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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Rhonda Smith
Viticulture Farm Advisor
Sonoma County

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

Estimate evaporative demand to determine how much water to apply.

Track plant water stress and/or soil water disappearance to learn how vines respond to each of your subsequent applications.
Vine Water Use vs. Soil Water Reservoir

Vine Water Use vs. Soil Water Reservoir
Soil Moisture Levels

- Saturation
- Field Capacity
- Permanent Wilting Point

Soil is a Reservoir for Water

- Saturation
- Field Capacity
- Permanent Wilting Point

Available Water

Unavailable 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

Available Water

Unavailable Water

Drainage
Soil is a Reservoir for Water

Saturation

Drainage

Field Capacity

Available Water

Evapo-Transpiration (ET)

Available Water

Permanent Wilting Point

Unavailable Water

Refill level

Refill level
Soil 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
Back hoe pit used to observe soil “profile”
Rock content of soil profile affects Available Water content

It would be a good idea to know your vineyard’s “effective rooting depth”

Available Water for Various Soil Types

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Available Water per Foot of Soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse textured sandy loams</td>
<td>1.00</td>
</tr>
<tr>
<td>Medium textured loams</td>
<td>1.50</td>
</tr>
<tr>
<td>Fine textured clay soils</td>
<td>2.00</td>
</tr>
</tbody>
</table>

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<sub>o</sub>)
- 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
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.

\[ K_c = 0.017 \times \text{Percent Shaded Area} \]

Factors contributing to shade:
- Canopy size
- Row spacing
- Trellis

\[ K_c = 0.017 \times \% \text{ of vineyard floor that is shaded} \]

Larry Williams, UC Davis
Assess vineyard canopy coverage to find your Kc

Kc = Percent of vineyard floor shaded x 0.017 = 0.68

Land surface shaded ---- 40 %
Covercrop ---- None
Kc values by row spacing and trellis type

<table>
<thead>
<tr>
<th>Degree days from bud break</th>
<th>Vertically shoot positioned</th>
<th>Lyre</th>
<th>Sprawl</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.19</td>
<td>0.15</td>
<td>0.13</td>
</tr>
<tr>
<td>100</td>
<td>0.20</td>
<td>0.17</td>
<td>0.14</td>
</tr>
<tr>
<td>200</td>
<td>0.23</td>
<td>0.19</td>
<td>0.16</td>
</tr>
<tr>
<td>300</td>
<td>0.26</td>
<td>0.22</td>
<td>0.18</td>
</tr>
<tr>
<td>400</td>
<td>0.30</td>
<td>0.25</td>
<td>0.18</td>
</tr>
<tr>
<td>500</td>
<td>0.35</td>
<td>0.30</td>
<td>0.22</td>
</tr>
<tr>
<td>600</td>
<td>0.40</td>
<td>0.35</td>
<td>0.25</td>
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<tr>
<td>700</td>
<td>0.45</td>
<td>0.37</td>
<td>0.27</td>
</tr>
<tr>
<td>800</td>
<td>0.50</td>
<td>0.39</td>
<td>0.30</td>
</tr>
<tr>
<td>900</td>
<td>0.55</td>
<td>0.40</td>
<td>0.33</td>
</tr>
<tr>
<td>1000</td>
<td>0.60</td>
<td>0.43</td>
<td>0.36</td>
</tr>
<tr>
<td>1100</td>
<td>0.65</td>
<td>0.45</td>
<td>0.39</td>
</tr>
<tr>
<td>1200</td>
<td>0.70</td>
<td>0.47</td>
<td>0.40</td>
</tr>
</tbody>
</table>

Adapted by Larry Williams, from Tables in “Modeling Grapevine Water Use” by Larry E. Williams
http://avf.org/assets/files/articles/87e125d35d5ac0e189659f23da49e0c044e4.pdf

Et₀ - Reference evapotranspiration

Etₐ - Crop evapotranspiration

Kc - Crop coefficient (0.2-0.8)

Etₐ = Et₀ x Kc = full potential water use
Example:

1.) Vine and row spacing = 6 x 8 ft. (48 ft²)
2.) Measured shaded area = 12 ft²
3.) % shaded area = 12/18 = 0.25 x 100 = 25
4.) % shaded area x 0.017 = K_c
   25 x 0.017 = 0.425
5.) Assume ET₀ = 1.2 inches (~17,500 gal/acre inch)
6.) ET₀ 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 = \( \text{ET}_0 \times K_c \)

But how much will you supply?

\( \text{ET}_0 \times K_c \times \% \, \text{deficit} \)
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

<table>
<thead>
<tr>
<th>Year</th>
<th>ET&lt;sub&gt;o&lt;/sub&gt; (inches)</th>
<th>ET&lt;sub&gt;c&lt;/sub&gt; (inches)</th>
<th>ET&lt;sub&gt;c&lt;/sub&gt; (gal/vine)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991</td>
<td>39</td>
<td>6.9</td>
<td>150</td>
</tr>
<tr>
<td>1992</td>
<td>39</td>
<td>9.3</td>
<td>202</td>
</tr>
<tr>
<td>1993</td>
<td>39</td>
<td>12.1</td>
<td>271</td>
</tr>
<tr>
<td>1994</td>
<td>40</td>
<td>18.1</td>
<td>396</td>
</tr>
<tr>
<td>1995</td>
<td>40</td>
<td>18.6</td>
<td>405</td>
</tr>
<tr>
<td>1996</td>
<td>39</td>
<td>19.5</td>
<td>425</td>
</tr>
</tbody>
</table>

from Larry Williams

Weekly or Daily Eto from CIMIS
### Long Term monthly Eto from CIMIS Camino station (in acre-inches)

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>1.41</td>
<td>1.88</td>
<td>2.99</td>
<td>4.47</td>
<td>5.91</td>
<td>7.46</td>
<td>9.00</td>
<td>8.21</td>
<td>6.23</td>
<td>4.19</td>
<td>1.84</td>
<td>1.37</td>
<td>54.96</td>
</tr>
</tbody>
</table>
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.
**Sample Irrigation Scheduling Worksheet - Windso**

**ETo × Kc =**  
FULL POTENTIAL VINE WATER USE (Etc)

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

<table>
<thead>
<tr>
<th>Date Period</th>
<th>A = Historical Eto</th>
<th>B = Crop Coefficientb</th>
<th>C = A × B: Potential Water Use</th>
<th>D = RDI coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 1-7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>July 8-14</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>July 15-21</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>July 22-28</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>July 29 to August 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>August 5-11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
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**Basics of Irrigation Scheduling Using ET Data from CIMIS**

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</table>
Determine Regulated Deficit % (RDI %)

- RDI % experiences:
  - 60% is conservative
  - 35% is risky

- Full Potential Water Use (ETc) × 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
ETc X RDI% minus soil water contribution minus effective rainfall = NET IRRIGATION REQUIREMENT

<table>
<thead>
<tr>
<th>E = Soil Contribution</th>
<th>F = Effective Rainfall(\text{c})</th>
<th>G = ([\text{C} \times \text{D} - \text{E} - \text{F}]): Net Irrigation Requirement</th>
<th>H = Emission Uniformity(d)</th>
<th>I = G/H: Gross Irrigation Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>(in)</td>
<td>(in)</td>
<td>(in)</td>
<td>(%)</td>
<td>(in)</td>
</tr>
</tbody>
</table>

Basics of Irrigation Scheduling Using ET Data from CIMIS
\[ G = [(C \times D) - E - F]: \text{Net Irrigation Requirement} \]

\[ H = \text{Emission Uniformity} \]

\[ I = \frac{G}{H}: \text{Gross Irrigation Amount} \]

\[ J = \text{Vine Spacing} \]

\[ K = (I \times J \times 0.623): \text{Gallons per Vine/ Period} \]

\[ L = \text{Average Application Rate} \]

\[ M = \frac{K}{L}: \text{Hours of Predicted Irrigation Time} \]

<table>
<thead>
<tr>
<th>G = [(C x D) - E - F]: Net Irrigation Requirement</th>
<th>H = Emission Uniformity</th>
<th>I = G/H: Gross Irrigation Amount</th>
<th>J = Vine Spacing</th>
<th>K = (I x J x 0.623): Gallons per Vine/ Period</th>
<th>L = Average Application Rate</th>
<th>M = (K/L): Hours of Predicted Irrigation Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>(in)</td>
<td>(%)</td>
<td>(in)</td>
<td>(sq ft)</td>
<td>(gal/week)</td>
<td>(gph/vine)</td>
<td>(hours)</td>
</tr>
<tr>
<td>92</td>
<td>48</td>
<td>0.96</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Basics of Irrigation Scheduling Using ET Data from CIMIS

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

This worksheet is online on two UC Cooperative Extension county websites. See next slides for instructions and addresses.
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

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.
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”

### Use plant and/or soil-based monitoring “tools” to determine when to apply water the first time.

**Estimate evaporative demand to determine how much water to apply.**

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