2018 | THE ALMOND CONFERENCE

SPEED TALKS: IRRIGATION MANAGEMENT

ROOM 312-313 | DECEMBER 6, 2018

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Almond Board of California

growing ADVANTAGE
The Almond Conference

AGENDA

- **Sebastian Saa**, Almond Board of California, moderator
- **Almond Board Funded Researchers**
  - Brian Bailey, UC Davis
  - Thomas Buckley & Matthew Gilbert, UC Davis
  - Khalid Bali, UC Kearney Agricultural Research and Extension & Mae Culumber, UCCE Fresno
  - Isaya Kisekka, UC Davis
  - Ken Shackel, UC Davis
  - Fraser Shilling, UC Davis

Assessment of Almond Water Status Using Inexpensive Thermal Imagery

Brian Bailey – U.C. Davis Dept. Plant Sciences

Project Personnel: Magalie Poirier-Pocovi – U.C. Davis Dept. Plant Sciences

Project Cooperators: Bruce Lampinen, Astrid Volder – U.C. Davis Dept. Plant Sciences

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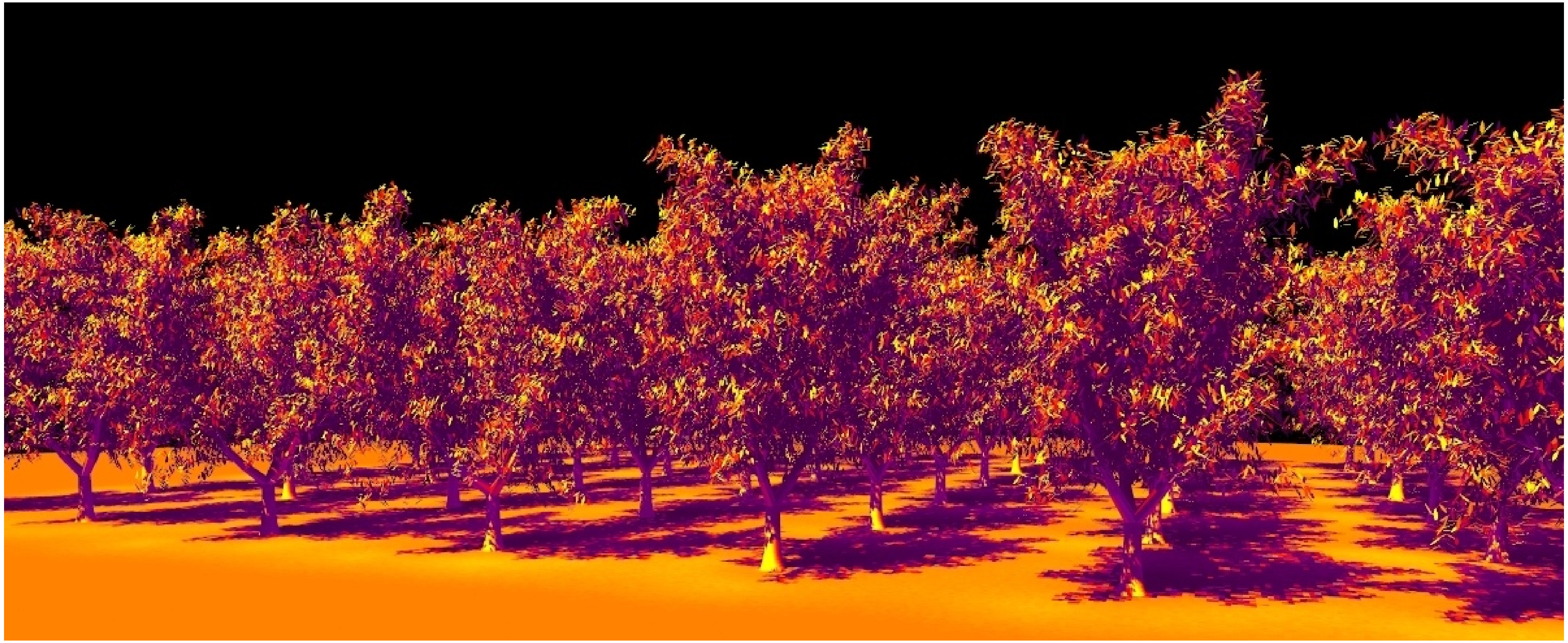
Project Goals

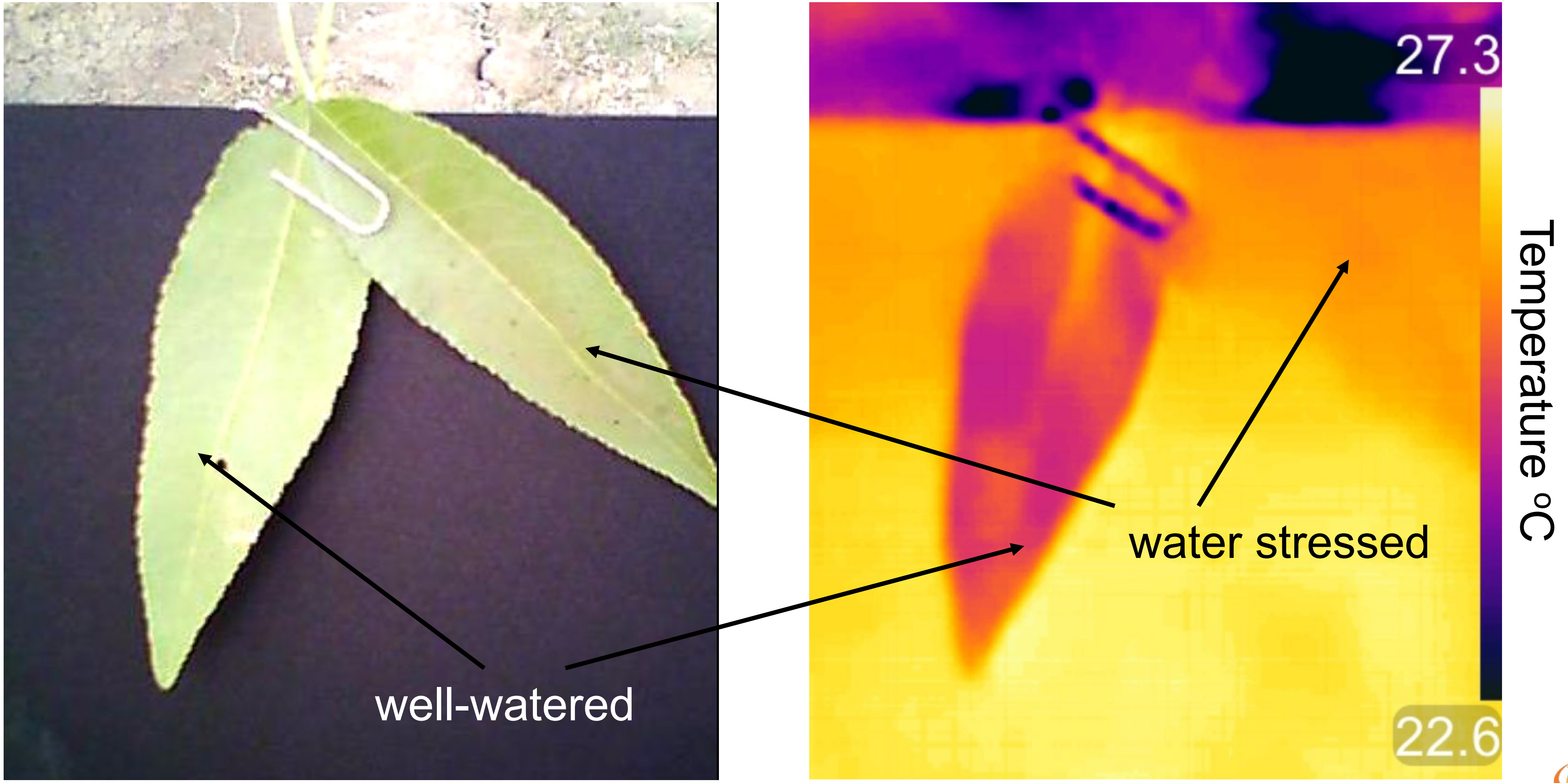
- Develop low-cost and low-time water status measurement method
- Develop a means for rapidly measuring spatial variability in water status



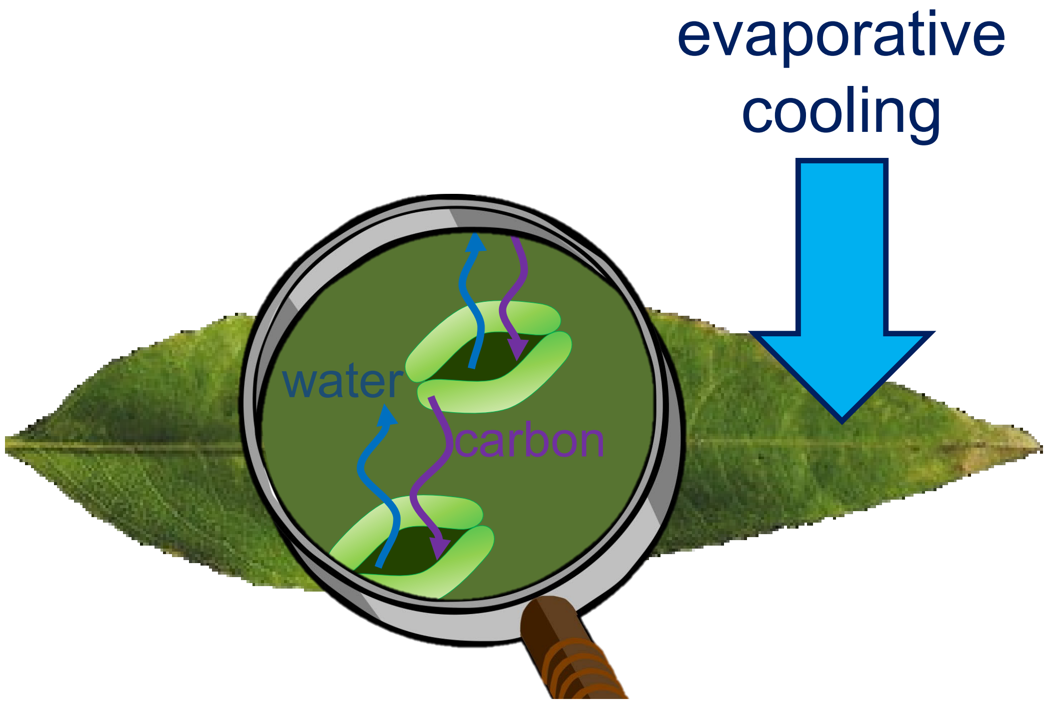
Inferring Water Status from Infrared Thermography

Color Image

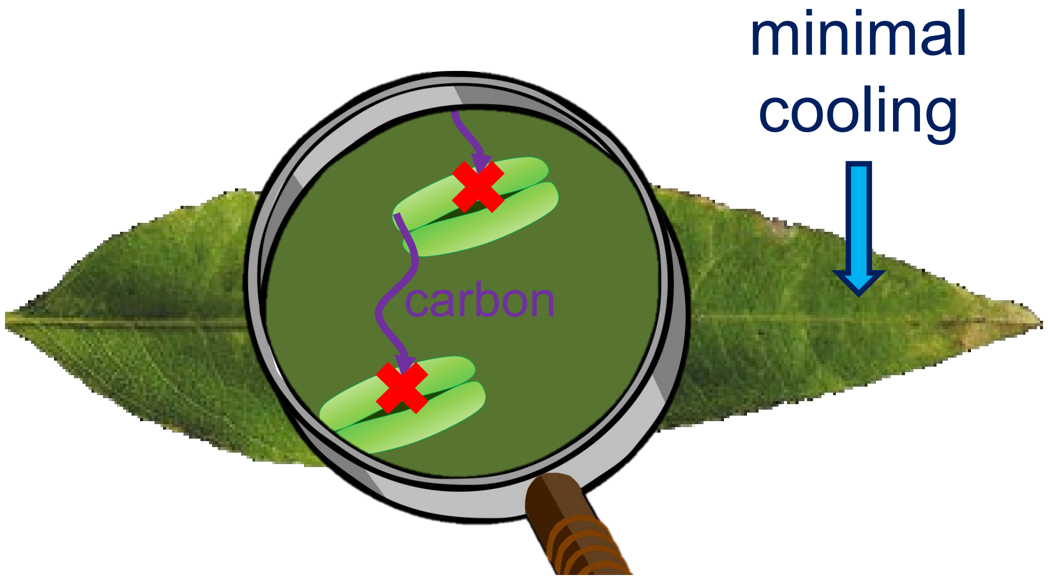
Thermal Image



Basic Theoretical Premise



well-watered



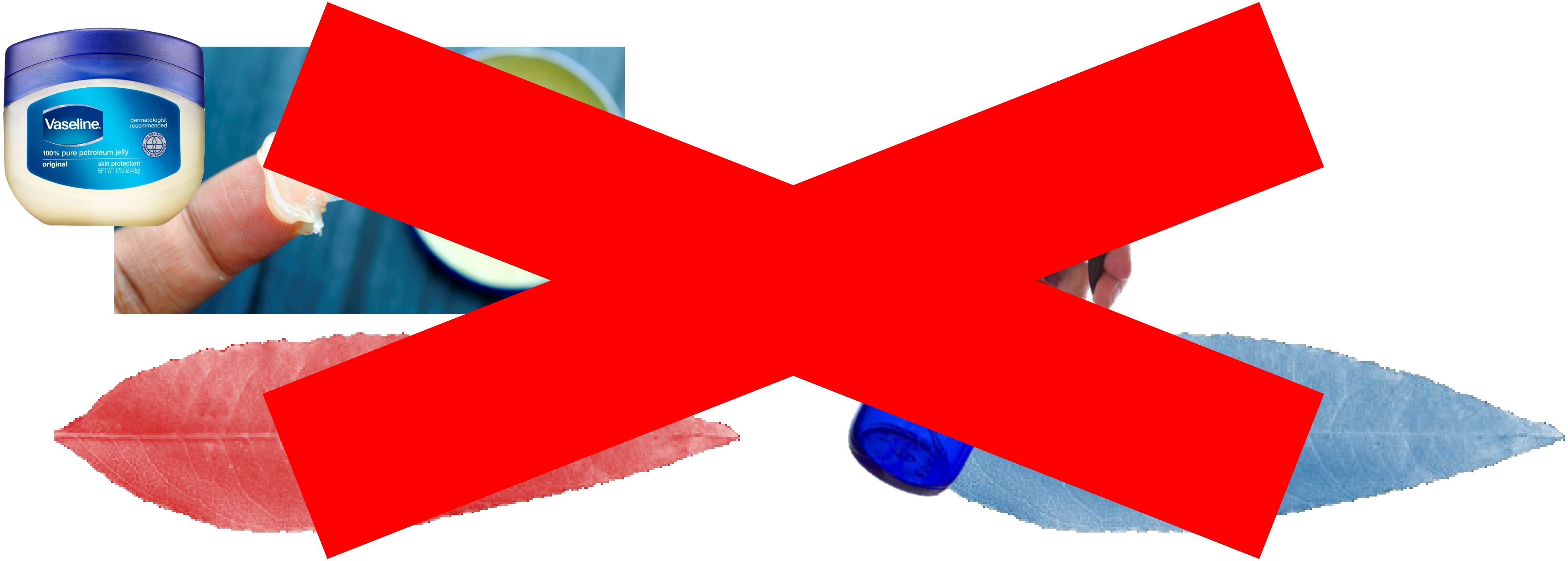
water stressed

Challenges:

The temperature of a leaf is influenced by many other factors besides how much we water the tree:

- Weather: sunlight, air temperature, humidity, etc.

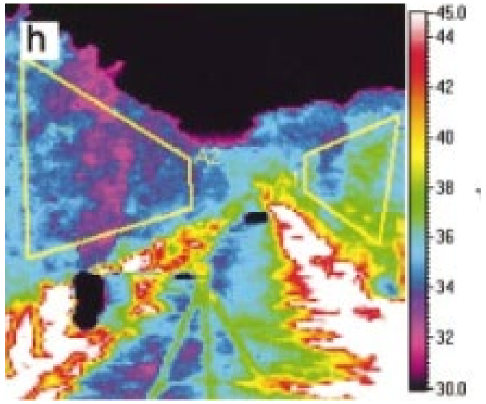
Calibrating for Weather Effects:



“dry” temperature (maximum)

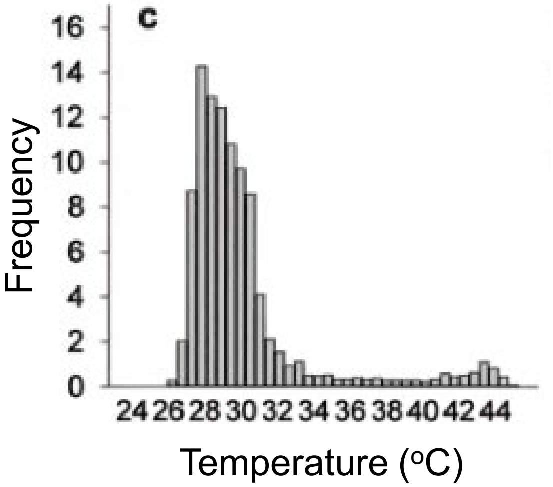
“wet” temperature (minimum)

Inferring Water Status from Infrared Thermography

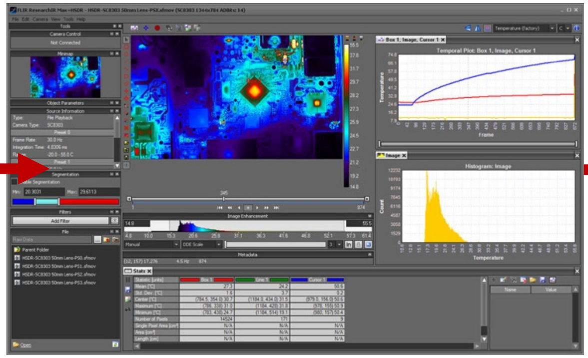


Inherent Limitations:

- Cost: starts at around $20,000
- Speed: We really want to do the data processing in real time to give an indication of water status.



$24,999



Export

3rd Party Software

Reducing the Cost

	Flir One Pro
Cost	$399
Resolution	160x120
Spectral Range	8-14 μm
Operating System	iOS or Android

Canopy-Level Measurement

Light penetration
(canopy density)

Thermal image

Model

data processing

Water Stress

Thank You

Contact:

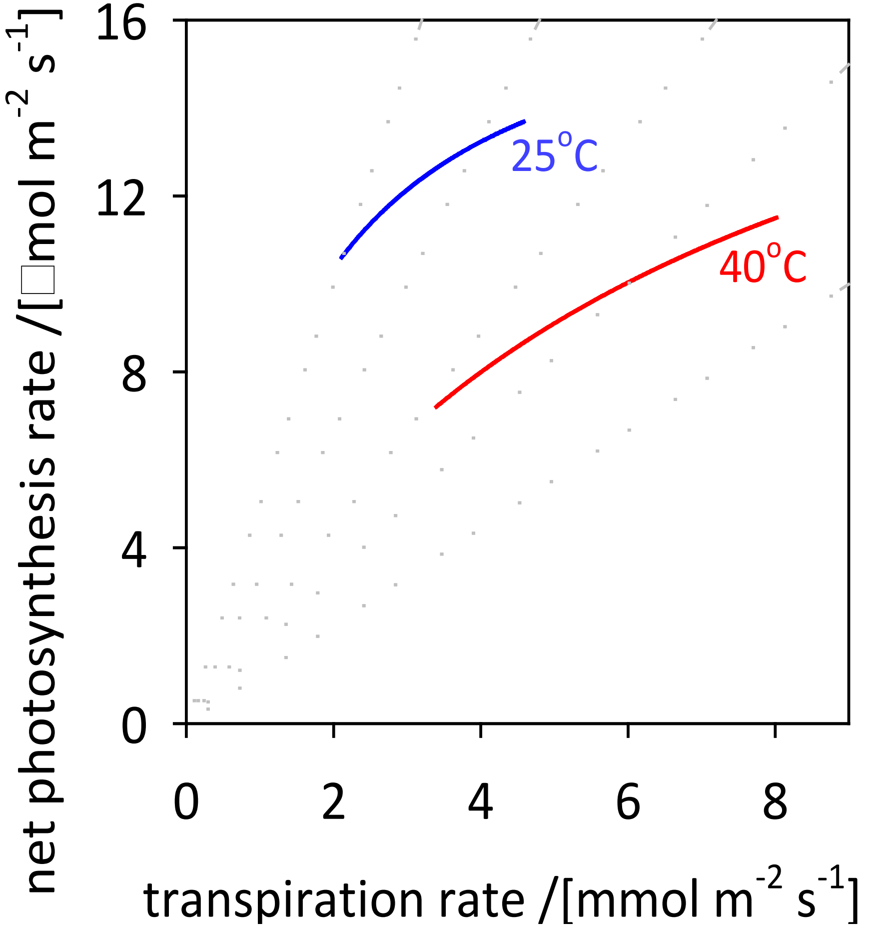
bnbailey@ucdavis.edu

baileylab.ucdavis.edu

UC DAVIS PLANT SIMULATION LABORATORY

This research was supported by the Almond Board of California project #17-HORT31-Bailey/ 18-HORT31-Bailey

Data-driven physiological modeling of canopy photosynthesis for precision irrigation management



PIs:

Tom Buckley[1]

Matthew Gilbert[1]

Cooperating personnel:

Bruce Lampinen[1]

Antonio Diaz-Espejo[2]

PhD student:

Heather Vice[1]

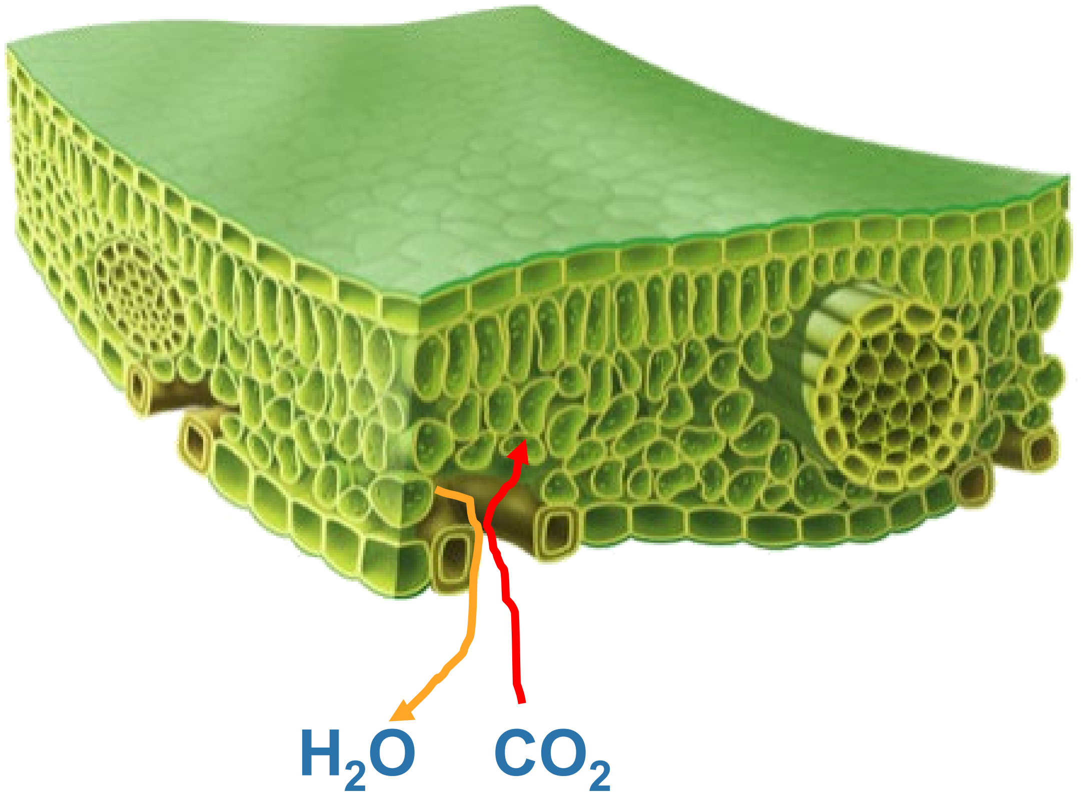
(1) UC Davis Department of Plant Sciences

(2) CSIC-IRNAS, Seville, Spain

Rationale

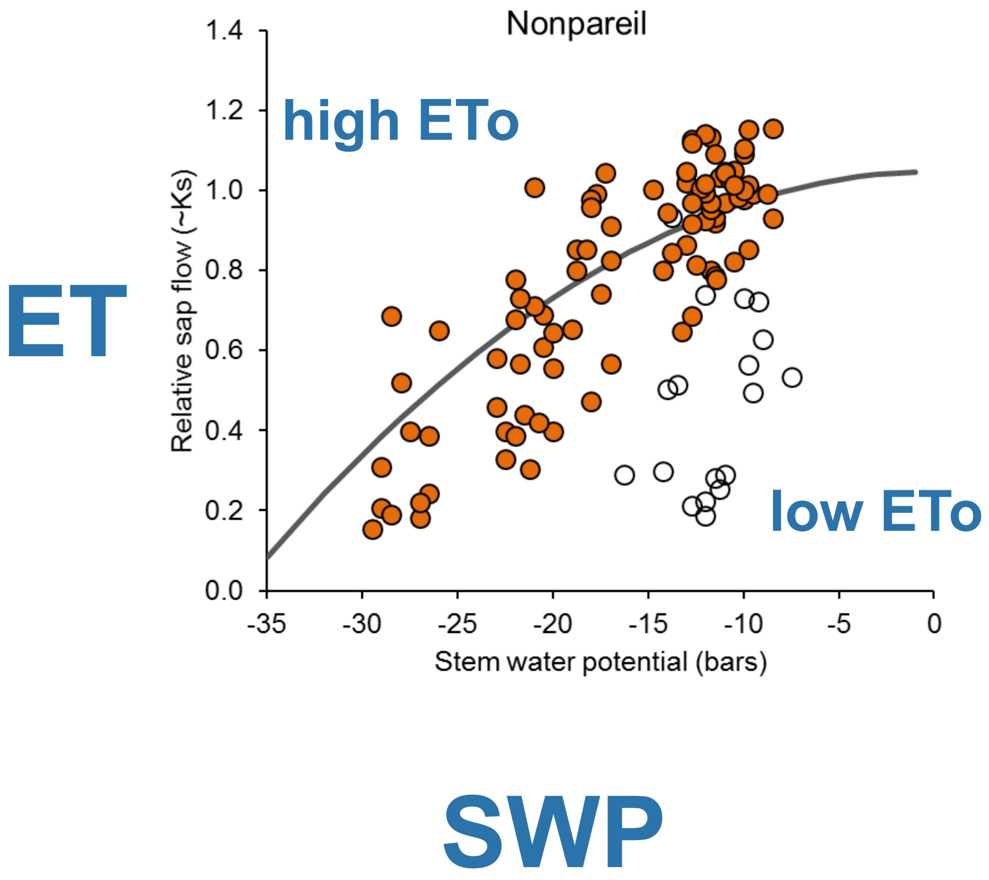
- Photosynthesis (PS) provides all carbon & energy for growth, biomass production & yield.

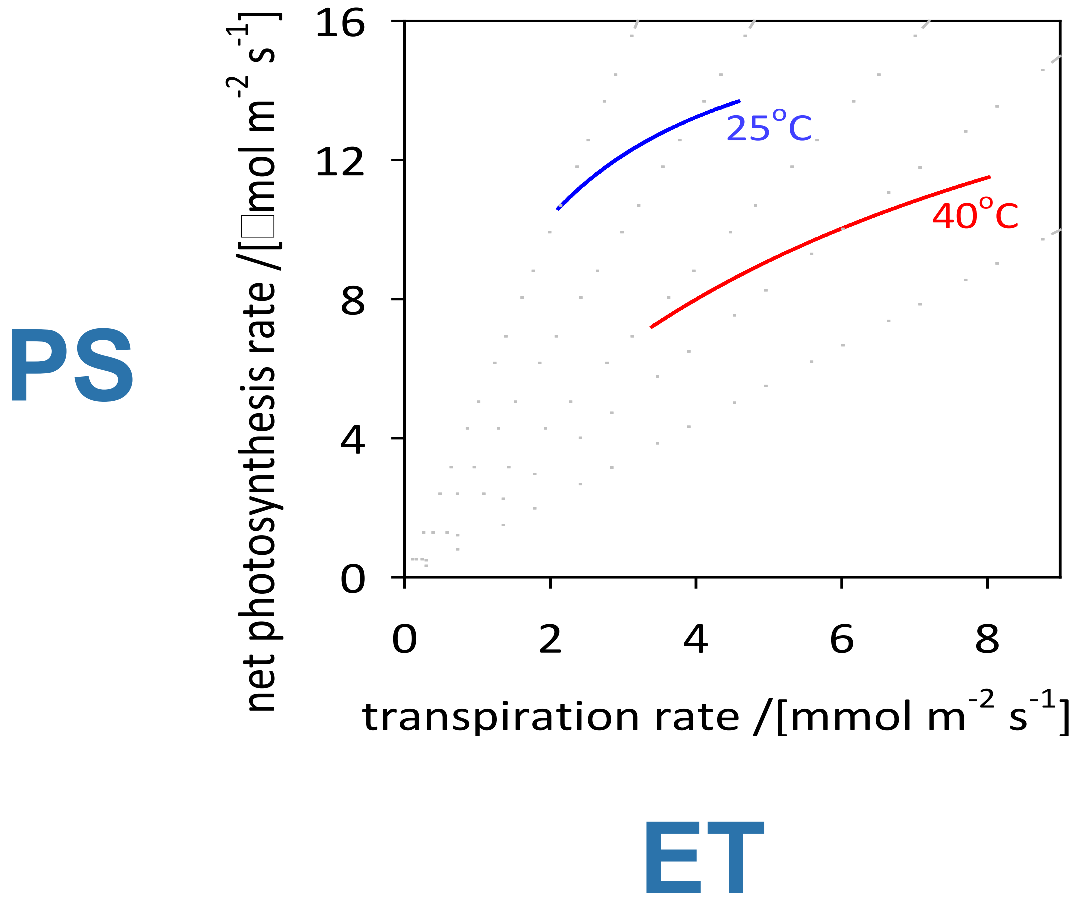
- Water availability limits photosynthesis via stomatal opening.



Stem water potential (SWP): a proxy of a proxy of photosynthesis

- SWP is proxy for transpiration (ET).
- ET is a proxy for photosynthesis.





Using photosynthesis to guide irrigation

- Photosynthesis "maxes" out at high irrigation levels.

- Growers can use the ratio of actual to potential canopy photosynthesis as a setpoint for irrigation.

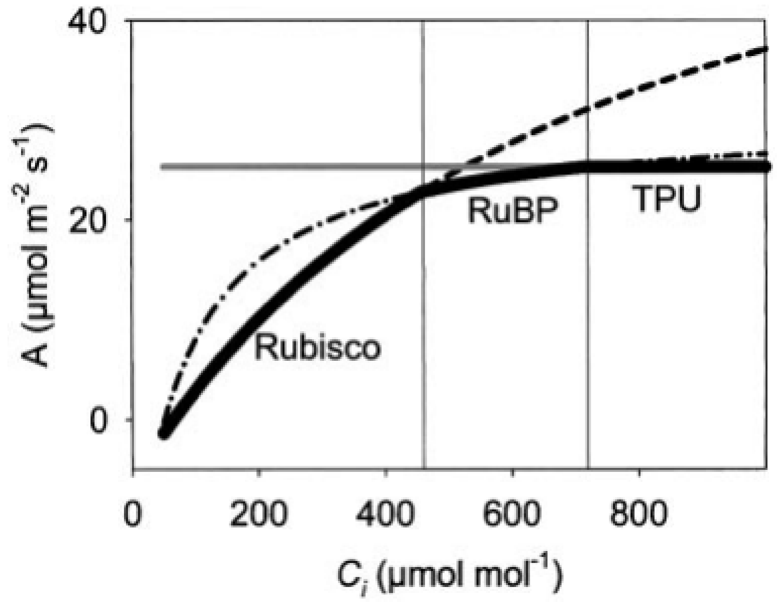
- This ratio can be modeled biochemically, driven by continuous measurements of sap flow, or by a physiological model of stomatal opening.

Estimating parameters for the photosynthesis model

- Measure photosynthetic CO_2 and light response curves

- Fit biochemical model to responses

- Extract parameters from fitted model



Long and Bernacchi (2003) J Exp Bot 54:2393

What about variation in photosynthetic parameter across an orchard?

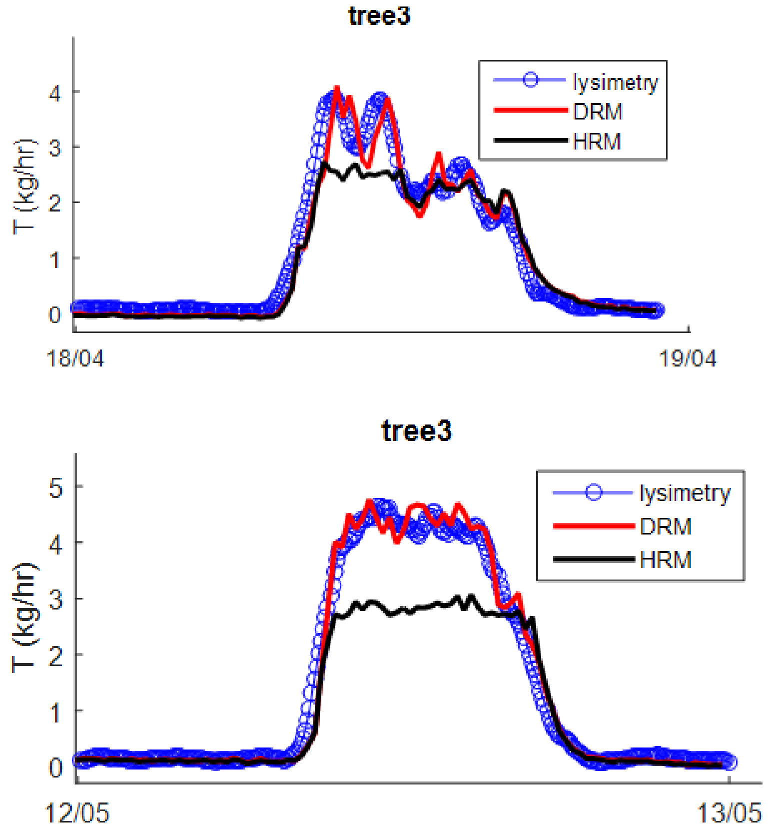
- **The quantity of interest is the ratio of actual to maximum PS.**

- **Variation in PS parameters = variation in maximum PS, *not* the *ratio of actual to maximum* PS.**

- **What matters is how the ratio of stomatal opening to PS varies; this can be quantified from leaf stable C isotope ratios ($^{13}C/^{12}C$).**

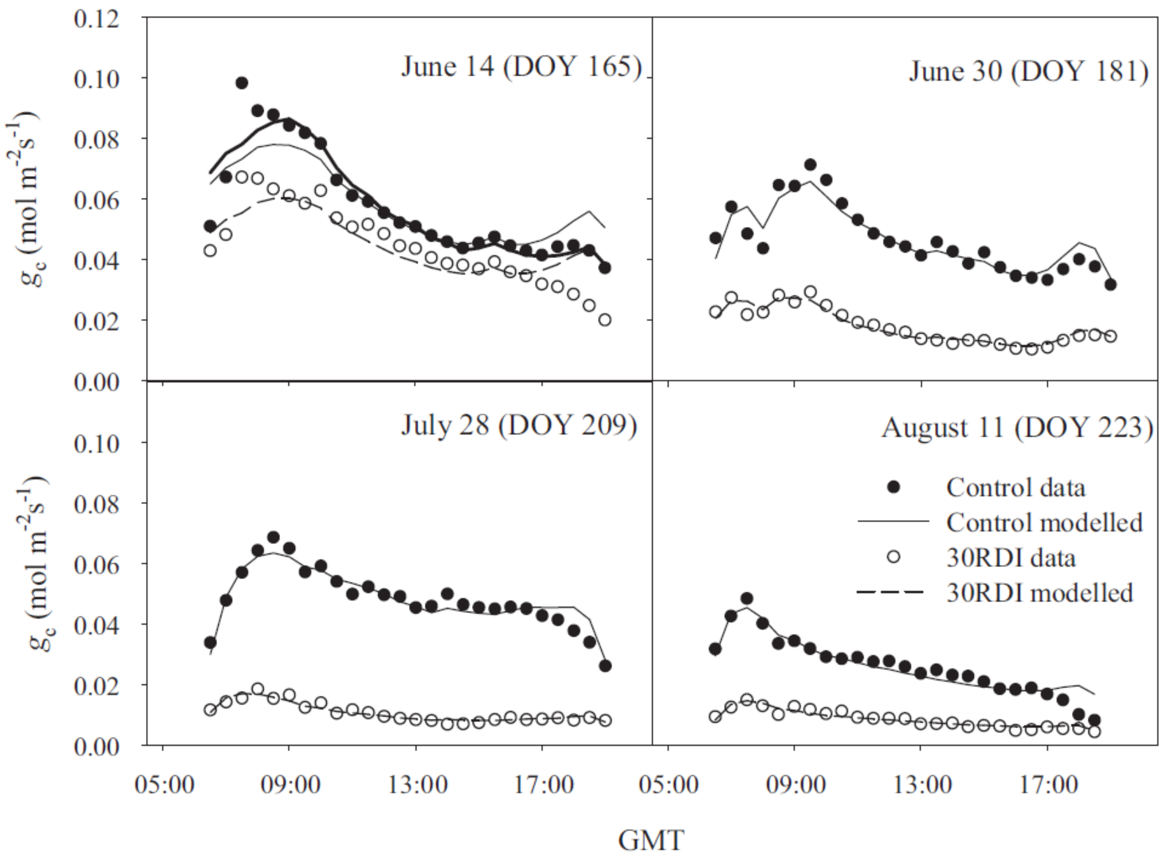
Driving the model with canopy conductance

- **Sap flow (DRM method)**



Buckley, Gilbert and Vice (unpublished)

- **Physiological model**



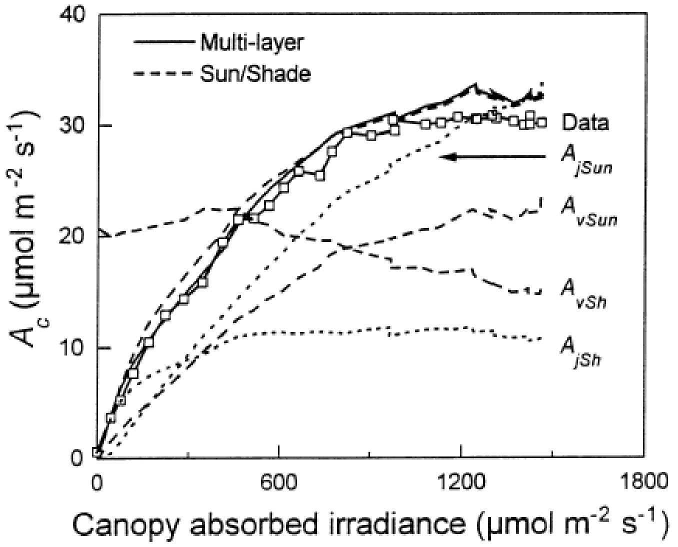
Diaz-Espejo, Buckley et al (2012) Agric Water Mgt 114:37

Scaling the model from leaf to canopy

- **Main variation = sunlit *vs* shaded leaves**

- **Sunlit fraction (*f*) can be modeled based on solar angle, after characterizing the relationship empirically**

- **Canopy PS can be calculated from sunlit- and shaded-leaf values (de Pury and Farquhar 2007).**



de Pury and Farquhar (1997) PCE 20:537

Stem water potential *vs* photosynthesis

- compare SWP and photosynthesis during experimental dry-downs

- use model to identify optimal strategies for "target" SWP

Variable Rate Irrigation Practices on Almond

Khaled Bali and Catherine Culumber

UC Kearney Agricultural Research and Extension Center and UCCE-Fresno County

Collaborators:

UCANR

Daniele Zaccaria (UCD), Alireza Pourreza (UCD, Digital Agricultural Lab), Dan Munk (UCCE-Fresno County), Bruce Lampinen (UCD), Blake Sanden (UCCE-Kern County), Allan Fulton (UCCE-Tehama County)

Almond Board of California

Spencer Cooper

Netafim

Todd Rinkenberger, Domonic Rossini, Itamar Nadav

Grower

James Nichols

Irrigation Scheduling

- Simple approach (Water budgeting using ETo and crop coefficients)

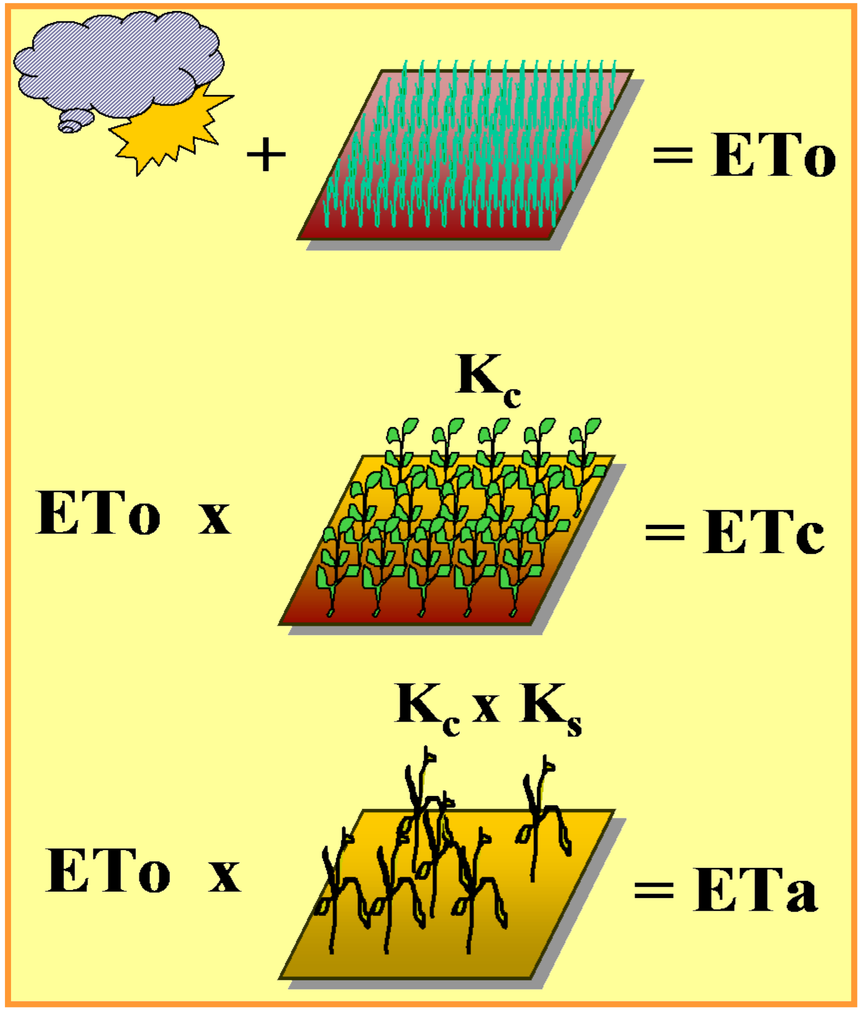
- Soil moisture measurement (requires extra work, soil sampling, soil moisture sensors, dataloggers, etc.)

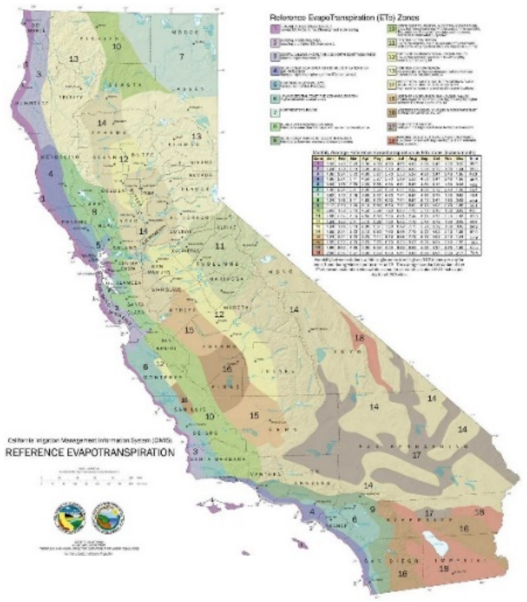
- Plant-based approach (pressure pump, temperature, sap flow, dendrometers, etc.)

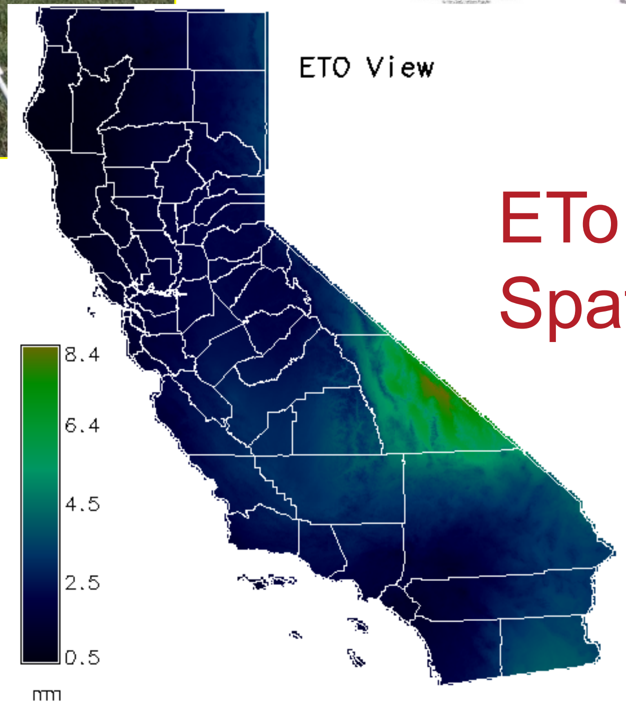
- A combination of the above three methods

- **Advances in irrigation technology such as**
  VRI and other methods to estimate ETc

ETc and ETa







ETo: Zones or Spatial CIMIS

ET_o - accounts for weather

Solar radiation, humidity, temperature, wind

- **K_c - accounts for crop**
  - **light absorption**
  - **canopy roughness**
  - **physiology**
  - **age**
  - surface wetness (irrigation system)
  - other factors (soil salinity, soil texture, etc.)

Variable Rate Irrigation (VRI) and Irrigation Water Management

- Applying the right amount of water to meet crop water requirements
- Timing of irrigation events (frequency, days between irrigations)
- Applying the water uniformly (efficiency)

VRI:

Consider several variables such as **soil type, growth stage, climatic conditions, soil salinity, water quality, irrigation system, and other site-specific factors in deciding when and how much water is needed to irrigate each zone.**

Develop a system to asset growers in defining **"zones" of similar characteristics** then develop variable irrigation scheduling programs for each zone to meet crop needs.

Redesign the current system for variable rate zones.

Benefits:

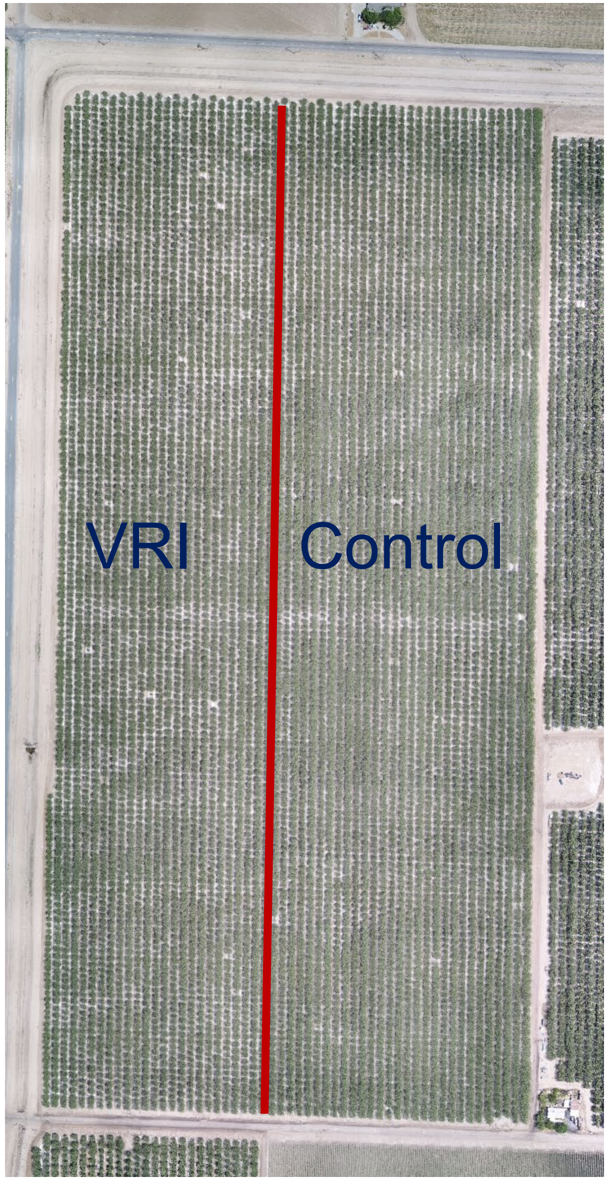
- **Reducing greenhouse gas emissions** through the **reduction in water and energy** use that is associated with improved irrigation and reduced pumping.

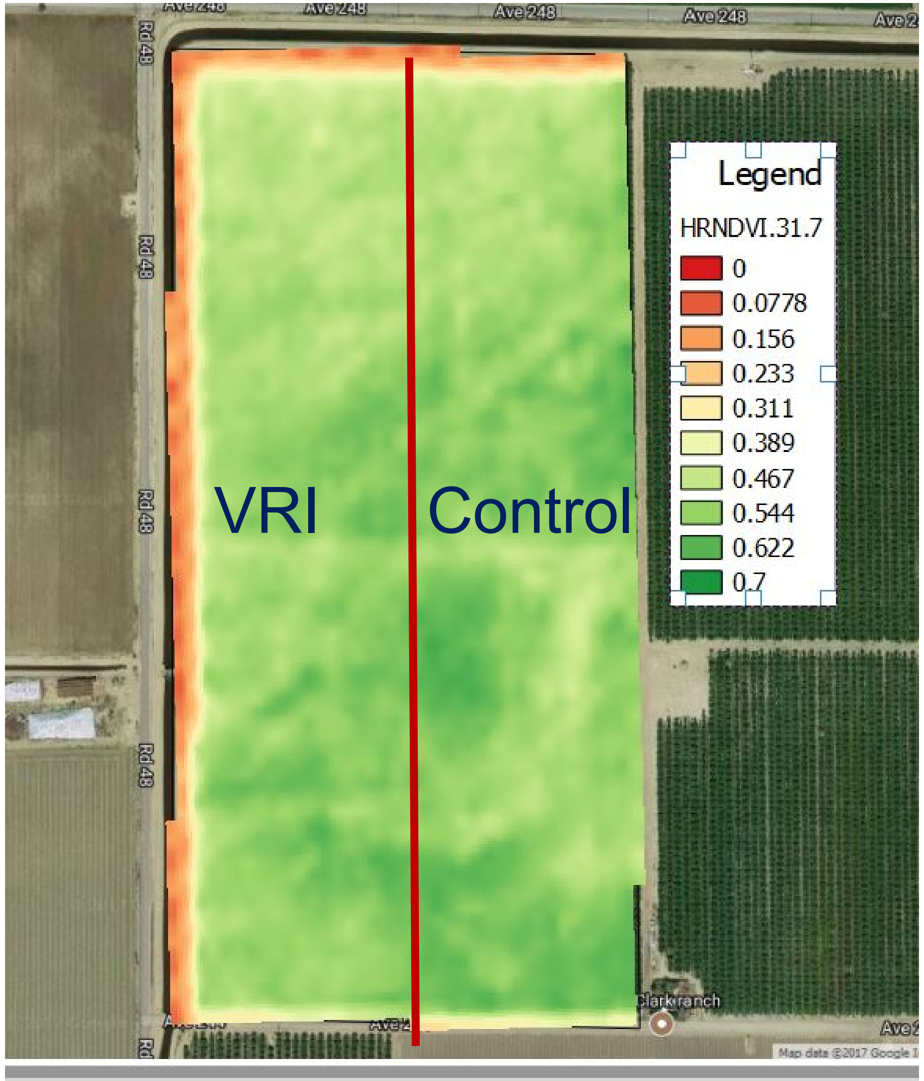
- Producing practical tools to improve water use efficiency and drought resilience by developing best management practices to improve irrigation efficiency and **reduce leaching of nitrogen** that is commonly associated with over irrigation.

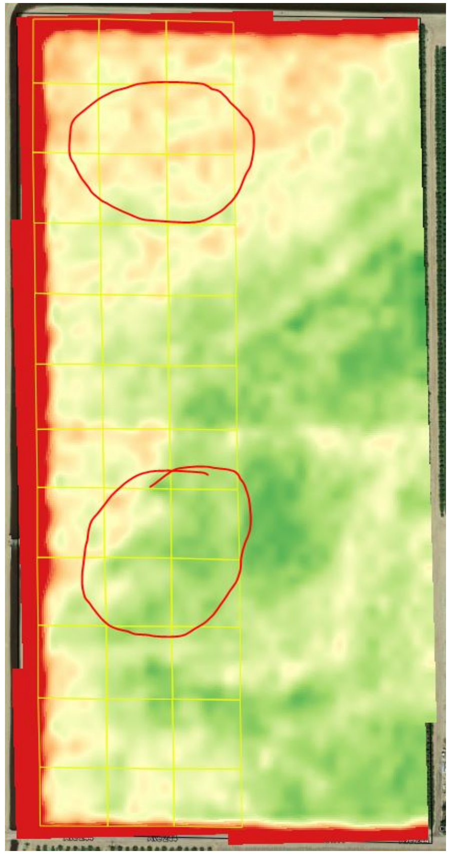
Methods:

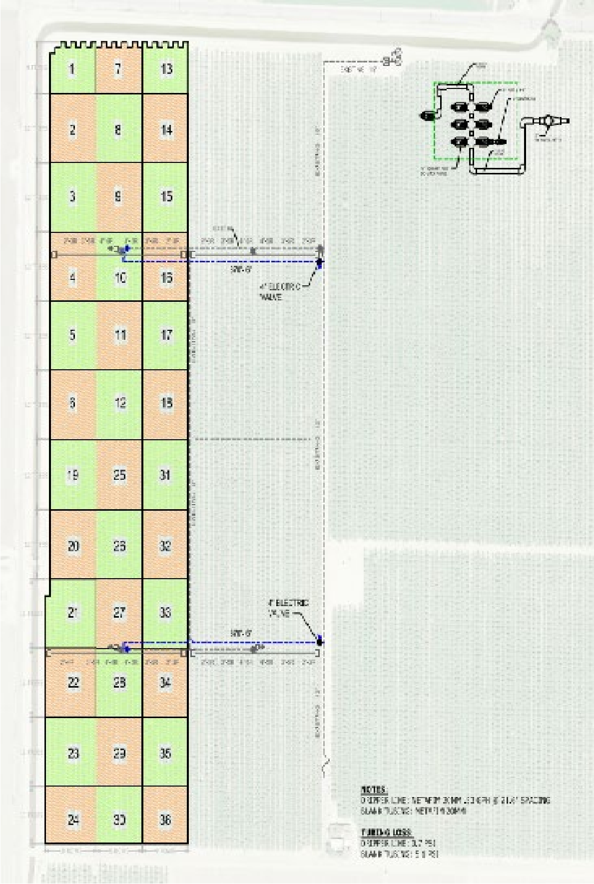
- 70-ac almond field was selected in Hanford, CA.
- Implement 1-acre zone on 50% of the field and irrigation scheduling using VRI technology
- Normal irrigation practices on the other 50%
- Compare yield, water use efficiency, productivity, cost/benefits, etc.

Tulare County- Variable Rate Irrigation (VRI)- NDVI



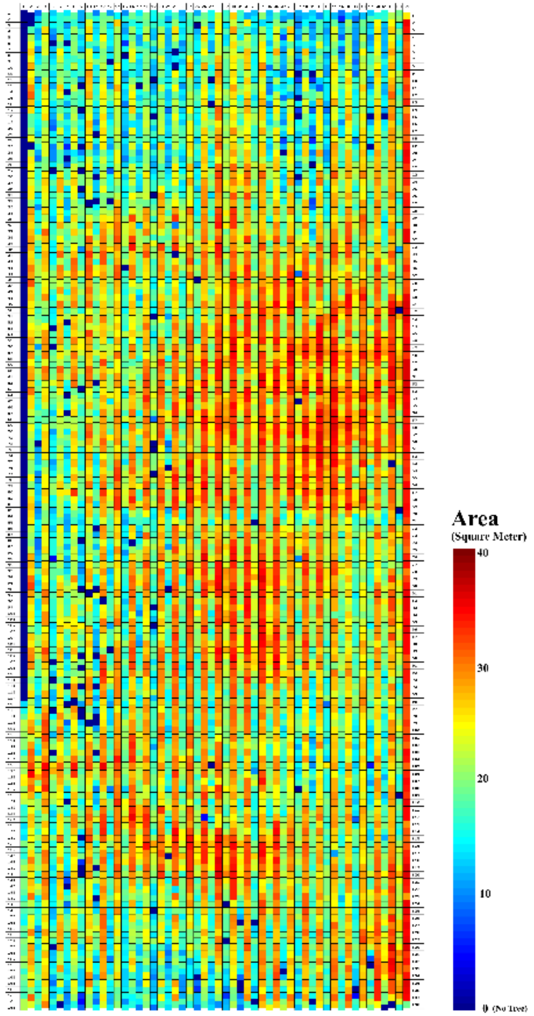


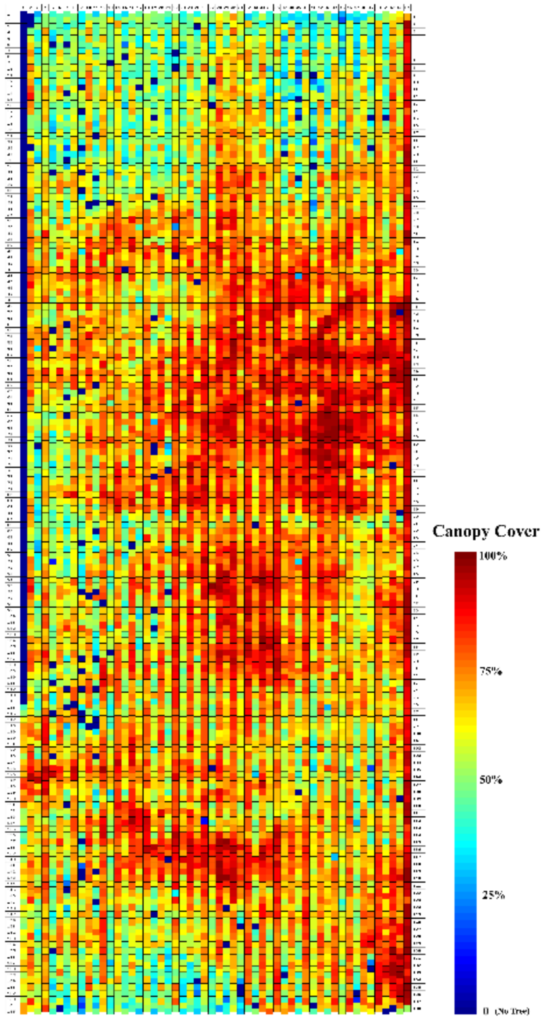


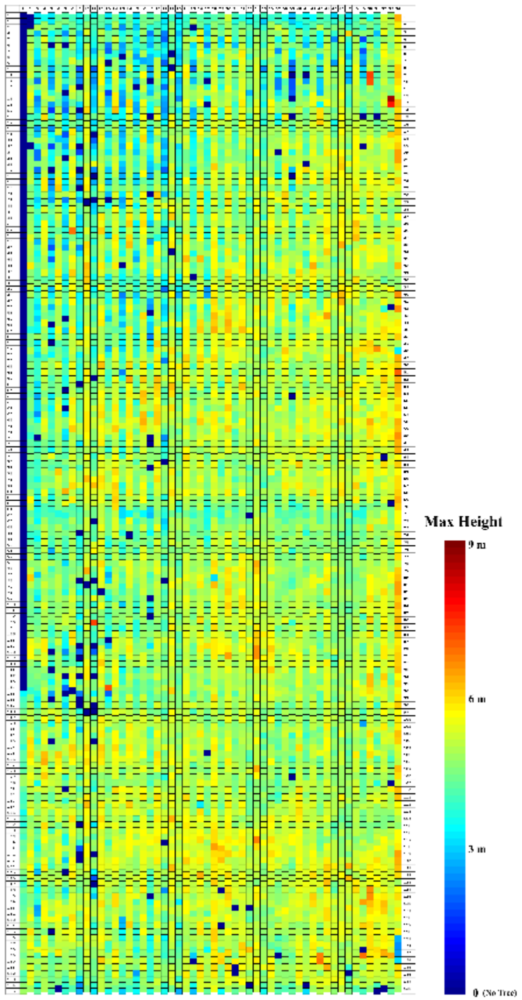


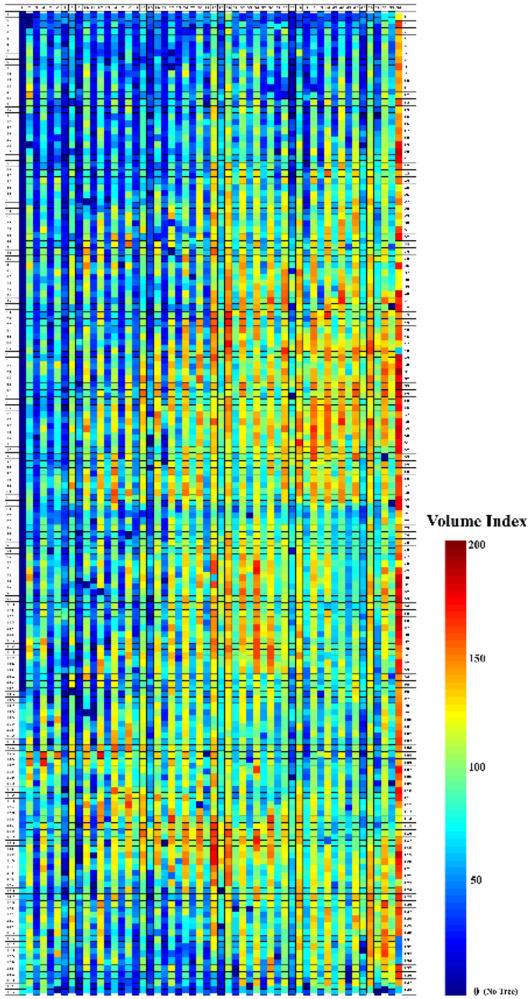
VRI- 1 acre zone

System design: irrigate 1 zone (1/36 of the field) or irrigate up to 36 zones all at once



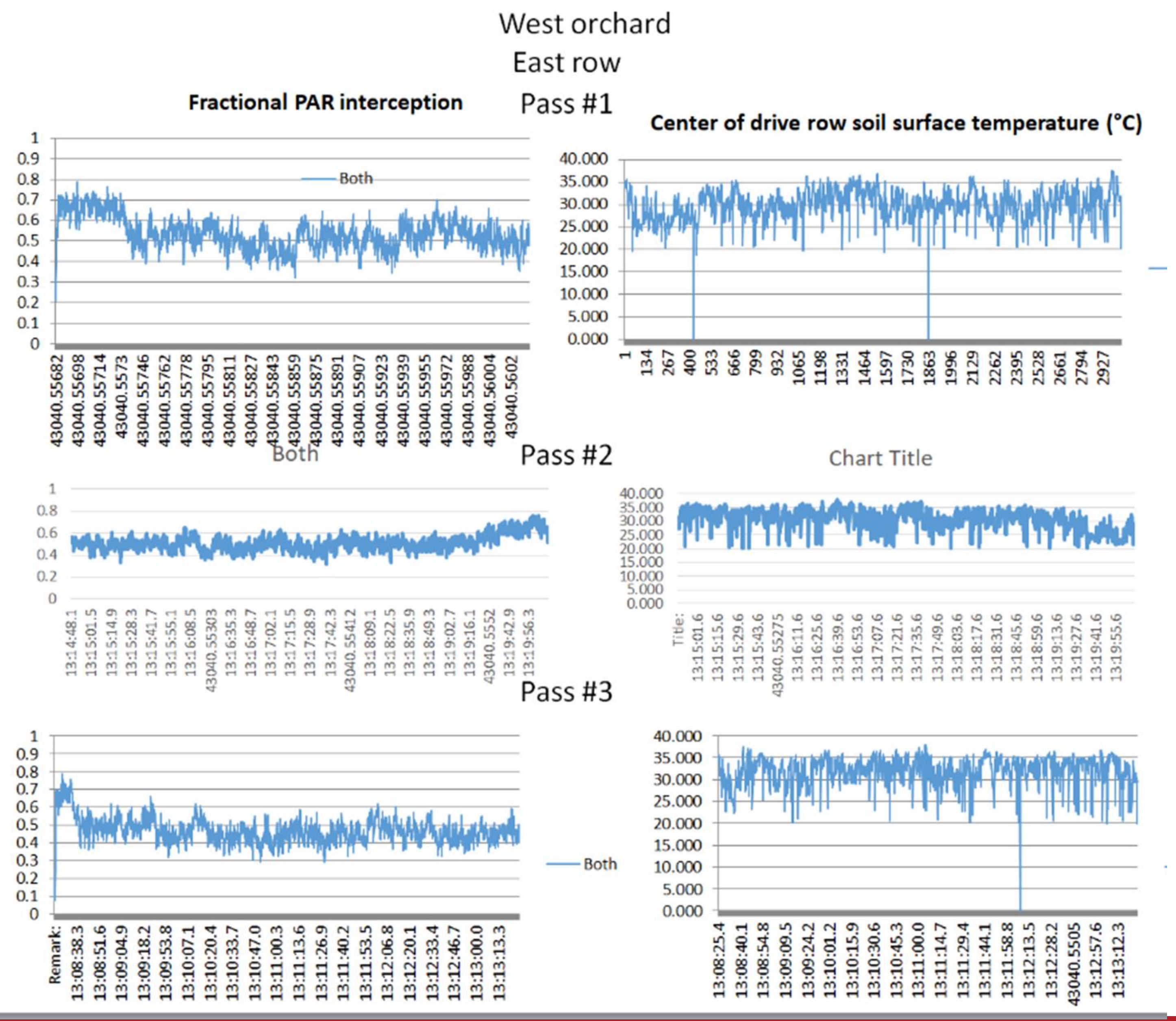






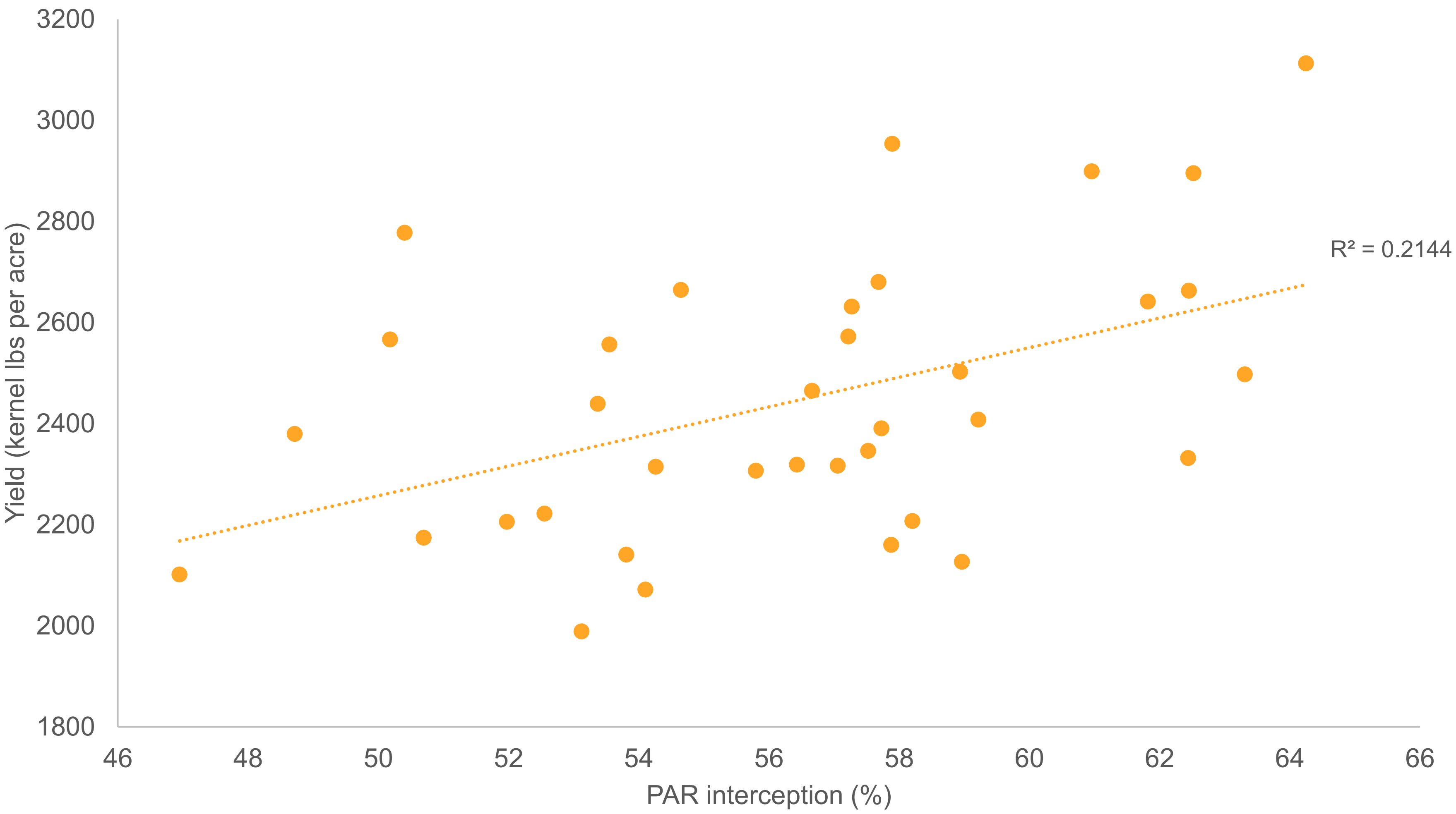
Clark Ranch 2018, UCD Digital Agriculture Lab

Tulare County- Variable Rate Irrigation (VRI)- PAR

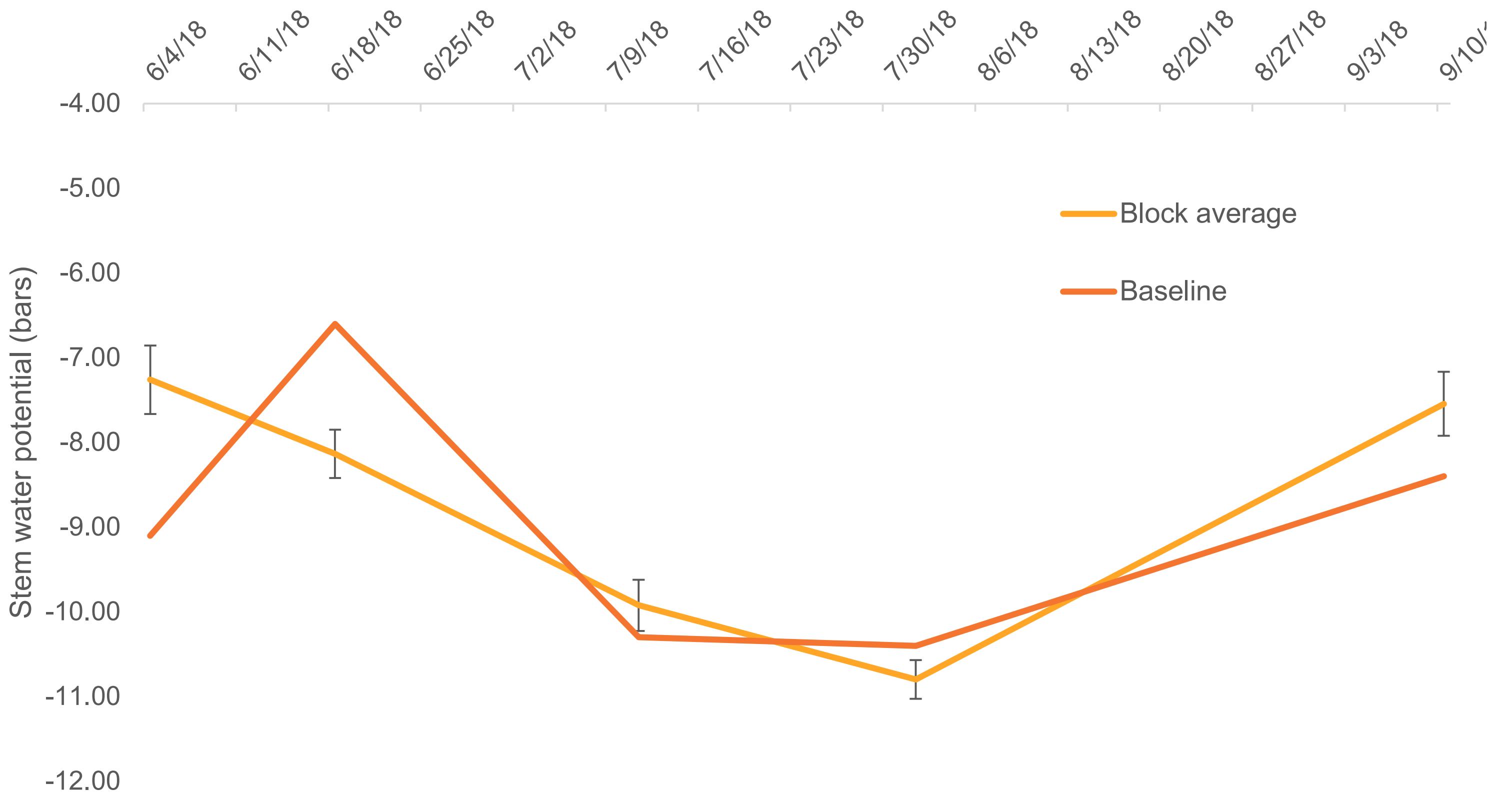


Source: Bruce Lampinen

2018 Yield and Percent Available Radiation (%)



Season-long tree water status



2018 baseline data

2019 growing season

Implementation of VRI

Benefits of VRI will be compared to standard practices

Thank You

Almond Irrigation Management by Variety during Pre-Harvest and Post-Harvest Periods

Isaya Kisekka and Kelley Drechsler

UC Davis, LAWR and BAE

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Outline

- Background
- Objectives
- Methods
- Results
- Future research
- Conclusions
- Acknowledgements

Background

- Almond production in California has unique water management challenges including:
  1. need for post-harvest irrigation
  2. presence of alternating rows of different varieties within the same orchard to establish effective pollination

- Different varieties may reach critical stages (i.e. hull-split, harvest, bud differentiation, etc.) at different times.

- May benefit from independent irrigation management.

Objectives

1. Evaluate effect of regulated deficit irrigation management by tree variety during pre-harvest and post-harvest periods and quantify effects on yield, nut quality, water stress, water applied, water productivity, light interception, and bloom density.

2. Develop a model to predict the tree response to environmental conditions and irrigation management decisions.

Methods

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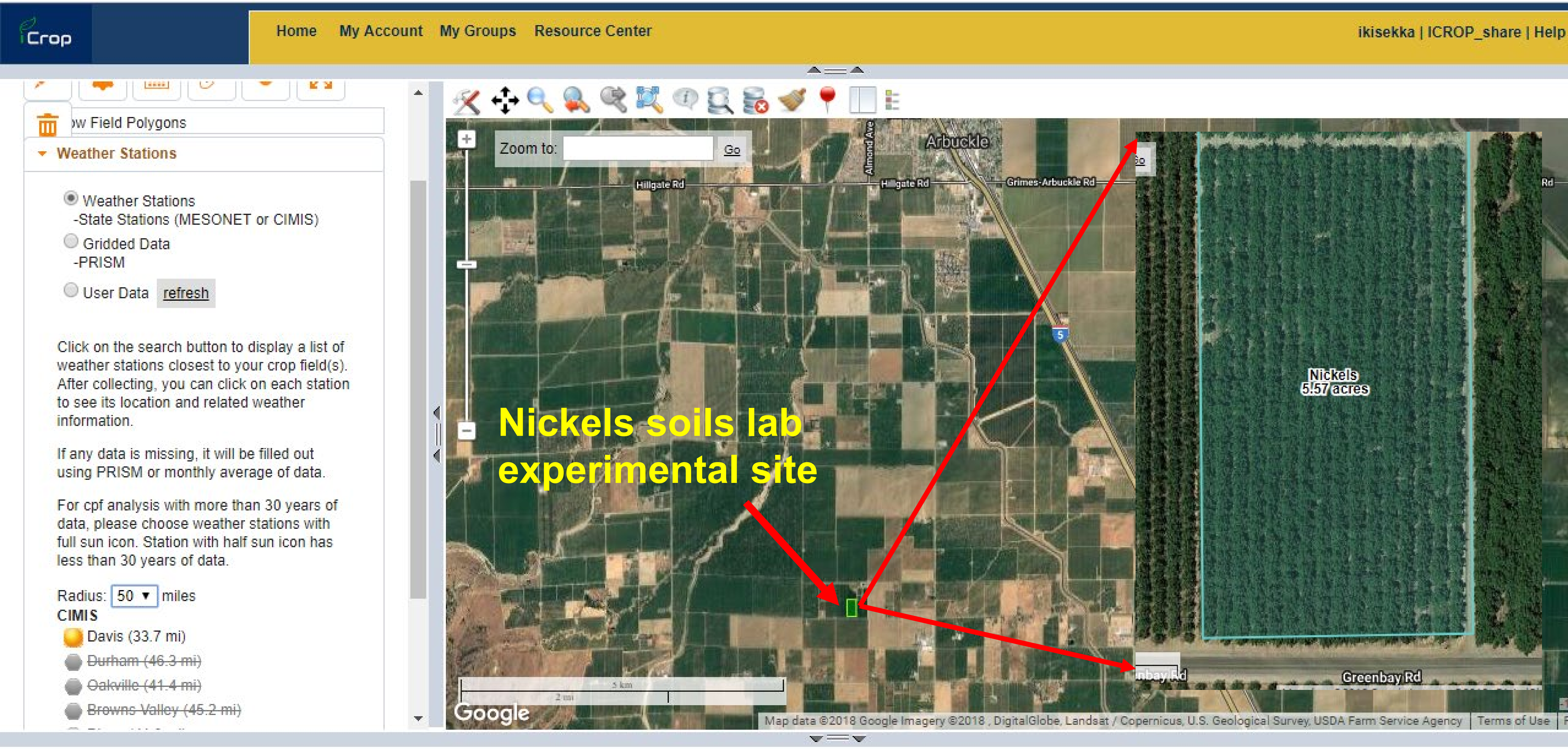
Study Location: Nickels Soil Lab Near Arbuckle CA



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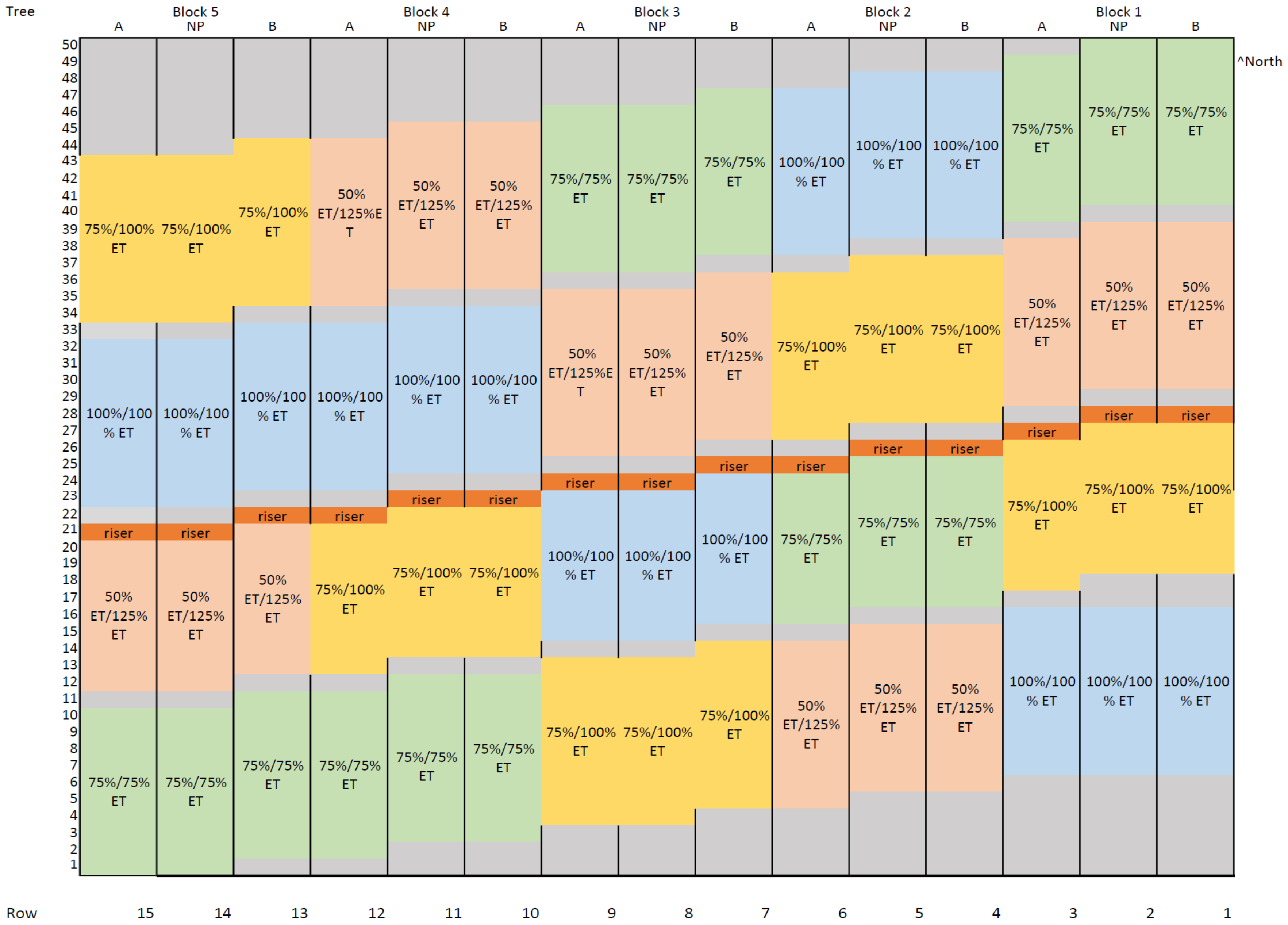
Experimental Layout



Treatments

- Three almond varieties: Nonpareil, Butte and Aldrich.
- Four irrigation treatments: 50-125% ET, 75-100% ET, 75-75% ET, 100-100% ET.
- Experimental design RCBD with 5 replications.
- Statistical analysis using Proc. GLIMMIX.
- Total: 15 rows.

Retrofitting Irrigation System to Irrigate Almond Trees by Variety

Changes we made

- Wireless nodes to open and close latching solenoid valves.
- Flow meter for each plot.
- Pressure sensors.
- Increased size of mainline coming to the block.
- Growers irrigation system left in place.

Canopy Light Interception Measurements

Stem Water Potential Measurements

Results

2018 season

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Yield: Average Yields Across Five Replicates of Irrigation by Variety Treatment Combinations

Irrigation Treatment		Average Kernel Weight (lb/acre)			Average Hull Weight (lb/acre)			Average Shell Weight (lb/acre)		
Pre-Harvest	Post-Harvest	Nonpareil	Aldrich	Butte	Nonpareil	Aldrich	Butte	Nonpareil	Aldrich	Butte
100% ET	100% ET	3428 a	3438 a	1998 b	6272 c	4069 d	3230 d	1745 e	2645 f	1735 e
75% ET	100% ET	3307 a	3243 a	2298 b	6564 c	4103 d	3775 d	2007 e	2378 f	2052 e
75% ET	75% ET	3306 a	3611 a	2462 b	6538 c	4400 d	4015 d	1728 e	2631 f	2135 e
50% ET	125% ET	3306 a	3336 a	2463 b	6614 c	4249 d	4321 d	1797 e	2379 f	1925 e
		NS		*	*	NS		NS	*	NS

- Effect of irrigation on yield within variety was not significant but it was significant across varieties.
- Butte yield were significantly lower than Nonpareil and Aldrich.

Quality: Average Nut Quality Across Treatment Combinations

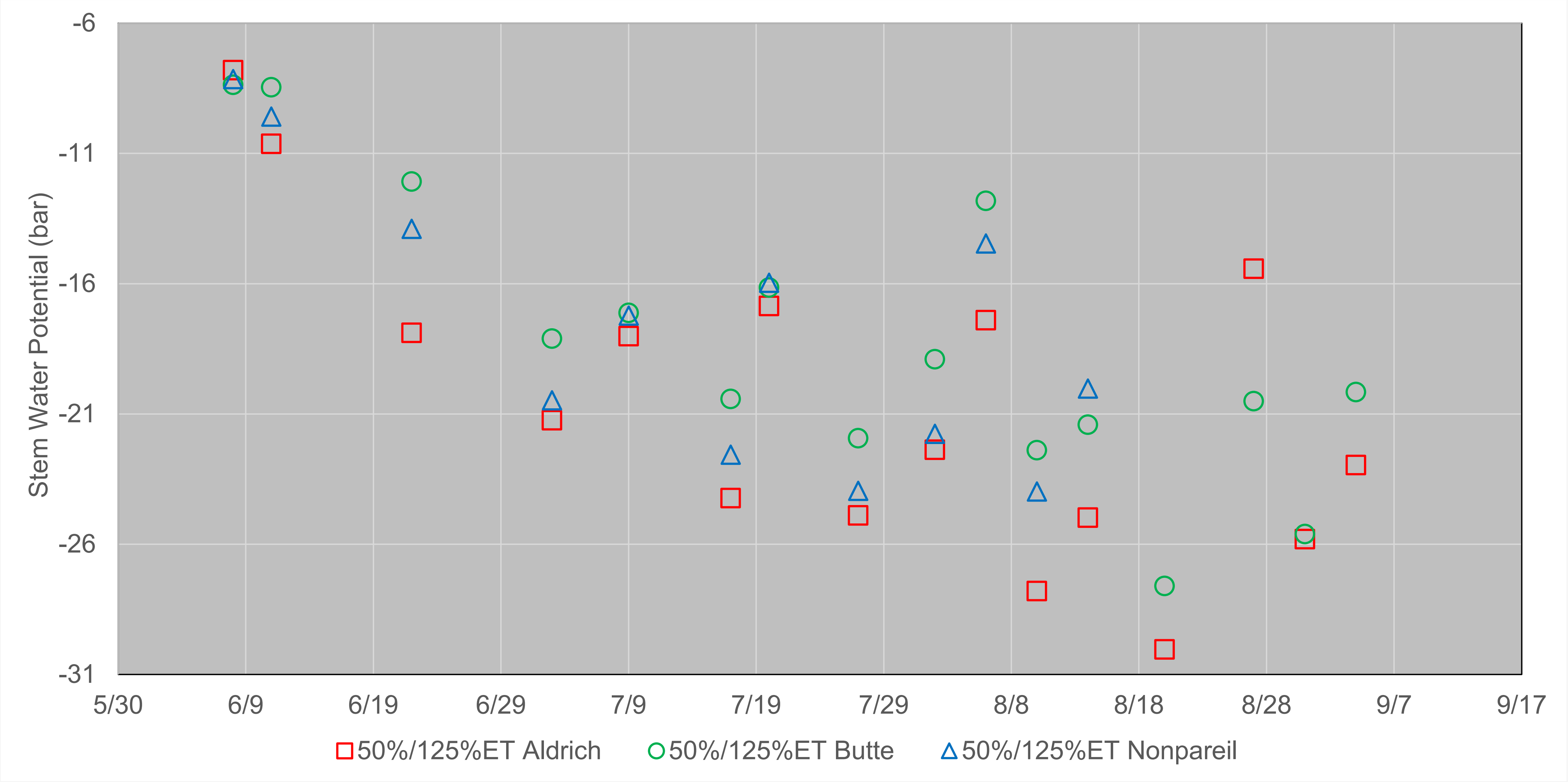
	Average Count per pound			
Pre-Harvest Treatment	**Post-Harvest Treatment**	**Nonpareil**	**Aldrich**	**Butte**
100% ET	100% ET	109 a	185 b	150 c
75% ET	100% ET	100 a	175 b	134 c
75% ET	75% ET	114 a	172 b	145 c
50% ET	125% ET	113 a	178 b	138 c
		*	**	***

Quality: Average Nut Quality Across Treatment Combinations

Irrigation Treatment		Average Kernel Width (cm)			Average Kernel Length (cm)			Average Kernel Thickness (cm)		
Pre-Harvest	Post-Harvest	Nonpareil	Aldrich	Butte	Nonpareil	Aldrich	Butte	Nonpareil	Aldrich	Butte
100% ET	100% ET	1.41 a	1.19 b	1.26 c	2.37 d	2.00 e	1.91 f	0.85 g	0.81 i	0.89 k
75% ET	100% ET	1.40 a	1.19 b	1.25 c	2.33 d	2.02 e	1.91 f	0.81 h	0.82 i	0.88 k
75% ET	75% ET	1.41 a	1.16 b	1.21 c	2.40 d	1.97 e	1.92 f	0.82 gh	0.80 i	0.86 k
50% ET	125% ET	1.38 a	1.19 b	1.24 c	2.36 d	2.00 e	1.92 f	0.82 gh	0.81 i	0.86 k
		*	**	***	*	**	***	*	**	***

Kernel width and length were significantly different across all varieties but not across irrigation treatments.

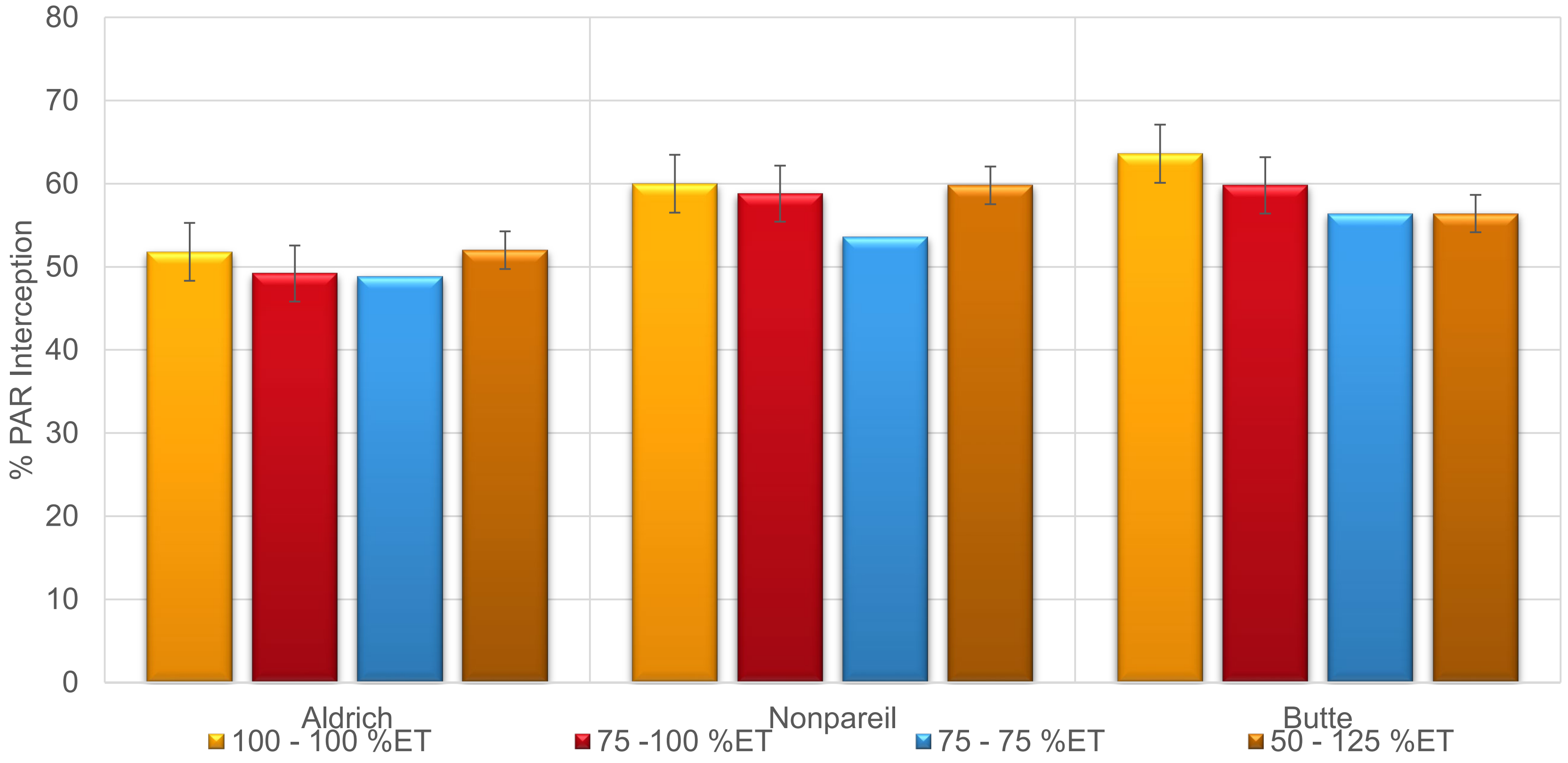
Pre-Harvest Stem Water Potential



Pre-harvest Aldrich stem water potential was significantly lower than the Butte and Nonpareil.

Sweeping nuts off pollinator lines to allow for irrigation of Butte and Aldrich after nonpareil harvest.

Post-Harvest Canopy % PAR interception



Deficit irrigation during pre-harvest appears to effect % PAR interception.
Avoiding deficit irrigation during post-harvest period improved % PAR interception.

Future research

- Soil water monitoring using a variety of sensors (Capacitance, neutron probe, cosmic ray).
- Model development to predict effect of irrigation management and environment on SWP.
- Understanding crop water use in young almond orchards.
- Variable Rate Microirrigation scheduling in Almonds.

ET Flux Tower Measuring Crop Water Use in a Young Almond Orchard in Corning CA

Conclusions

- Regulated deficit irrigation did not have a significant effect on yield within each variety probably due to effect of irrigation management from prior years.
- Almond tree variety had a significant effect on yield at all irrigation levels.
- Nut quality was significantly affected by variety but not by irrigation.
- Pre-harvest Aldrich stem water potential was significantly lower than the Butte and Nonpareil.
- Avoiding deficit irrigation during post-harvest period improved % PAR interception.
- Study will be continued for several years to determine effect of irrigating almond tree varieties differently on orchard productivity.

Acknowledgements

- Almond Board of California for Funding
- Nickels Soil Lab
- Franz Niederholzer
- Allan Fulton
- Stan Cutter
- Bruce Lampinen and Samuel Metcalf
- Andre Daccache
- Alireza Pourreza

Thank You

Isaya Kisekka

E-mail: ikisekka@ucdavis.edu

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Thank you!

Water Management for a Dry Winter

Ken Shackel

Bruce Lampinen

Mohammad Yaghmour

Michael Rawls

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Is winter irrigation a good idea:

1) In a high average rainfall area (e.g., N. Sac. Valley)?
   - Probably not, (risking prolonged periods with saturated soil)

2) In a low average rainfall area (e.g., South SJV)?
   - Leach salts: good
   - Recharge aquifers: good (although salts are not good for aquifers)

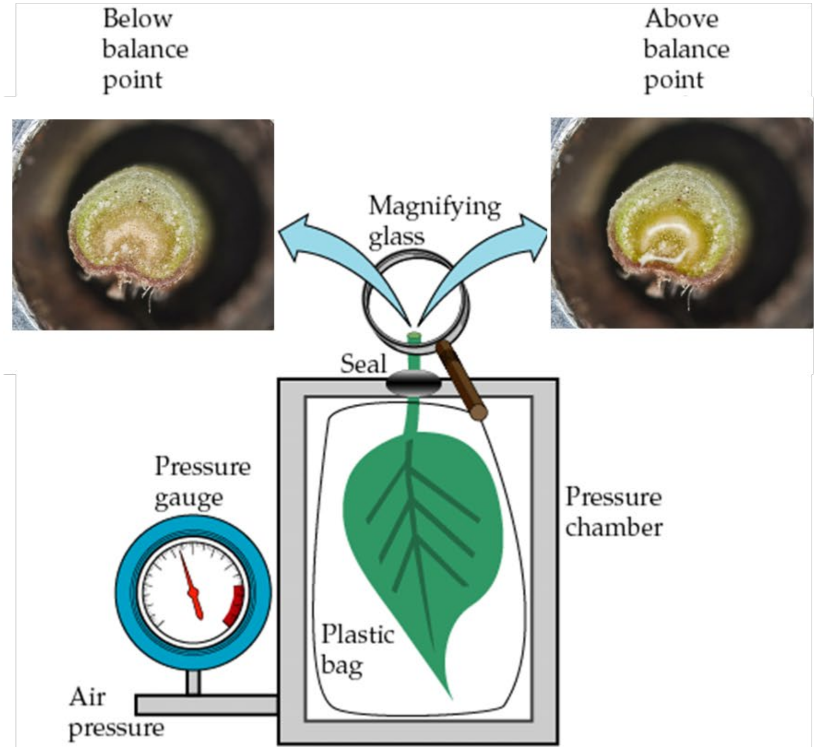
But, do trees need additional water in the winter?

- There are no leaves and water demand (ET_o) is low
- Does the tree need water for:
  - chill
  - pos
  - to s

Of course it does, but how much water is “enough?”

Pressure Bomb: The way we measure "enough" during the irrigation season

Pressure chamber method for measuring water stress in trees and vines



Like measuring the "blood pressure" of the plant

Pressure Chamber Reading (- bars)	ALMOND
0 to –2.0	Not commonly observed
-2.0 to –4.0	↓
-4.0 to –6.0	↓
-6.0 to –8.0	Low stress, indicator of fully irrigated conditions, ideal conditions for shoot growth. Suggest maintaining these levels from leaf-out through mid June.
-8.0 to –10.0	↓
-10.0 to –12.0	Mild to moderate stress, these levels of stress may be appropriate during the phase of growth just before the onset of hull split (late June).
-12.0 to –14.0	↓
-14.0 to –18.0	Moderate stress in almond. Suggested stress level during hull split, Help control diseases such as hull rot and alternaria, if diseases are present. Hull split occurs more rapidly
-18.0 to –20.0	Transitioning from moderate to higher crop stress levels
-20 to -30	High stress, wilting observed, some defoliation
↓	↓
-60 bars	"I'm not dead yet"

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Pilot field test: Belridge almonds, 2014
Dry winter - only 1.1” rain from November to March

Date	Baseline SWP (bar)	Treatment	
		Wet	Dry
		SWP (bar) or irrigation (inches)	
Jan 14	-5.4	-4.7	-4.9

Pilot field test: Belridge almonds, 2014
Dry winter - only 1.1" rain from November to March

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Mar 28	-6.0	-6.4	-7.4

Pilot conclusion: either that winter wasn’t dry enough, or there was enough soil water left over from last season to last the winter.

2018/19: New field test established in Shafter
Photos: November 19, 2018

Wet treatment (last irrigation Oct 23)

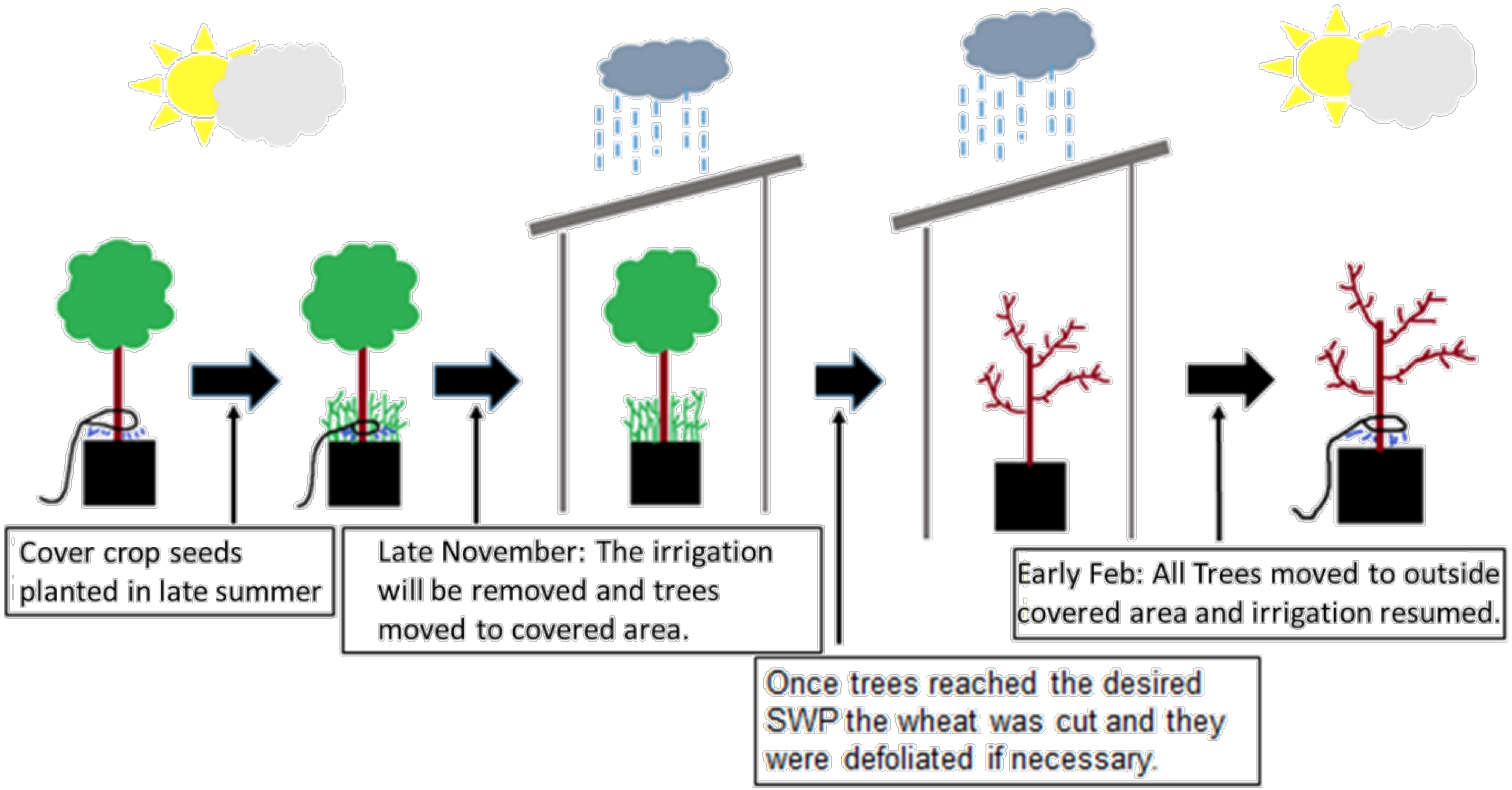
Predawn SWP about -4 bars

2018/19: New field test established in Shafter
Photos: November 19, 2018

Dry treatment (last irrigation Oct 10)

Predawn SWP about -15 bars

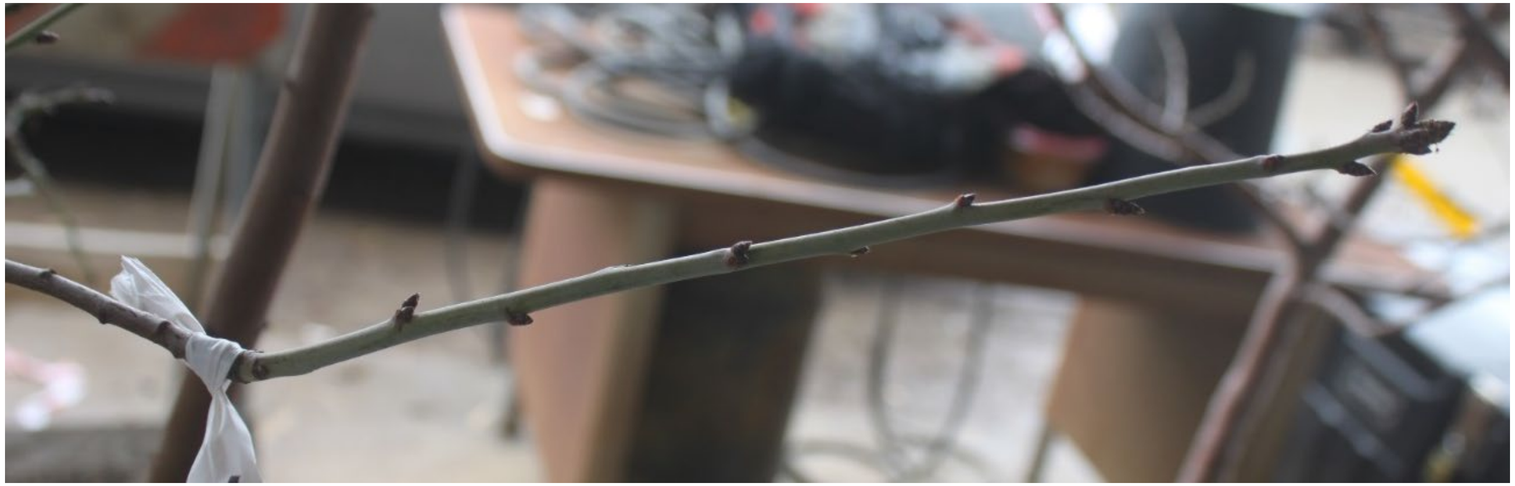
Potted tree study to regulate the levels and timing of winter water stress in almonds (UCD)



Bloom in potted trees, February, 2018

Comparison of typical control and high stress trees January 4, 2018

Control
(SWP about -3 bars)



High Stress
(SWP about -25 bars)

Comparison of typical control and high stress trees February 16, 2018 (all trees irrigated Feb 1)

Control

High Stress

Comparison of typical control and high stress trees March 7, 2018

Control

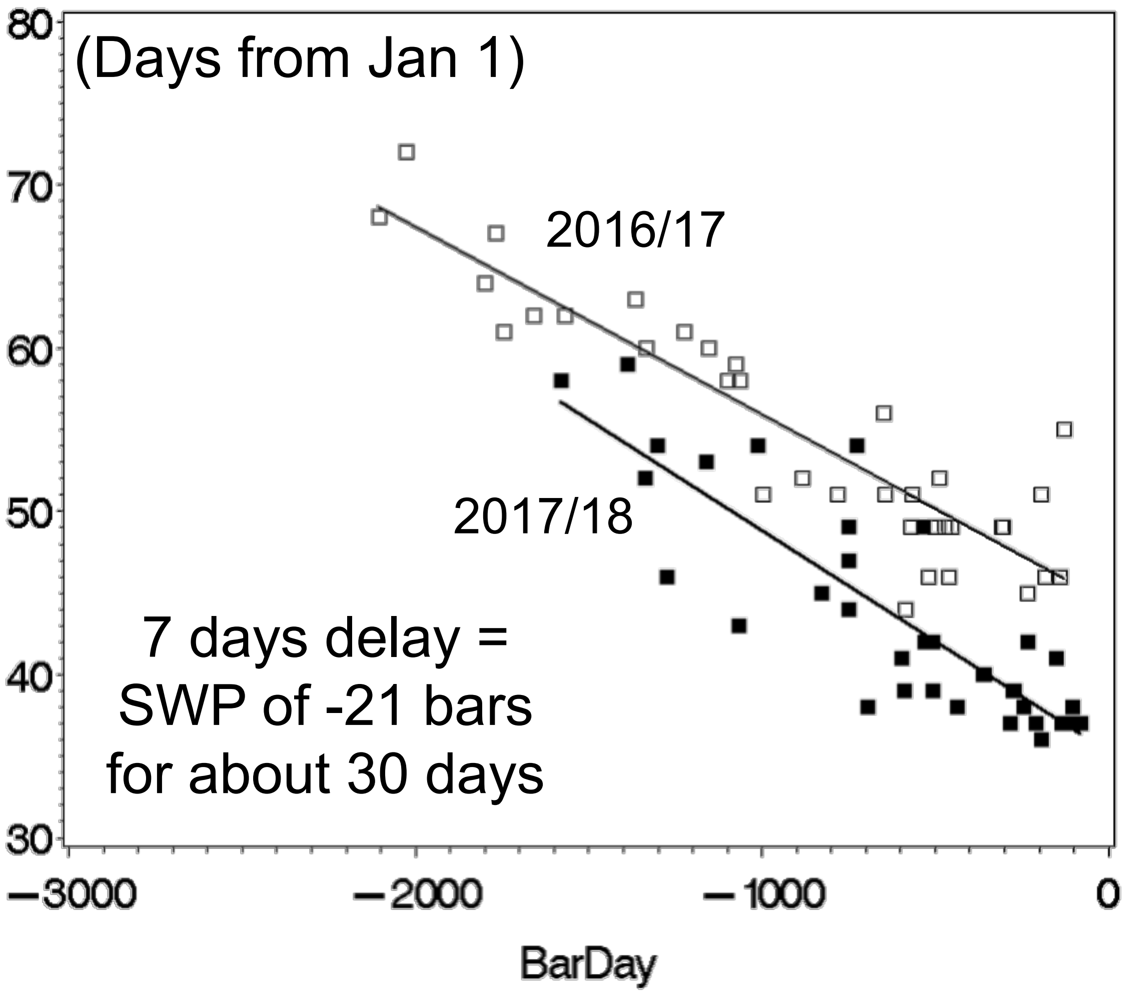
High Stress

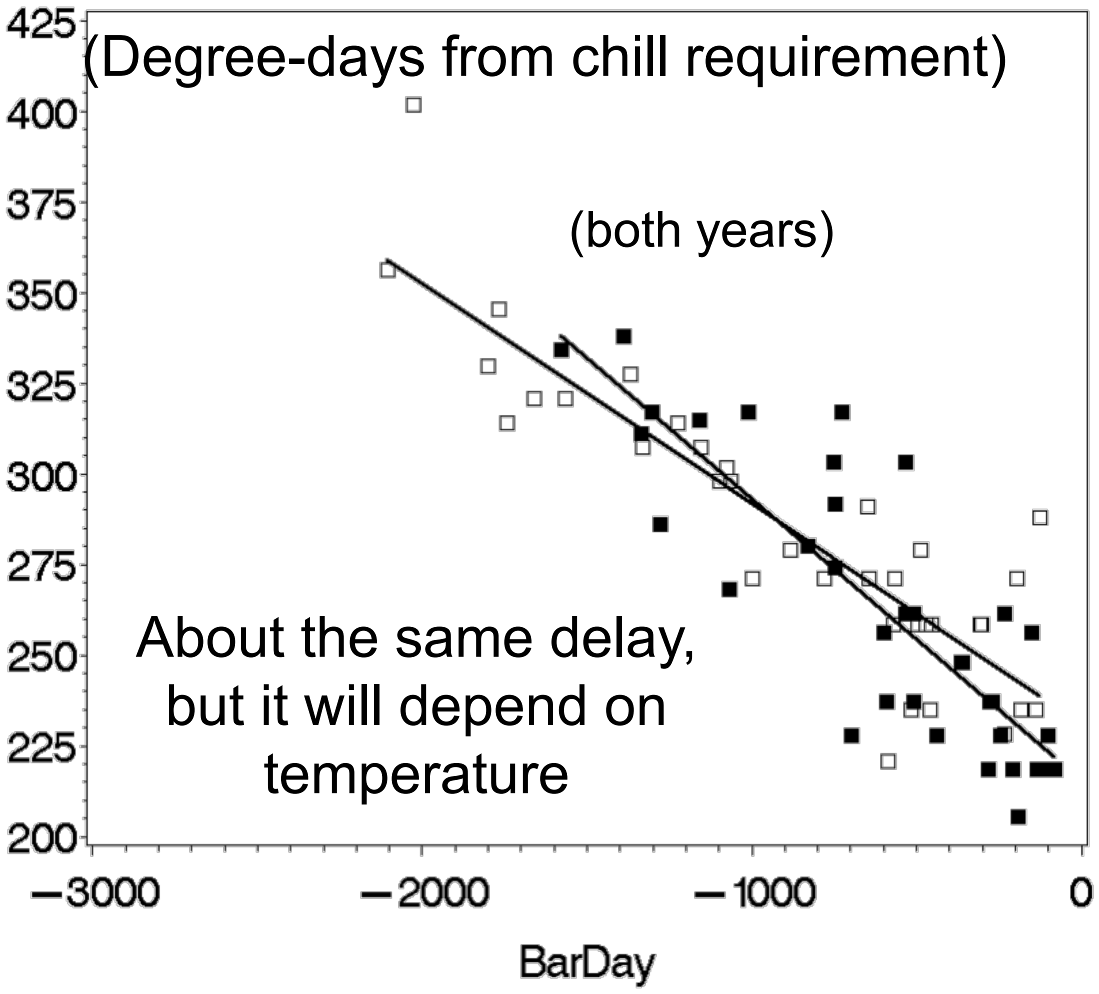
Comparison of typical control and high stress trees March 11, 2018

Control

High Stress

More bloom delay with more stress in dormancy





Pot study results so far

- Water stress during dormancy delays bloom
  - Could be a good thing, depending on spring weather
  - Q: Does water stress influence chilling or only post-chill bud development?
- Water stress had no influence at all on leaf out
  - Control trees bloom before leaf out, stressed trees after leaf out
  - May have implications for pollination, tree carbon budget, etc.
- Highest Stressed Trees still flowered and set fruit
- Final flower % was slightly reduced at the highest stress level (needs confirmation)

More detail at the poster!

Thanks for your support and attention!

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(Net)Almond Water Footprint

Fraser Shilling & Julian Fulton

UC Davis and Sacramento-State University

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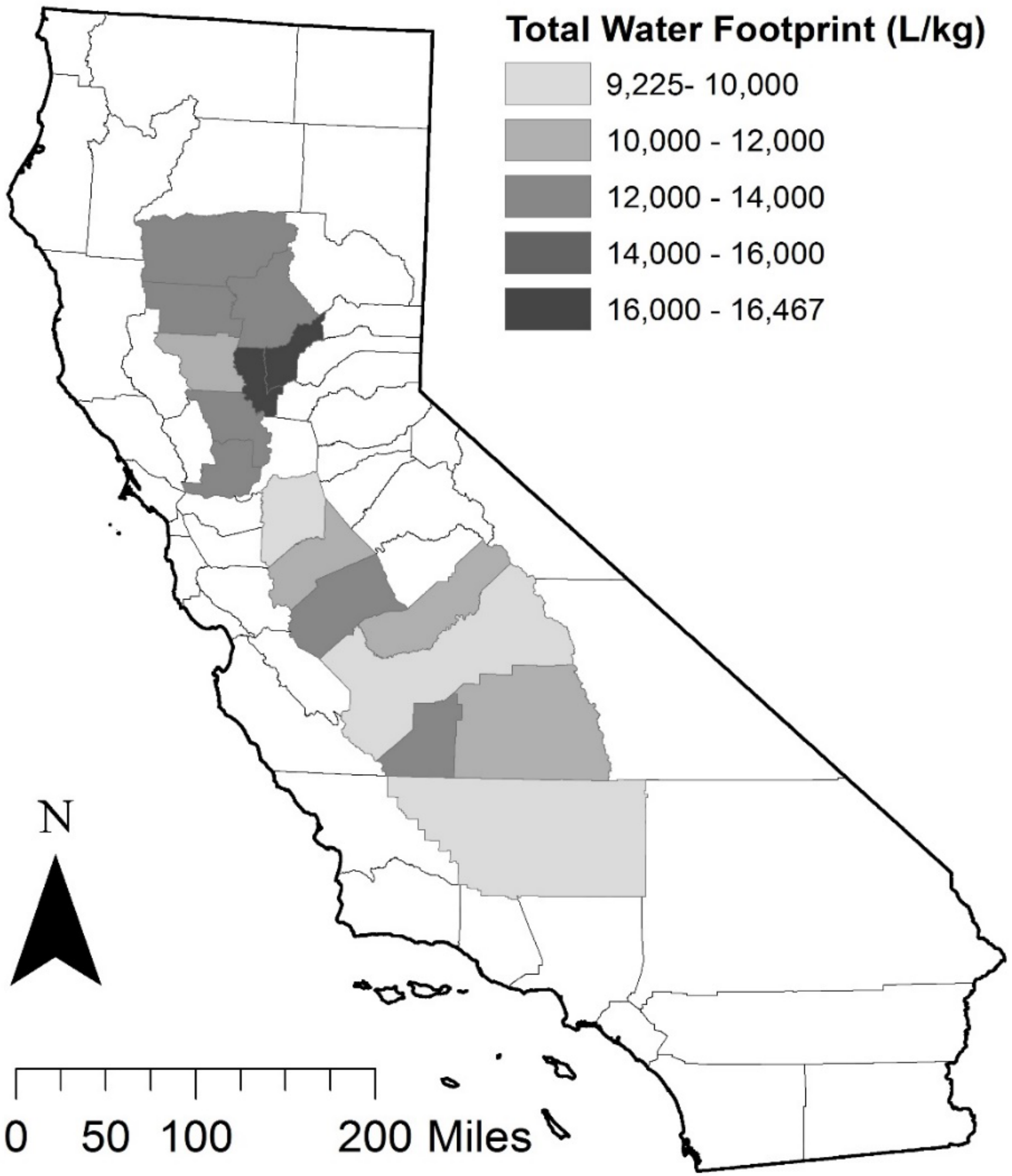
- Michael Norton, Hongfei Wang, Camila Bonilla Cedrez, Patrick Brown (UC Davis)
- Joel Kimmelshue (LandIQ)

What is Water Footprint?

- Blue Water
- Green Water
- Gray Water



Almond Water Footprint

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Water-indexed benefits and impacts of California almonds

Julian Fulton[a,*], Michael Norton[b], Fraser Shilling[b]

[a] Department of Environmental Studies, California State University Sacramento, 6000 J Street, Sacramento, CA 95819-6001, United States
[b] Department of Environmental Science and Policy, University of California, Davis, One Shields Avenue, Davis, CA 95616, United States

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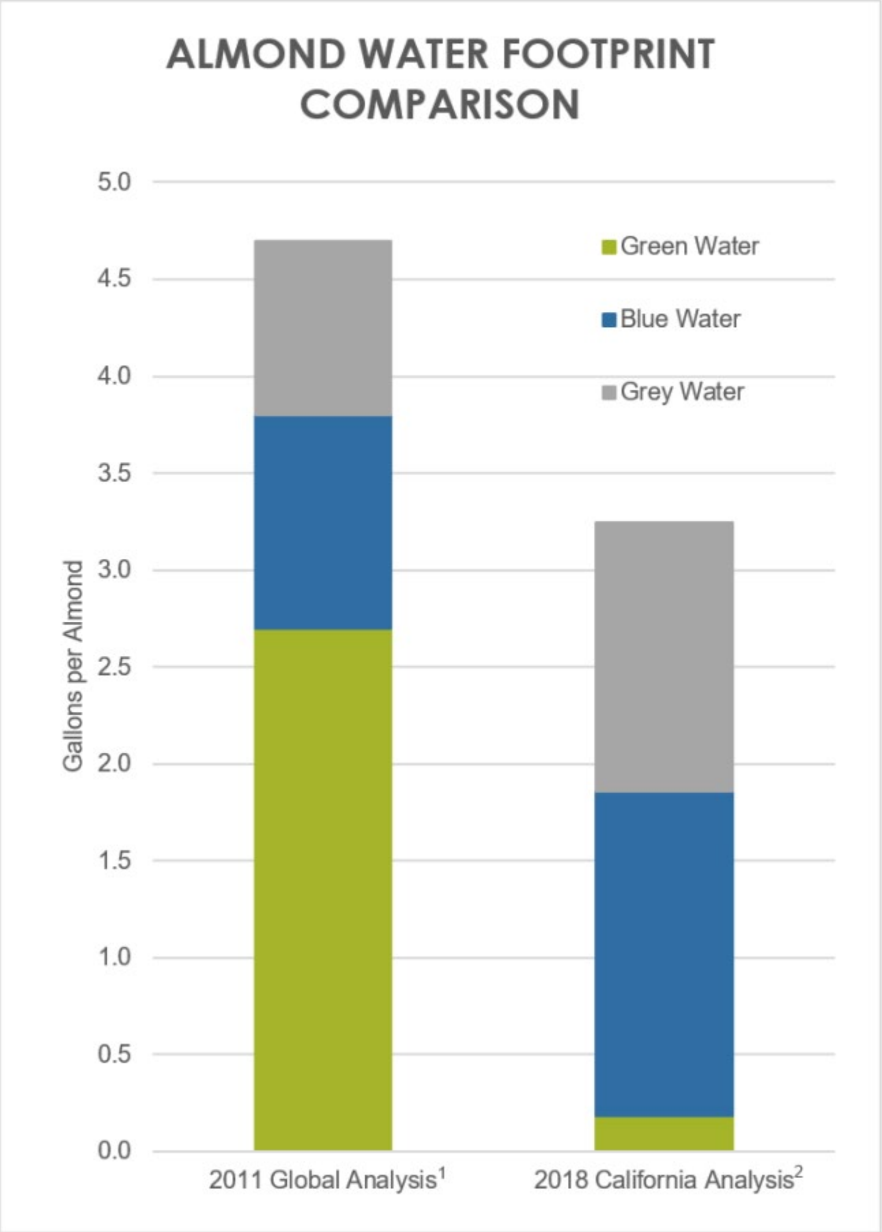
ABSTRACT

California almonds have been the focus of recent media scrutiny because of the large amount of water required to grow individual nuts and, by extension, for the industry as a whole. With almond orchard acreage doubling in the last two decades and becoming California's most extensive irrigated crop, the questions arise: what are the benefits and impacts derived from this use of scarce water? Can we use this information to make decisions about growing and consuming this particular crop? We first use a water footprint approach to estimate total impact on water per unit of almond production in California, including variation in the water footprint over time (2004–2015) and across the production area. We then compare almonds to a set of other foods and crops grown in California using water footprint values and three other dimensions: nutritional value, per-unit-weight economic value, and total economic value. The water footprint of California almonds averaged 10,240 liters per kilogram kernels (or, 12 liters per almond kernel), with substantial variation over the time period analyzed. Water footprint values also varied twofold across the production area, with the smallest water footprint being in the southern counties of California's Central Valley. In relation to dietary benefits, almonds were among the top three foods analyzed providing the greatest nutritional benefit per unit weights, however they had the highest water footprint value per unit weight. The direct economic benefits of almond production based on market sales were also greater than for any other major crop in California, however almonds again had the largest water footprint on a per-unit and aggregate basis. We find that nutritionally and economically indexed water footprint indicators provide information to better-inform discussions on the benefits and impacts of growing almonds using California's limited water resources, relative to other crops. Such composite indices can be used in combi-



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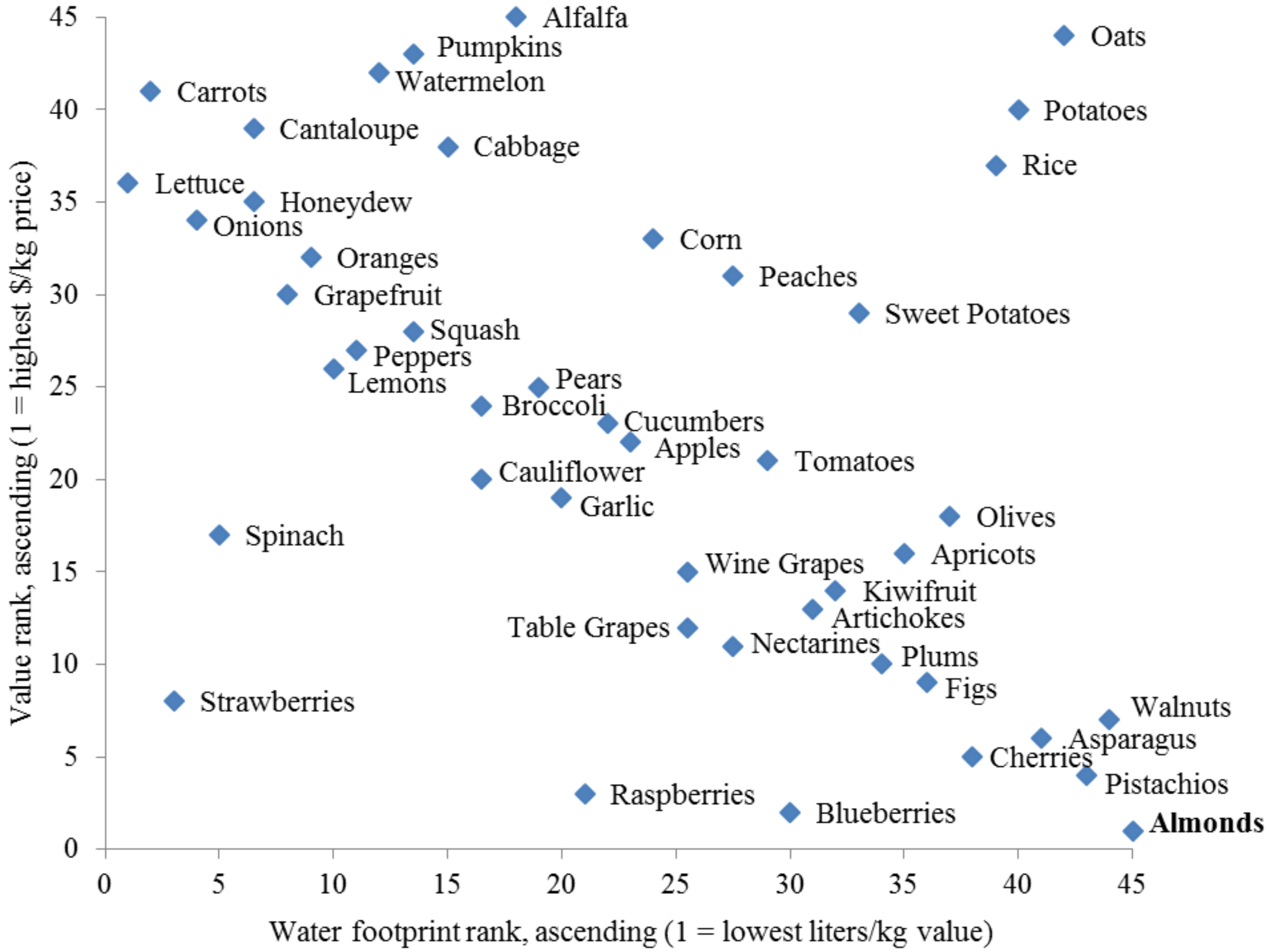
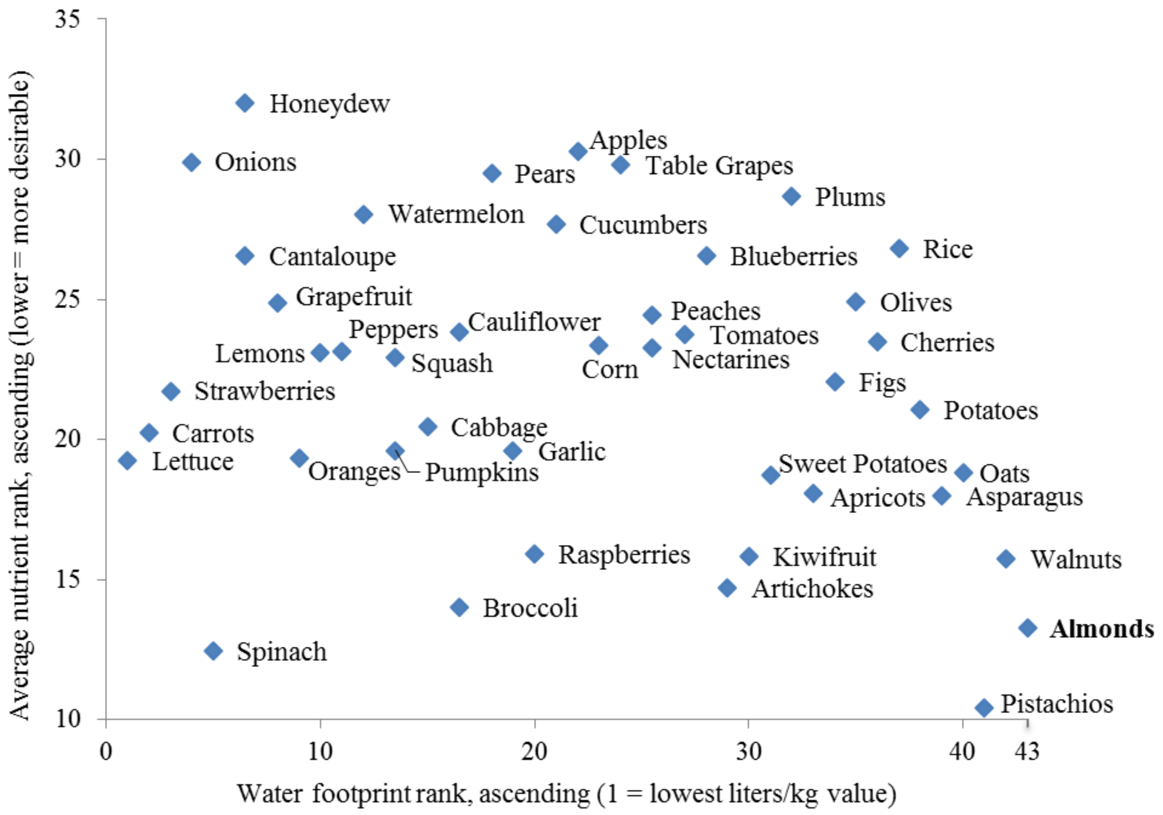
Almond vs other crops





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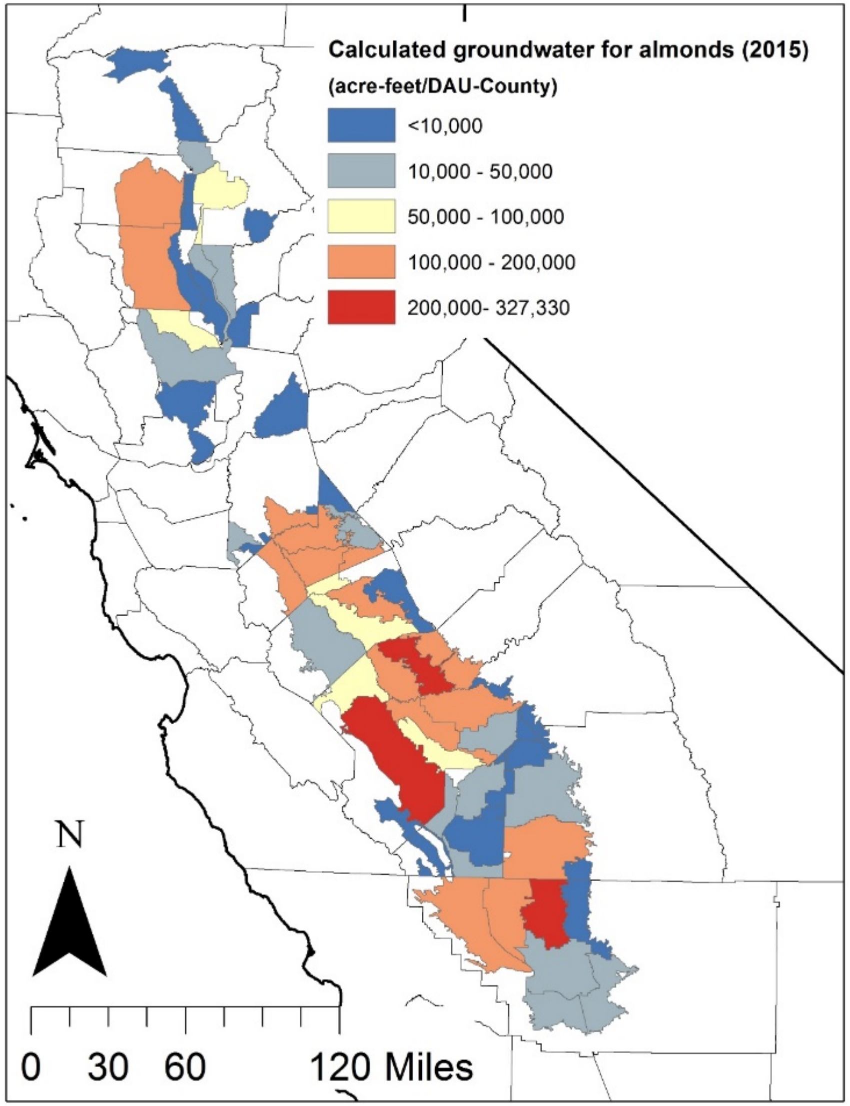
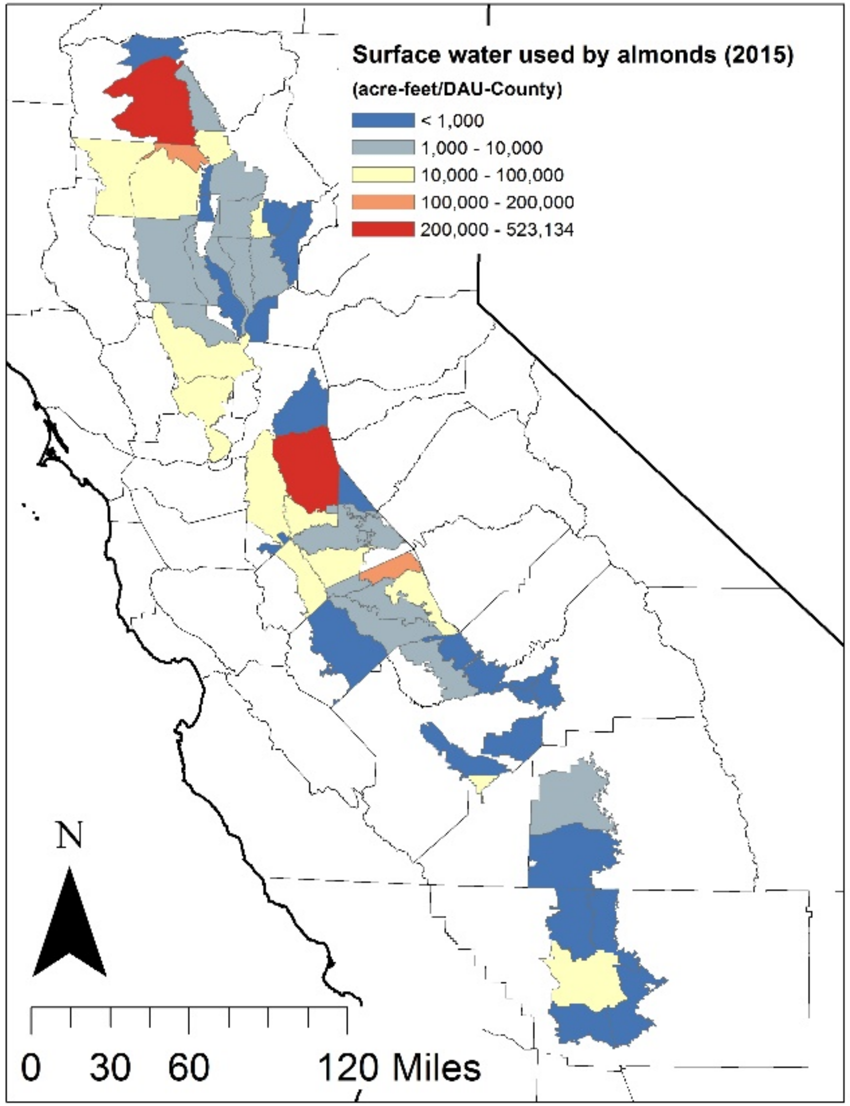
Water Supply



Almond groundwater demand/use per DAU-County , total = 3.2 million acre-feet and 65% of estimated total demand*



Estimated surface water use for almond production in 2015, per DAU-County. Total = 1.7 million acre-feet

Threats to Supply

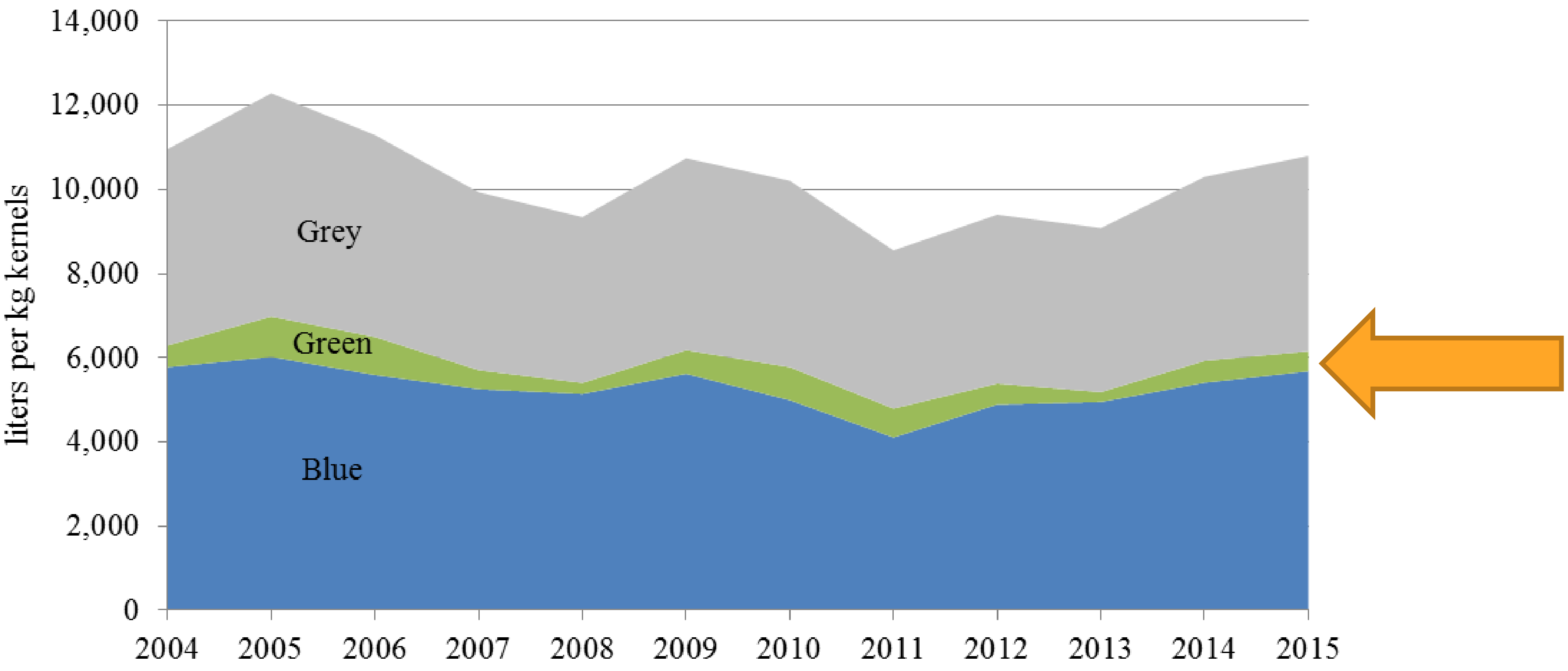
- SGMA -- >90% of almond production is within priority basins under SGMA

- Surface water supplies are expected to decline as snowpack and total precipitation declines with climate change, will lead to increased competition for increasingly rare resource

Proposed Next Steps

What is actionable for growers?

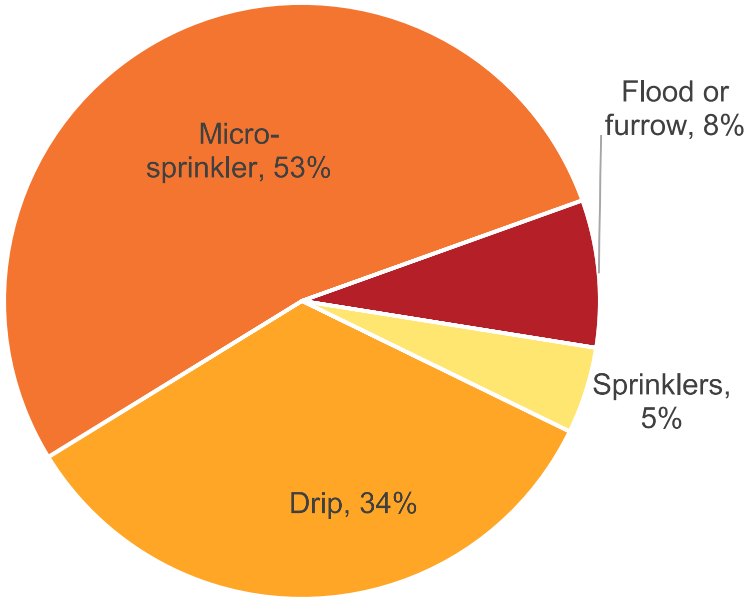
estimate the off-setting value of sustainability actions relative to the calculated water footprint



Proposed Next Steps: WF Reduction

Examine practices that contribute to reduced WF and extend WF quantification to specific recommendations and sustainability metrics

Blue WF



Irrigation technologies used (A) (N=212) reported in almond grower self-assessments (SureHarvest, 2017).

Proposed Next Steps: WF Reduction

Examine practices that contribute to reduced WF and extend WF quantification to specific recommendations and sustainability metrics

Gray WF

nutrient budgeting techniques (98%, n=119)
recommended timing of fertilizer applications (100%, n=75)
fertigation (93%, n=107)

Nutrient management from almond grower self-assessments (SureHarvest, 2017).

Proposed Next Steps: Offsets

Quantify practices that could be considered offsetting for WF

- – Groundwater recharge
- – Biomass to biochar
- – Biomass to energy
- – Biomass to livestock feed


(Aric Crabb/Bay Area News Group)

fmshilling@ucdavis.edu
Julian.fulton@csus.edu