The basics of irrigation scheduling using ET data from CIMIS

Presented at

Inches to Hours: An Irrigation Workshop for Foothill Wine Grape Growers

UC Cooperative Extension-Central Sierra

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UC CE | University of California
Agriculture and Natural Resources | Cooperative Extension

Use plant *and/or* soil-based monitoring tools to determine <u>when</u> to apply water the first time.

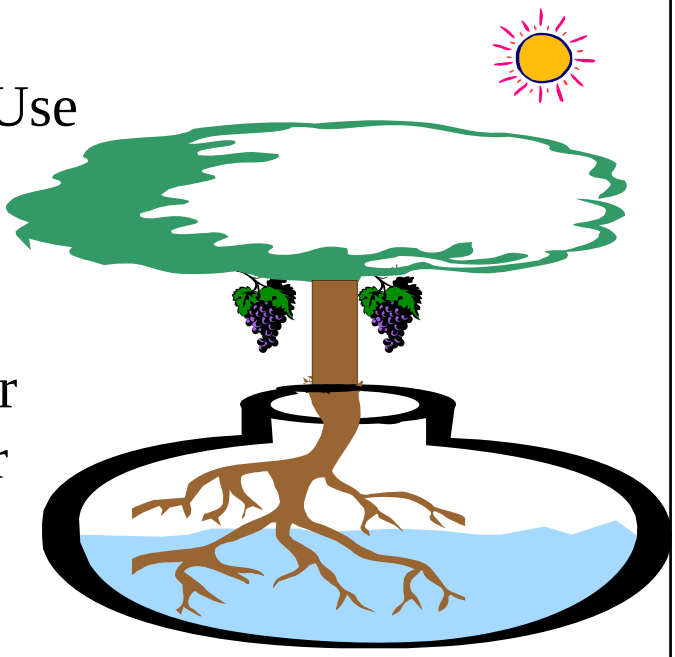
Estimate *evaporative demand* to determine <u>how much</u> water to apply.

Track plant water stress and/or soil water disappearance to <u>learn how vines respond</u> to each of your subsequent applications.

Vine Water Use

vs.

Soil Water Reservoir



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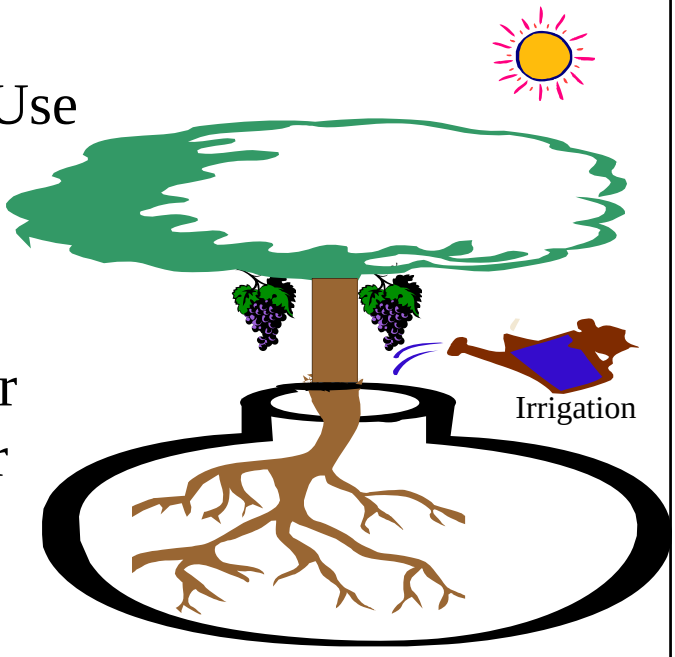
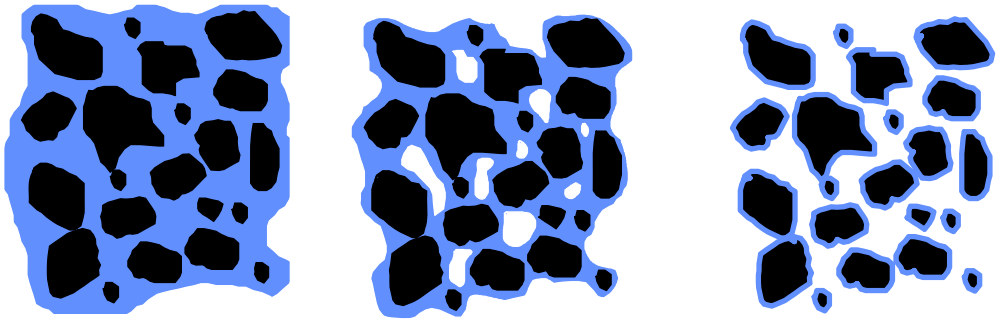
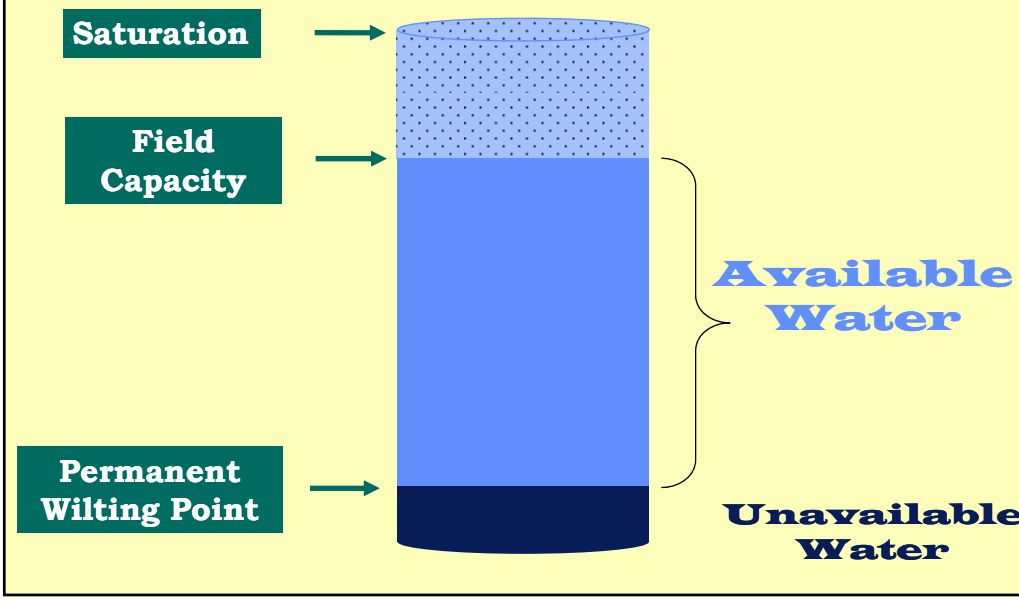


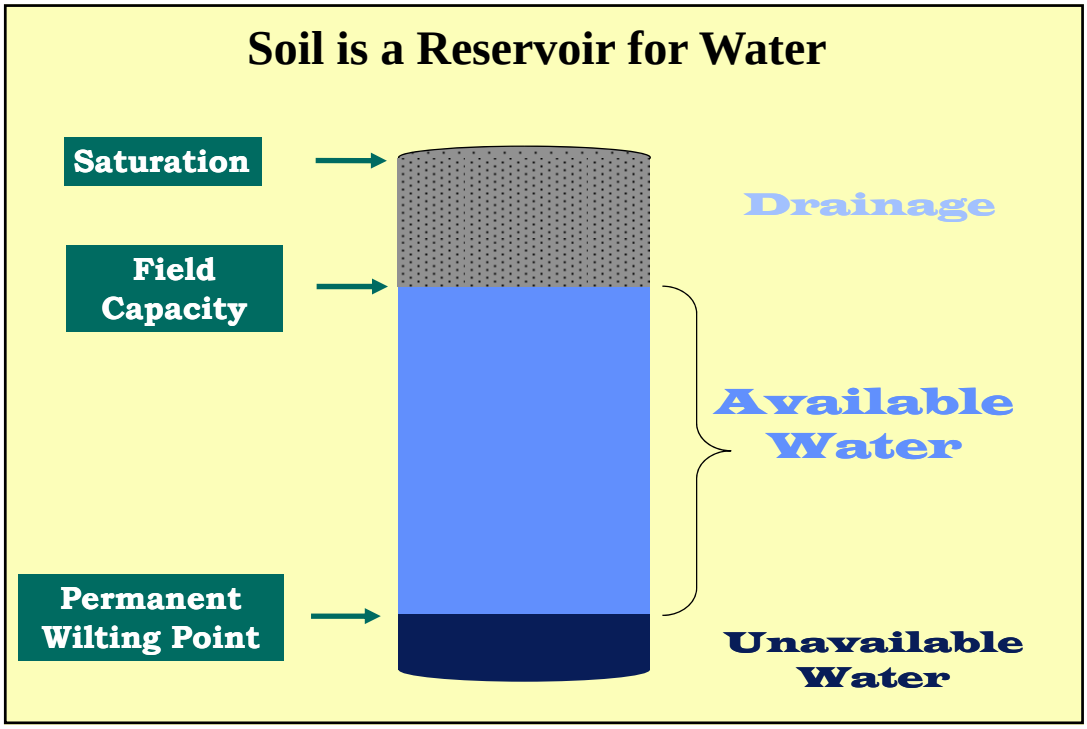
Soil Moisture Levels

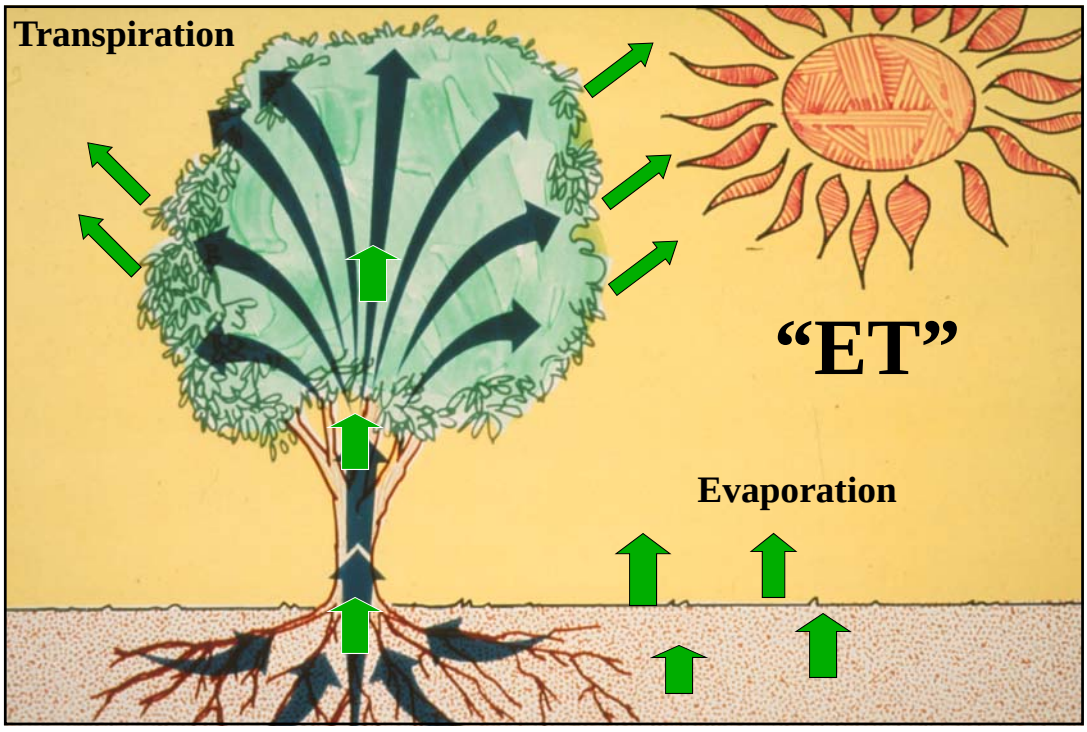


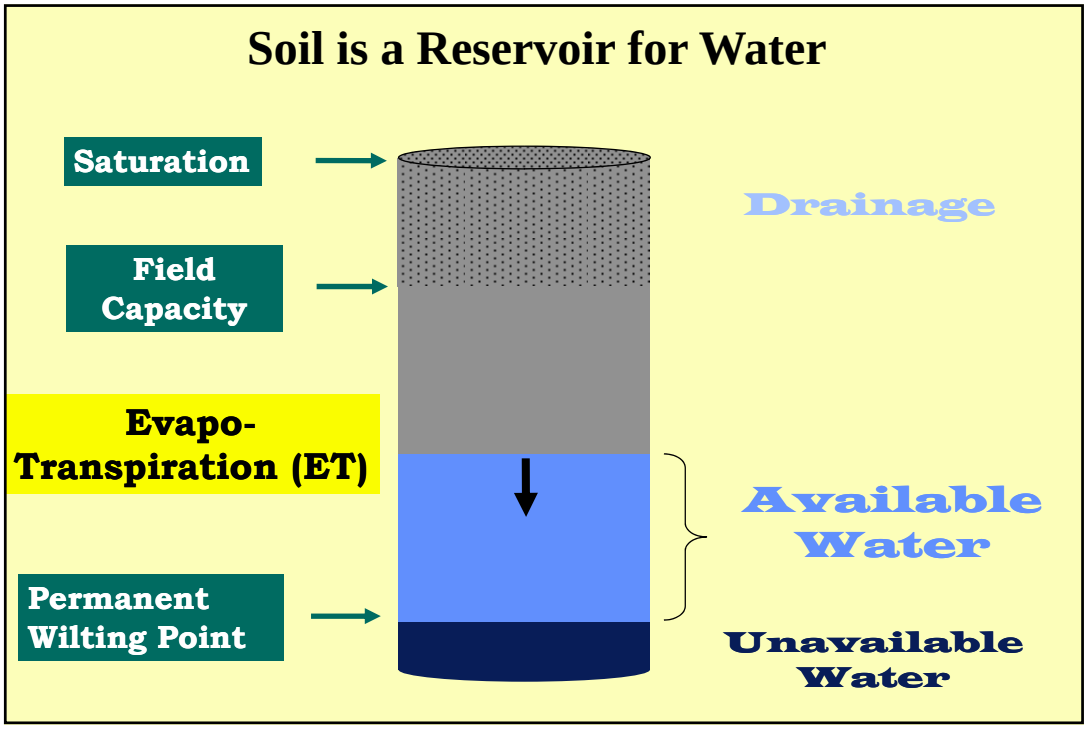
Saturation | Field Capacity | Permanent Wilting Point

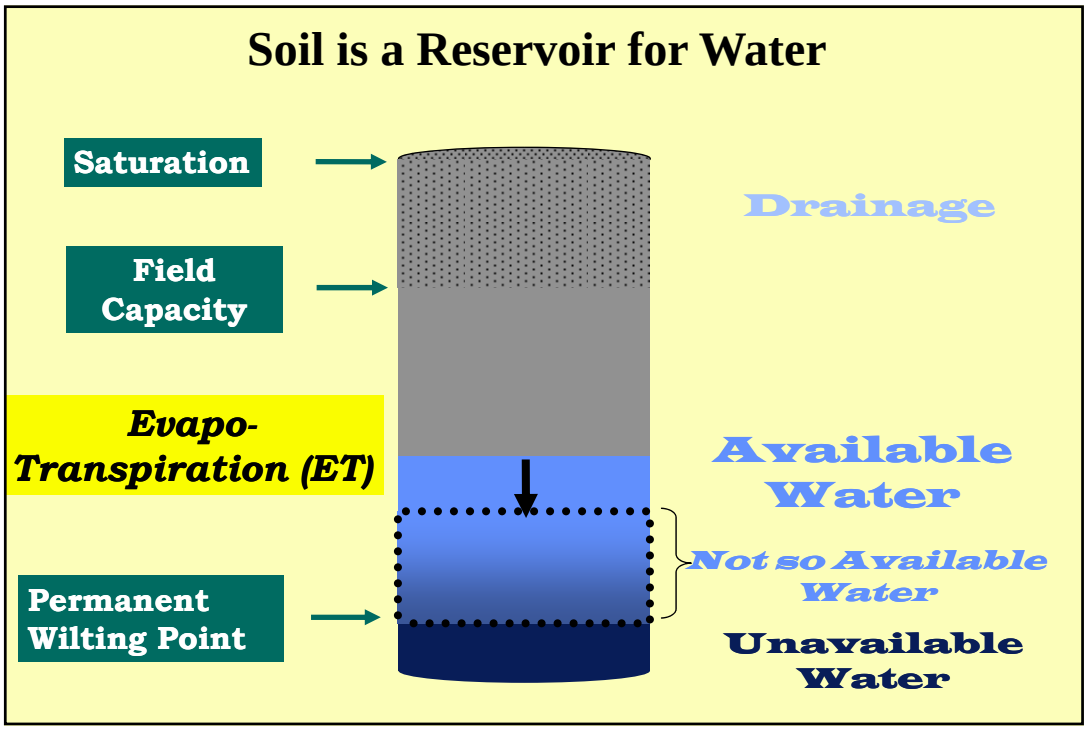
Soil is a Reservoir for Water



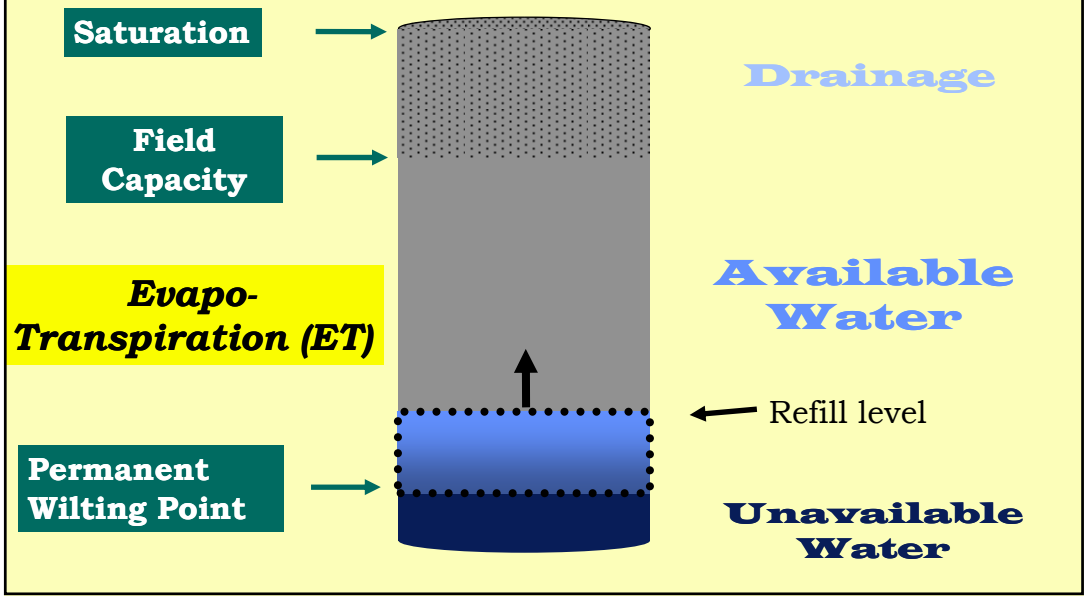

Soil is a Reservoir for Water
Saturation
Field Capacity
Permanent Wilting Point
Drainage
Available Water
Unavailable Water


Transpiration
"ET"
Evaporation

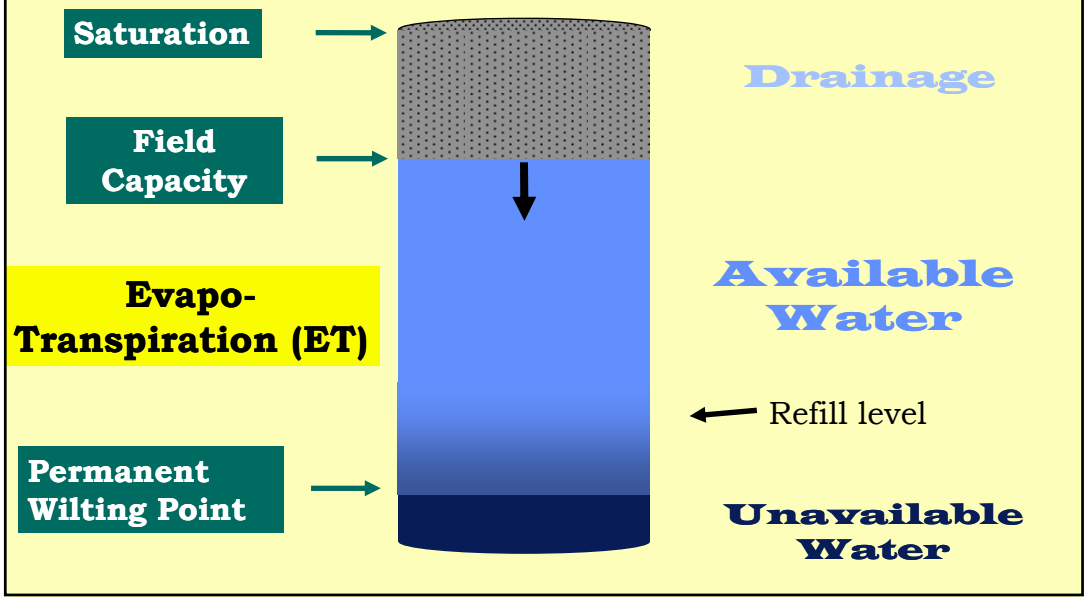

Soil is a Reservoir for Water
Saturation
Field Capacity
Evapo-Transpiration (ET)
Permanent Wilting Point
Drainage
Available Water
Unavailable Water


Soil is a Reservoir for Water
Saturation
Field Capacity
Evapo-Transpiration (ET)
Permanent Wilting Point
Drainage
Available Water
Not so Available Water
Unavailable Water

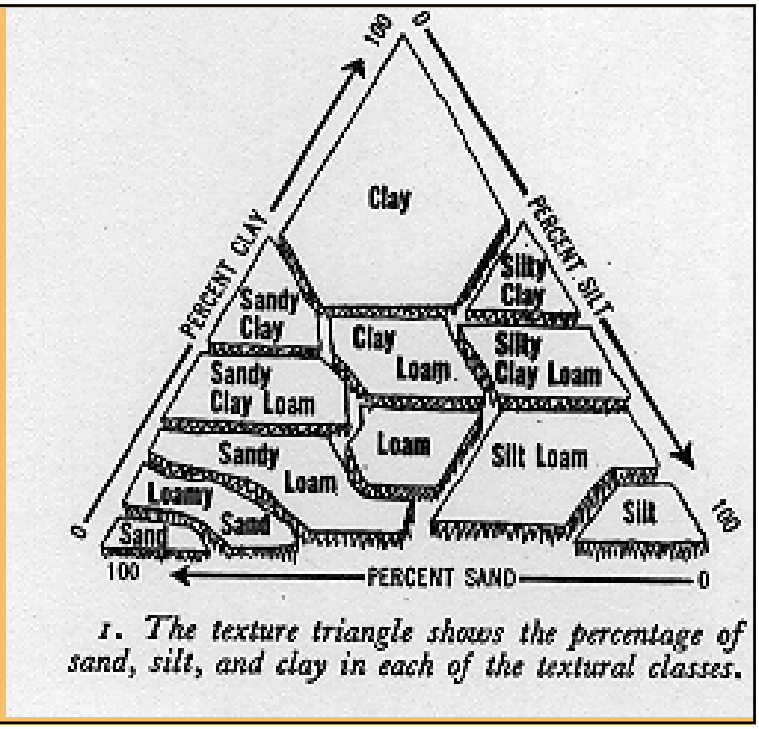
Soil is a Reservoir for Water



Soil is a Reservoir for Water



Soil Textural Classes

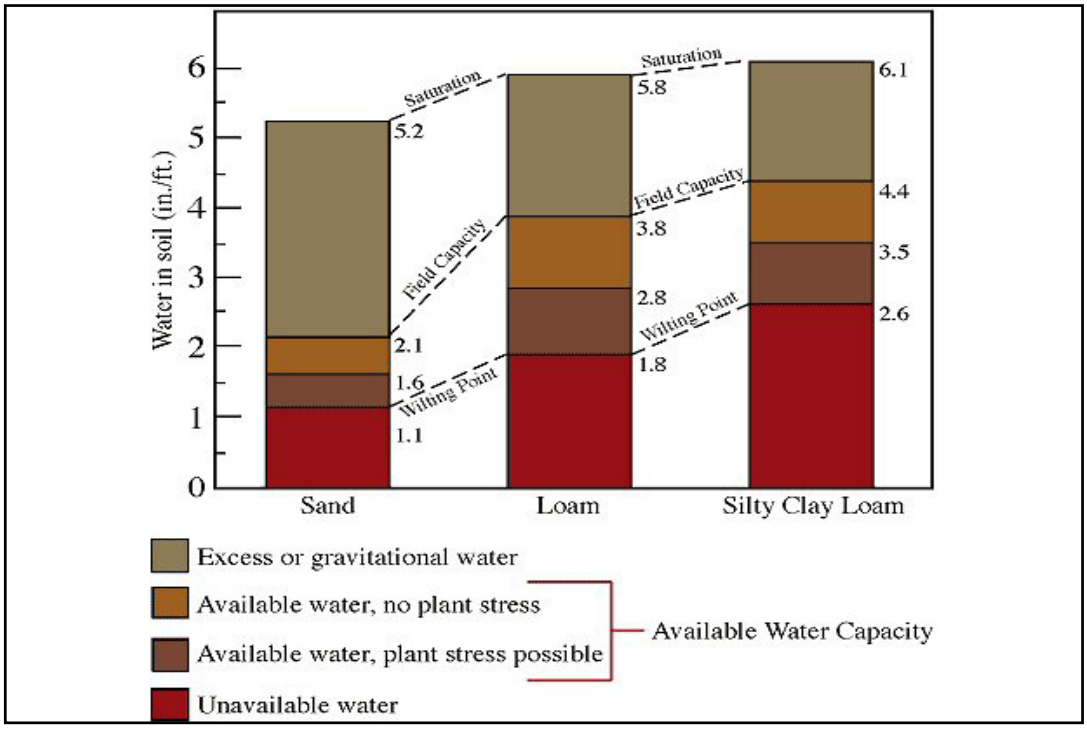


1. The texture triangle shows the percentage of sand, silt, and clay in each of the textural classes.

Units of water: "acre-inch" and "acre-foot"

1 acre-inch of water = 27,154 gallons of water

12-inches of water over 1 acre of land = 325,848 gallons of water


Water in soil (in./ft.)
0
1
2
3
4
5
6
Saturation
Field Capacity
Wilting Point
5.2
2.1
1.6
1.1
5.8
3.8
2.8
1.8
6.1
4.4
3.5
2.6
Sand
Loam
Silty Clay Loam
Excess or gravitational water
Available water, no plant stress
Available water, plant stress possible
Unavailable water
Available Water Capacity


Back hoe pit used to observe soil “profile”

Rock content of soil profile *affects* Available Water content

Available Water for Various Soil Types

	Acre-inches/ foot of soil
Coarse textured sandy loams	1.00
Medium textured loams	1.50
Fine textured clay soils	2.00

1 acre-inch = 27,154 gallons

Vineyard 1: Yolo Clay Loam

- 3-feet effective rooting depth
- Available water is 2.0 inches per foot
- Vines spaced 8’ x 12’ = 454 vines per acre

6 acre-inches available water = ~163,000 gallons
359 gallons available water per vine

1 acre-inch = 27,154 gallons

Vineyard 2: course rocky shale

- 2.5-feet effective rooting depth
- Available water is 1.0 inch per foot
- Vines spaced 5’ x 10’ = 871 vines per acre

2.5 acre-inches available water = ~68,000 gallons
78 gallons available water per vine

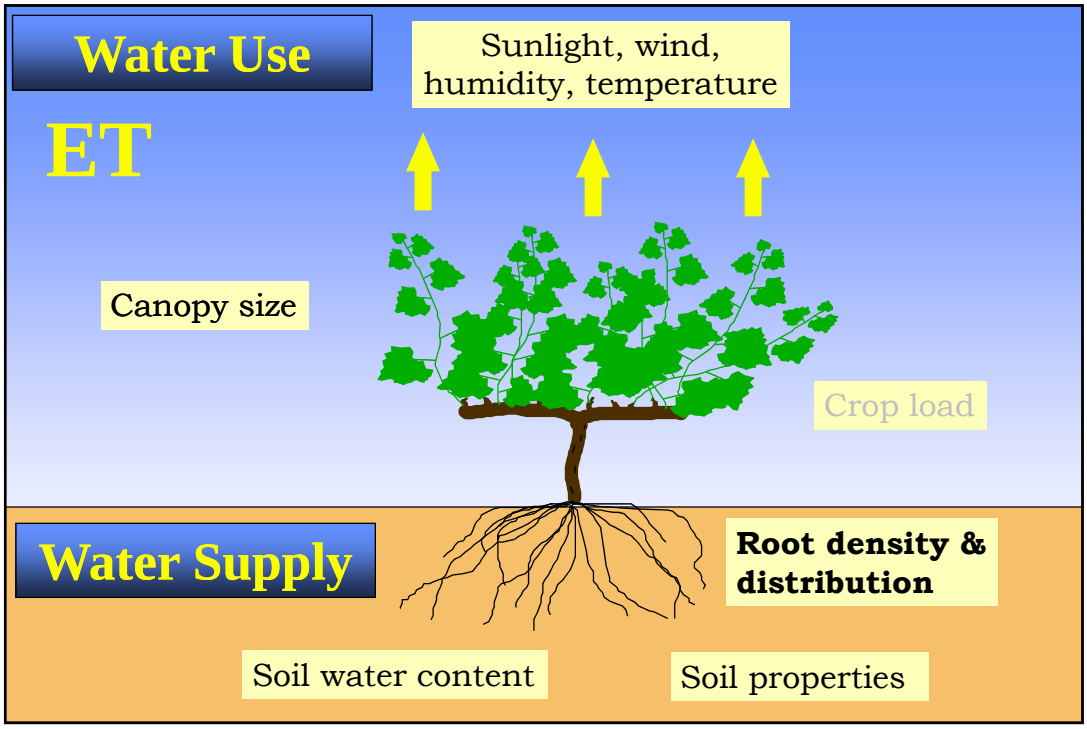
1 acre-inch = 27,154 gallons

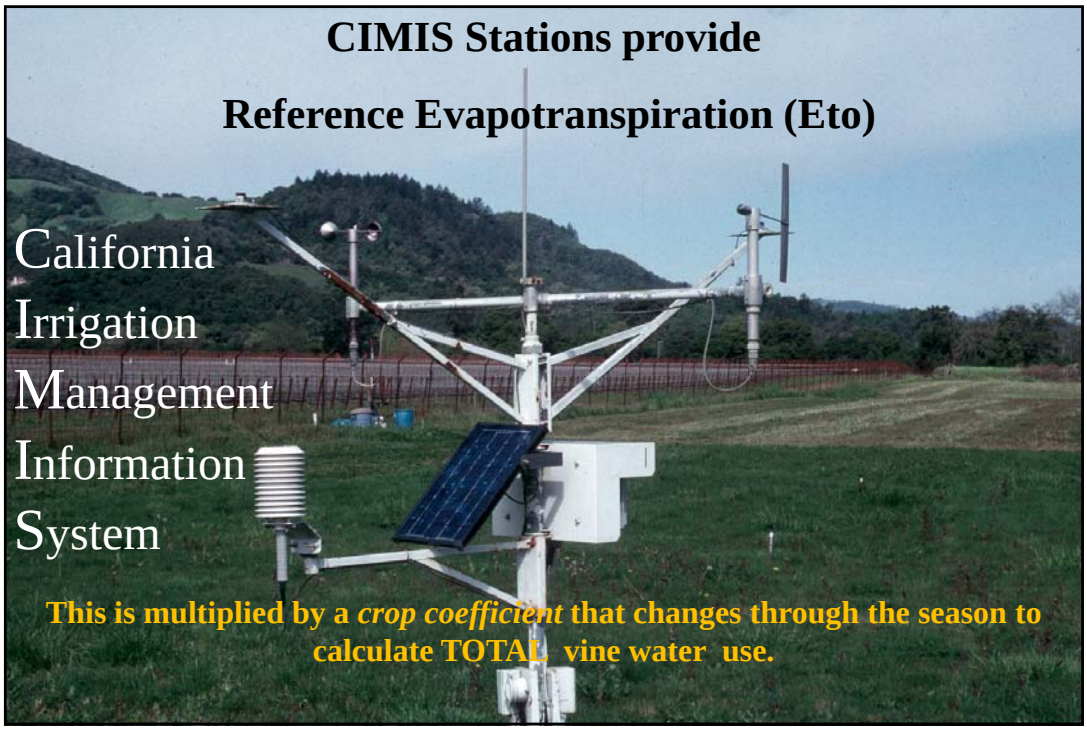
Assessing Water Needs

- Soil-based monitoring
- Plant-based monitoring
- Climate monitoring

Factors affecting vineyard water use (per land area).

- Evaporative demand (ET_o)
- Seasonal growth of the vine
- Ultimate canopy size (trellis type)
- Spacing between rows
- Amount of water in the soil profile
- Presence of a cover crop


Water Use
ET
Sunlight, wind, humidity, temperature
Canopy size
Crop load
Water Supply
Root density & distribution
Soil water content
Soil properties

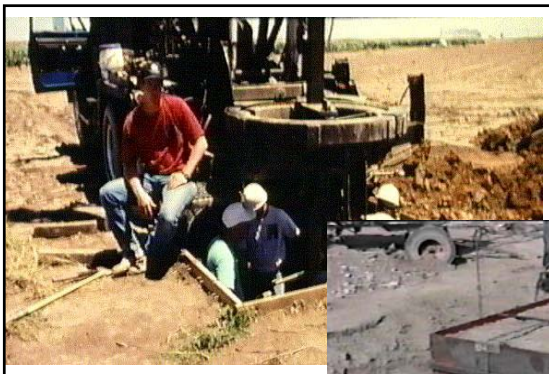

CIMIS Stations provide
Reference Evapotranspiration (Eto)
California
Irrigation
Management
Information
System
This is multiplied by a *crop coefficient* that changes through the season to calculate TOTAL vine water use.

CIMIS stations provide *reference evapotranspiration* (**ETo)** which is ET of **grass**.

To determine a crop's ET, you must multiply the reference ET by a "crop coefficient" (**kc**). The result is **Etc** which is ET of the crop.

Vineyard water use will change over the season as canopy expands, therefore **kc** changes up until the shoots stop growing.

Kc is affected by:
Seasonal growth Canopy size (trellis) Row Spacing



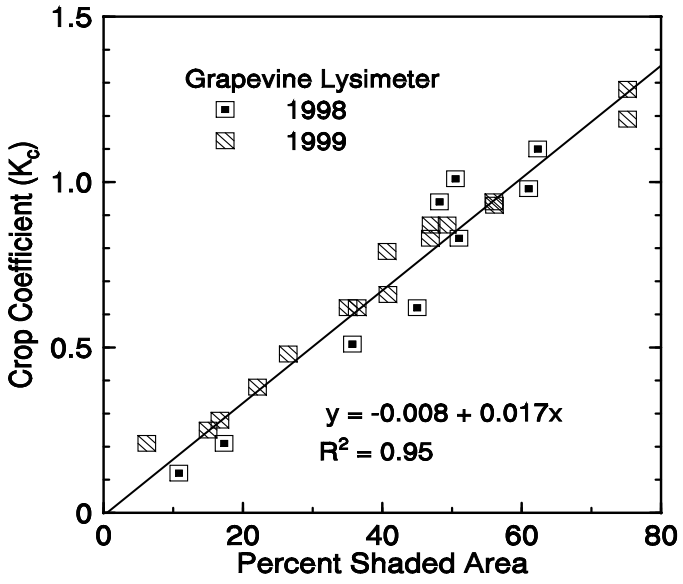
Weighing Lysimeter

- installation

Vineyard is planted over the top.

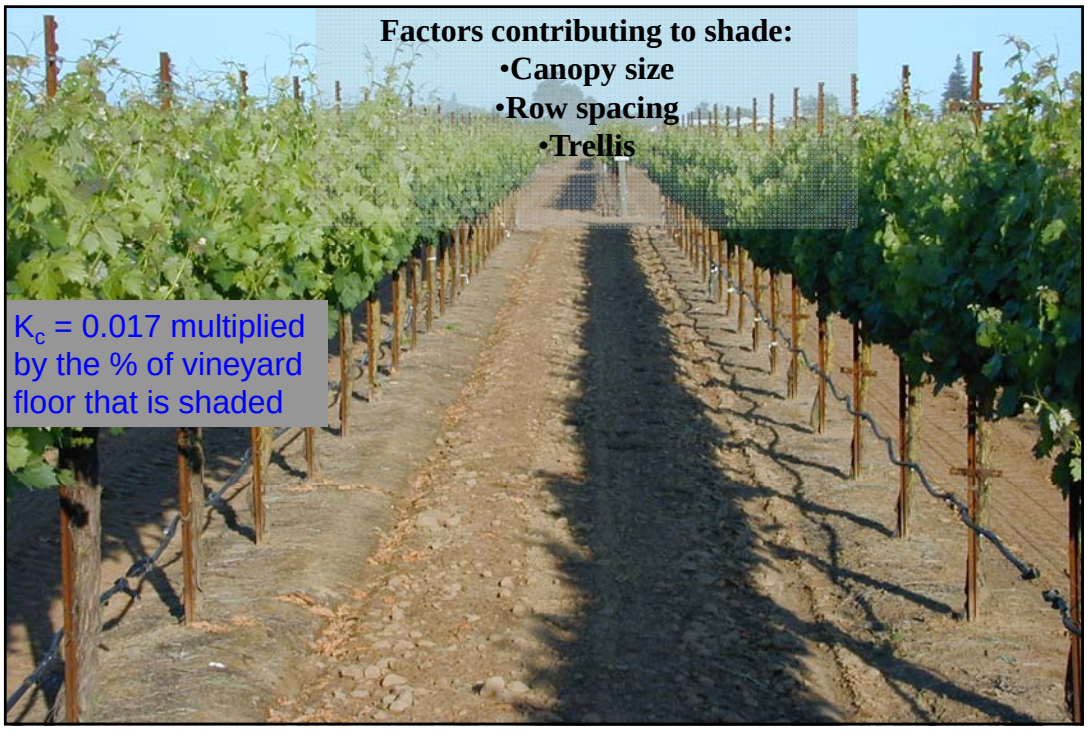
- actual *full* ET is weighed daily and the total amount of water used can be replaced daily.

Shaded area measured beneath the two vines' canopies were highly correlated with the crop coefficient.



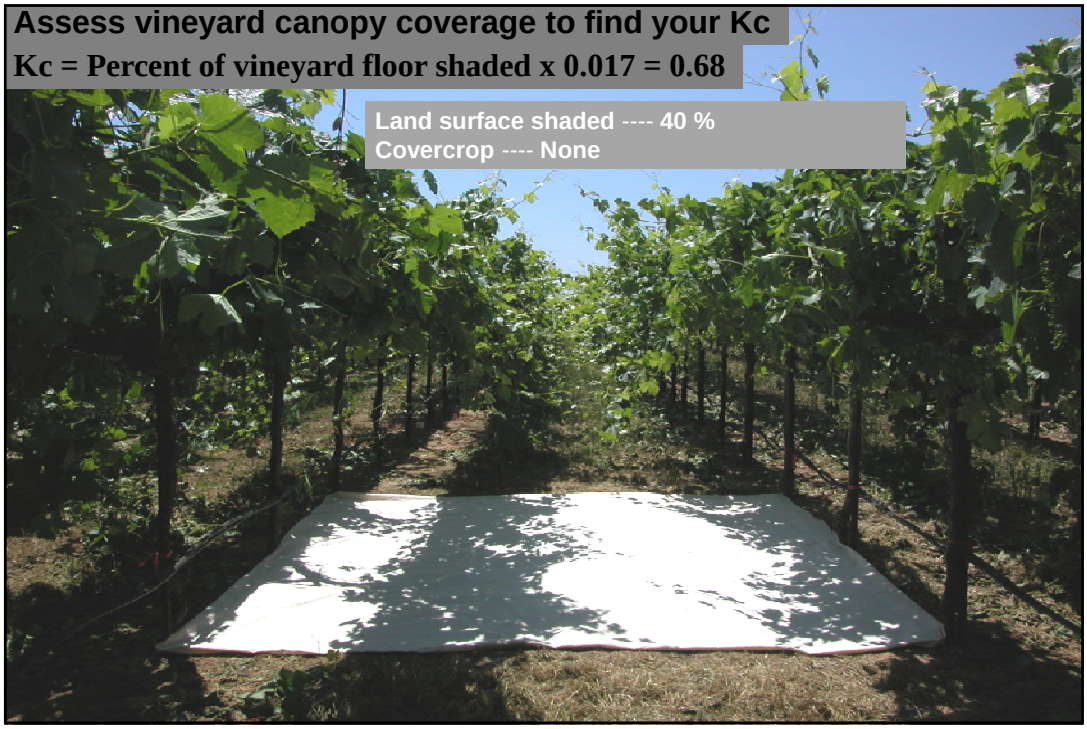
K_c = 0.017 multiplied by the % of vineyard floor that is shaded

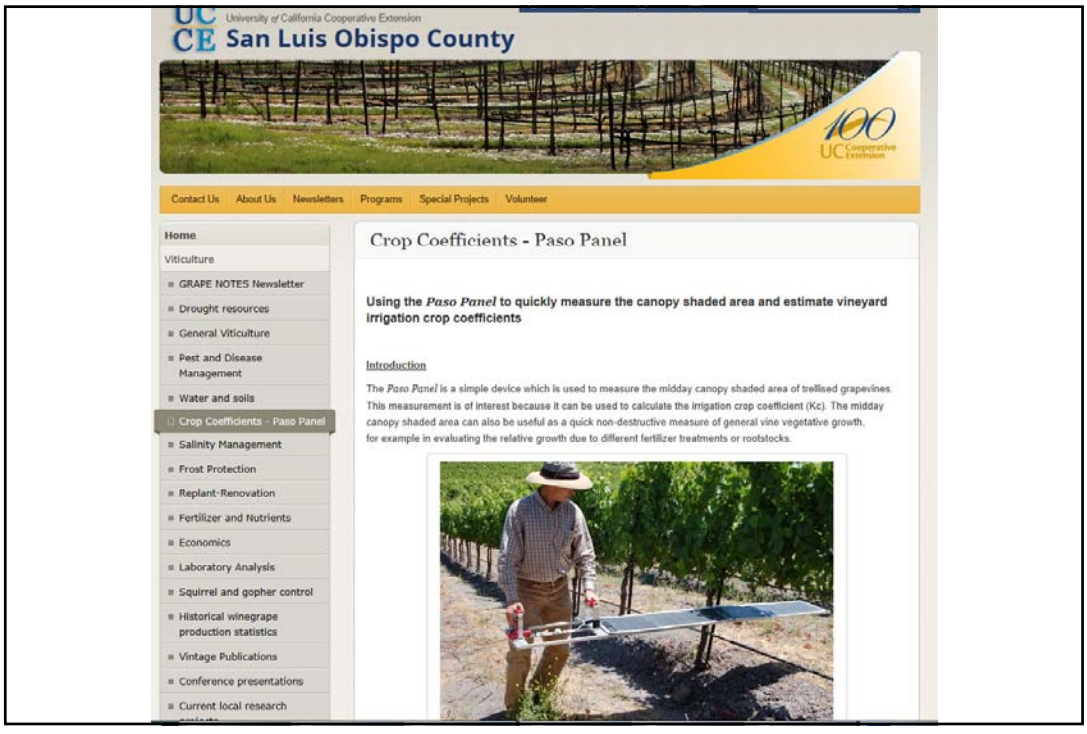
Larry Williams, UC Davis



Assess vineyard canopy coverage to find your Kc

Kc = Percent of vineyard floor shaded x 0.017 = 0.68





Kc values by row spacing and trellis type

Degree days from bud break

Row spacing

Vertically shoot positioned | Lyre | Sprawl

DD	4	5	6	7	8	9	10	11	12	10	12	10	11	12
0	0.19	0.15	0.13	0.11	0.10	0.09	0.08	0.07	0.06	0.10	0.09	0.12	0.11	0.10
180.00	0.25	0.20	0.17	0.14	0.13	0.11	0.10	0.09	0.08	0.18	0.15	0.21	0.19	0.18
360.00	0.33	0.26	0.22	0.19	0.16	0.15	0.13	0.12	0.11	0.29	0.25	0.34	0.31	0.28
540.00	0.42	0.33	0.28	0.24	0.21	0.18	0.17	0.15	0.14	0.43	0.36	0.49	0.44	0.41
720.00	0.51	0.41	0.34	0.29	0.26	0.23	0.21	0.19	0.17	0.57	0.48	0.63	0.57	0.52
900.00	0.62	0.50	0.41	0.35	0.31	0.28	0.25	0.23	0.21	0.69	0.57	0.74	0.67	0.61
1080.00	0.73	0.58	0.48	0.41	0.36	0.32	0.29	0.26	0.24	0.77	0.64	0.81	0.74	0.67
1260.00	0.83	0.66	0.55	0.47	0.41	0.37	0.33	0.30	0.28	0.81	0.68	0.85	0.77	0.71
1440.00	0.92	0.74	0.61	0.53	0.46	0.41	0.37	0.34	0.31	0.84	0.70	0.88	0.80	0.73
1620.00	1.00	0.80	0.67	0.57	0.50	0.45	0.40	0.36	0.33	0.85	0.71	0.89	0.81	0.74
1800.00	1.07	0.86	0.71	0.61	0.54	0.48	0.43	0.39	0.36	0.86	0.72	0.89	0.81	0.75
1980.00	1.13	0.90	0.75	0.64	0.56	0.50	0.45	0.41	0.38	0.86	0.72	0.90	0.82	0.75
2160.00	1.17	0.93	0.78	0.67	0.58	0.52	0.47	0.42	0.39	0.87	0.72	0.90	0.82	0.75
2340.00	1.20	0.96	0.80	0.69	0.60	0.53	0.48	0.44	0.40	0.87	0.72	0.90	0.82	0.75
2520.00	1.23	0.98	0.82	0.70	0.61	0.54	0.49	0.45	0.41	0.87	0.72	0.90	0.82	0.75
2700.00	1.24	0.99	0.83	0.71	0.62	0.55	0.50	0.45	0.41	0.87	0.72	0.90	0.82	0.75

Veraison

Adapted by Larry Williams, from Tables in
"Modeling Grapevine Water Use" by Larry E. Williams
http://avf.org/assets/files/articles/87e125d35d5ac0e189659f23da49eee0cd4ea4.pdf

Et_o - Reference evapotranspiration

Et_c - Crop evapotranspiration

K_c - Crop coefficient (0.2-0.8)

$Et_c = Et_o \times K_c$ = *full* potential water use

Example:

1.) Vine and row spacing = 6 x 8 ft. (48 ft^2)

2.) Measured shaded area = 12 ft^2

3.) % shaded area = 12/48 = 0.25 x 100 = 25

4.) % shaded area x 0.017 = K_c

25 x 0.017 = 0.425

5.) Assume ET_o = 1.2 inches (~17,500 gal/acre inch)

6.) ET_o x K_c = ET_c

7.) 1.2 x 0.425 = 0.612 inches = 16,830 gal/acre

8.) 16,830 gal/907 vines $acre^{-1}$ = 18.6 gal/vine

From: Larry Williams, Department of Viticulture and Enology, UC Davis and Kearney Research and Extension Center

The vineyard is using:
***full* ET vine = ETo x kc**

But how much will you supply?

ETo x kc x <u>% deficit</u>

Regulated Deficit Irrigation

The amount of water that is applied is only a percent of full Etc.
Irrigating to a 40% RDI means less water is applied than if you irrigated using a 60% RDI

Applied water volume = ETo x Kc x “management factor”

Management factor considerations

- Bud break through set: 70-80% during grand period of growth (if and when you decide you need to apply water)*
- Set through veraison: 60% down to 35% depending on variety, winery, brand, etc.
- Veraison through harvest: increase % as needed
- Avoid imposing more stress in locations that stress by default.
- Don’t stress young vines

*Be careful - you must support what you “build”!

Carneros Chardonnay Water Use Starting with young vines in 1991

Year	ET_o (inches)	ET_c (inches)	ET_c (gal/vine)
1991	39	6.9	150
1992	39	9.3	202
1993	39	12.1	271
1994	40	18.1	396
1995	40	18.6	405
1996	39	19.5	425

from Larry Williams

Weekly or Daily Eto from CIMIS

CIMIS (California Irrigation Management Information System)

Daily Report

Rendered in English Units.
July 1, 2013 - July 7, 2013
Printed on April 28, 2014

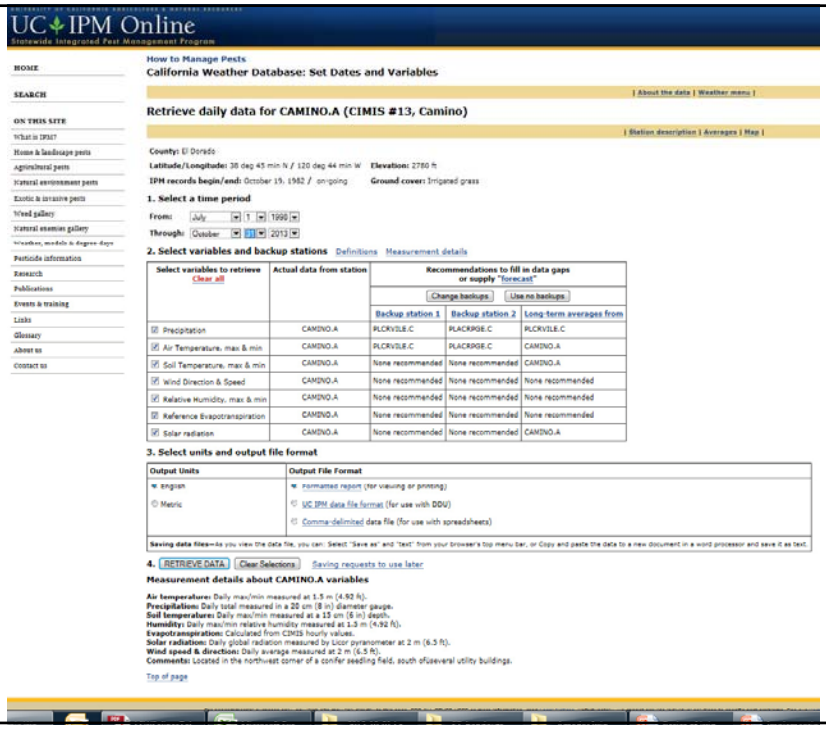
Camino - Sierra Foothill - Station 13

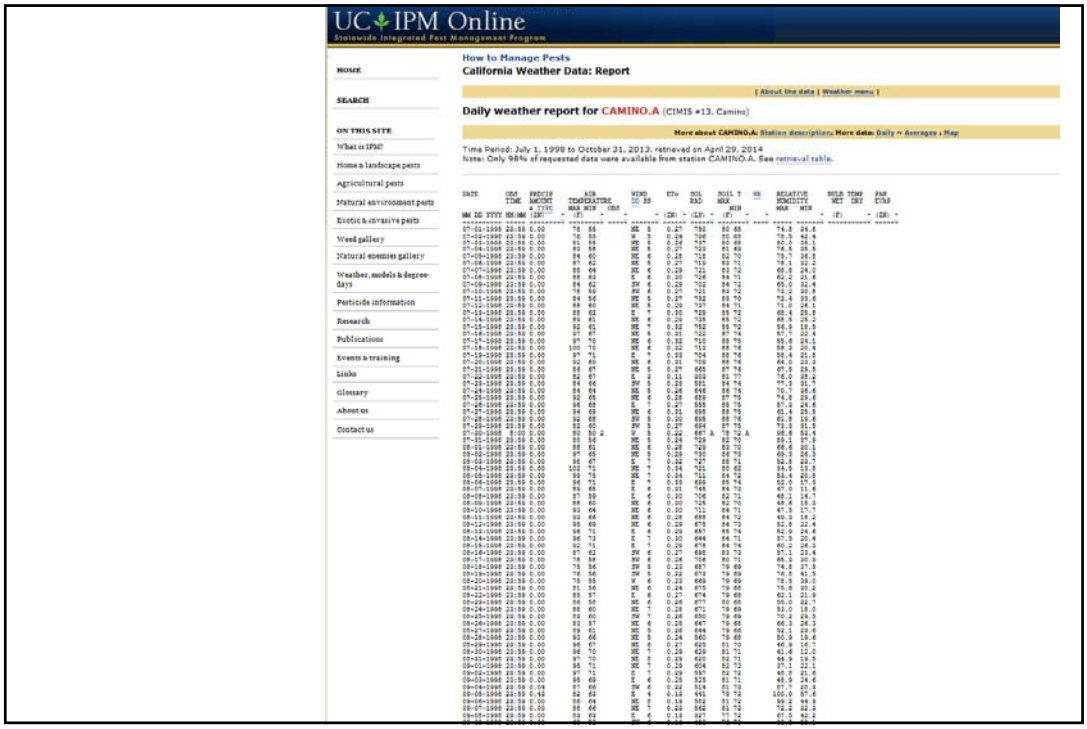
Date	CIMIS ETo (in)	Precip (in)	Sol Rad (Ly/day)	Avg Vap (mBars)	Max Air Temp (°F)	Min Air Temp (°F)	Avg Air Temp (°F)	Max Rel Hum (%)	Min Rel Hum (%)	Avg Rel Hum (%)	Dew Pt (°F)	Avg wSpd (MPH)	Wind Run (miles)	Avg Soil Temp (°F)
07/01/2013	0.32	0.00	677	14.1	98.5	74.1 Y	86.0	48	19	33	53.7	5.4	129.4	67.5
07/02/2013	0.32	0.00	662	14.9	97.2	75.8 Y	86.3	56	27	35	55.2	5.4	131.0	68.1
07/03/2013	0.31	0.00	673	15.5	96.8	73.9	85.9	56	26	37	56.3	4.7	114.2	68.8
07/04/2013	0.31	0.00	661	15.2	96.5	74.0 Y	85.5	51	21	36	55.9	6.0	144.2	69.3
07/05/2013	0.31	0.00	718	11.5	87.3	66.1	77.8	58	23	36	48.3	6.2	150.1	69.4
07/06/2013	0.29	0.00	713	11.0	86.3	62.3	74.8	62	26	38	47.2	5.4	130.8	68.7
07/07/2013	0.31	0.00	706	9.5	88.6	63.4	76.6	61	20	30	43.2	5.8	140.6	68.3
Tots/Avgs	2.17	0.00	666	13.1	93.0	69.9	81.6	53	23	35	51.4	5.6	134.3	68.6

Flag Legend		
A - Historical Average	I - Ignore	R - Far out of normal range
C or N - Not Collected	M - Missing Data	S - Not in service
H - Hourly Missing or Flagged Data	Q - Related Sensor Missing	Y - Moderately out of range
Conversion Factors		
Ly/day/2.065=W/sq.m	inches * 25.4 = mm	(F-32) * 5/9 = c
mph * 0.447 = m/s	mBars * 0.1 = kPa	--

Long Term monthly Eto from CIMIS Camino station (in acre-inches)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1.41	1.88	2.99	4.47	5.91	7.46	9	8.21	6.23	4.19	1.84	1.37	54.96





Determining the Volume of Water to Apply

- Use HISTORICAL ETo to calculate predicted hours to irrigate for a selected period of time.
- Immediately after the period of time has passed, use REAL TIME ETo to determine the actual hours of irrigation.
- Adjust the hours of irrigation for the following period of time.

ETo X Kc = FULL POTENTIAL VINE WATER USE (Etc)

Assumptions
1. Leaf Water Potential trigger was reached July 1.
2. Harvest Date was October 1.

Date	A = Historical Eto	B = Crop Coefficient[b]	C = A x B: Potential Water Use	D = RDI coefficient
Period	Inches/Period	Kc	(in)	Krdi
July 1-7				
July 8-14				
July 15-21				
July 22-28				
July 29 to August 4				
August 5-11				

Full Potential Water Use x RDI

Assumptions
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Date	A = Historical Eto	B = Crop Coefficient[b]	C = A x B: Potential Water Use	D = RDI coefficient
Period	Inches/Period	Kc	(in)	Krdi
July 1-7				
July 8-14				
July 15-21				
July 22-28				
July 29 to August 4				
August 5-11				

Determine Regulated Deficit % (RDI %)

- RDI % experiences:
  - 60% is conservative
  - 35% is risky
- Full Potential Water Use (ETc) X RDI%

Scheduling Inputs

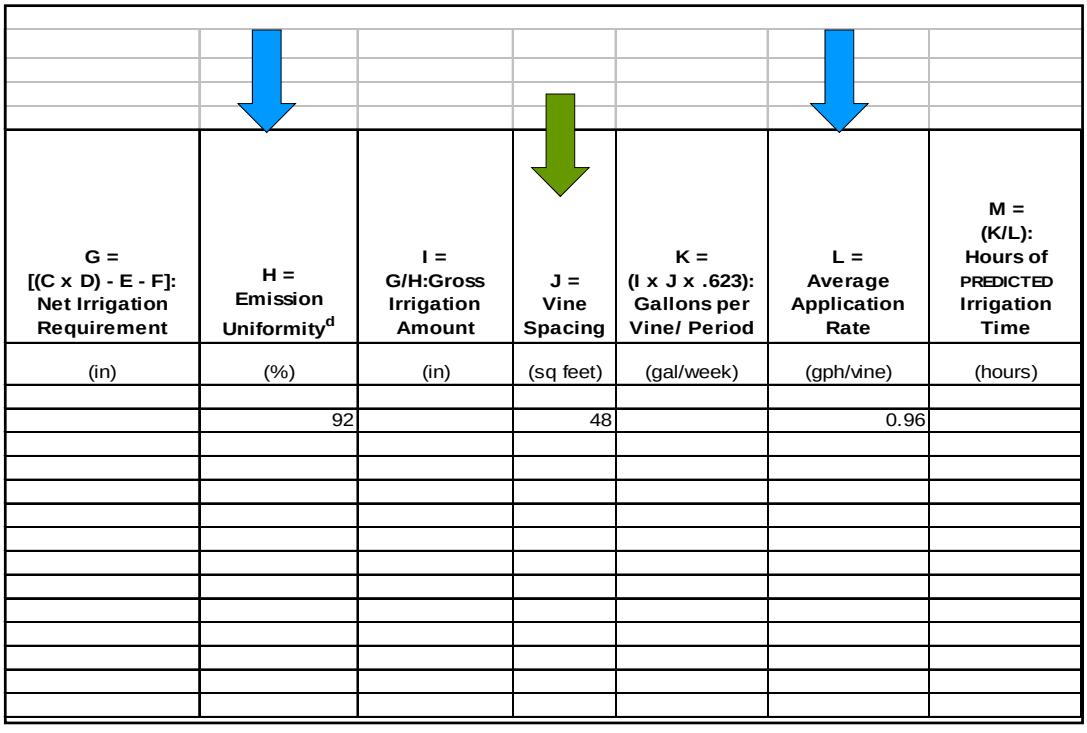
- ETo (Reference ET)
- Kc (Crop Coefficient)
- ETc (Full Potential Vine Water Use)
- RDI% (Net Water Volume Needed)
- Soil water contribution between the start of the irrigation season and harvest
- In-season effective rainfall
- Emission Uniformity
- Application rate of drippers

E = Soil Contribution	F = Effective Rainfall[c]	G = [(C x D) - E - F]: Net Irrigation Requirement	H = Emission Uniformity[d]	I = G/H:Gross Irrigation Amount
(in)	(in)	(in)	(%)	(in)

ETc X RDI% minus soil water contribution minus effective rainfall = NET IRRIGATION REQUIREMENT

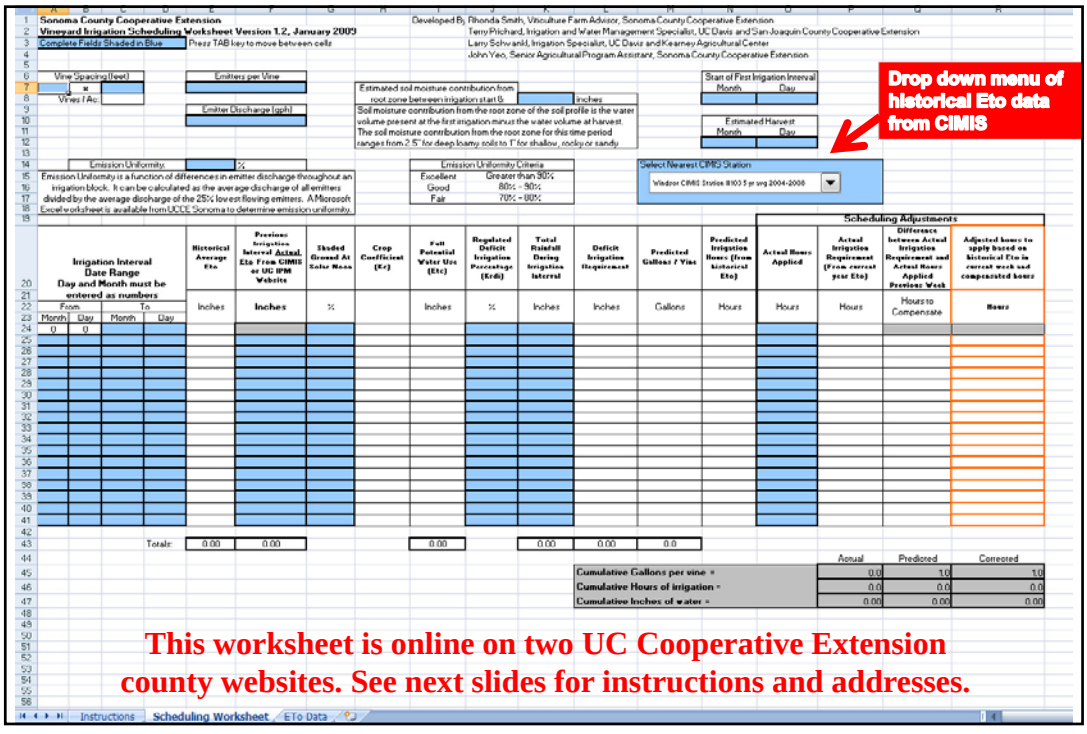
E = Soil Contribution	F = Effective Rainfall[c]	G = [(C x D) - E - F]: Net Irrigation Requirement	H = Emission Uniformity[d]	I = G/H:Gross Irrigation Amount
(in)	(in)	(in)	(%)	(in)

G = [(C x D) - E - F]: Net Irrigation Requirement	H = Emission Uniformity[d]	I = G/H:Gross Irrigation Amount	J = Vine Spacing	K = (I x J x .623): Gallons per Vine/ Period	L = Average Application Rate	M = (K/L): Hours of PREDICTED Irrigation Time
(in)	(%)	(in)	(sq feet)	(gal/week)	(gph/vine)	(hours)



G = [(C x D) - E - F]: Net Irrigation Requirement	H = Emission Uniformity[d]	I = G/H:Gross Irrigation Amount	J = Vine Spacing	K = (I x J x .623): Gallons per Vine/ Period	L = Average Application Rate	M = (K/L): Hours of PREDICTED Irrigation Time
(in)	(%)	(in)	(sq feet)	(gal/week)	(gph/vine)	(hours)
	92		48		0.96	

M = (K/L): Hours of PREDICTED Irrigation Time	Must be entered by hand (should be column R same week.): Hours of ACTUAL Irrigation Time	Linked from 'real time Eto' sheet: Hours of irrigation based on REAL TIME Eto	columns O-P previous week. Net diff of ACTUAL and REAL TIME hours PREVIOUS WK	columns N-Q same week. Actual Hours of irrigation after previous week's adjustment
(hours)	(hours)	(hours)	(hours)	(hours)
8.1	8.1	7.2		
7.3	6.4	9.2	0.9	6.4
6.2	9.0	9.0	-2.8	9.0
5.9	6.0	5.6	0.0	6.0
6.3	5.9	6.1	0.4	5.9
5.5	5.7	5.9	-0.2	5.7
5.8	0.0	8.5	-0.2	6.0
5.1	13.6	8.0	-8.5	13.6
4.5	4.5		5.6	-1.1



Online Irrigation Scheduling Worksheets
- important stuff -

- Remember that on each website, the worksheets automatically access historical Eto data from CIMIS stations that are in or near the UC Viticulture Farm Advisor's county. Those data are linked to the worksheets. You can choose which data set you wish to use by using the **drop down menu** (see previous slide).

Continued on next slide

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Online Irrigation Scheduling Worksheets (continued)

- The historical CIMIS data options on each county's worksheet were calculated for you by the farm advisors.
- To use more relevant CIMIS data:
  - Select the last option on the drop down menu "User entered Eto data".
  - Follow directions on Lynn Wunderlich's website to access a local CIMIS station and request Eto data for a particular week in 2013.
  - Back on the Scheduling worksheet, open the "Eto Data" tab at the bottom of the worksheet and enter your Eto values into the first column.

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Online Irrigation Scheduling Worksheets
- web addresses -

- Sonoma County
  - http://cesonoma.ucanr.edu/viticulture717/Vineyard_Irrigation/

  In the left menu, select "Excel irrigation scheduling worksheet" and scroll down to see links to the sheet.

- San Luis Obispo County
  - http://cesanluisobispo.ucanr.edu/Viticulture/Water_and_soils/

  Look at the section headings in the center of the page and find "Irrigation Scheduling Calculators"

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Use plant *and/or* soil-based monitoring "tools" to determine <u>when</u> to apply water the first time.

Estimate *evaporative demand* to determine <u>how much</u> water to apply.

Track plant water stress and/or soil water disappearance to <u>learn how vines respond</u> to each of your subsequent applications.