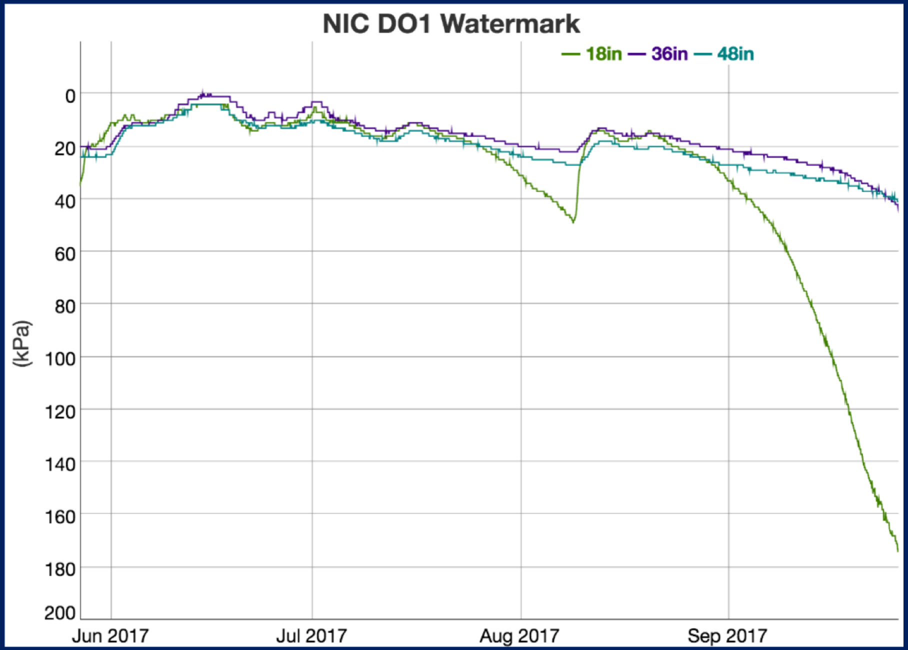
Soil Type	Soil Moisture Tension (centibars)
Sand or loamy sand	40-50
Sandy loam	50-70
Loam	60-90
Clay loam or clay	90-120

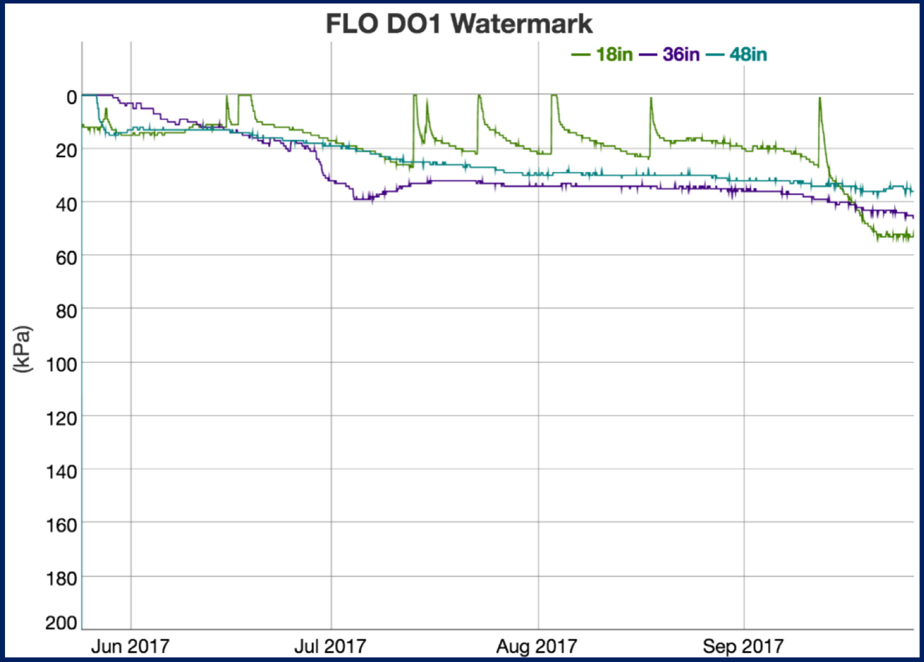
Soil moisture content at which irrigation should occur (@ 50% of PAW depleted)

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 WATER FLOW AND NON-HOMOGENEOUS SOIL MOISTURE

SM CAN BE USED AS FEEDBACK INFORMATION AFTER IRRIGATIONS

NEED TO LOOK AT THE PLANT WATER AND SOIL WATER STATUS

Methods to Monitor Plant Water Status (and Stress)

Leaf/Stem Water Potential

Sap Flow

Canopy Temperature

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.



Dendrometers and Other Plant Sensors

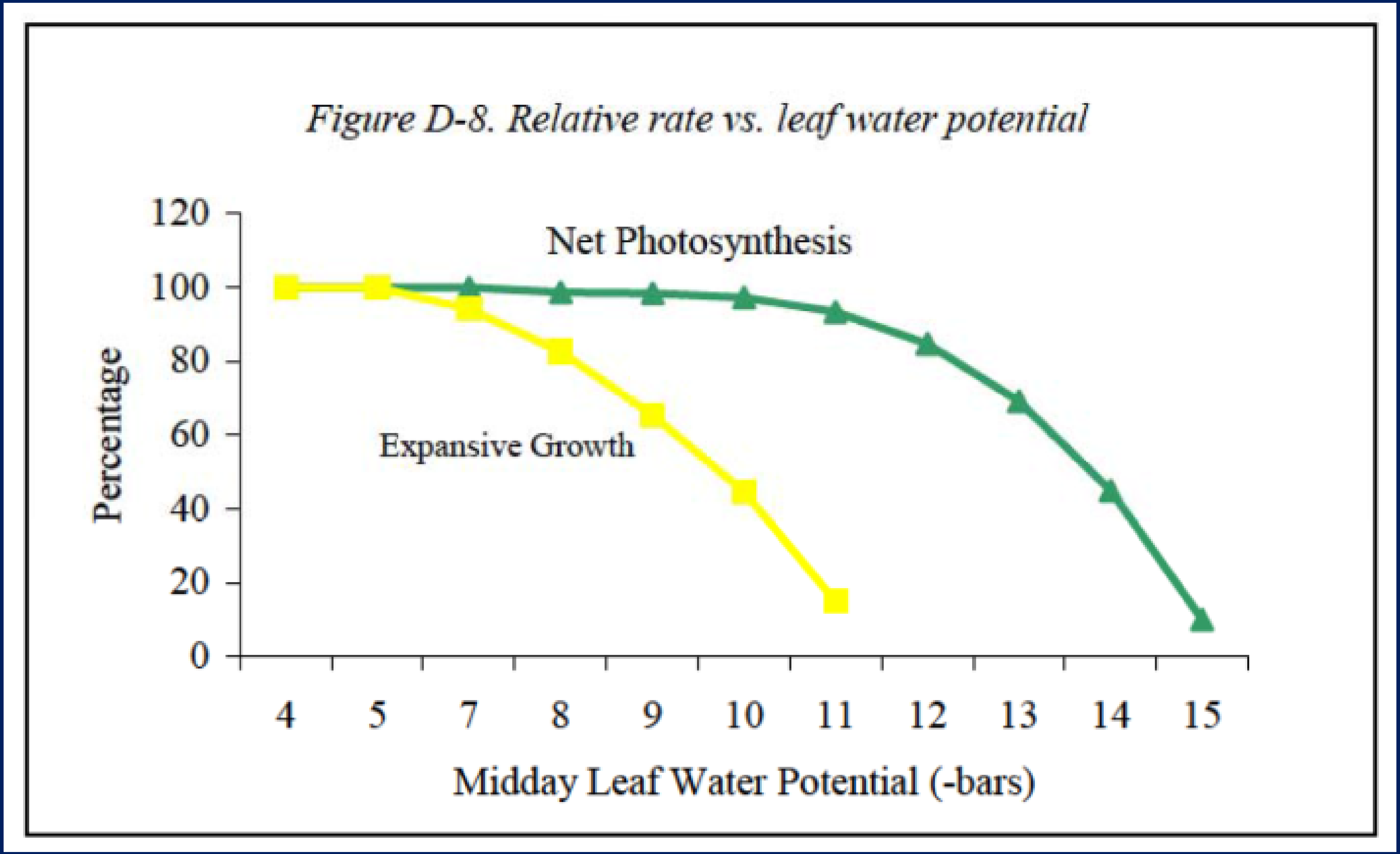
COMBINATIONS OF DIFFERENT APPROACHES

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**

Mild-Moderate water deficits in the period pre-veraison to veraison can control expansive vegetative growth while still allowing photosynthesis at unaffected rates to produce carbohydrates



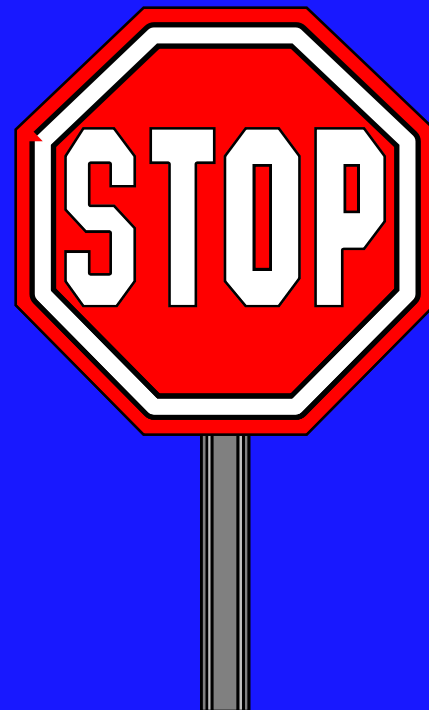
Irrigation Scheduling based on Deficit Threshold/RDI Level

Tested Irrigation Treatments: timing of applications and volumes of water applied

Treatment Number	Leaf Water Potential Trigger at Which Irrigation Will Begin	Criteria for Subsequent Irrigation (RDI%)
1	no trigger <-10 bars	supply full water
2	-12 bars	supply 60% of daily full water use
3	-12 bars	supply35% of daily full water use
4	-14 bars	supply 60% of daily full water use
5	-14 bars	supply 35% of daily full water use
6	-12 bars	supply 35-60% (variable) of daily full water use

Experimentation in the Sacramento Valley and North Coast showed that -12 -13 bars for white varieties and -14 -15 bars for red varieties are reasonable water deficit thresholds to start irrigation

A RDI after the deficit threshold can be selected to reduce vegetative growth, ensure continued photosynthesis, adequate fruit cover to protect from heat and sunburn, and to prevent new vegetative growth.


STOP

BENEFITS OF IRRIGATION SCHEDULING

1) Increase on-farm profit (reduced water and energy costs, increased yields and/or production quality, etc.)

2) Control vegetative growth

3) Reduce pruning costs, edging and shoots/leaves removal

4) Improve fruit quality and value

5) Prevent/mitigate frost/heat damages

6) Reduce losses of fertilizers and chemicals by deep percolation and off-site runoff

INACCURATE IRRIGATION SCHEDULING OFTEN LEADS TO:

- ✓ **Higher costs** (labor, water, nutrients, pumping)
- ✓ **Crop yield lower than max potential** (or alternate bearing)
- ✓ **Leaching nutrients, fertilizers and pesticides**
- ✓ **Uneven/slow plants development & production**

First Step for Water-Efficient Irrigation of Vineyards

Define the Irrigation Strategy
(to Pursue Yield/Quality Targets)

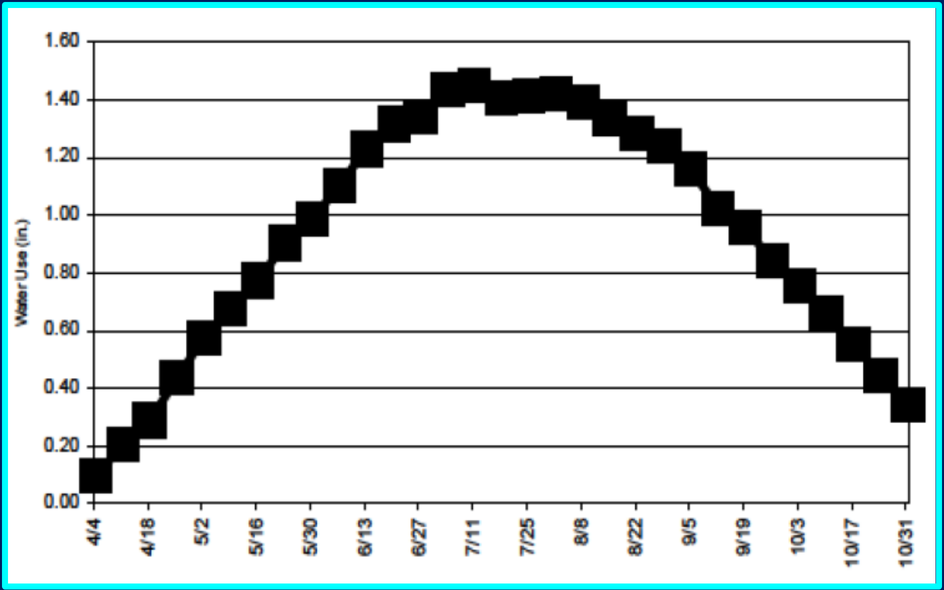
Full Irrigation

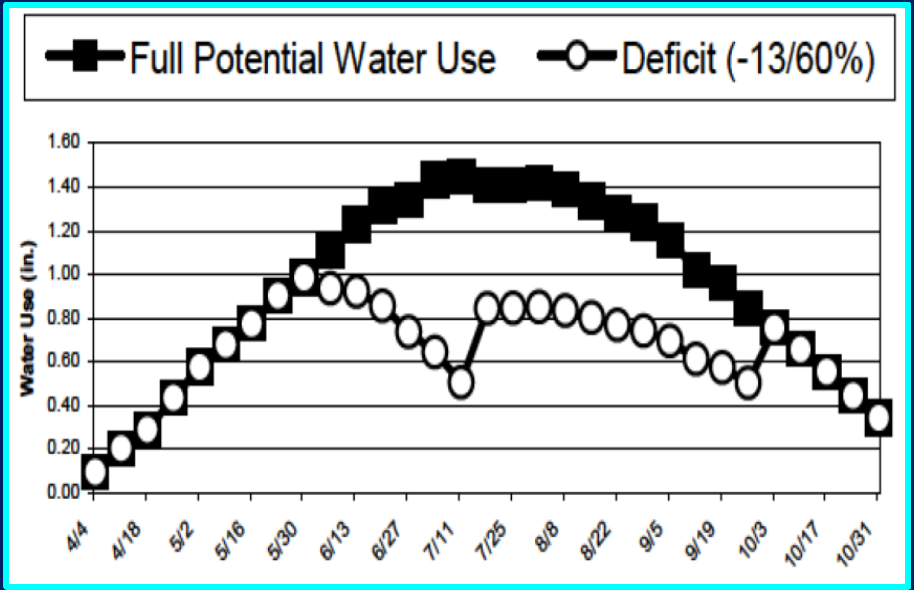
(full replenishment of water needs)

Partial (Deficit) Irrigation or RDI

(partial replenishment of water needs)

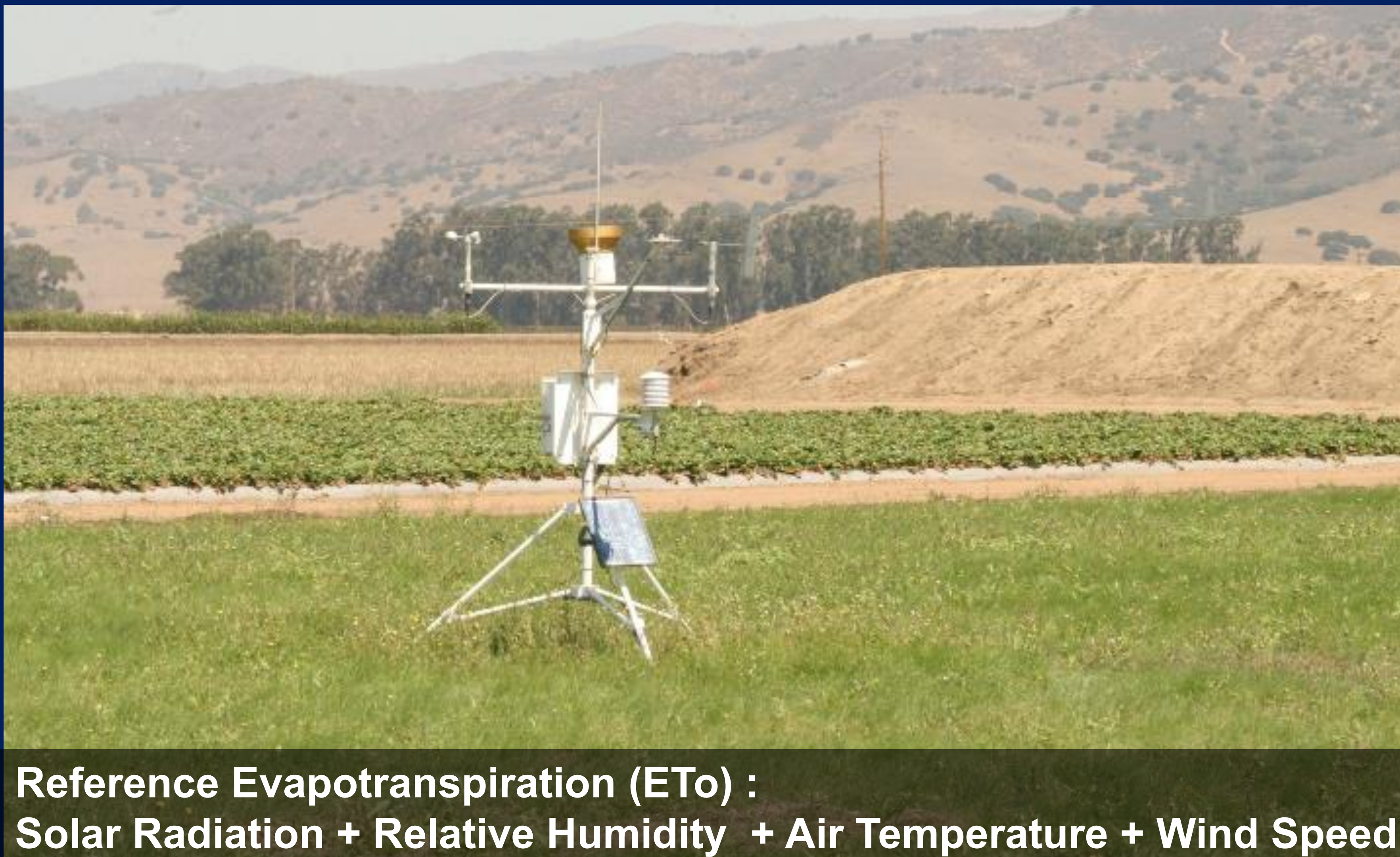
Timing & Levels of Water Deficits





WEATHER-BASED SCHEDULING

It relies on measurements of solar radiation, relative humidity, air temperature and wind speed to estimate reference (grass) ET (ETo)



Reference Evapotranspiration (ETo) :
Solar Radiation + Relative Humidity + Air Temperature + Wind Speed

Can ET be used also to determine when to irrigate?

We can define an accounting system (check-book) with a threshold for no-stress called Maximum Allowable Depletion (MAD)

Like in a Bank Account, we withdraw money until a certain threshold is reached. At that level, we have to deposit some money to refill the account and avoid deficit **(RED)**

Estimate Maximum Allowable Depletion (ft.)

1. Rooting depth of the crop (ft.)
2. Water holding capacity of soil (in./ft.)
3. Maximum depletion of available soil moisture (40-60%)

Soil texture	Water-holding capacity Range In./ft	Average In./ft
1. Very coarse texture—very coarse sands	0.38-0.75	0.50
2. Coarse texture—coarse sands, fine sands, and loamy sands	0.75-1.25	1.00
3. Moderately coarse texture—sandy loams	1.25-1.75	1.50
4. Medium texture—very fine sandy loams, loams, and silt loams	1.50-2.30	2.00
5. Moderately fine texture—clay loams, silty clay loams, and sandy clay loams	1.75-2.50	2.20
6. Fine texture—sandy clays, silty clays, and clays	1.60-2.50	2.30
7. Peats and mucks	2.00-3.00	2.50

Crop: Grapevine

Effective Root depth: 4.0 ft.

Soil: Sandy Loam

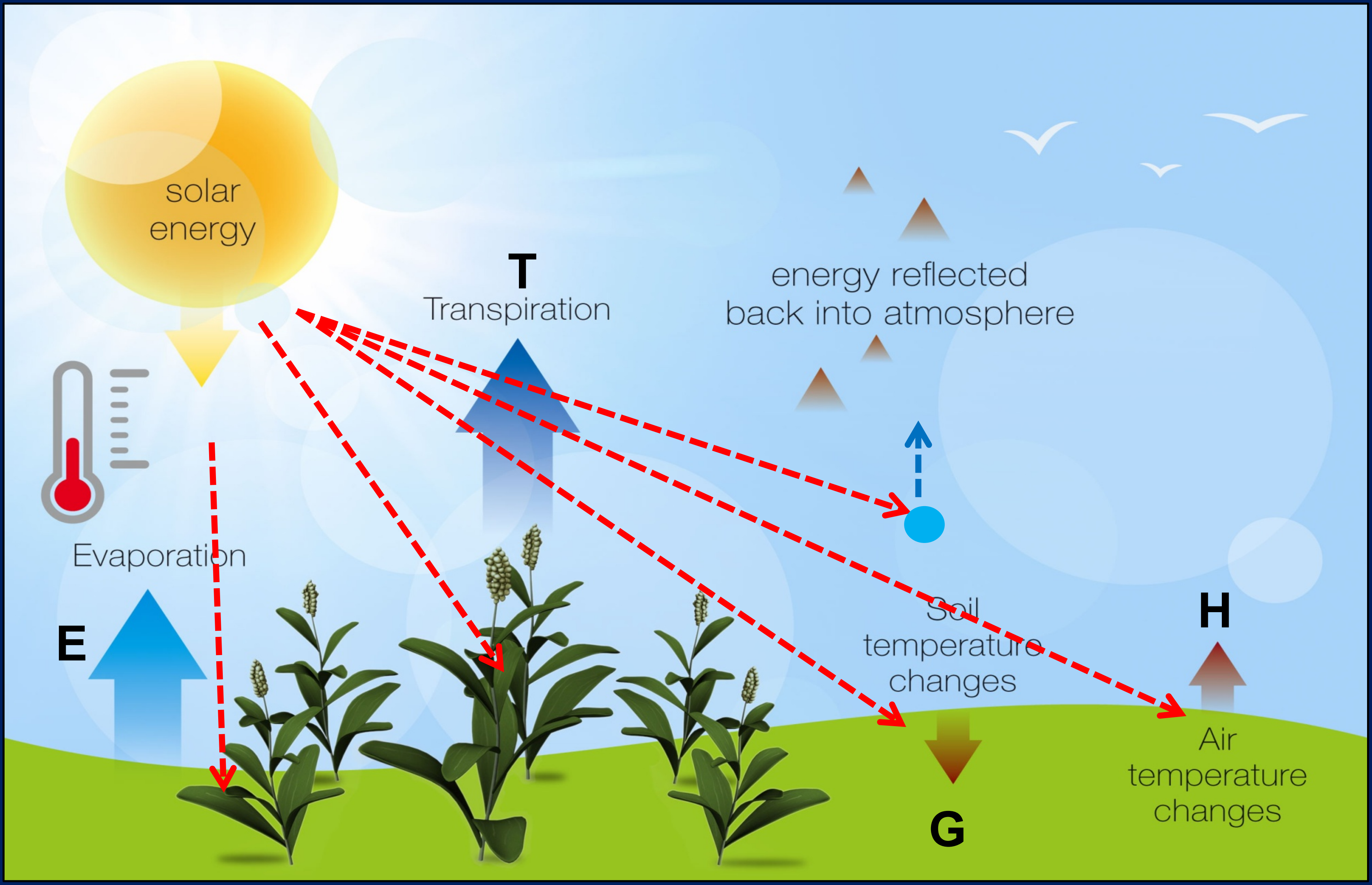
Water holding capacity: 1.5 in/ft

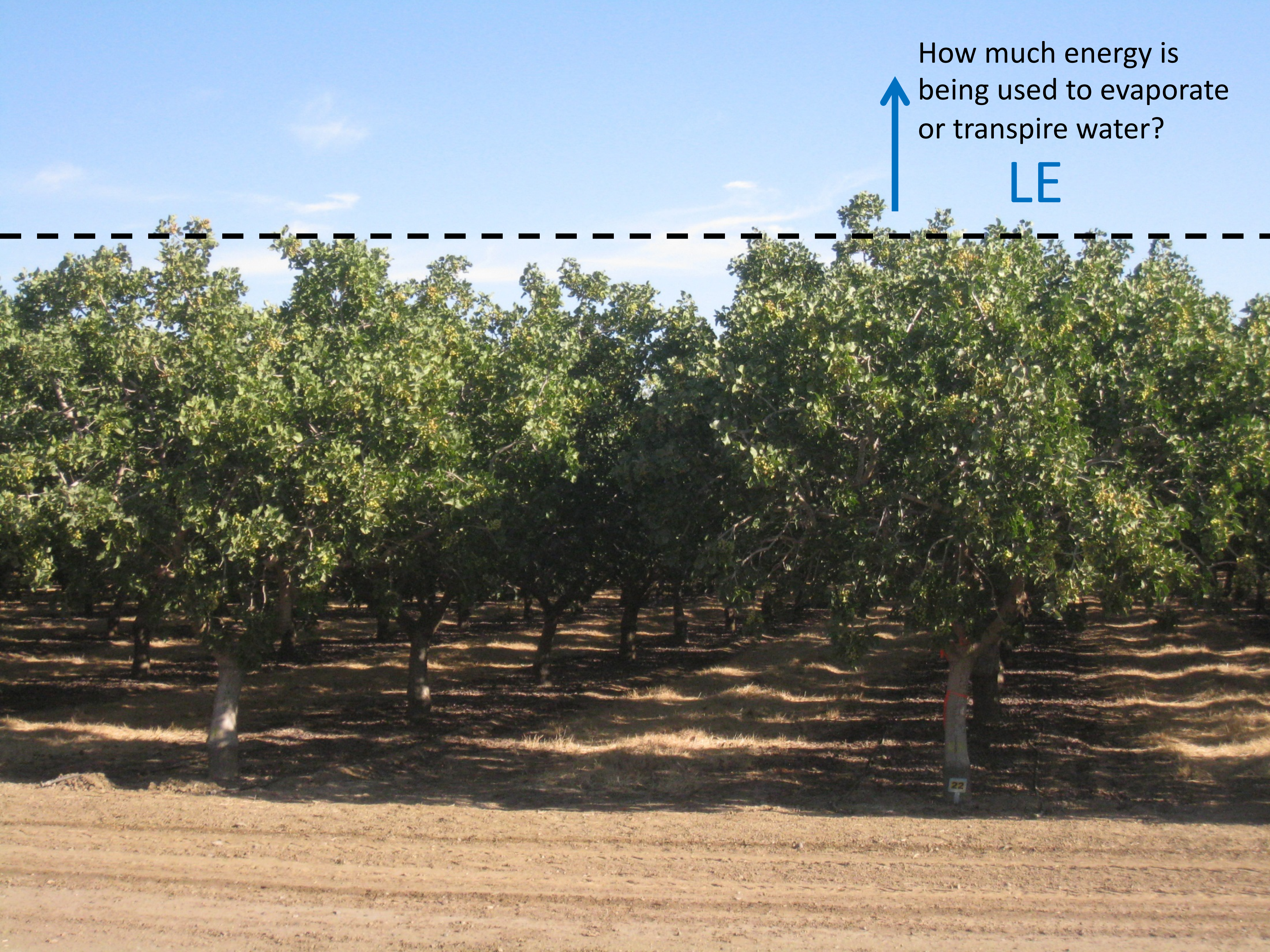
MAD: 60 %

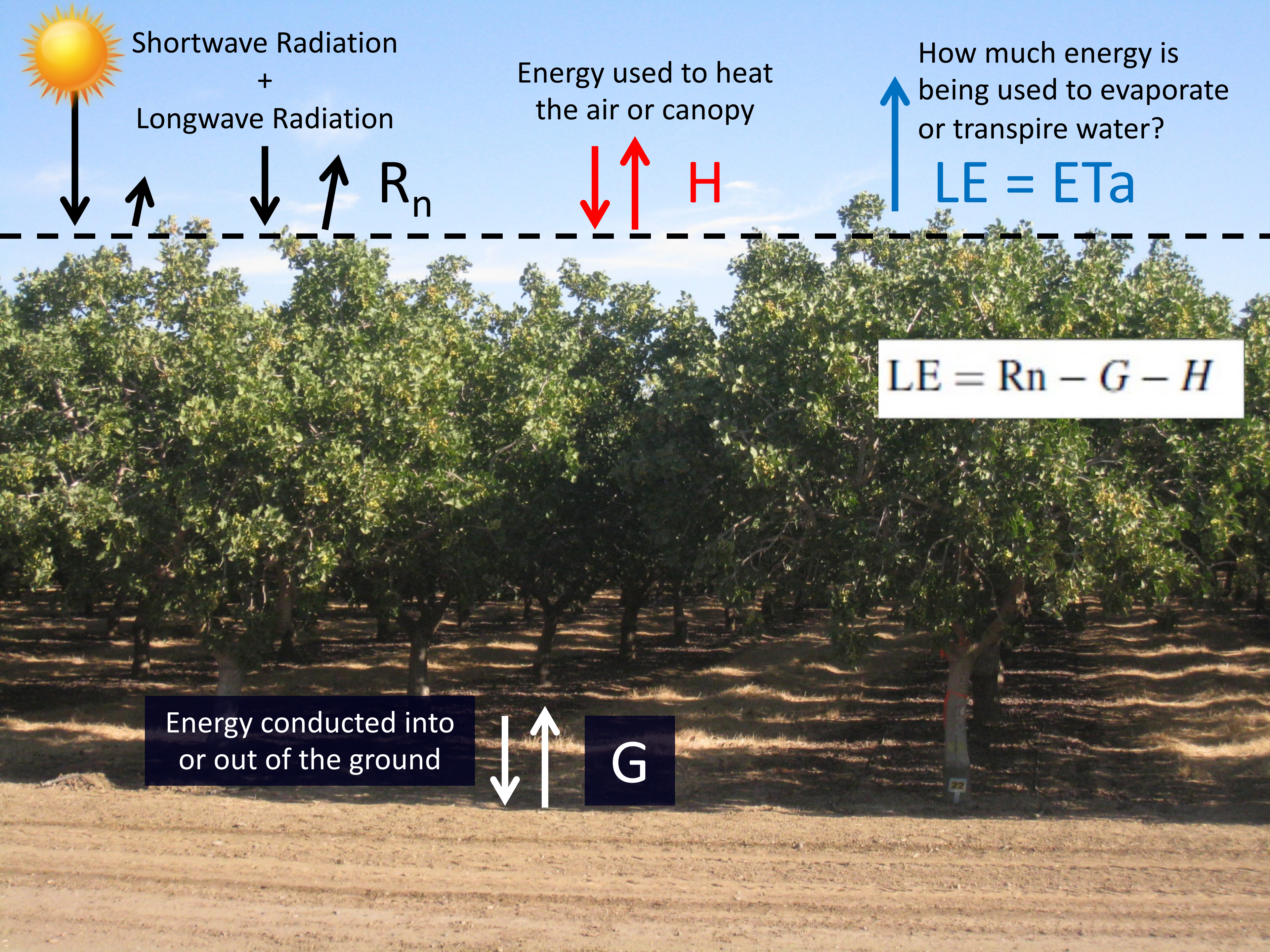
Maximum Allowable Depl.: 3.6 in.

Crop	Root Depth (ft)	MAD (%)
Alfalfa	8.0	55
Pasture	2.5	50
Turf	1.5	50
Small Grains	4.5	55
Beans	3.0	40
Corn	5.5	50
Potatoes	3.5	40
Sugar Beets	4.0	50
Cotton	5.0	55
Orchards	8.0	50-65
Grapes	6.0	65

SOLAR ENERGY DRIVES CROP EVAPOTRANSPIRATION




How much energy is
being used to evaporate
or transpire water?
LE


Shortwave Radiation
+
Longwave Radiation
R_n
Energy used to heat
the air or canopy
H
How much energy is
being used to evaporate
or transpire water?
LE = ETa
$LE = Rn - G - H$
Energy conducted into
or out of the ground
G

Residual of Energy Balance Method for Calculating Actual Crop Evapotranspiration

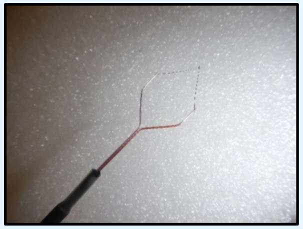
measured

$$LE = \underbrace{R_n - G - H}_{}$$

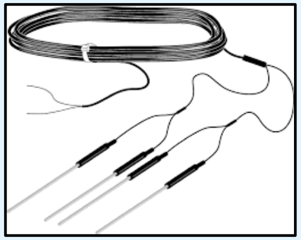
Sensible Heat Flux

Eddy Covariance

Surface Renewal



Net Radiation



Ground Heat Flux

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.).

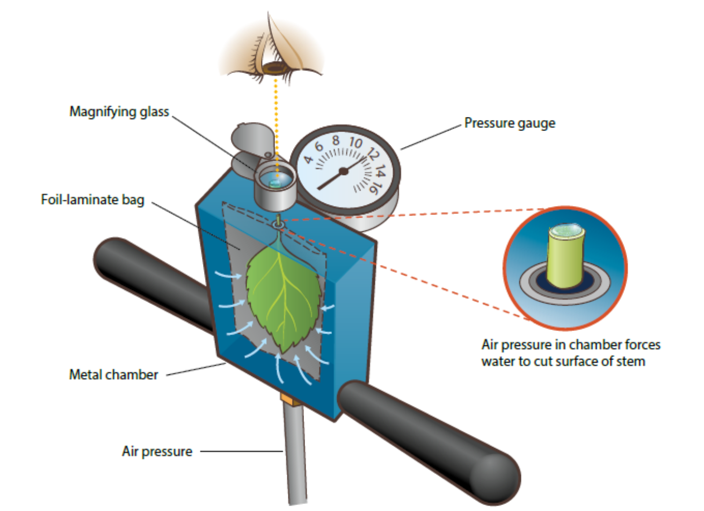
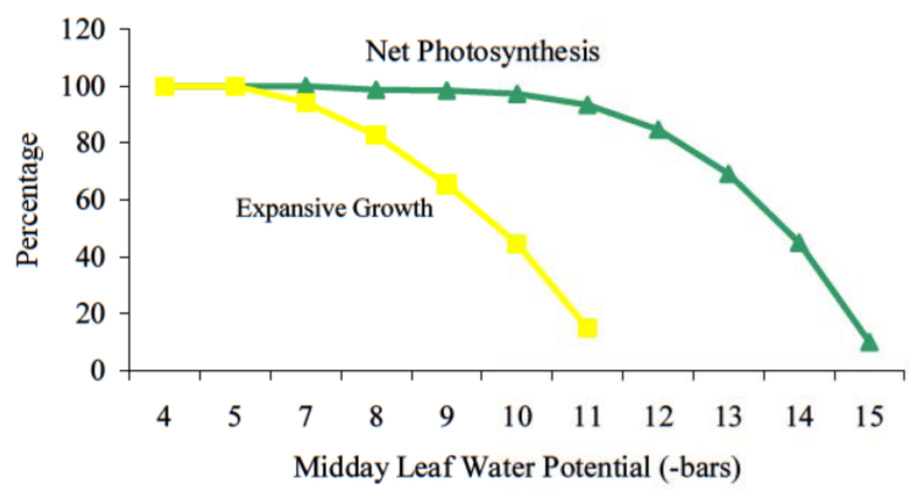


Figure 2. Schematic showing how water potential is measured in a severed leaf and stem (petiole) using a handheld pump-up pressure chamber. *Source:* Adapted from Plant Moisture Stress (PMS) Instrument Company.

Figure D-8. Relative rate vs. leaf water potential



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