Precision Irrigation Management: What’s Now and What’s New (Part 2)

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Bob Curtis, Almond Board of California
Precision Irrigation Management: What’s Now and What’s New (2)
Blake Sanden
UCCE Irrigation/Soils Advisor, Kern Co.

- Estimating crop water use, ETc
- Measuring ETo and CIMIS
- Real Almond ETc and Crop Coefficients (Kc)
Where am I on the “IRRIGATION CONTINUUM”? What’s the main thing that keeps the crop growing?

- Optimal photosynthesis
- Maximum carbon dioxide uptake
- Leaf cooling/water loss from transpiration
Reduced water/deficit irrigation, causes less turgor pressure in the plant, reduces the size of stomatal openings; thus decreasing transpiration/water loss, the uptake of carbon dioxide and reducing vegetative growth.
Increased conductance = increased transpiration (water loss)
Orchard water use is made up of EVAPORATION (E) from the wet soil and leaves and TRANSPIRATION (T), hence ET.
But all I ever hear is the term “ET”. So how can I know how much water goes to productive tree transpiration vs. evaporation?
Is all this water available to my 1st leaf trees with a small developing rootzone? What about evaporative losses and deep percolation?

For optimal growth these young trees may only use 50% of the applied water with this type of system the first 2 years.

Check soil moisture here for optimal tree growth.

Check soil moisture here for maximum water use efficiency.

Do micro systems always lose less water to evaporation and are more efficient than flood?
Calculating ET for crops:

\[ \text{ET}_{\text{crop}} = \text{ET}_o * K_c * E_f \]

\( \text{ET}_o \) = reference crop (tall grass) ET

\( K_c \) = crop coefficient for a given stage of growth as a ratio of grass water use. May be 0 to 1.3, standard values are good starting point.

\( E_f \) = an “environmental factor” that can account for immature permanent crops and/or impact of salinity. May be 0 to 1.1, determined by site specific factors – soil/salinity/system DU
From 1968 to 1990 detailed records of Class A pan evaporation were recorded in dozens of locations around the SJV. Using:

\[ \text{ETo} = 0.85 \text{ Evaporation} \]

a 20 year average ETo of 49.3 inches was published by CA Dept of Water Resources in 1993.

Potential or Reference evapotranspiration (ETo) is the water use of well-watered pasture grass. First estimated using Class A evaporation pans and weighing lysimeters.
CIMIS Weather Station

CALIFORNIA IRRIGATION MANAGEMENT INFORMATION SERVICE

Courtesy of Mark Anderson, DWR
The whole Central Valley covers Zones 12 to 16: for an “normal year” ETo of 53.3 to 62.5 in/yr, with most area @ 53 to 58 inches.
Why did “normal year” ETo increase from 1993-1999? Our understanding and accuracy of environmental and plant systems keeps improving. Then does this mean the old Kc values are always accurate?
OK on ETo for my area. Where do I get the right (?) crop coefficients, Kc

- [http://www.cimis.water.ca.gov/](http://www.cimis.water.ca.gov/)
- [http://www.almonds.com/irrigation#tc-irrigation-management](http://www.almonds.com/irrigation#tc-irrigation-management) (Almond Board website)
- [https://www.sustainablealmondgrowing.org/](https://www.sustainablealmondgrowing.org/)  
  - (full on irrigation calculator, must sign in, sponsored by ABC)
- [http://ucmanageddrought.ucdavis.edu/Agriculture/Crop_Irrigation_Strategies/Almonds/](http://ucmanageddrought.ucdavis.edu/Agriculture/Crop_Irrigation_Strategies/Almonds/)
Drought Strategies Explained

Stress at any period reduces vegetative growth, affects future yield!

Severe Deficit in this period will increase shriveled nuts
Deficit in this period will decrease nut/fruit size
Deficit in this period will increase “texturing”, decrease kernel weight
Deficit in this period has minimal effects

Deficit in this period effects fruit bud set
Comparison of Grass and Almond ET

Full cover almond ET lags behind pasture ET and then surpasses grass water use from June through September.

Uncut well watered pasture grass $K_c = 1.0$
<table>
<thead>
<tr>
<th>Week</th>
<th>Normal Year Grass ETo (in)</th>
<th>Mature Crop Coefficient (Kc)</th>
<th>1st Leaf @ 40%</th>
<th>2nd Leaf @ 55%</th>
<th>3rd Leaf @ 75%</th>
<th>4th Leaf @ 90%</th>
<th>Mature</th>
<th>Monthly Total</th>
<th>Daily Avg</th>
<th>20X22 Spacing Gallon / day / tree</th>
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<td><strong>Total</strong></td>
<td><strong>57.90</strong></td>
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<td><strong>20.91</strong></td>
<td><strong>28.75</strong></td>
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<td><strong>52.27</strong></td>
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Weekly crop report on ETc for Kern – courtesy of DWR and UCCE (available for Fresno and Tehema also, others maybe coming)
Changes in Almond Kc / ET Estimates Over 50 Years

Average Kc 4/1 - 11/15:
- Older Avg Kc = 0.81
- Sanden Avg Kc = 0.93
- Measured Avg Kc = 1.05

Calculated Avg ET:
- 42.3 in (4/1 - 11/15)
- 52.3 in (year)
- 59.6 in (year)

(Using CIMIS Zone 15 "Historic Eto" = 57.9 in)
Do you get 6,000 lb/ac with 60” ET? (Brown fertility trials, 275 lb/ac N yields)
Almond yield by light (PAR) & water

(Courtesy of Bruce Lampenin)
Correlation of 2016 Nonpareil yield with applied water improved 2x to 0.51

\[ y = 27.286x + 1781 \]

\[ R^2 = 0.5129 \]
3/25-9/22/2015 average almond plot CONDUCTANCE by 2015 applied irrigation (10 flyovers)

Canopy Temp/Water Stress by Irrigation Treatment (CERES Spectral Imaging 6/17/2015)
Equipment for making irrigation decisions

• Most Common Method – Use a sharper tool!
3 foot push or slide hammer probe ($150-$250)
Dendrometers track small changes in tree water stress and trunk growth – utilizing and integrating the relative stress throughout the rootzone.

High quality/continuously reading soil moisture sensors (capacitance, TDR, tensiometric) track the adequacy of refill and leaching. In-field weather stations combined with flowmeters track the daily water balance.
Technology is helpful, but the most valuable thing you can put in the field is your shadow.
SOME SIMPLE ECONOMIC CONCLUSIONS:

1) There is no perfect number for almond Kc or ET
2) A tree may yield 5,000 lb/ac on 50, 60 or 70” in the SJV
3) Real-time monitoring is the only way to insure minimum stress and maximum efficiency and yield.

• Cheap water, good prices, no soil sealing: not a big payback on “saved water”…
• $60 water, on 150 acres: 6” = $4,500
• $100 water on 150 acres: 6” = $7,500
• $1000 water on 150 acres: 6” = $75,000

• 500 lb/ac kernals on 150 acs:
  @ $2 net after harvest costs = $150,000
Andrew McElrone, USDA-ARS, Davis
Development of Surface Renewal Technology

Collaborators: Paw U, Snyder, Williams, Battany
Student/Post Docs: Shapland, Calderon, Parry
Funding: J Lohr Vineyards, NIFA-SCRI, AVF, USDA
Surface Energy Balance: Partitioning of energy at the surface
Successfully removed the need for calibration of Surface Renewal against Eddy Covariance
New Surface Renewal System:
A reliable & automated ET measurement system

Eddy Covariance
~$10,000

New Surface Renewal
~$200
Mimicked Arduino for programming ease
Proof of concept:
Compare to lysimeter & eddy covariance (both gold standards)
Surface Renewal vs. Lysimeter
Kearney Ag Center - 2012 & 2013

$y = 0.95x + 0.47$
$R^2 = 0.96$
In past several years, measured in 10+ plots within wine and table grape vineyards; slopes range from 0.9 - 1.05
Surface Renewal vs. Soil Water Budget
Kearney Ag Center- 2012 & 2013

\[ y = 0.87x + 0.84 \]

\[ R^2 = 0.96 \]
How to use the technology?

Example #1: Amount lost = amount applied

- Not possible previously on a site by site basis
- As if there is a weighing lysimeter at each site

- Automated reports to users—layered approach
- One, simple actionable number: Pump run time
How to use the technology?

Example #2: Targeted deficit based on effective water use

- Measured by Surface Renewal
- Cumulative ET$_a$
- Cumulative Irrigation (L vine$^{-1}$)

Wet Treatment

Overwatering

Week
How to use the technology?

Example #2: Targeted deficit based on effective water use

Medium Treatment

Cumulative ET$_a$ or Cumulative Irrigation (L vine$^{-1}$)

Week

- Cum. ET$_a$
- Cum. irrigation

Measured by Surface Renewal
How to use the technology?

Example #2: Targeted deficit based on effective water use

- Measured by Surface Renewal
- Dry Treatment
- Cumulative ET<sub>a</sub> or Cumulative Irrigation (L vine<sup>-1</sup>)
- Increasing deficit

Week
Measure water use AND vine stress

During stress, vines can’t keep up with demand from atmosphere
Measure water use **AND** vine stress

Paso Robles - J Lohr Cabernet Sauvignon

-1.65 MPa
-1.36 MPa
-1.35 MPa

-1.63 MPa
-1.61 MPa

July 9
Sept 7
Licensing patented technology from UC Davis
• Fundamental work with applied results in ~6 yrs
• In 2016, >1000 stations across varied crops
Alternative automated methods/technologies to track stress

Infrared Radiometers (IRTs): used to measure plant canopy temperatures for plant water stress estimation
Alternative automated methods/technologies to track stress

Infrared Radiometers (IRTs): used to measure plant canopy temperatures for plant water stress estimation

Crop Water Stress Index
or
Stomatal Conductance Ratio

Plant temp can indicate water stress—when stomata close and leaf temps increase
Acknowledgements

• Funding Sources:
  – J. Lohr Vineyards and Wines
  – American Vineyard Foundation
  – National Grape and Wine Initiative
  – NIFA-Specialty Crops Research Initiative
  – USDA-ARS Sustainable Vit CRIS

• Jim Ayars- USDA-ARS
• Felipe Barrios Masias- UC Davis
• Mark Battany- UC ANR
• Daniel Bosch- Constellation Brands
• Arturo Calderon- UC Davis
• Sean Castorani- ARS Davis
• Nick Dokoozlian- E&J Gallo
• Ashley Eustis- USDA-ARS
• Kevin Fort- UC Davis
• Jerry Lohr- Grower Cooperator
• Kyaw Tha Paw U- UC Davis
• Jean Mari Peltier- NGWI

• Anji Perry- J Lohr V&W
• Rod Scheaffer- Constellation Brands
• Tom Shapland- UC Davis
• Ruby Stahel- USDA-ARS
• Rick Snyder- UC Davis
• Gwen Tindula- UC ANR
• Yannis Toutountzis- Constellation Brands
• Vlade Tudor- Tudor Farms
• Andy Walker- UC Davis
• Larry Williams- UC Davis
• Andrew Zaninovich- Sunview Vineyards
Allan Fulton,
UCCE – Tehama County
Turning Orchard Variability into Opportunity

Allan Fulton
Farm Advisor, UC Cooperative Extension
Tehama, Glenn, Colusa, and Shasta Counties

Topics:

• What are the opportunities?
• Tools to help understand orchard variability
• Introduce zone irrigation concept
Opportunities if variability can be managed:

• Increase long term average yield
  - Twelve years after planting, potential of 400 to 1000 lbs/ac/yr more yield across 87 percent of this orchard

• More uniform crop development
  - Assist pest management (root diseases, hull split sprays, mites, weed control)
  - Improve harvestability and reduce shaker injury

• Greater efficiency – More production per unit of water, energy, N, bees, and $$$
Soil diagnostic tools to help understand causes of orchard variability

Electromagnetic (EM) soil sensors

Serpentine travel pattern

Sensors measure EC$_a$

- Apparent EC of soil depends on
  - Texture
  - Structure
  - Moisture
  - Salinity
  - Other properties

Electrical conductivity soil sensors (Veris)
Percent gravel, sand, silt, and clay in relation to ECa (mS/m) measured with EM38 in almond orchard
Almonds, approximately 10 years after planting

EM38 variability map for almond orchard – Four soil zones

Veris variability map for almond orchard – Nine soil zones

Long-term almond yields in respective soil zones identified with EM38 and Veris mapping methods

Almond yield (lbs/acre)
Zone or variable rate irrigation concept

Soil variability map (Veris)

Zone irrigation design to match soil variability

Light
Medium
Heavy
Kent Stenderup, Stenderup Ag Partners
Variable Rate Irrigation
Kent Stenderup, Arvin, CA
Discovery, Design and Implementation

• Veris
• Aerial Imagery, Infrared
• Soil Analysis
• Irrigation System Type
• Real-time Soil Moisture Sensors by Zone
Variability Map
An overview of the range of soil variability in the field

Findings:
The variability identified within the field makes up 3 areas, 45.2%, 47.6% and 7.2%.
Area 1 (45.2%) is identified as blue on the Variability Map.
Area 2 (47.6%) is identified as green to yellow on the Variability Map.
Area 3 (7.2%) is identified as orange on the Variability Map.

Conductivity readings indicate sandy loam to sandy clay loam range in soil type.
Within the 3 areas, 12 to 13 possible sample zones exist.

Estimated Areas of Variability:

<table>
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<tr>
<th>Area</th>
<th>Acres</th>
<th>% of Total Field</th>
<th>EC Range</th>
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<tbody>
<tr>
<td>Area 1</td>
<td>67.3</td>
<td>45.2%</td>
<td>0 - 34</td>
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<tr>
<td>Area 2</td>
<td>70.9</td>
<td>47.6%</td>
<td>35-60</td>
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<td>Area 3</td>
<td>69.8</td>
<td>7.2%</td>
<td>&gt; 60</td>
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Phase 2: Variable Rate Amending (VRA)

How much do you spend on a given amendment, per acre? Calculate your standard amendment cost per acre below and then calculate your savings with the VRA estimate to the right.

Standard amendment application:

- Pounds/acre: 2000
- Cost/pound: 0.0625

\[
\text{Total cost} = \text{pounds/acre} \times \text{cost/pound} = 2000 \times 0.0625 = \$125
\]

The field has an estimated two areas that most likely need to be amended differently. Percent savings are calculated from a standard rate, assuming 100% of the standard rate is applied to the area that most needs amending.

Estimated VRA savings:

\[
\text{Estimated % of savings on standard amendment cost or rate per acre using VRA} = 34.5\%
\]

Client: Stenderup
Grower: Stenderup
Ranch ID: 25
Field ID: 03
Total Acres: 149
3 Distinct Soil Types
Zone Change

Soil Moisture Monitoring
Arvin, California
The Garden in the Sun
Questions?