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

December 7, 2016

Almond Board of California

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

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

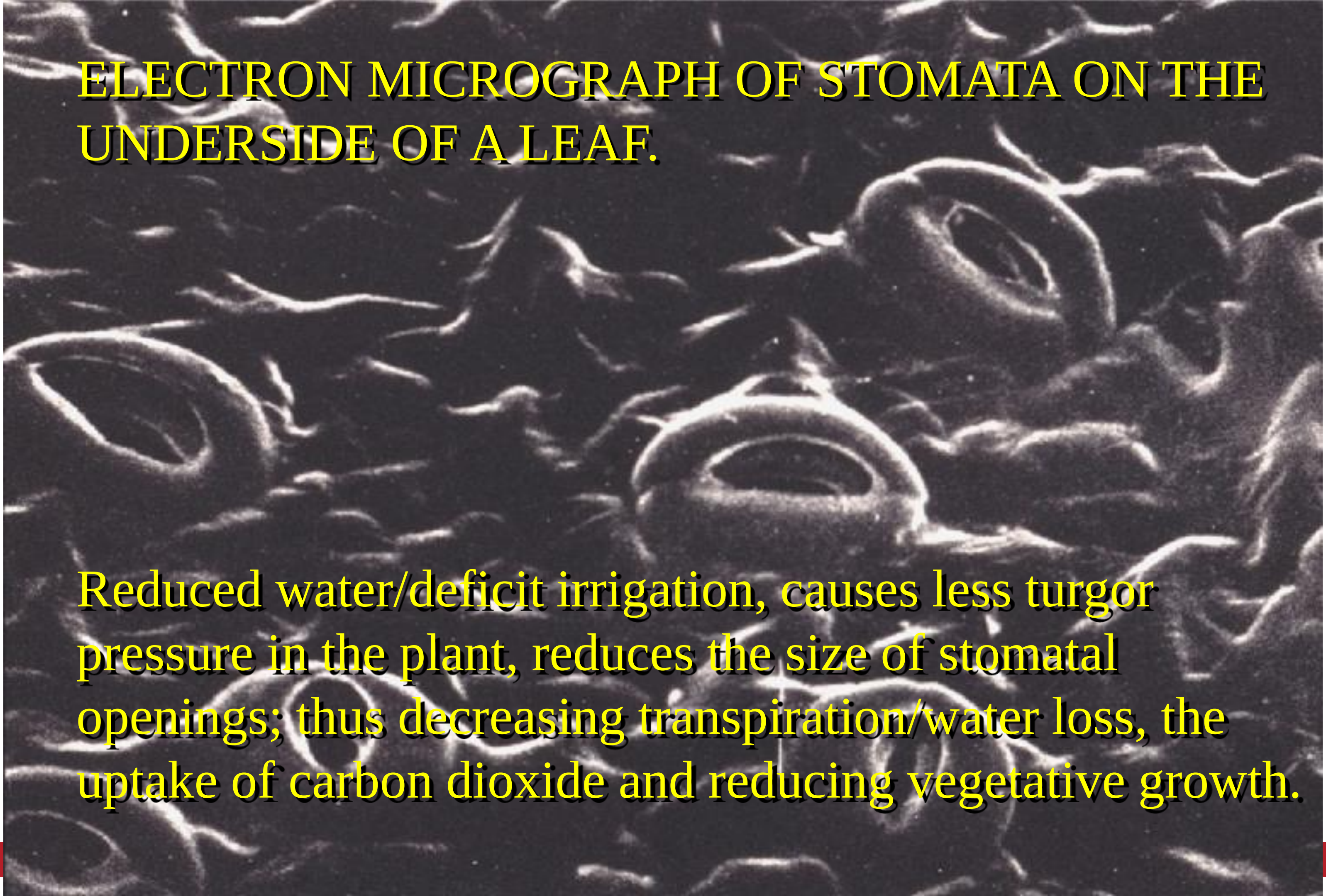
Blake Sanden
UCCE Irrigation/Soils Advisor, Kern Co.

- **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**

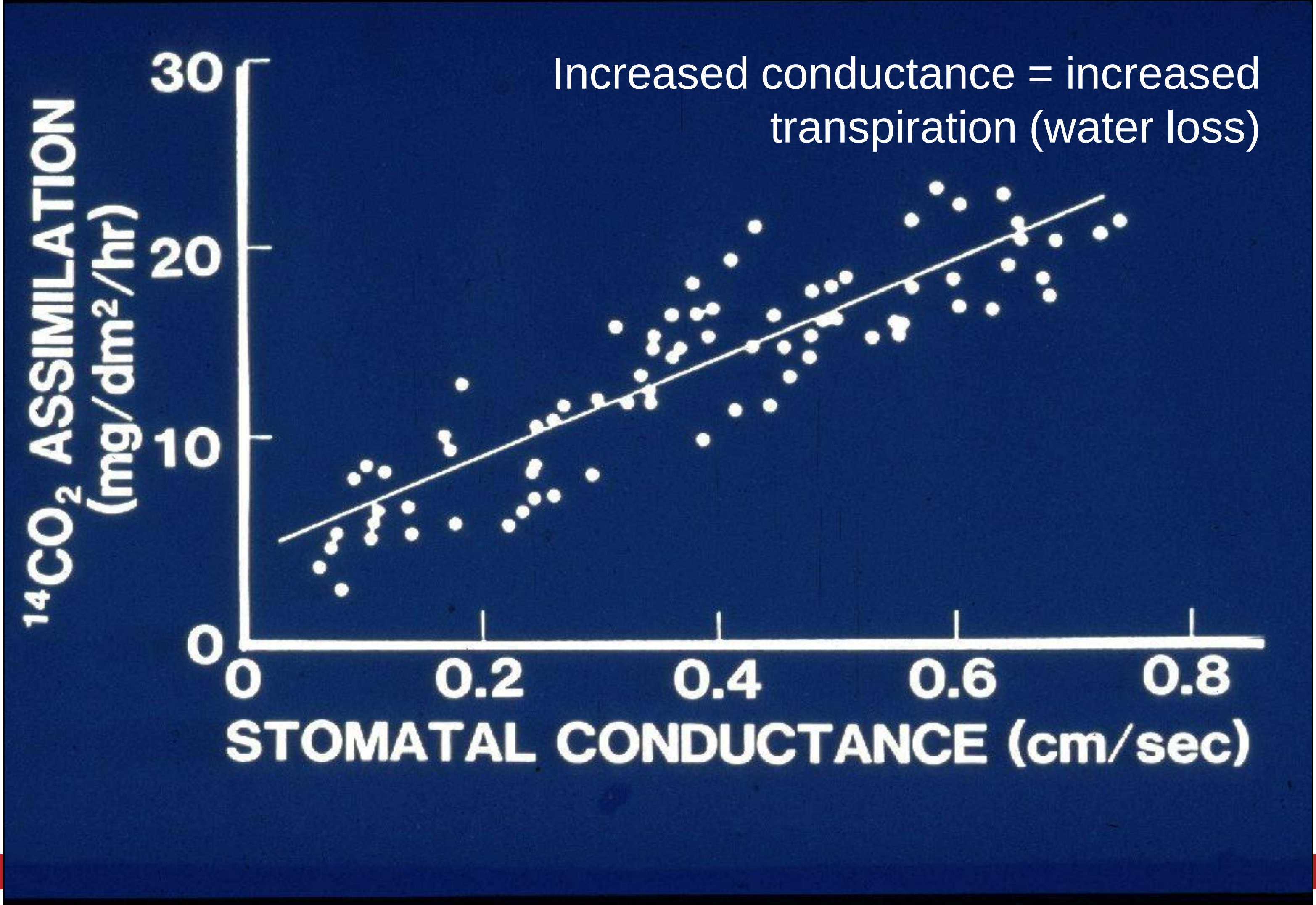
IRRIGATION 1.0, 2.0, 3.0
WHO knows?



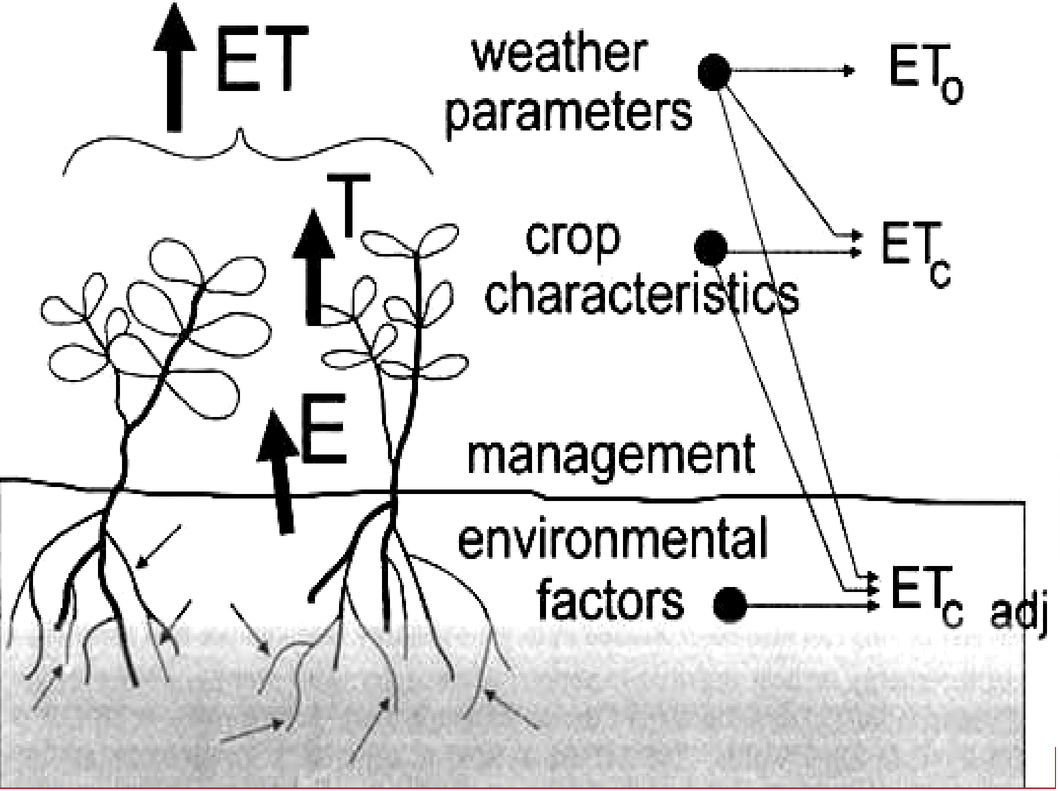
ELECTRON MICROGRAPH OF STOMATA ON THE UNDERSIDE OF A LEAF.

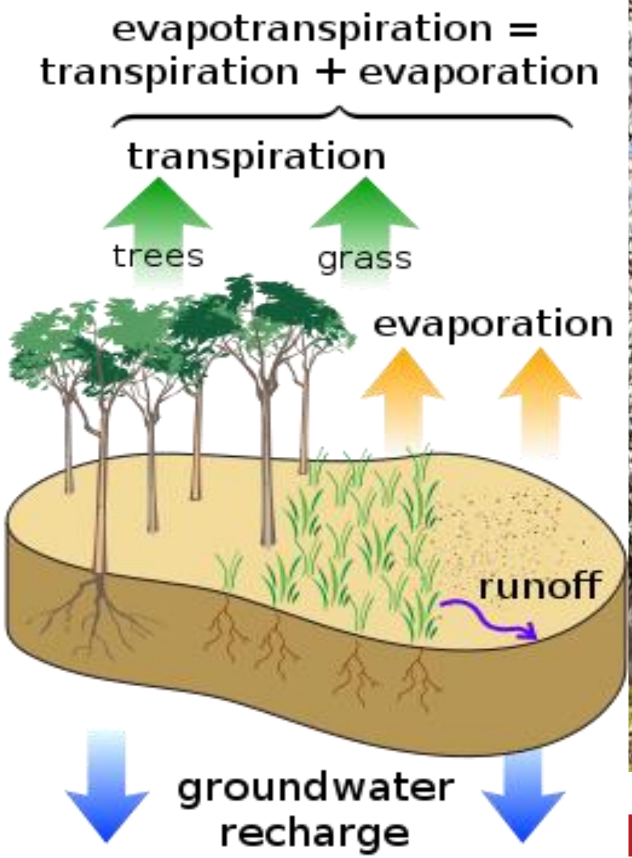
Reduced water/deficit irrigation, causes less turgor pressure in the plant, reduces the size of stomatal openings; thus decreasing transpiration/water loss, the uptake of carbon dioxide and reducing vegetative growth.

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?

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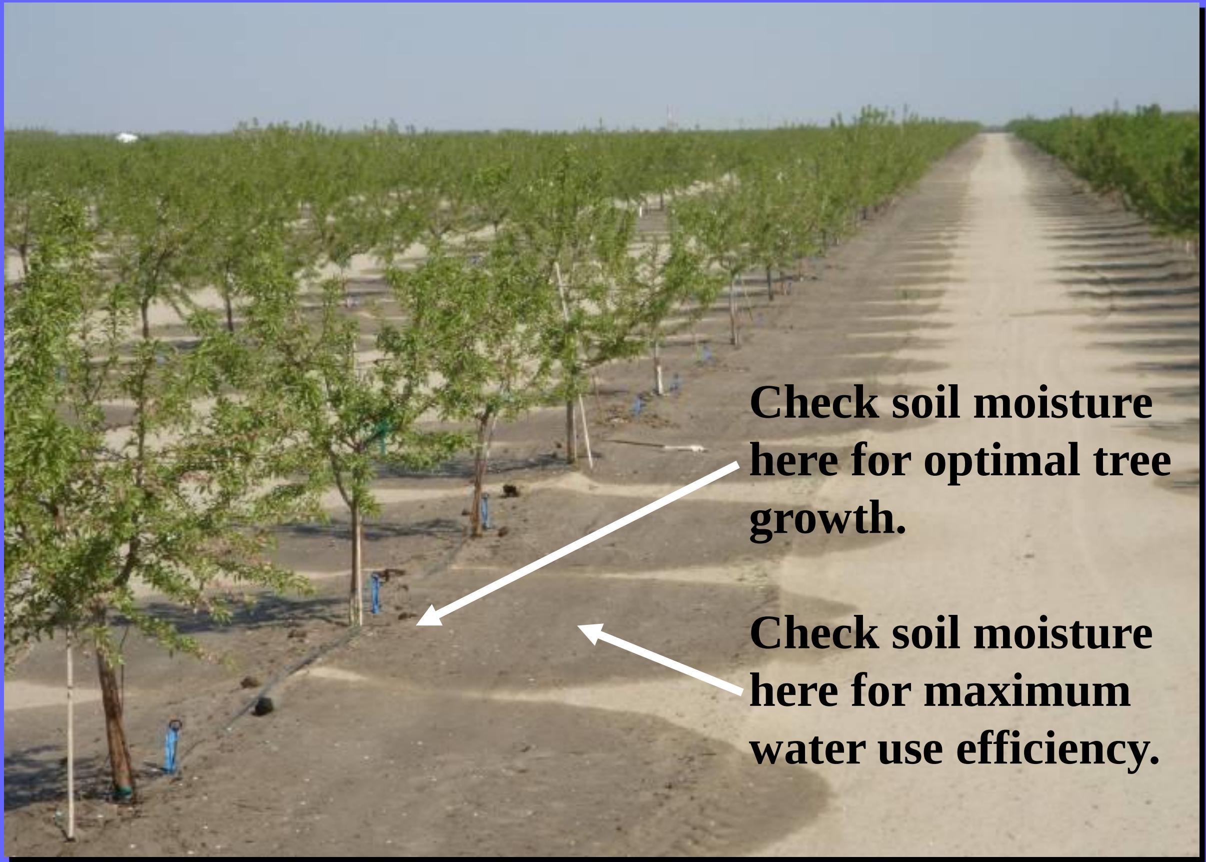
Do micro systems *always* lose less water to evaporation and are more efficient than flood?

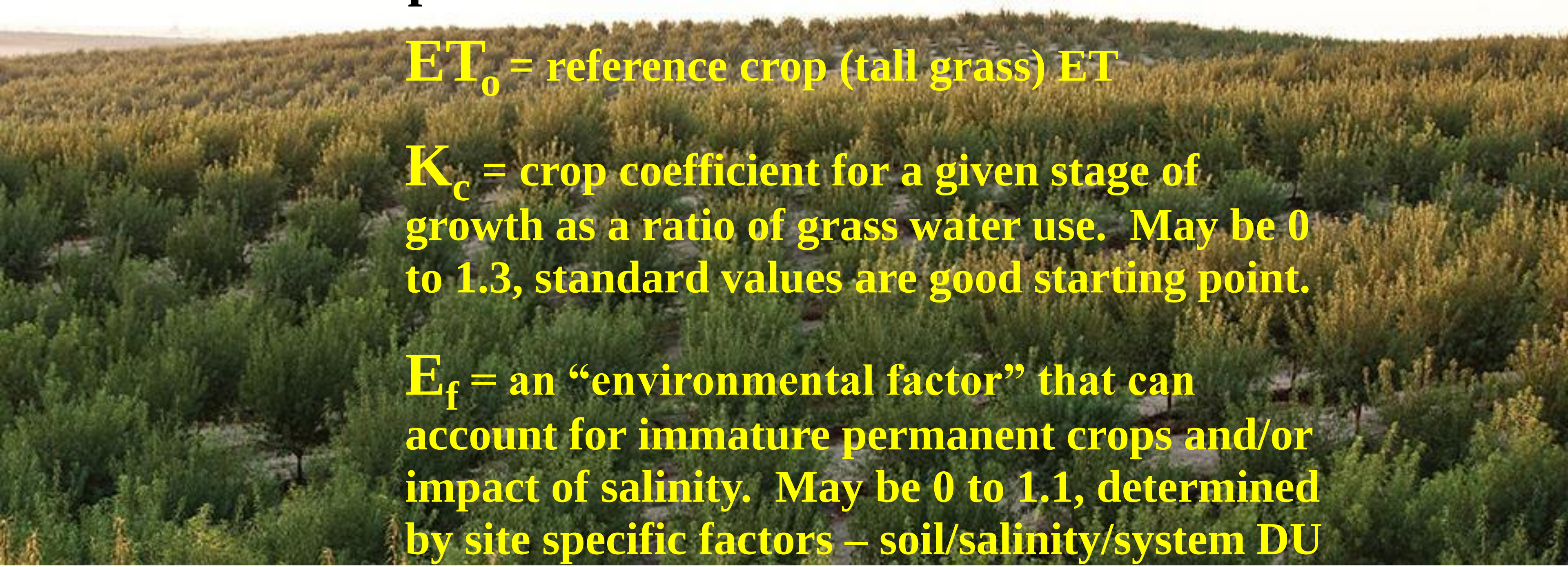


Is all this water available to my 1st leaf trees with a small developing rootzone? What about evaporative losses and deep percolation?

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

Calculating ET for crops:

$$ET_{crop} = ET_o * K_c * E_f$$



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:

ETo = 0.85 Evaporation

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

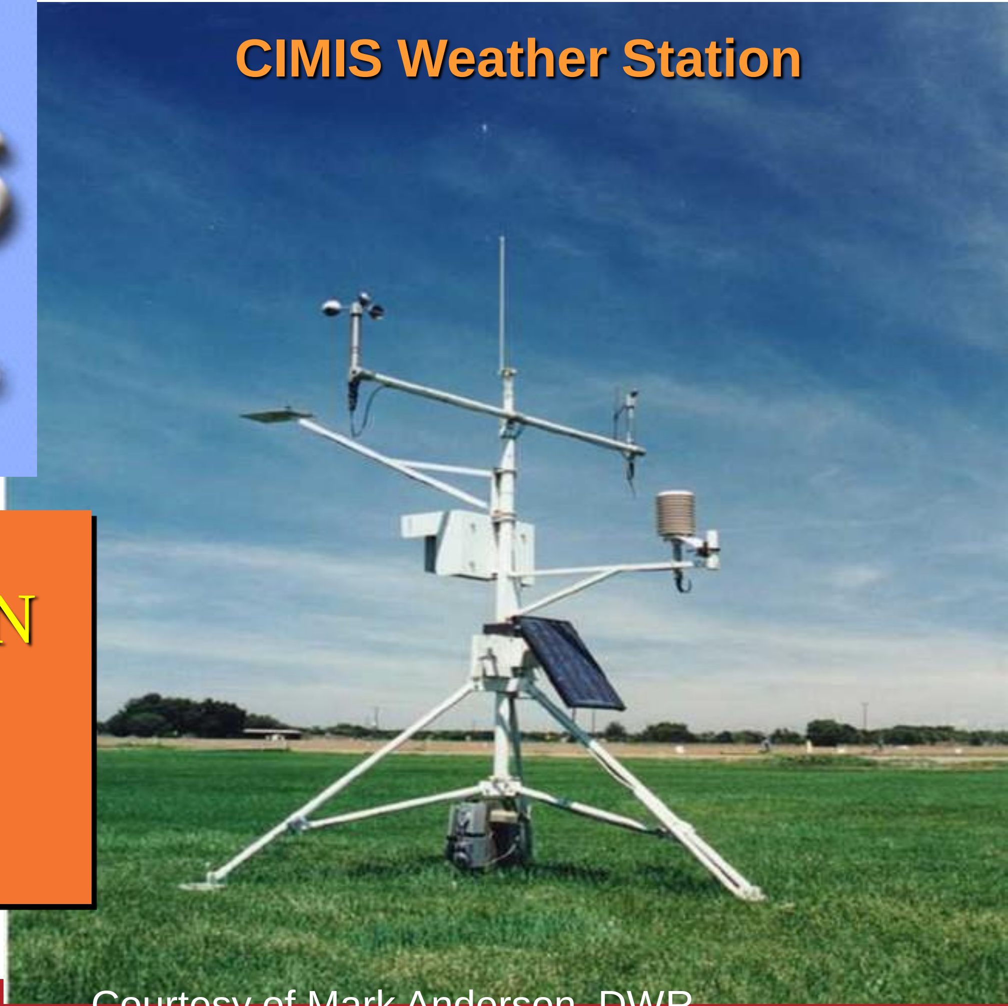
Potential or Reference evapotranspiration (ETo) is the water use of well-watered pasture grass. First estimated using Class A evaporation pans and weighing lysimeters.

CIMIS

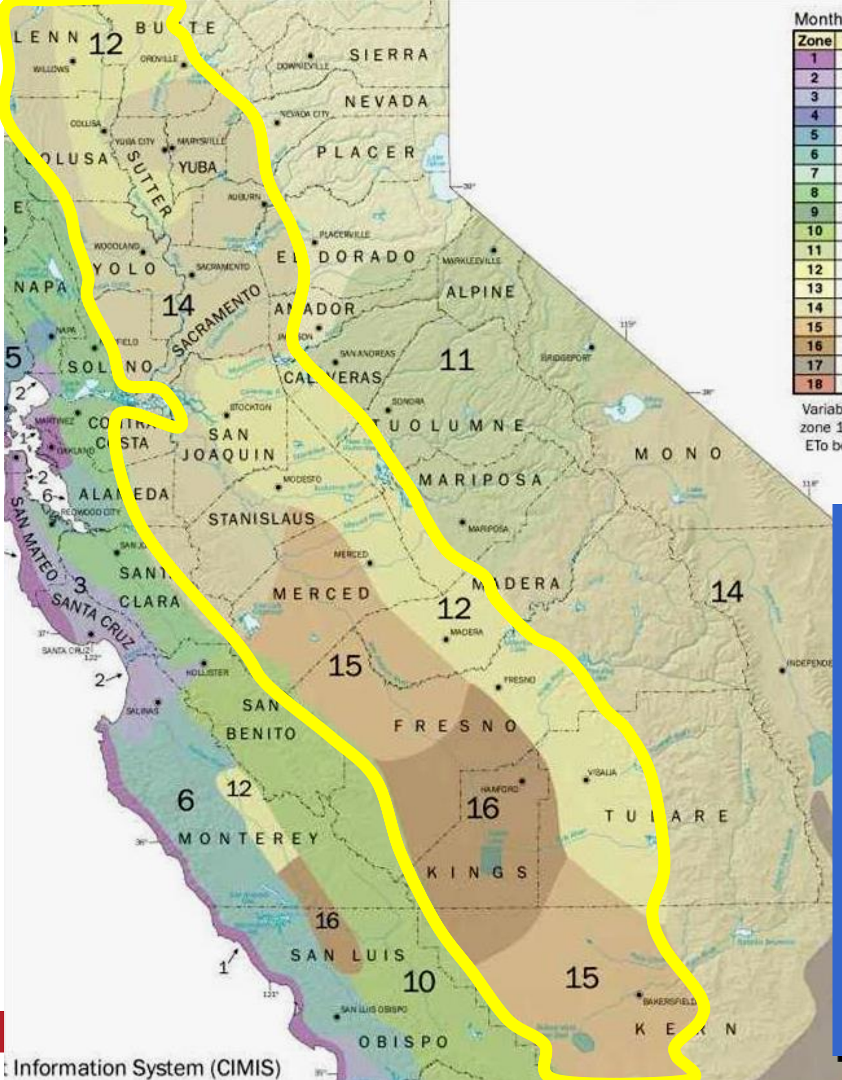
Department of Water Resources
State of California

CALIFORNIA IRRIGATION MANAGEMENT INFORMATION SERVICE

CIMIS Weather Station



Courtesy of Mark Anderson, DWR



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

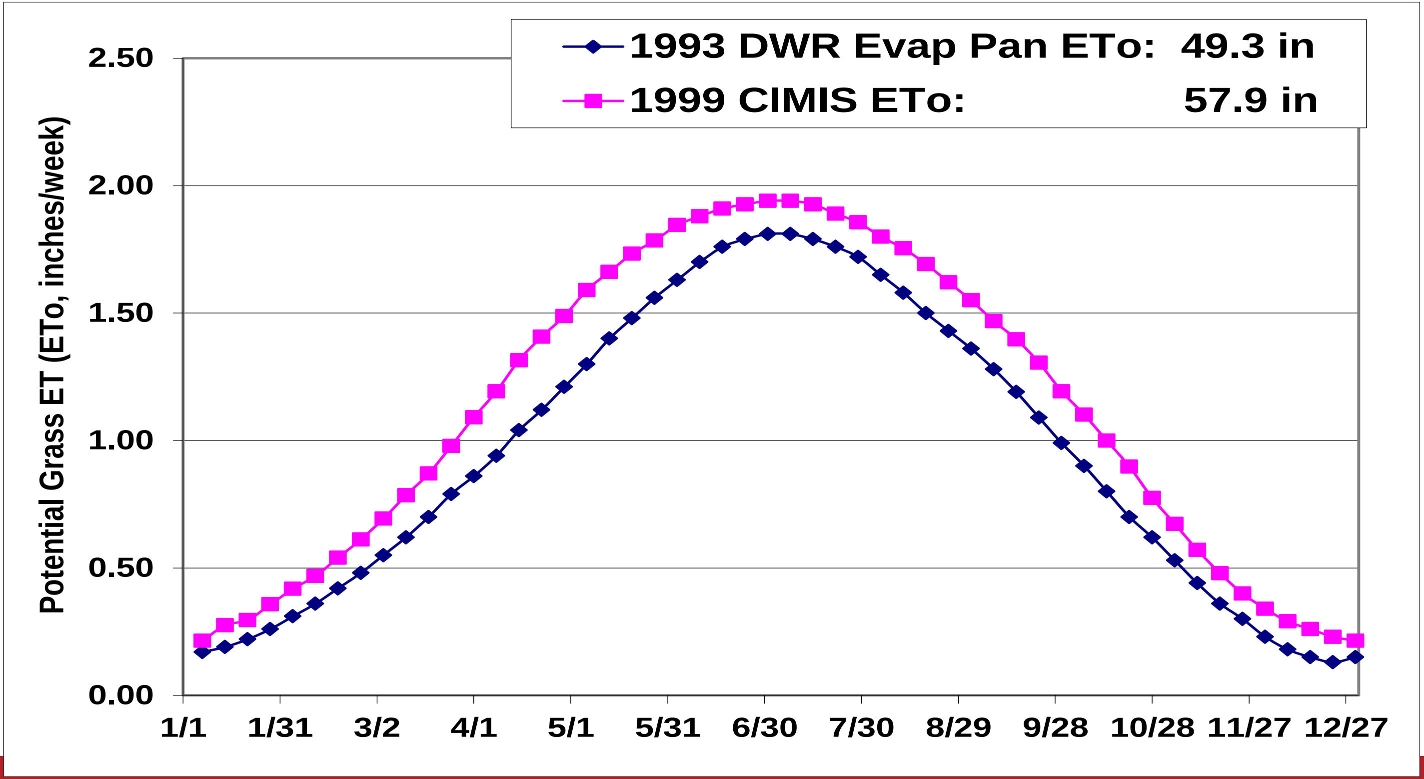
Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	0.93	1.40	2.48	3.30	4.03	4.50	4.65	4.03	3.30	2.48	1.20	0.62	33.0
2	1.24	1.68	3.10	3.90	4.65	5.10	4.96	4.65	3.90	2.79	1.80	1.24	39.0
3	1.86	2.24	3.72	4.80	5.27	5.70	5.58	5.27	4.20	3.41	2.40	1.86	46.3
4	1.86	2.24	3.41	4.50	5.27	5.70	5.89	5.58	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
13	1.24	1.96	3.10	4.80	6.51	7.80	8.99	7.75	5.70	3.72	1.80	0.93	54.3
14	1.55	2.24	3.72	5.10	6.82	7.80	8.68	7.75	5.70	4.03	2.10	1.55	57.0
15	1.24	2.24	3.72	5.70	7.44	8.10	8.68	7.75	5.70	4.03	2.10	1.24	57.9
16	1.55	2.52	4.03	5.70	7.75	8.70	9.30	8.37	6.30	4.34	2.40	1.55	62.5
17	1.86	2.80	4.65	6.00	8.06	9.00	9.92	8.68	6.60	4.34	2.70	1.86	66.5
18	2.48	3.36	5.27	6.90	8.68	9.60	9.61	8.68	6.90	4.96	3.00	2.17	71.6

Variablity between stations within single zones is as high as 0.02 inches per day for zone 1 and during winter months in zone 13. The average standard deviation of the ETo between estimation sites within a zone for all months is about 0.01 inches per day for all 200 sites.

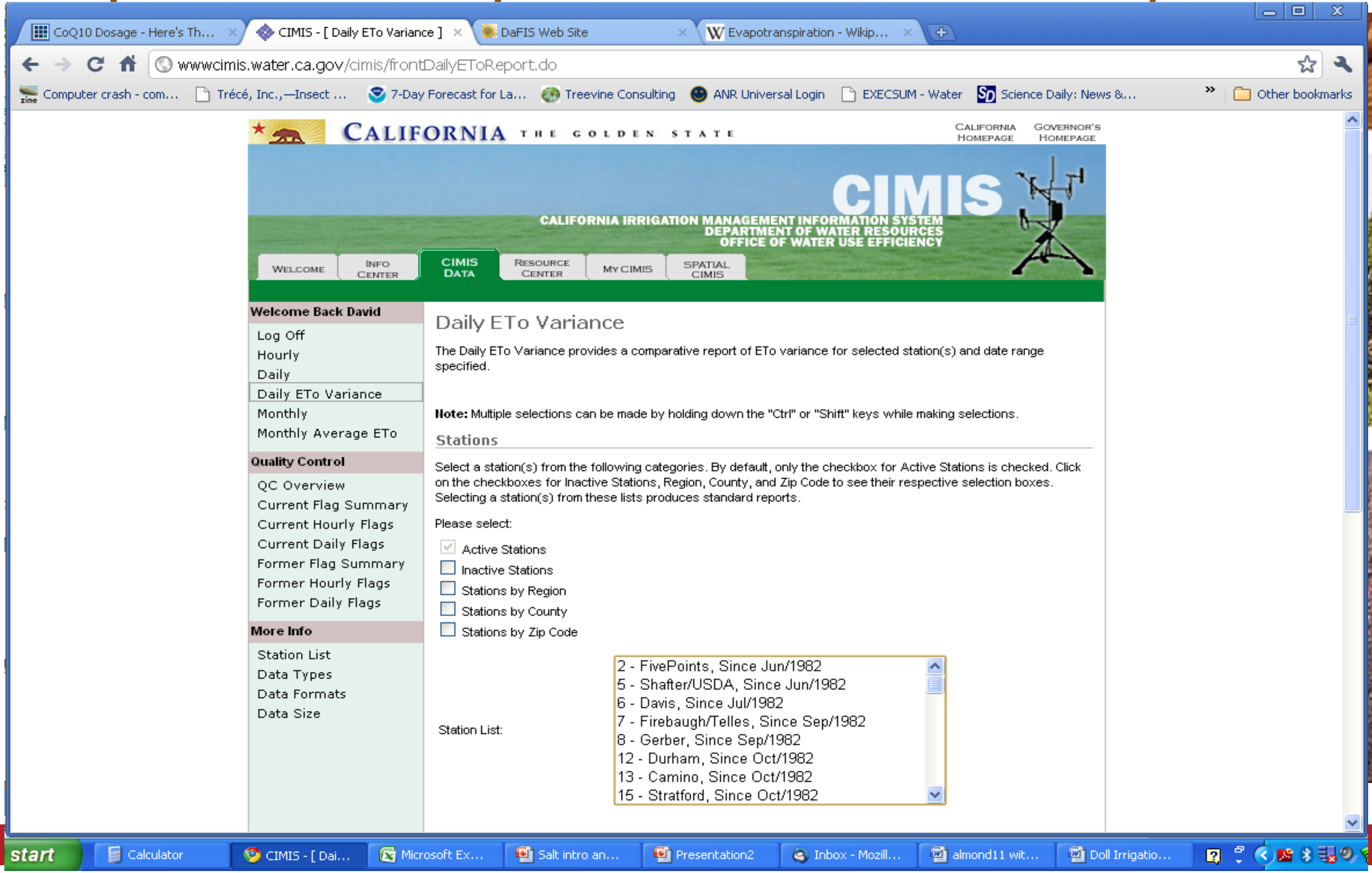
The whole Central Valley covers Zones 12 to 16: for an "normal year" ETo of 53.3 to 62.5 in/yr, with most area @ 53 to 58 inches.

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?



How do we figure out ETo? Access California Irrigation Management Information System on-line.

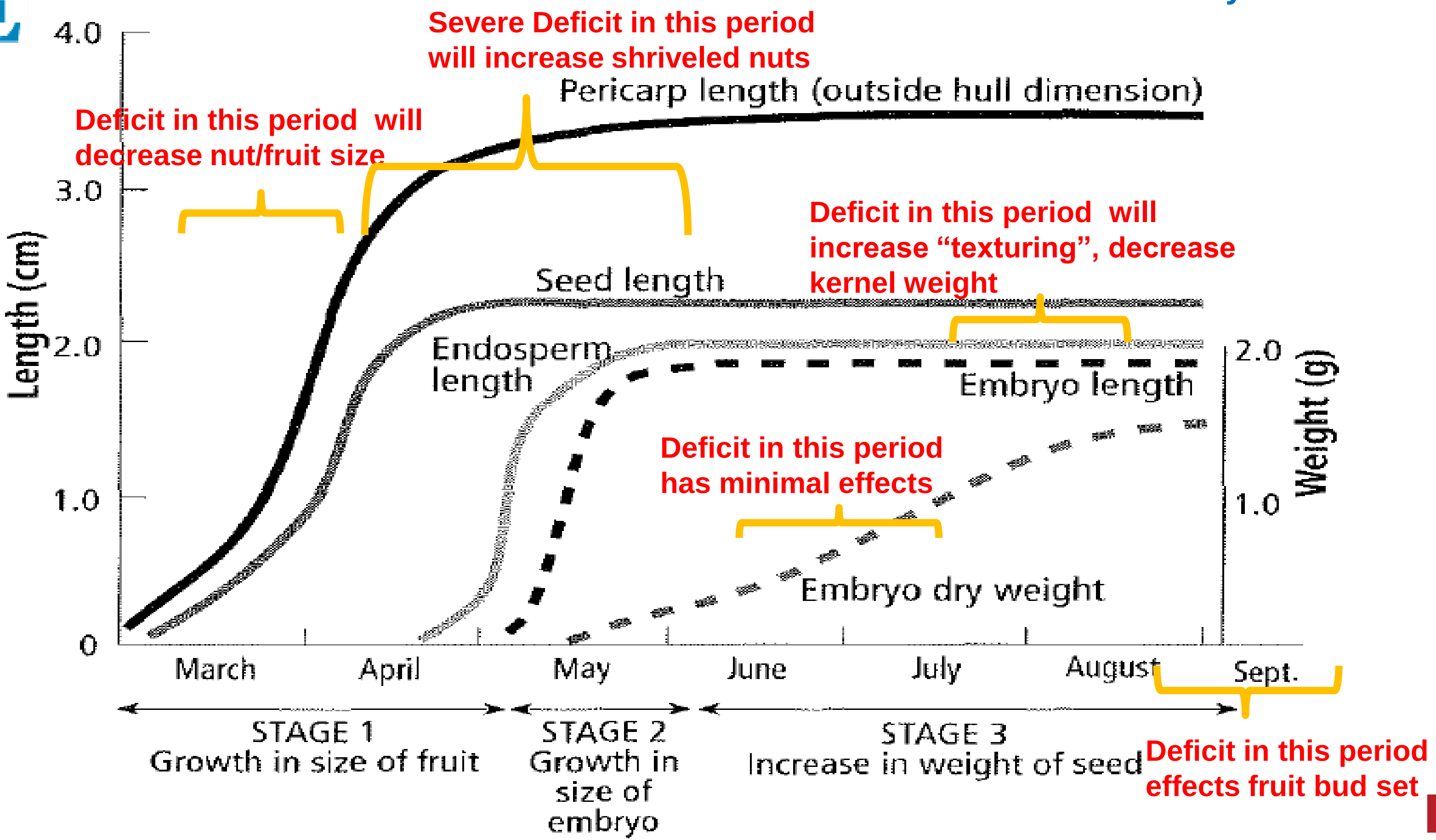


OK on ETo for my area. Where do I get the right (?) crop coefficients, Kc

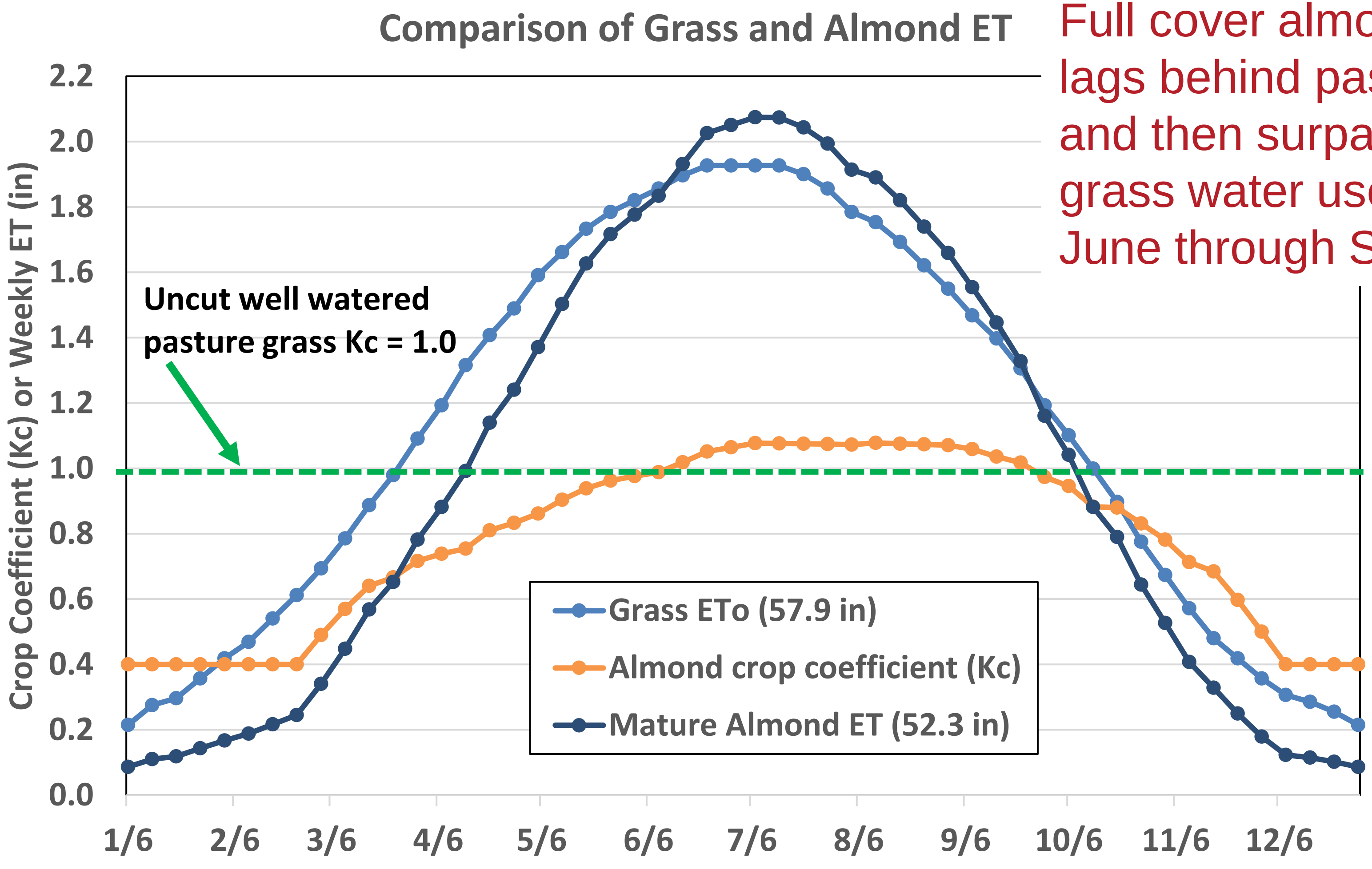
- http://wwwcimis.water.ca.gov/
- http://cekern.ucanr.edu/Irrigation_Management/Almond_Drip_-_Microsprinkler_-_Flood_Weekly_ET/
- http://www.almonds.com/irrigation#tc-irrigation-management (Almond Board website)
- https://www.sustainablealmondgrowing.org/
  - (full on irrigation calculator, must sign in, sponsored by ABC)
- http://thealmonddoctor.com/irrigation-management/
- http://ucmanagedrought.ucdavis.edu/Agriculture/Crop_Irrigation_Strategies/Almonds/

Drought Strategies Explained

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



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



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Google: “cekern irrigation almond ET” for Kc / ET table.

ET Estimates Using CIMIS Zone 15 Southern SJV "Historic" ETo (1st published 2002)

Week	Normal Year Grass ETo (in)	Mature Crop Coef-ficient (Kc)	Almond ET -- Minimal Cover Crop, MIcrosprinkler (inches, S. San Joaquin Valley) 1st Leaf @ 40%	2nd Leaf @ 55%	3rd Leaf @ 75%	4th Leaf @ 90%	Mature	Monthly Total	Daily Avg	20X22 Spacing Gallon / day / tree
1/6	0.21	0.40	0.03	0.05	0.06	0.08	**0.09**		0.01	**3**
1/13	0.28	0.40	0.04	0.06	0.08	0.10	**0.11**		0.02	**4**
1/20	0.30	0.40	0.05	0.07	0.09	0.11	**0.12**		0.02	**5**
1/27	0.36	0.40	0.06	0.08	0.11	0.13	**0.14**	**JAN** 0.46	0.02	**6**
2/3	0.42	0.40	0.07	0.09	0.13	0.15	**0.17**		0.02	**7**
2/10	0.47	0.40	0.08	0.10	0.14	0.17	**0.19**		0.03	**7**
2/17	0.54	0.40	0.09	0.12	0.16	0.19	**0.22**		0.03	**8**
2/24	0.61	0.40	0.10	0.13	0.18	0.22	**0.24**		0.03	**10**
3/3	0.69	0.42	0.12	0.16	0.22	0.26	**0.29**	**FEB** 1.02	0.04	**11**
5/5	1.59	0.86	0.55	0.75	1.03	1.23	**1.37**		0.20	**54**
5/12	1.66	0.90	0.60	0.83	1.13	1.35	**1.50**		0.21	**59**
5/19	1.73	0.94	0.65	0.89	1.22	1.46	**1.63**		0.23	**64**
5/26	1.78	0.96	0.69	0.94	1.29	1.54	**1.72**		0.25	**67**
6/2	1.85	0.98	0.72	0.99	1.35	1.62	**1.80**	**MAY** 7.15	0.26	**71**
6/9	1.86	0.99	0.73	1.01	1.38	1.65	**1.83**		0.26	**72**
6/16	1.90	1.02	0.77	1.06	1.45	1.74	**1.93**		0.28	**76**
6/23	1.93	1.05	0.81	1.11	1.52	1.82	**2.03**		0.29	**79**
6/30	1.93	1.06	0.82	1.13	1.54	1.85	**2.05**	**JUN** 8.36	0.29	**80**
10/27	0.77	0.83	0.26	0.35	0.48	0.58	**0.64**	**OCT** 3.49	0.09	**25**
11/3	0.67	0.78	0.21	0.29	0.39	0.47	**0.53**		0.08	**21**
11/10	0.57	0.71	0.16	0.22	0.31	0.37	**0.41**		0.06	**16**
11/17	0.48	0.68	0.13	0.18	0.25	0.30	**0.33**		0.05	**13**
11/24	0.42	0.60	0.10	0.14	0.19	0.22	**0.25**		0.04	**10**
12/1	0.36	0.50	0.07	0.10	0.13	0.16	**0.18**	**NOV** 1.32	0.03	**7**
12/8	0.31	0.40	0.05	0.07	0.09	0.11	**0.12**		0.02	**5**
12/15	0.29	0.40	0.05	0.06	0.09	0.10	**0.11**		0.02	**4**
12/22	0.25	0.40	0.04	0.06	0.08	0.09	**0.10**		0.01	**4**
12/29	0.21	0.40	0.03	0.05	0.06	0.08	**0.09**	**DEC** 0.47	0.01	**3**
Total	**57.90**		**20.91**	**28.75**	**39.20**	**47.05**	**52.27**	**52.27**		

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WEEKLY SOIL MOISTURE LOSS IN INCHES

(Estimated Crop Evapotranspiration or ETc)

07/18/16 through 07/24/16

Crops (Leafout Date)	#5 Shafter Past Week of Water Use	#5 Shafter Accum'd Seasonal Water Use	#5 Shafter Next Week's Estimated ETc	#125 Arvin-Edison Past Week of Water Use	#125 Arvin-Edison Accum'd Seasonal Water Use	#125 Arvin-Edison Next Week's Estimated ETc	#146 Belridge Past Week of Water Use	#146 Belridge Accum'd Seasonal Water Use	#146 Belridge Next Week's Estimated ETc
Almonds (2/22) *	2.06	32.14	1.98	2.37	34.72	2.24	2.04	32.33	2.07
Pistachio (3/28) * **	2.06	22.68	1.98	2.36	24.67	2.24	2.04	22.58	2.07
Citrus	1.21	24.26	1.14	1.41	25.96	1.33	1.19	24.69	1.23
Grapes (3/10) (late season table, 75% cover)	2.49	24.88	0.00	2.93	27.45	0.00	2.47	24.89	0.00
Winegrapes (3/10) (50% cover) ***	0.94	15.05	0.91	1.09	16.05	1.05	0.93	14.91	0.95
Alfalfa	1.78	34.59	1.70	2.08	37.06	1.96	1.76	35.21	1.79
Cotton (4/4)	2.22	17.99	2.12	2.60	20.07	2.45	2.19	17.95	2.25
Past 7 days precipitation (inches)	0.00			0.00			0.00		
Accumulated precipitation (inches)	3.73			6.39			3.95		

...all event

...eekly estimates

Weekly crop report on ETc for Kern – courtesy of DWR and UCCE (available for Fresno and Tehema also, others maybe coming)

PAST WEEKLY APPLIED WATER IN INCHES, ADJUSTED FOR EFFICIENCY 1

Crops	#5 Shafter				#125 Arvin-Edison				#146 Belridge			
System Efficiency >>	65%	75%	85%	95%	65%	75%	85%	95%	65%	75%	85%	95%
Almonds (2/22)	3.2	2.7	2.4	2.2	3.6	3.2	2.8	2.5	3.1	2.7	2.4	2.1
Pistachio (3/28)	3.2	2.7	2.4	2.2	3.6	3.1	2.8	2.5	3.1	2.7	2.4	2.1
Citrus	1.9	1.6	1.4	1.3	2.2	1.9	1.7	1.5	1.8	1.6	1.4	1.3
Grapes (3/10) (late season table, 75% cover)	3.8	3.3	2.9	2.6	4.5	3.9	3.4	3.1	3.8	3.3	2.9	2.6
Winegrapes (3/10) (50% cover)	1.4	1.3	1.1	1.0	1.7	1.5	1.3	1.1	1.4	1.2	1.1	1.0
Alfalfa	2.7	2.4	2.1	1.9	3.2	2.8	2.4	2.2	2.7	2.3	2.1	1.9
Cotton (4/4)	3.4	3.0	2.6	2.3	4.0	3.5	3.1	2.7	3.4	2.9	2.6	2.3

1 The amount of water required by a specific irrigation system to satisfy evapotranspiration. Typical ranges in irrigation system efficiency are: Drip, 80%-95%; Micro-sprinkler, 80%-90%; Sprinkler, 70%-85%; and Border-furrow, 50%-75%.

For further information concerning all counties receiving this report, contact the Kern Co. Farm Advisor's office at (661) 868-6218.

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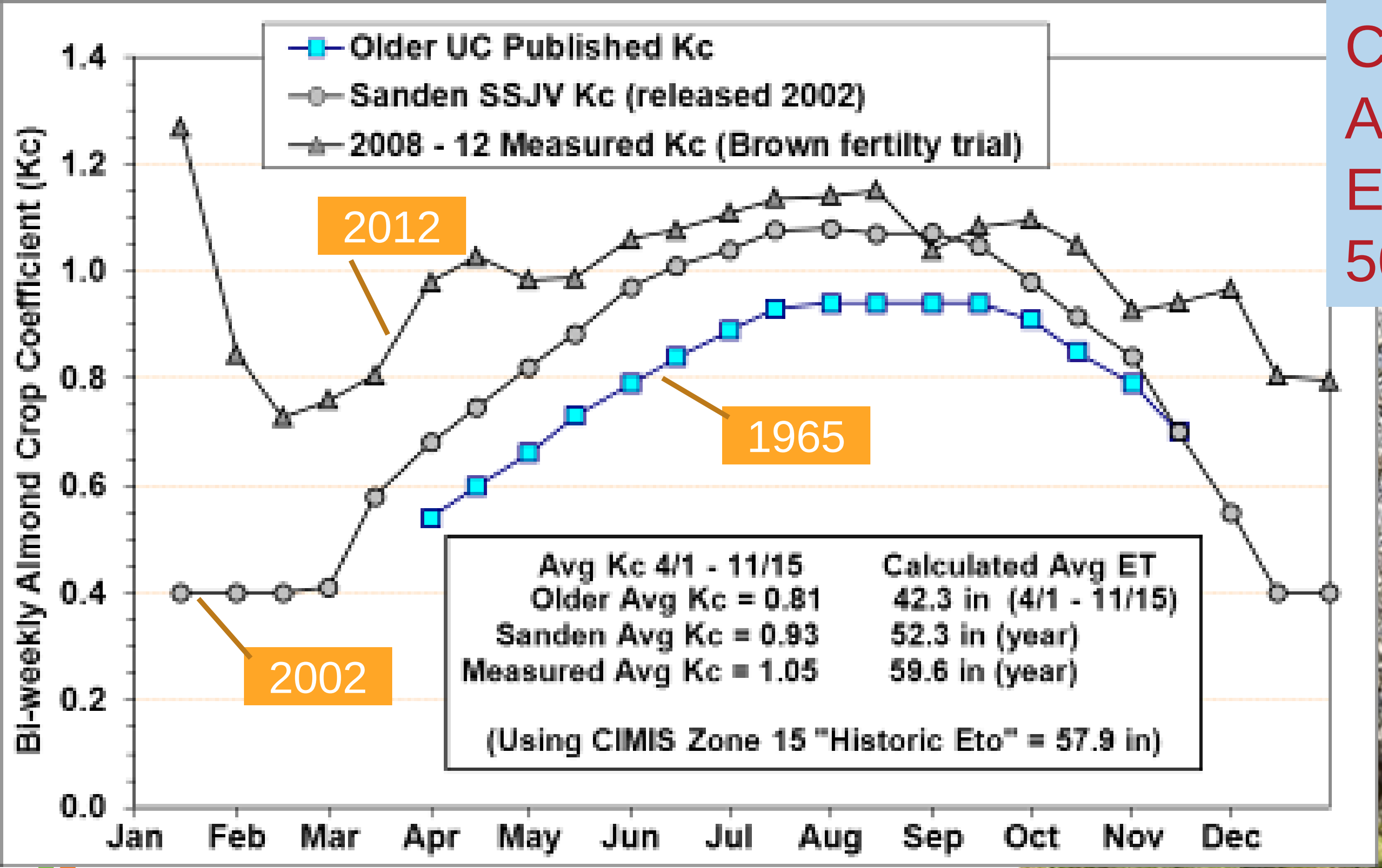
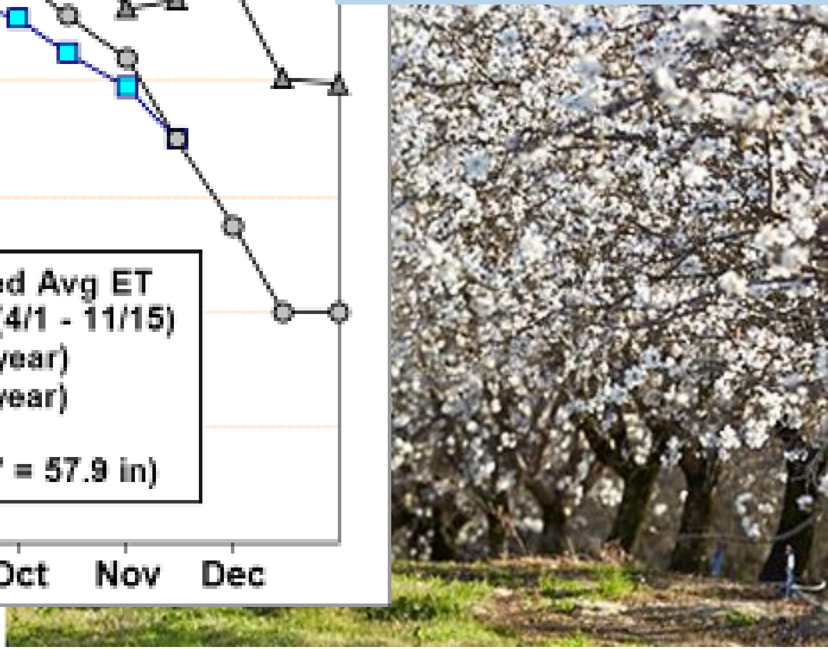
Changes in Almond Kc / ET Estimates Over 50 Years





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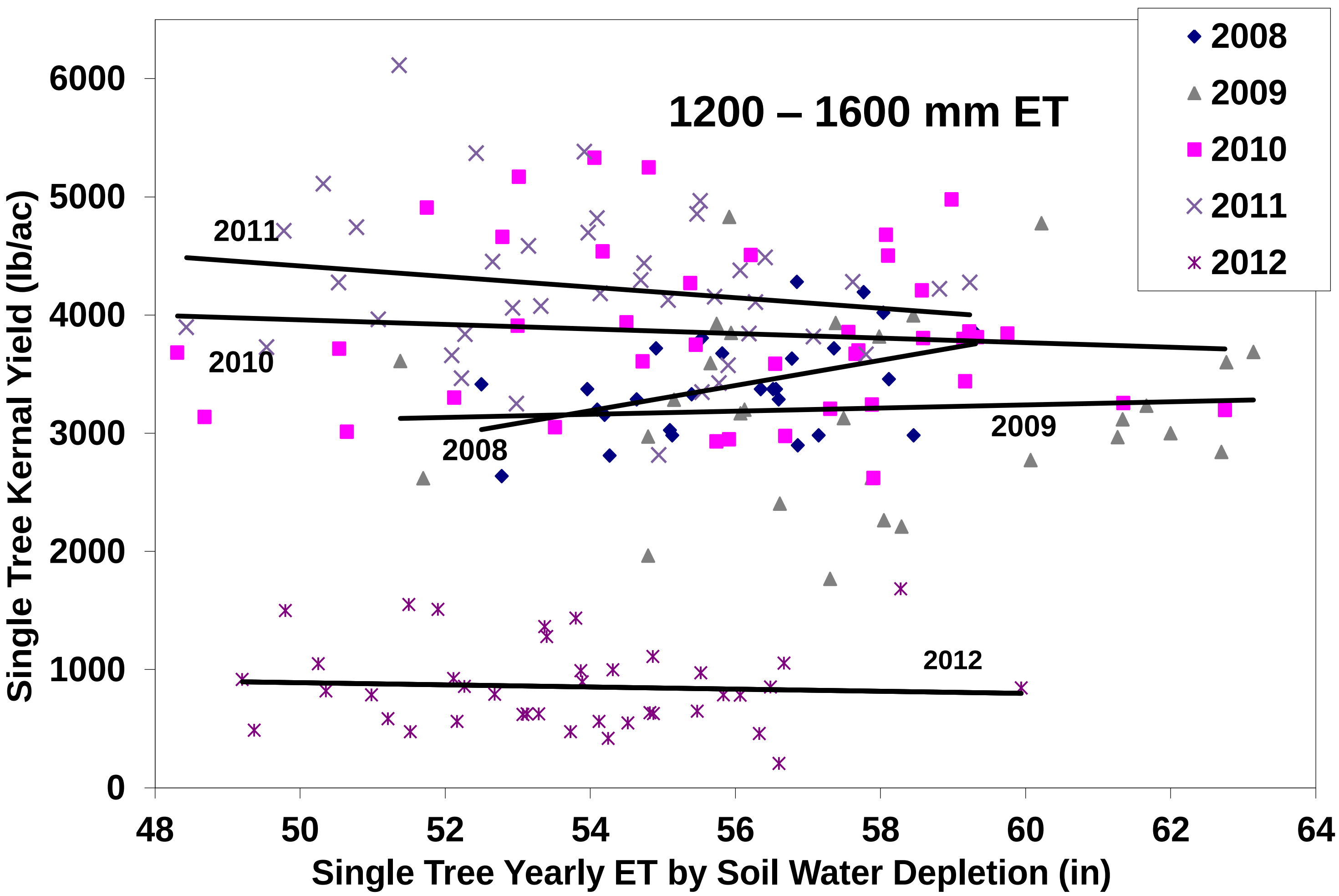
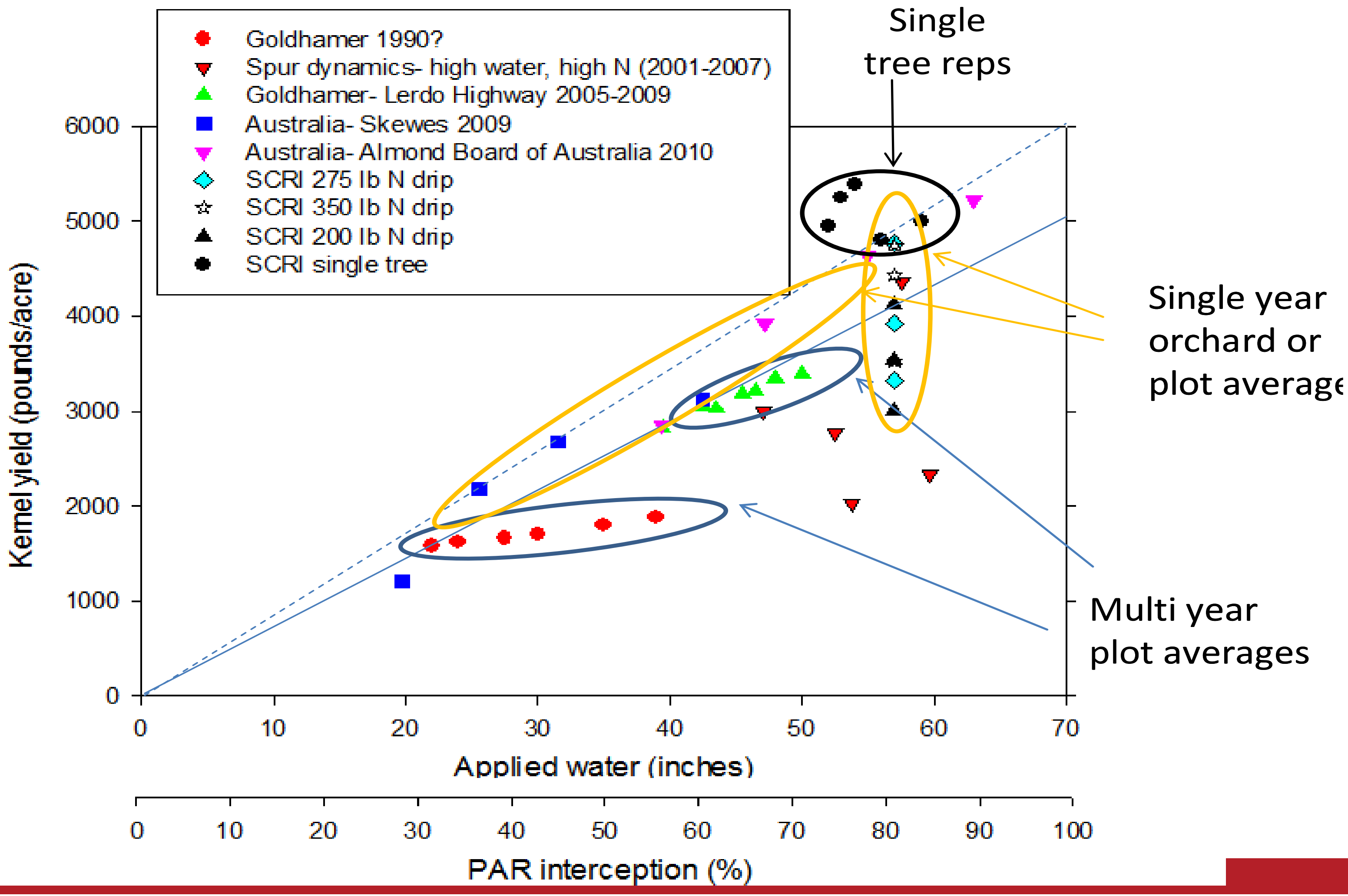
Do you get 6,000 lb/ac with 60” ET? (Brown fertility trials, 275 lb/ac N yields)



Almond yield by light (PAR) & water

(Courtesy of Bruce Lampenin)



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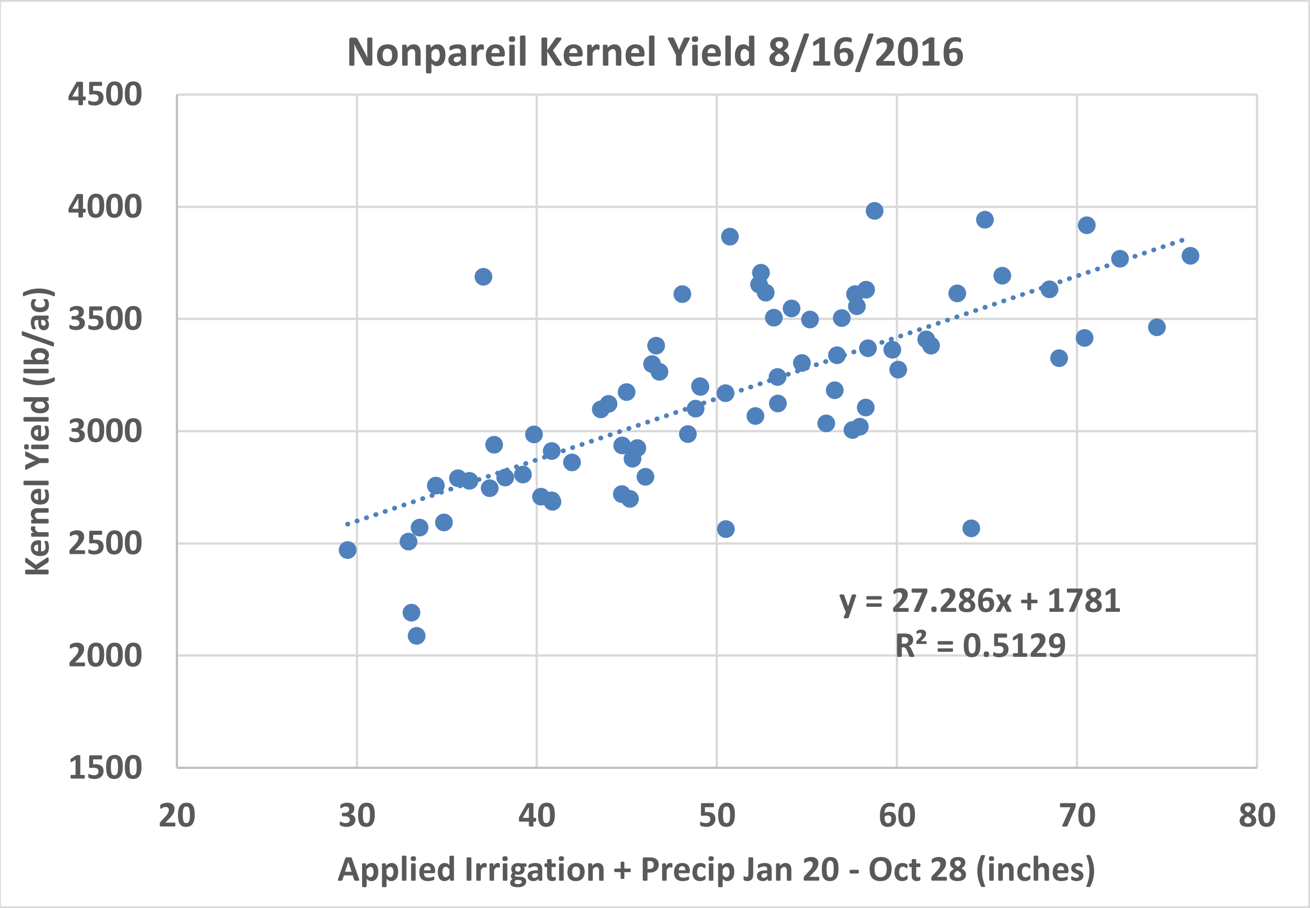
Correlation of 2016 Nonpareil yield with applied water improved 2x to 0.51



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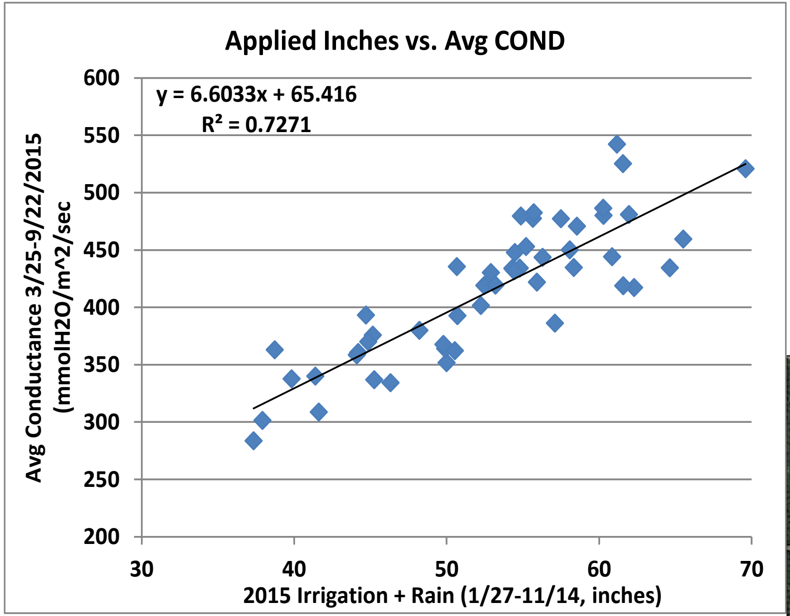
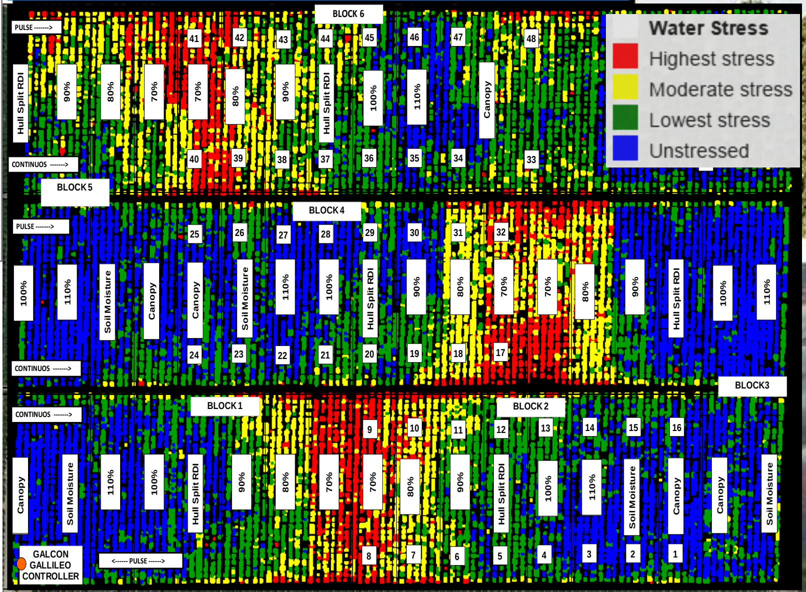


3/25-9/22/2015 average almond plot CONDUCTANCE by 2015 applied irrigation (10 flyovers)

AERIAL IMAGERY CAN IDENTIFY IRRIGATION/STRESS NON-UNIFORMITY



<u>Canopy Temp/Water Stress by Irrigation Treatment</u>

(CERES Spectral Imaging 6/17/2015)

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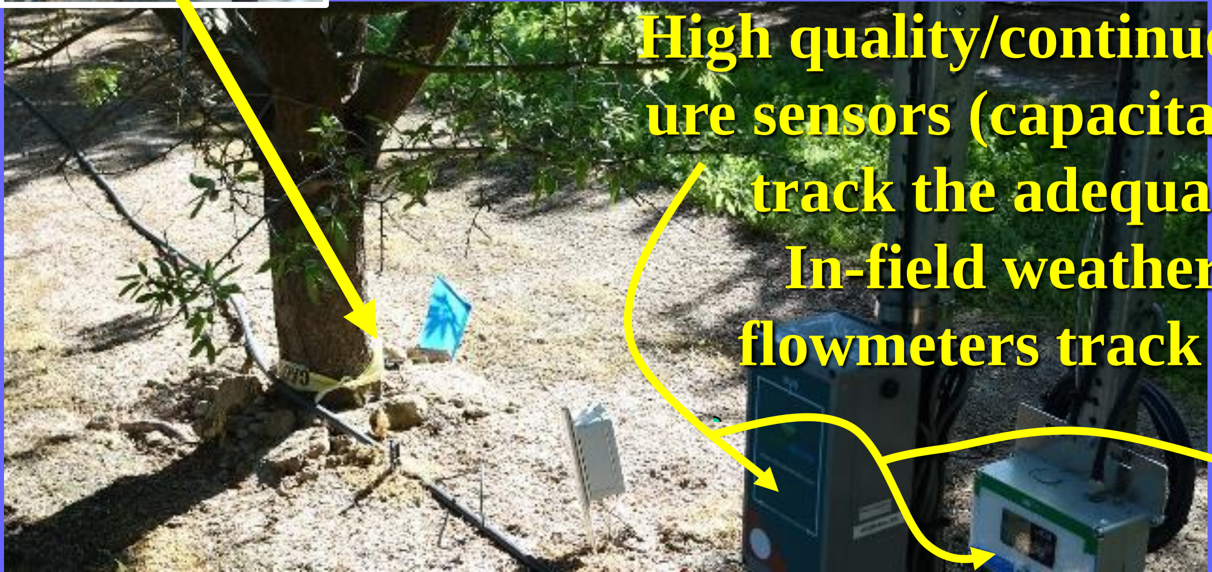
Equipment for making irrigation decisions

- 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.



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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

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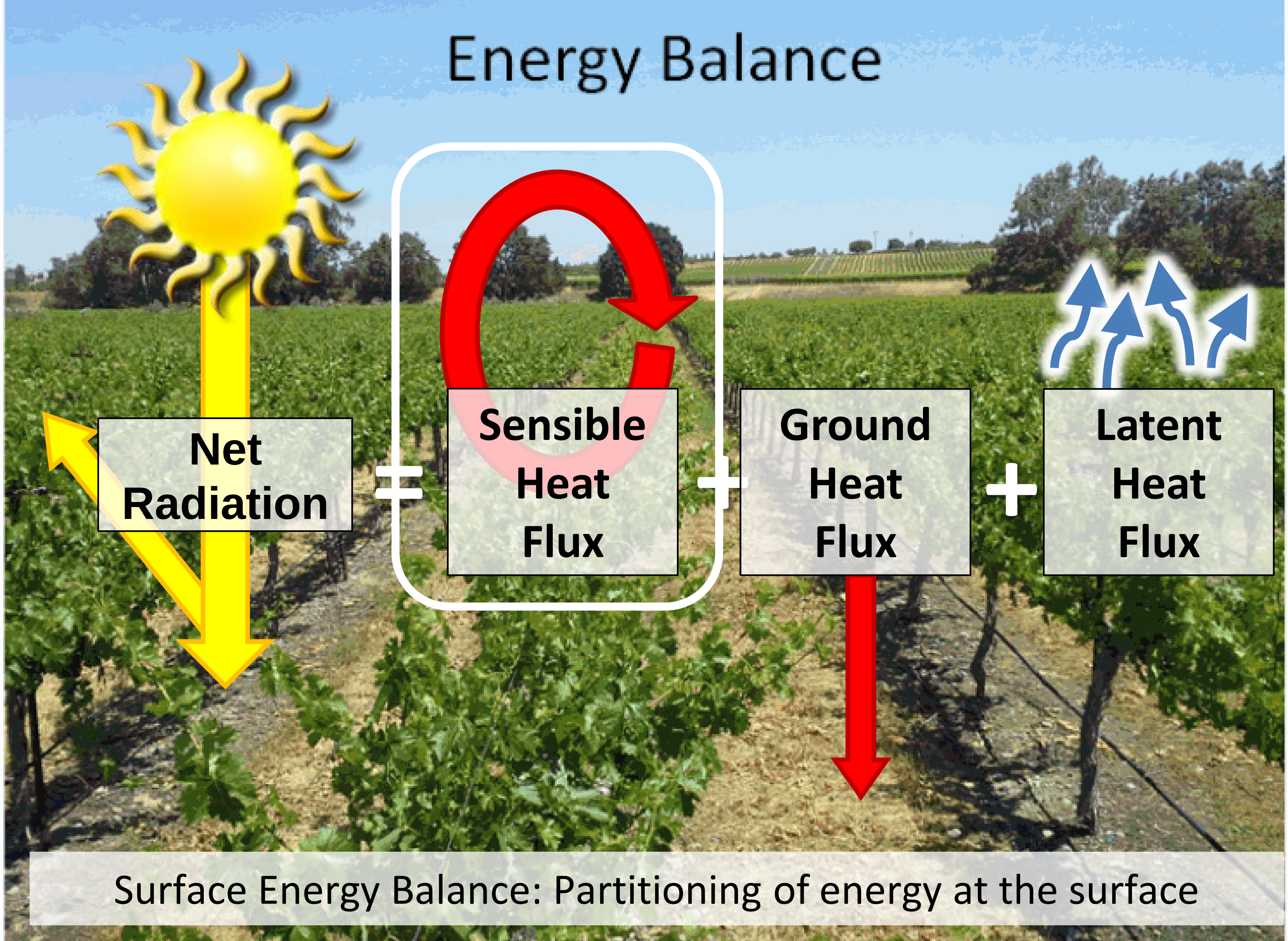
Andrew McElrone, USDA-ARS, Davis

Development of Surface Renewal Technology

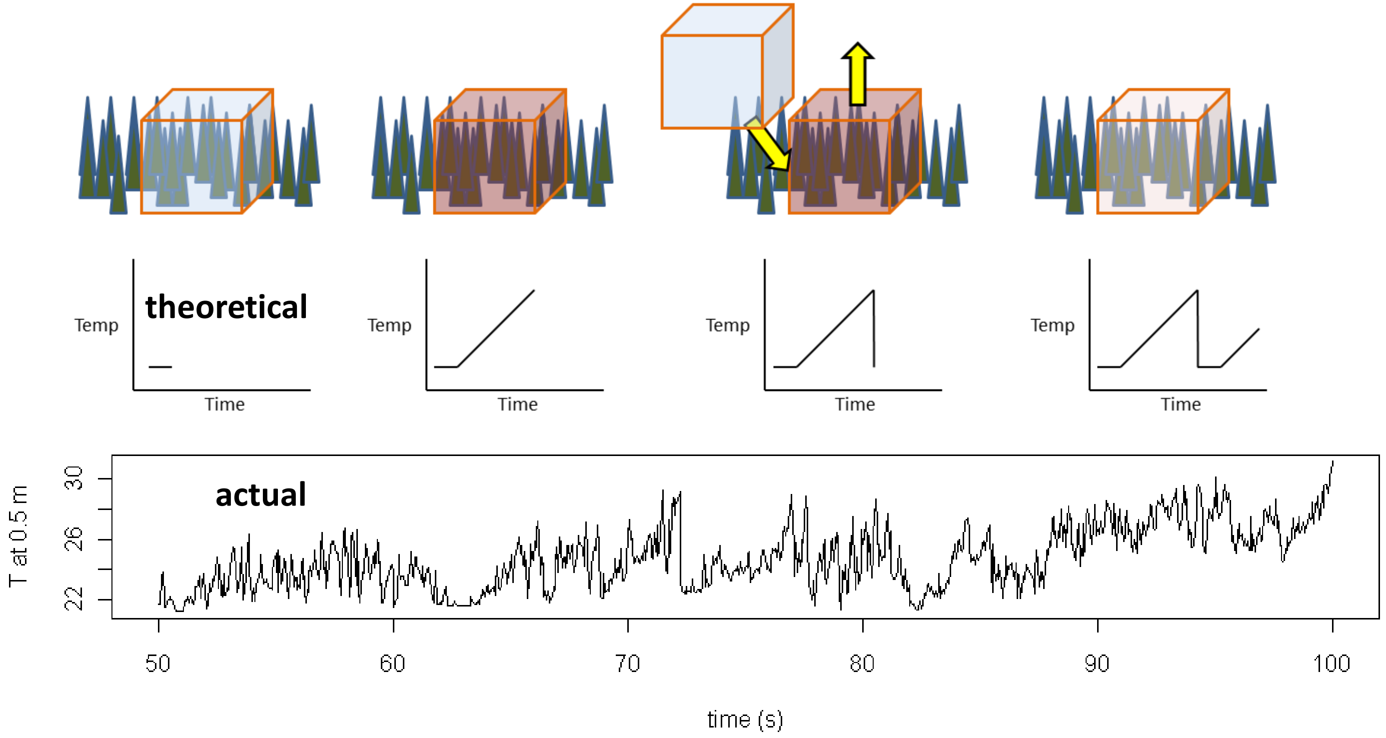
Collaborators: Paw U, Snyder, Williams, Battany

Student/Post Docs: Shapland, Calderon, Parry

Funding: J Lohr Vineyards, NIFA-SCRI, AVF, USDA


Energy Balance
Net Radiation
=
Sensible Heat Flux
+
Ground Heat Flux
+
Latent Heat Flux
Surface Energy Balance: Partitioning of energy at the surface

Surface Renewal Technology Development



Successfully removed the need for calibration of Surface Renewal against Eddy Covariance

New Surface Renewal System:
A reliable & automated ET measurement system

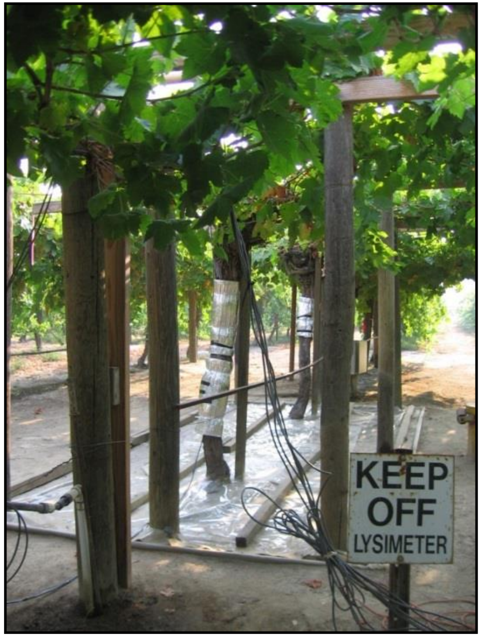
Eddy
Covariance
~$10,000

New Surface Renewal
~$200

Mimicked Arduino for programming ease

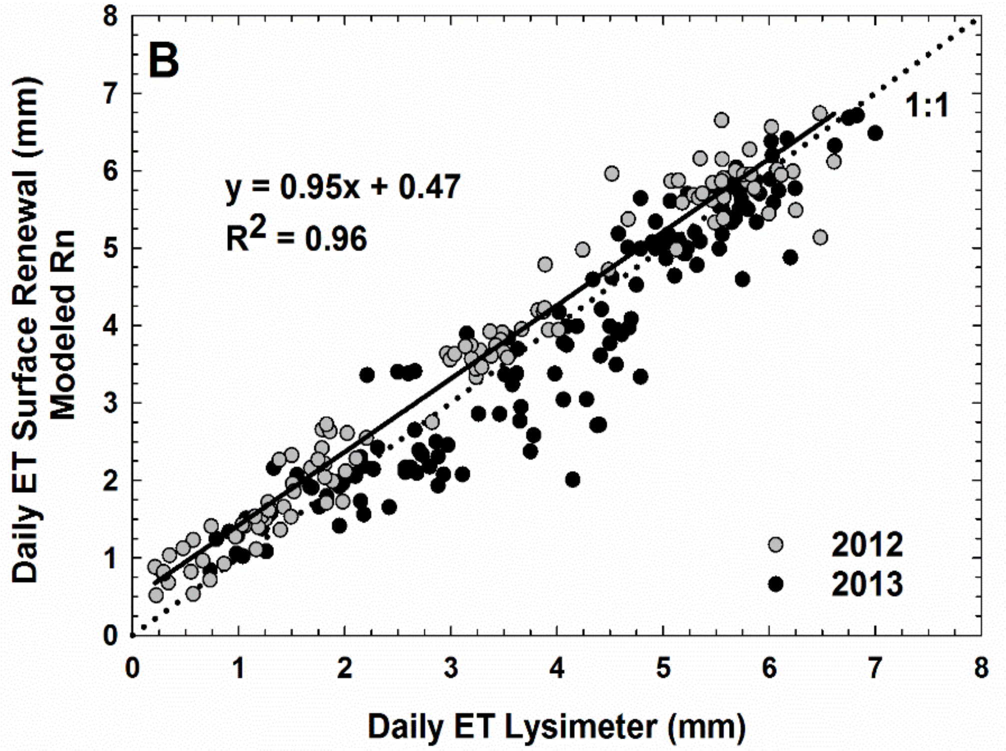
Proof of concept:

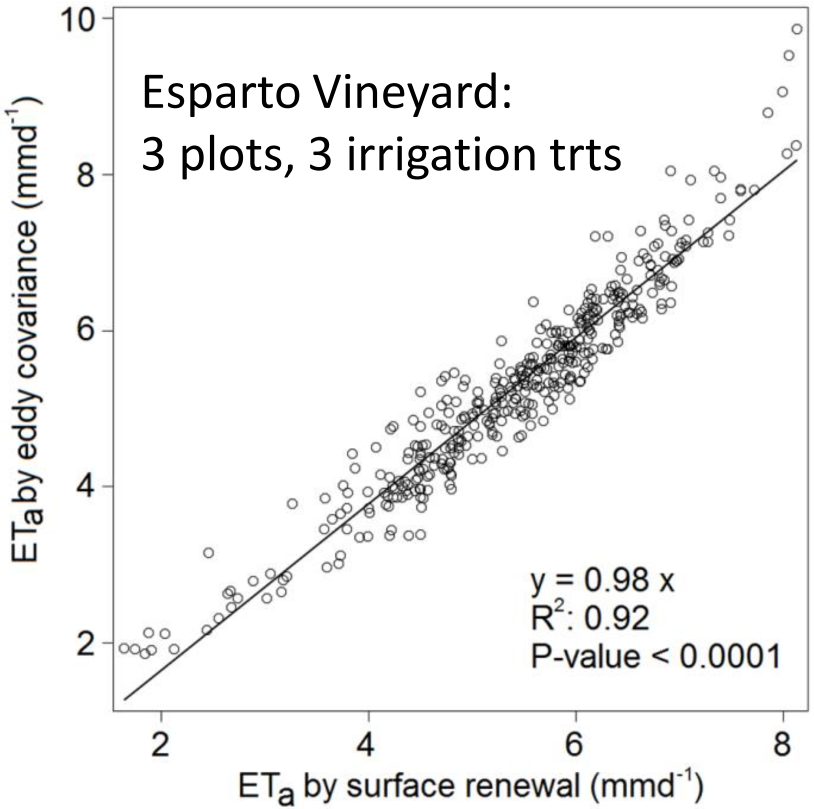
Compare to lysimeter & eddy covariance (both gold standards)



Kearney Agricultural Center
Univ. of California- Parlier CA

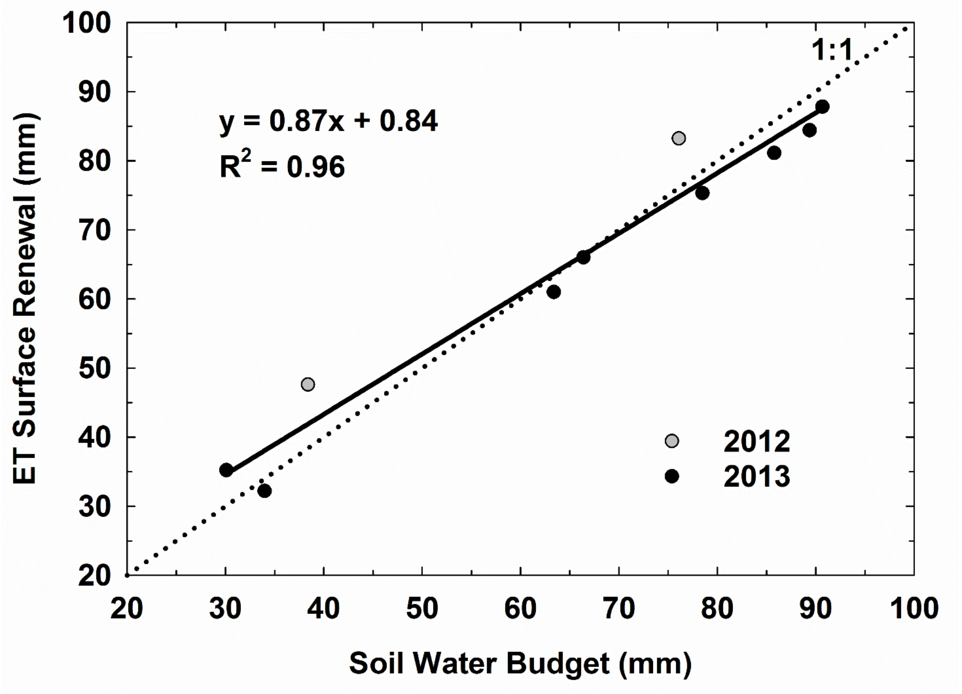
Surface Renewal vs. Lysimeter
Kearney Ag Center- 2012 & 2013





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



How to use the technology?

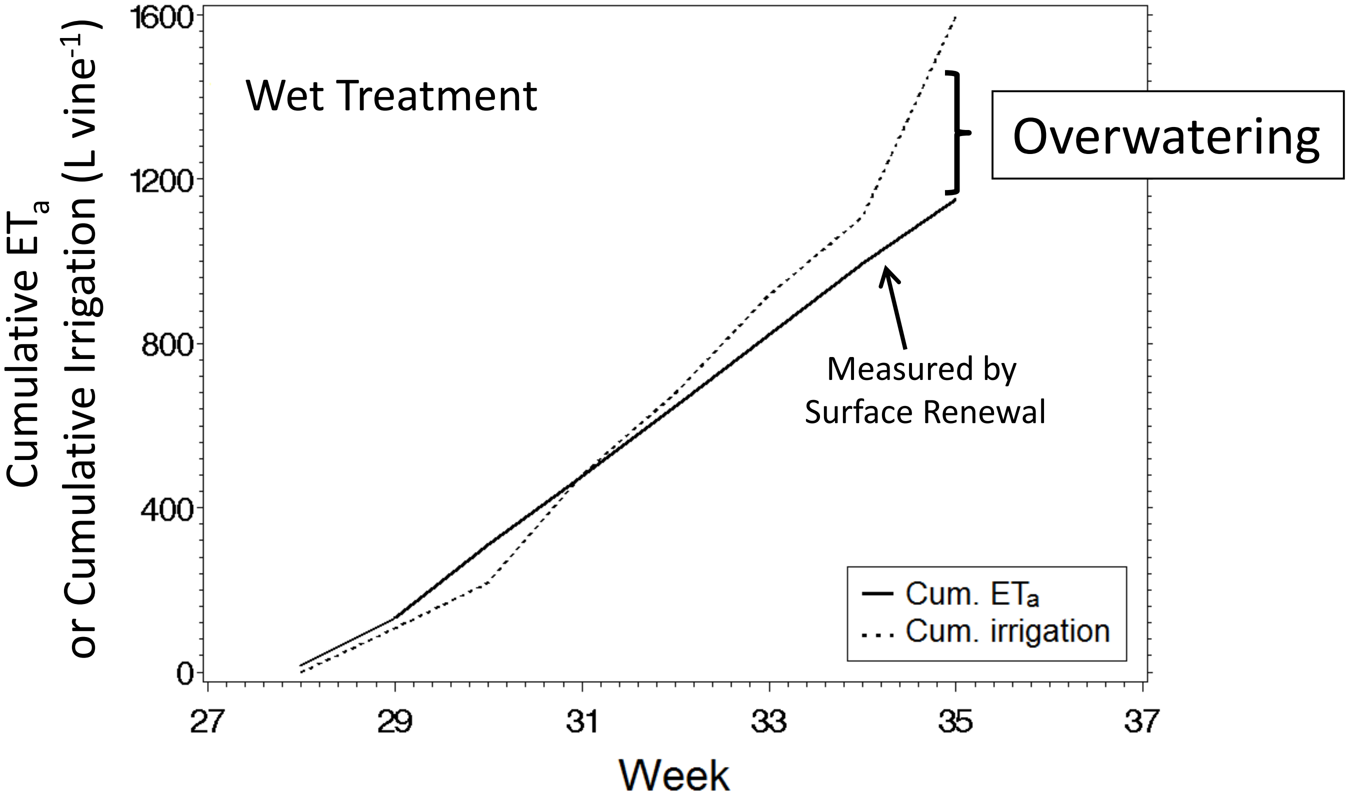
Example #1: Amount lost = amount applied

- 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

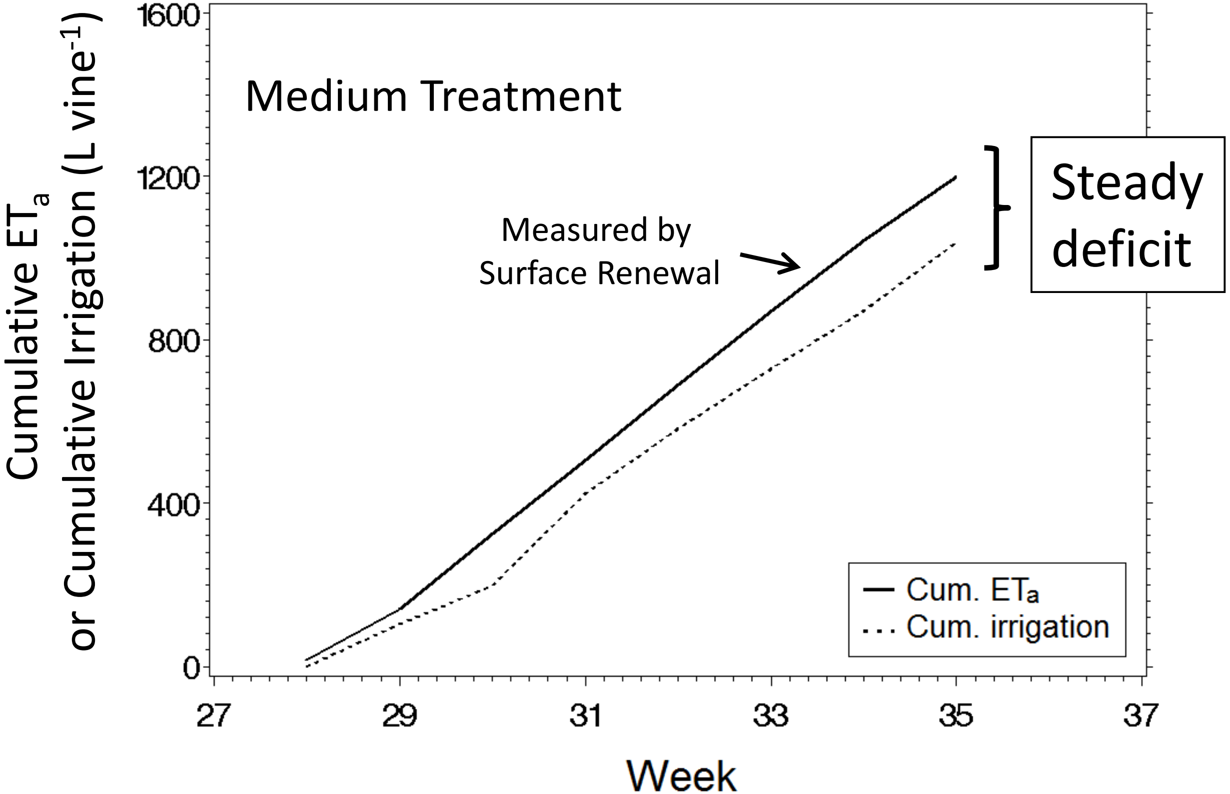
How to use the technology?

Example #2: Targeted deficit based on effective water use



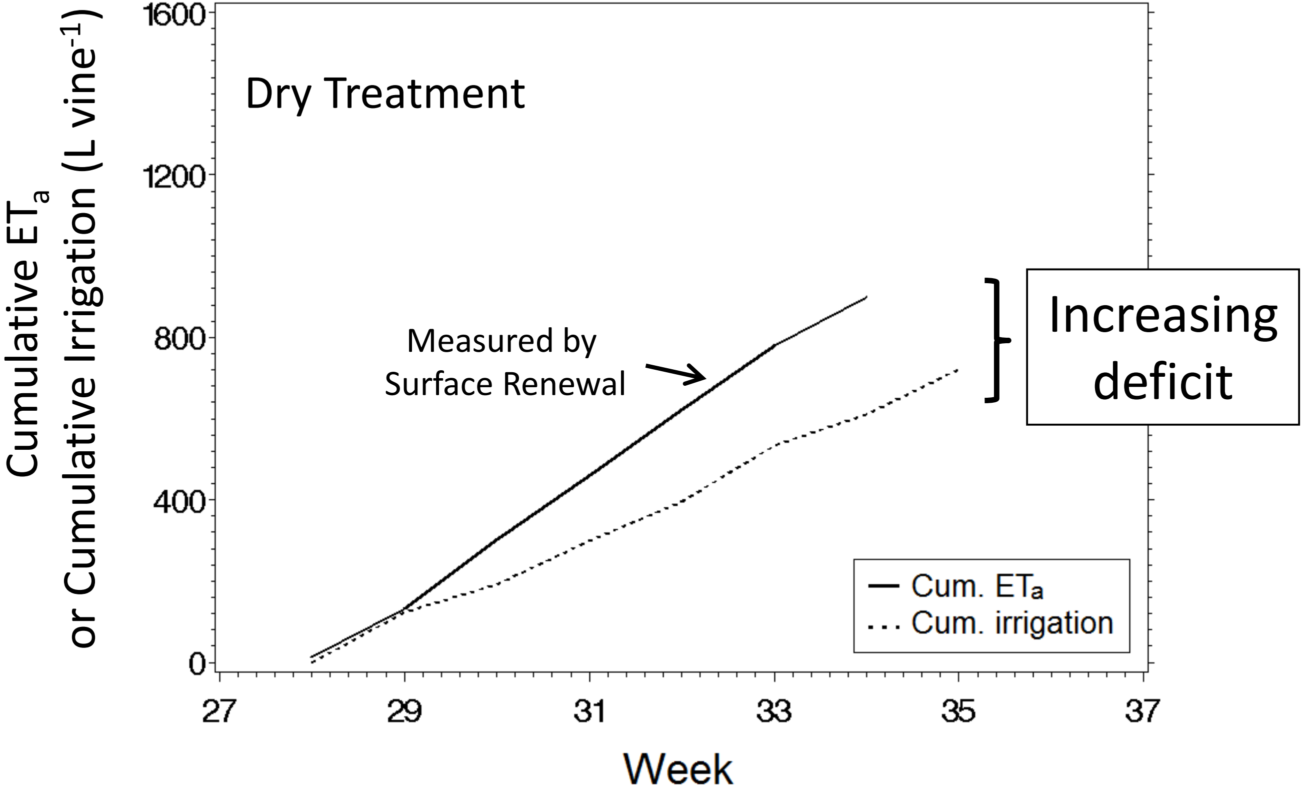
How to use the technology?

Example #2: Targeted deficit based on effective water use



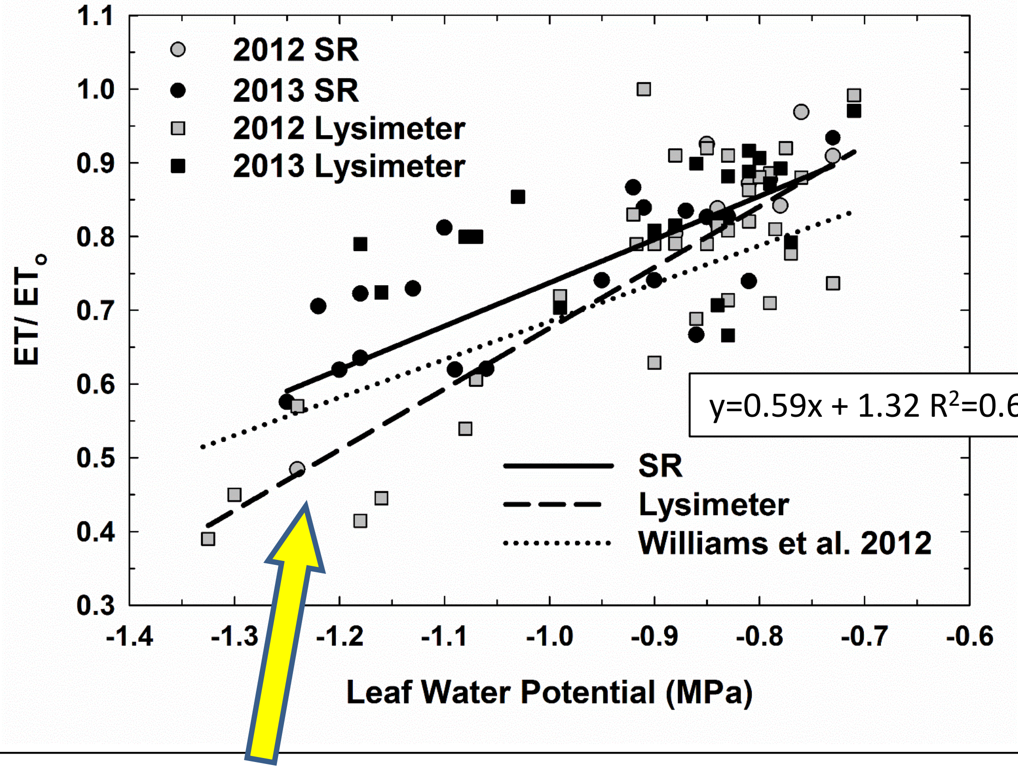
How to use the technology?

Example #2: Targeted deficit based on effective water use



Measure water use AND **vine stress**

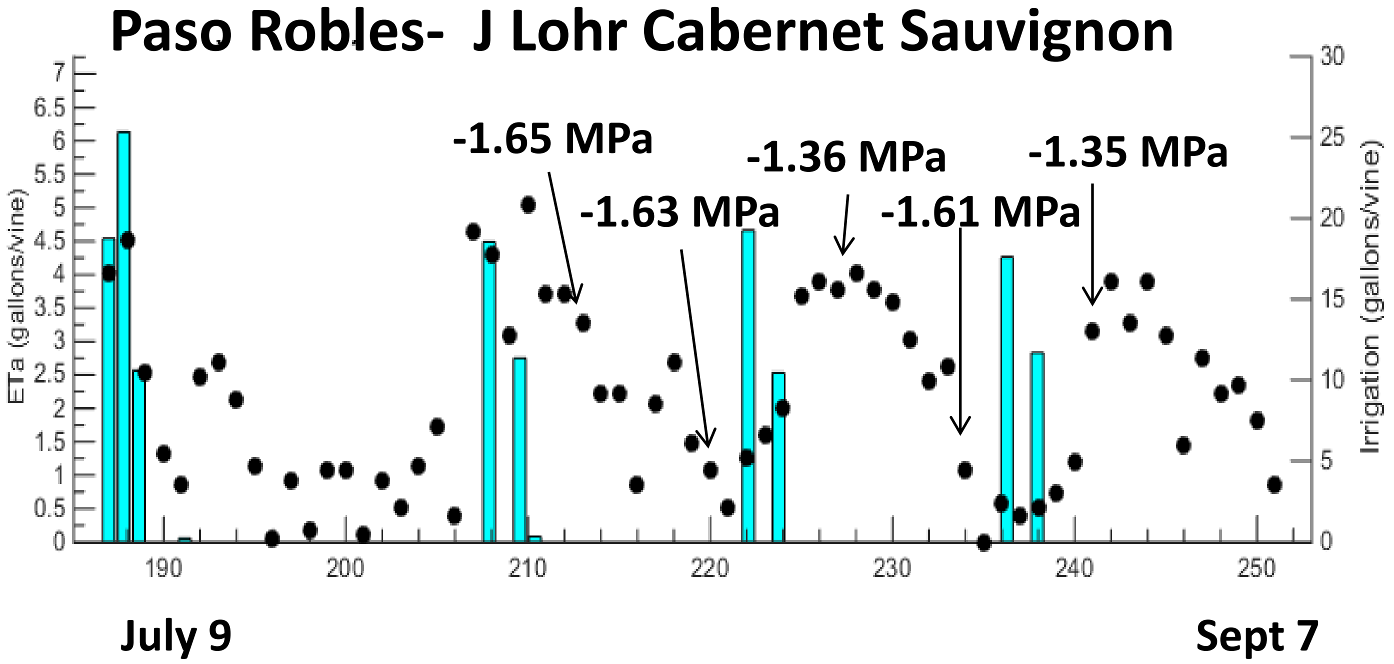
Lysimeter Vineyard-Kearney Ag Center

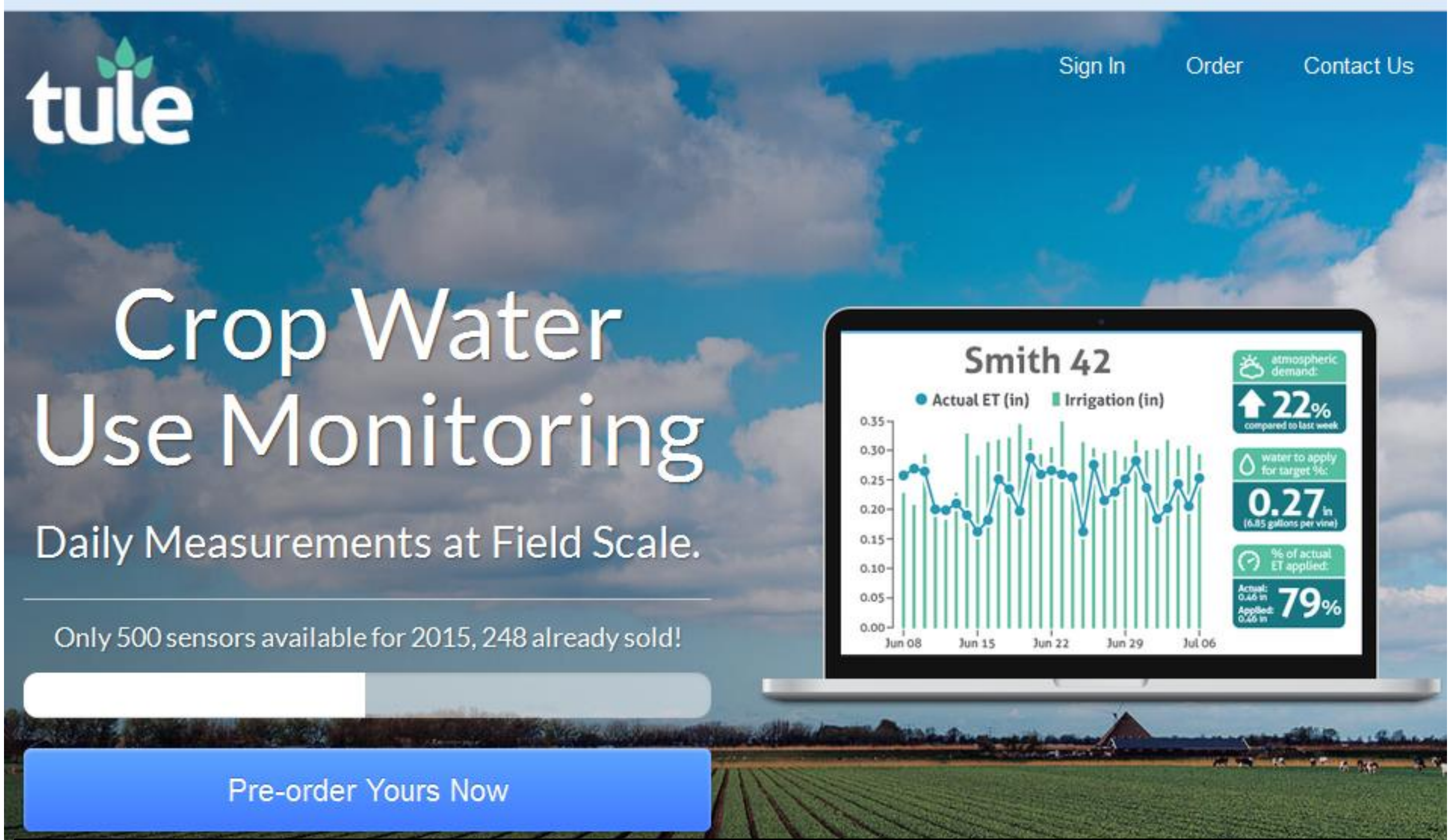


y=0.59x + 1.32 R^2=0.69; P<0.0001

During stress, vines can't keep up with demand from atmosphere

Measure water use AND **vine stress**

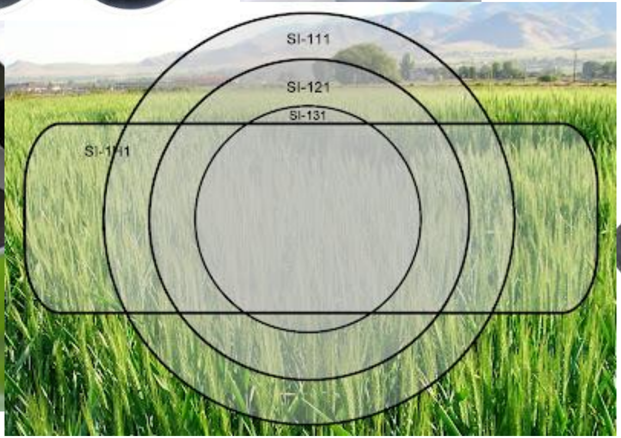




- Licensing patented technology from UC Davis
- Fundamental work with applied results in ~6 yrs
- In 2016, >1000 stations across varied crops

Alternative automated methods/ technologies to track stress

<u>Infrared Radiometers (IRTs):</u> 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

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

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- Andy Walker- UC Davis
- Larry Williams- UC Davis
- Andrew Zaninovich- Sunview Vineyards

Allan Fulton,
UCCE – Tehama County

Turning Orchard Variability into Opportunity

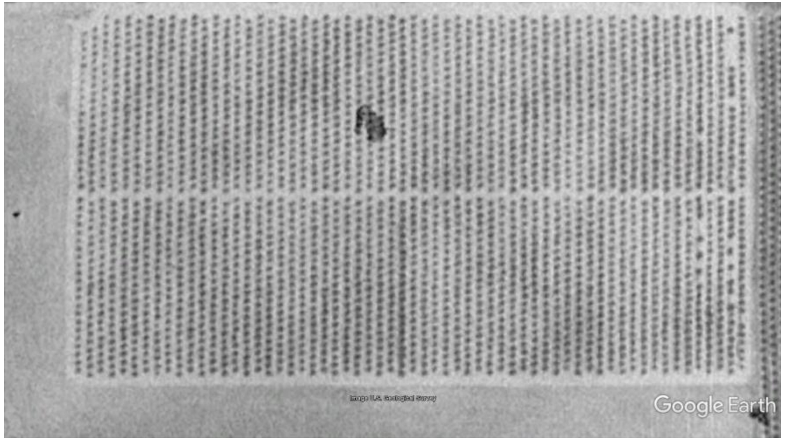
Allan Fulton
Farm Advisor, UC Cooperative Extension
Tehama, Glenn, Colusa, and Shasta Counties

Topics:

- What are the opportunities?
- Tools to help understand orchard variability
- Introduce zone irrigation concept

growing ADVANTAGE The Almond Conference

1993 – almonds, soon after planting



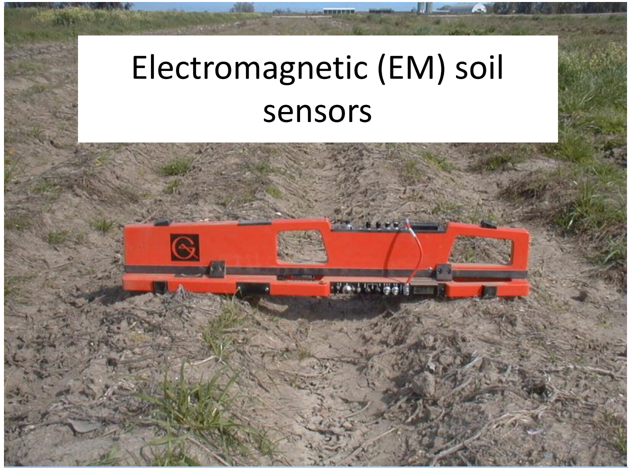
Almonds, approximately 10 years after planting

Almonds, approximately 20 years after planting

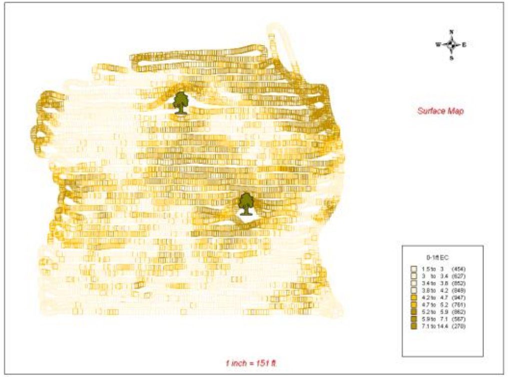
Opportunities if variability can be managed:

- 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

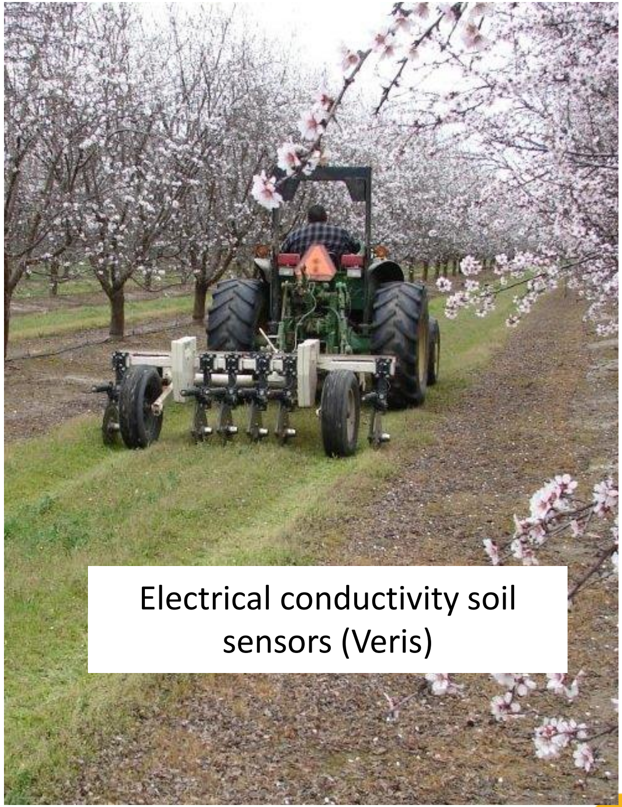


Serpentine travel pattern

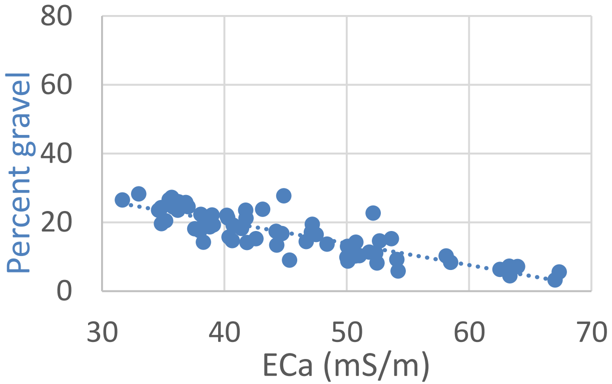


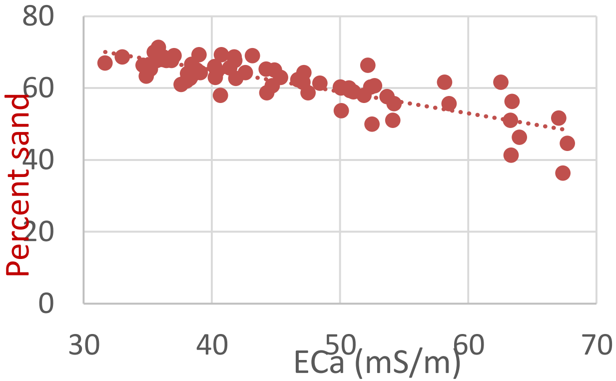
Sensors measure EC_a

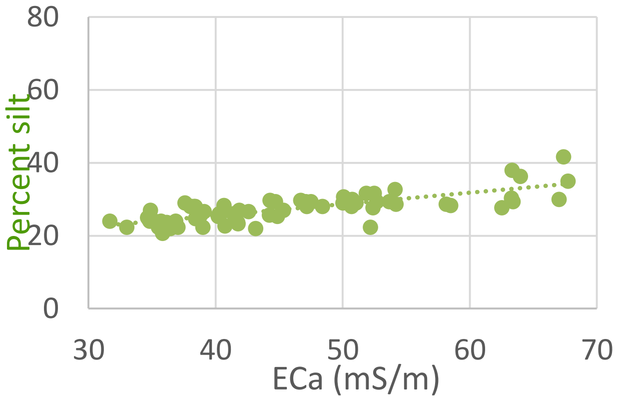
- Apparent EC of soil depends on
  - Texture
  - Structure
  - Moisture
  - Salinity
  - Other properties

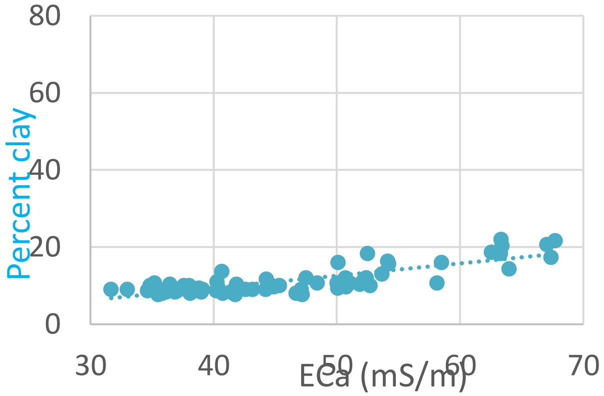


Percent gravel, sand, silt, and clay in relation to ECa (mS/m) measured with EM38 in almond orchard



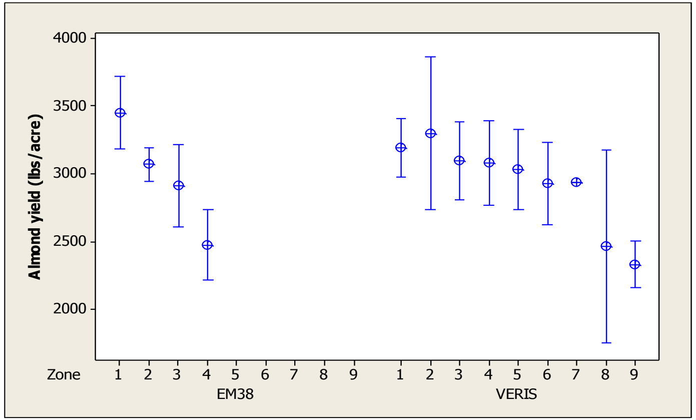


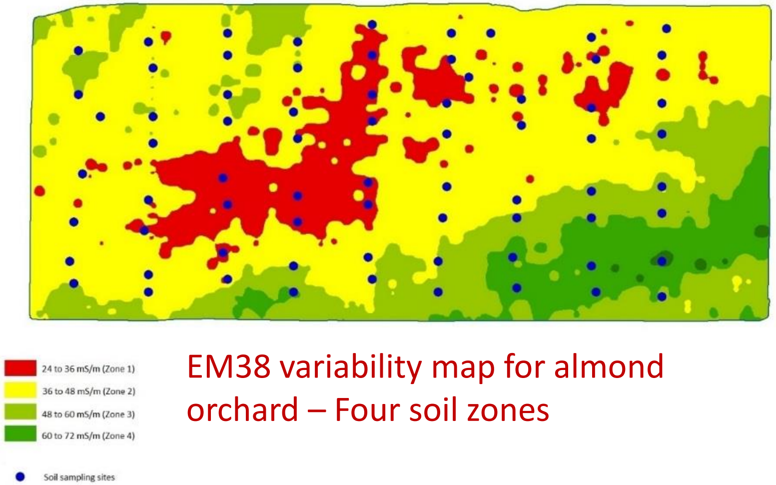




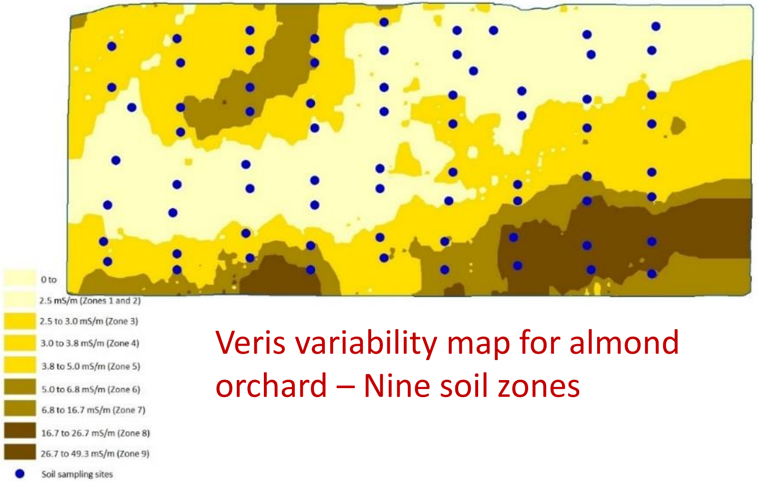
Almonds, approximately 10 years after planting

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





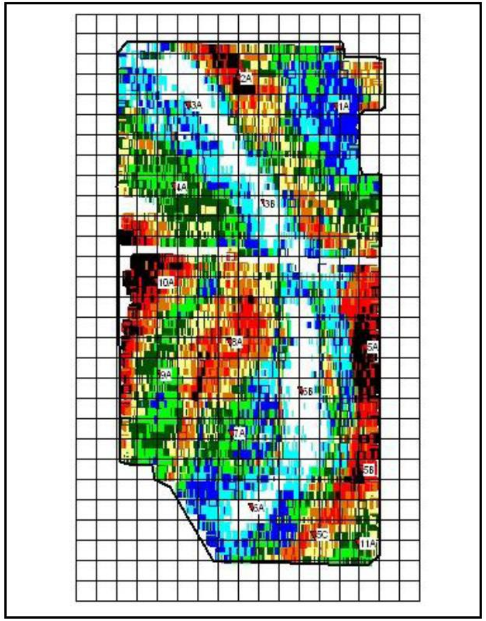
EM38 variability map for almond orchard – Four soil zones



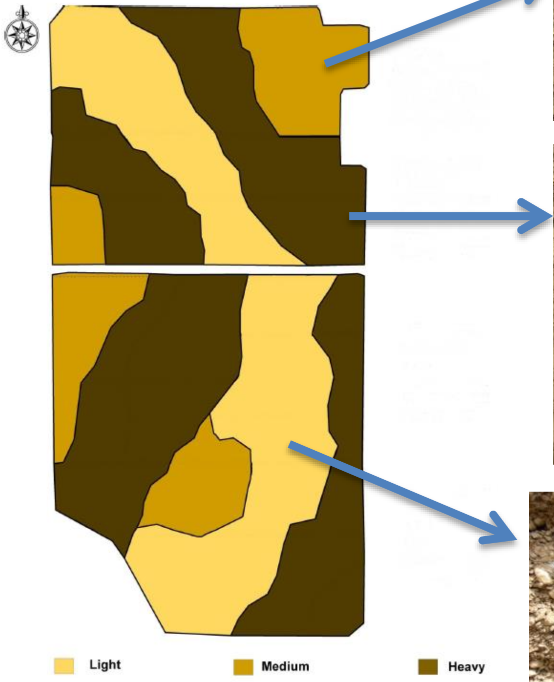
Veris variability map for almond orchard – Nine soil zones

Zone or variable rate irrigation concept

Soil variability map (Veris)



Zone irrigation design to match soil variability



Kent Stenderup,
Stenderup Ag Partners

Variable Rate Irrigation

Kent Stenderup, Arvin, CA

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Discovery, Design and Implementation

- Veris
- Aerial Imagery, Infrared
- Soil Analysis
- Irrigation System Type
- Real-time Soil Moisture Sensors by Zone

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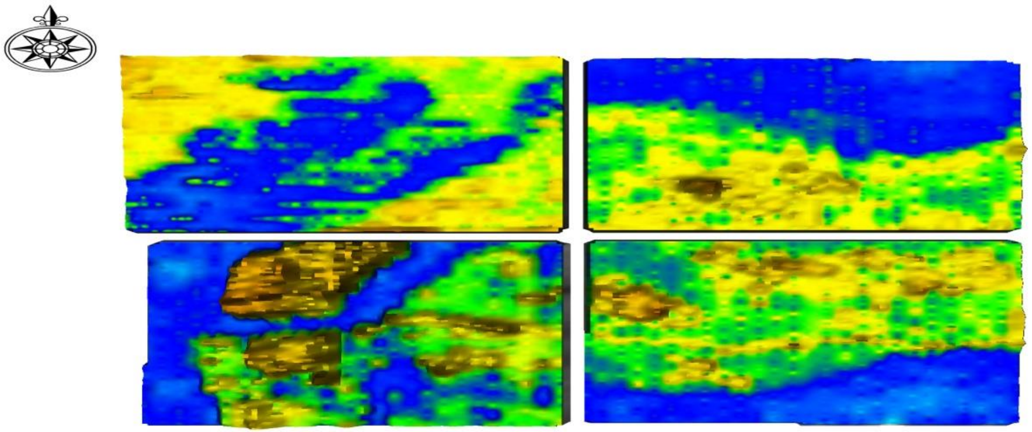
Variability Map

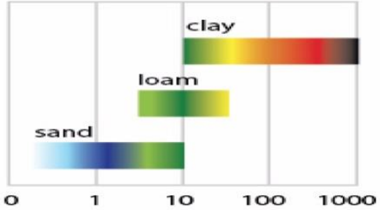
An overview of the range of soil variability in the field



H2O-Optimizer **Phase 1**

Client: Stenderup
Grower: Stenderup
Ranch ID: 25
Field ID: 03
Total Acres: 149

Likely Soil Type Based On Conductivity Reading



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:

	Acres	% of Total Field	EC Range
Area 1	67.3	45.2%	0 - 34
Area 2	70.9	47.6%	35-60
Area 3	10.8	7.2%	> 60

Phase 2: Variable Rate Amending (VRA)

NEXT STEP

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	.0625
= $	$125

standard amendment cost/acre

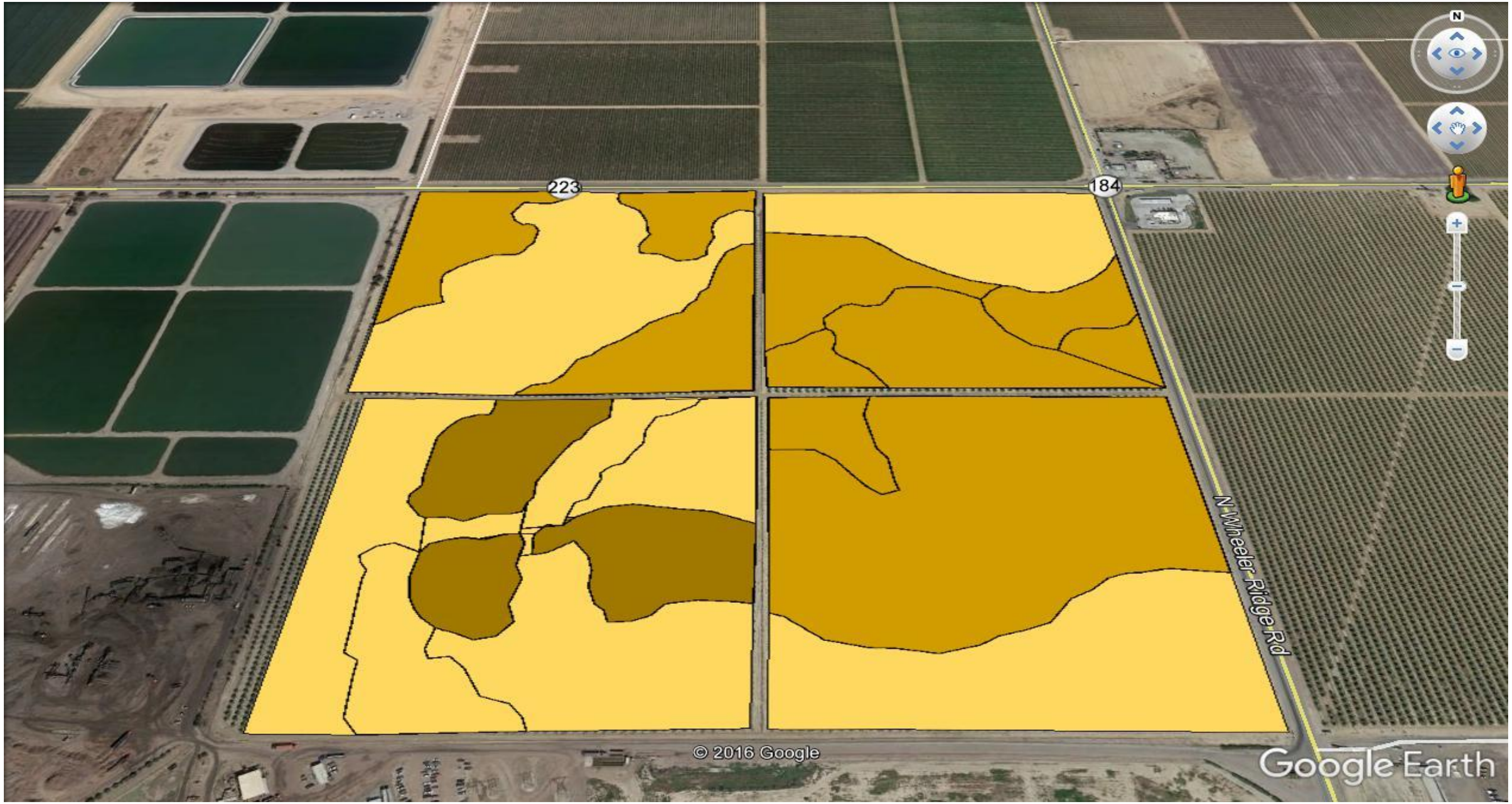
The field has an estimated two areas that most likely need to be amended differently. Percent savings are calculated from a standard rate, assuming 100% of the standard rate is applied to the area that most needs amending.

Estimated VRA savings:

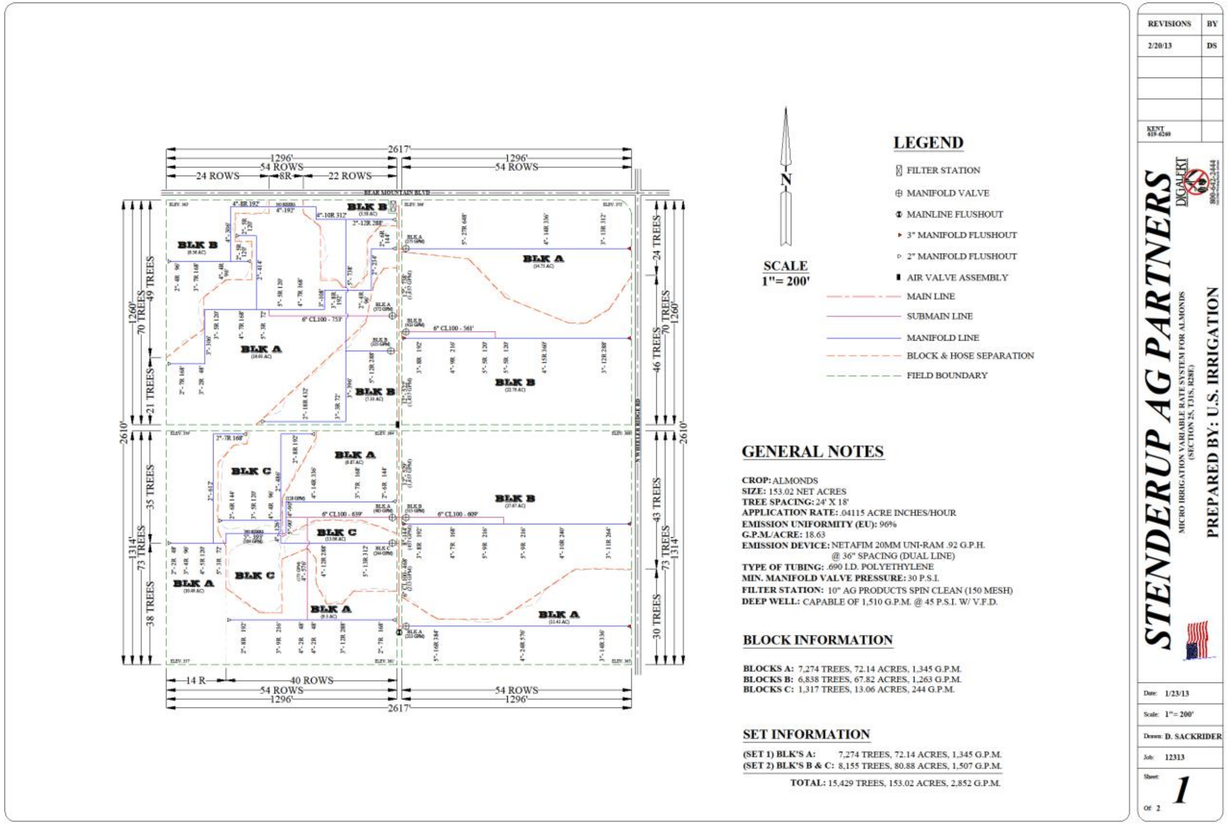
	(% below standard rate	50	22.6%
	on Area 1 (% of field))	45.2%	
+	(% below standard rate	25	11.9%
	on Area 2 (% of field))	47.6%	
+	(% below standard rate	0	0%
	on Area 3 (% of field))	10.8%	

estimated % of savings on standard amendment cost or rate per acre using VRA = **34.5%**

3 Distinct Soil Types



Irrigation System Design



Zone Change

Soil Moisture Monitoring


Arvin, California
The Garden in the Sun

Questions?

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