2018 | THE ALMOND CONFERENCE

SPEED TALKS: ORCHARD MANAGEMENT

ROOM 312-313 | DECEMBER 5, 2018

AGENDA

- **Gabriele Ludwig & Sebastian Saa**, Almond Board of California, moderators
- **Almond Board Funded Researchers**
    - Roger Duncan, UCCE Stanislaus
    - Franz Niederholzer, UCCE Colusa
    - Maciej Zwieniecki, UC Davis
    - Astrid Volder, UC Davis
    - William Horwath & Helen Dahlke (Hannah Waterhouse), UC Davis
    - Peter Nico, Lawrence Berkeley Labs
    - Rosemary Knight, UC Berkeley

Integration of Higher Tree Density and Minimal Pruning for Efficient Almond Production (?)

Roger Duncan, UCCE Stanislaus County

University *of* California
Agriculture and Natural Resources

Goal when designing an almond orchard
– maximize yield potential by maximizing light capture:

- Capture as much sunlight as early and for as long as possible.
- Each 1% of intercepted sunlight ~ 50 pounds of yield potential.
- Does higher tree density = higher yield in short term? Long term??
- What is the limit? Do high density orchards crash over time?
- What role does pruning play in maintaining yield?

Almond Spacing & Pruning Trial

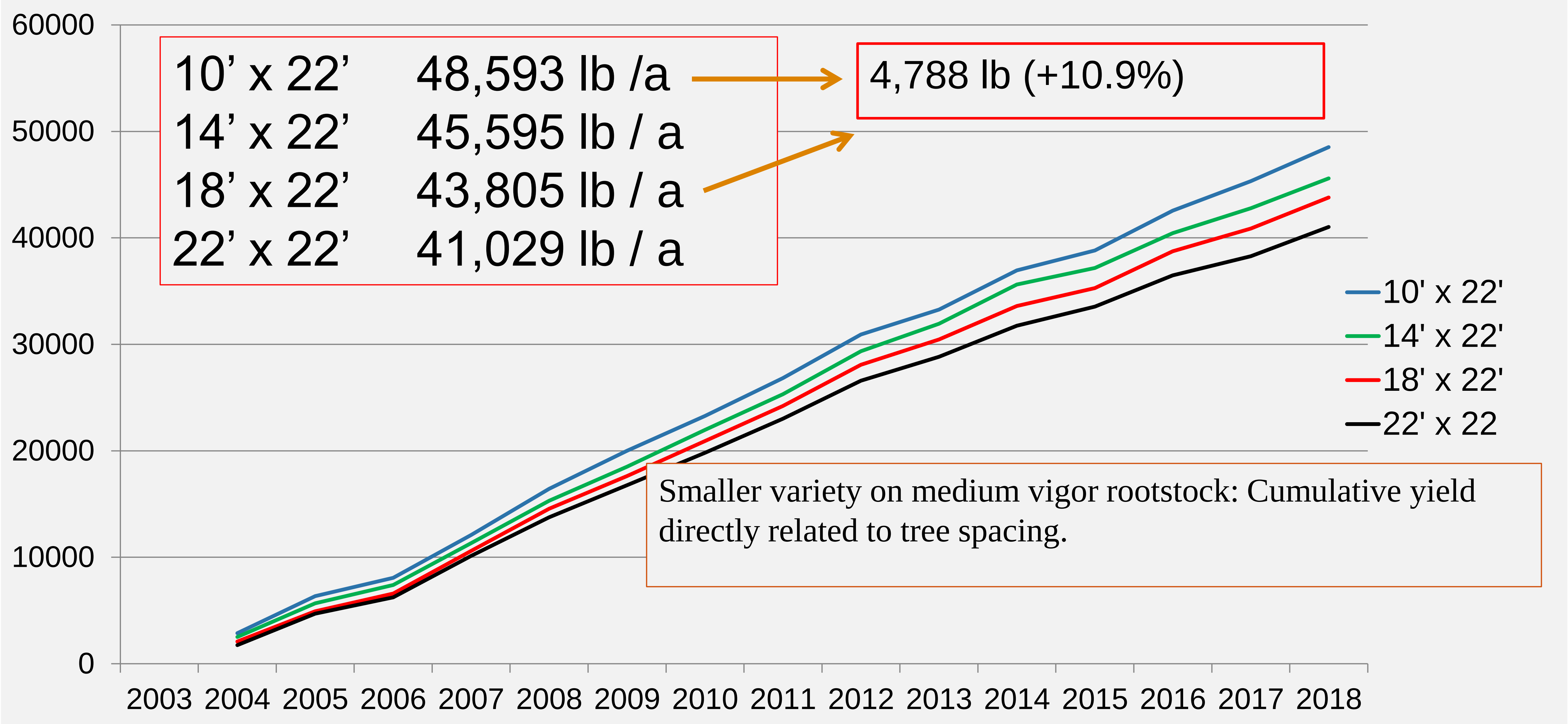
- Planted fall, 1999
- 37 acres
- Four tree densities
  - 10’ x 22’ (198 trees / acre)
  - 14’ x 22’ (141 trees / acre)
  - 18’ x 22’ (110 trees / acre)
  - 22’ x 22’ (90 trees per acre)

- Overlaid with four pruning strategies and two rootstocks (Nemaguard & Hansen)


10’ x 22’

22’ x 22’

The Effect of Tree Spacing on Cumulative Yield Through 19th Season
Carmel on Nemaguard



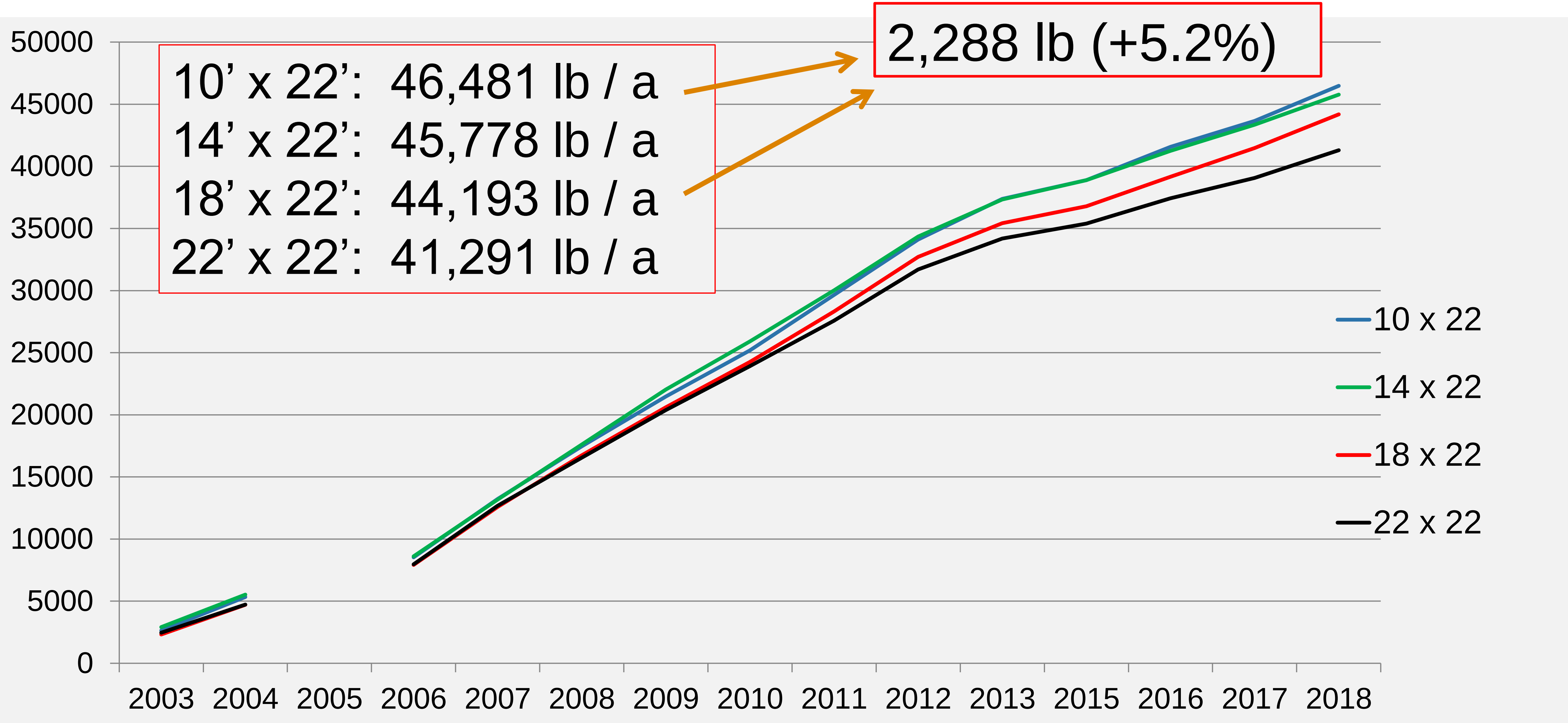
10’ x 22’ 48,593 lb /a
14’ x 22’ 45,595 lb / a
18’ x 22’ 43,805 lb / a
22’ x 22’ 41,029 lb / a

4,788 lb (+10.9%)

Smaller variety on medium vigor rootstock: Cumulative yield directly related to tree spacing.

The Effect of Tree Spacing on Cumulative Yield Through 19th Season

Nonpareil on Nemaguard

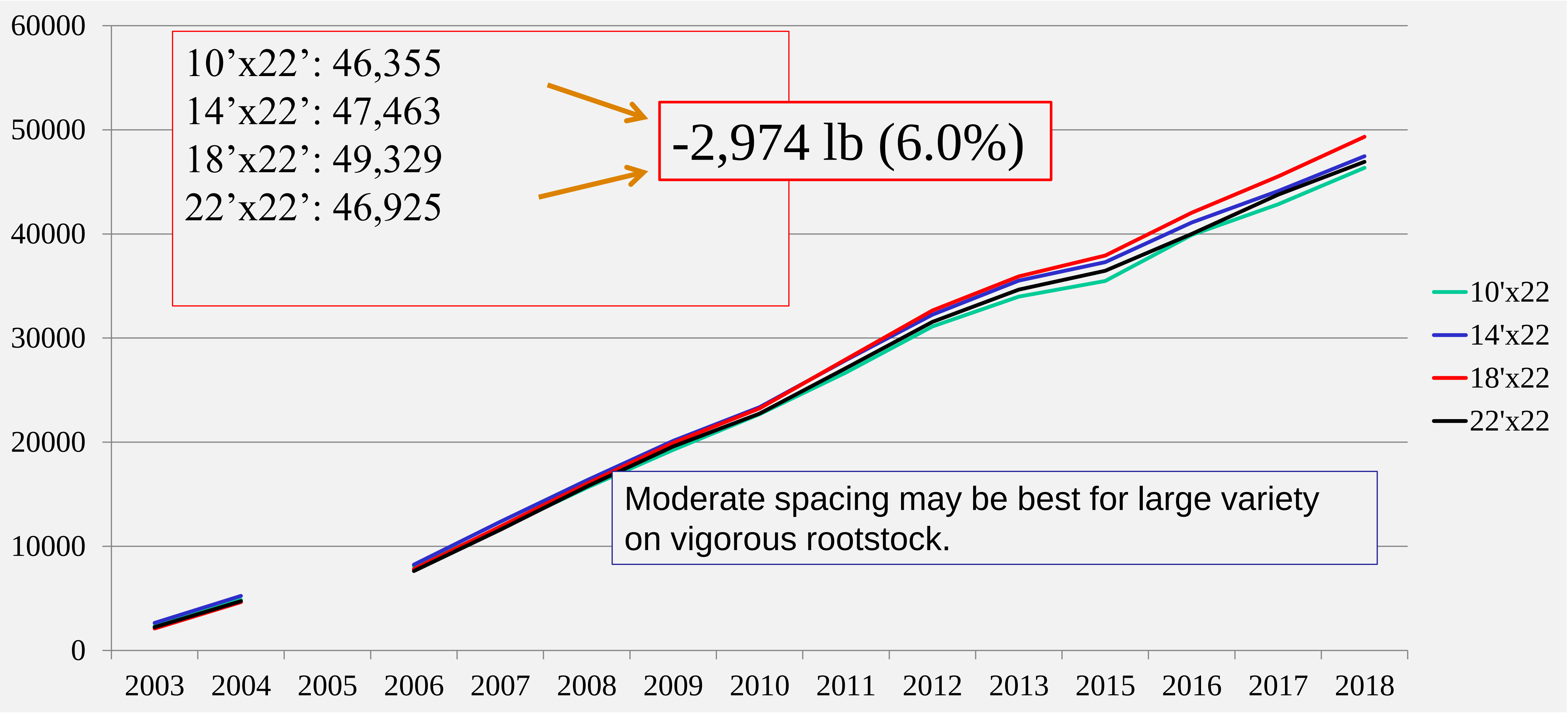


10’ x 22’: 46,481 lb / a
14’ x 22’: 45,778 lb / a
18’ x 22’: 44,193 lb / a
22’ x 22’: 41,291 lb / a

2,288 lb (+5.2%)

The Effect of Tree Spacing on Cumulative Yield Through 19th Leaf

Nonpareil on Hansen



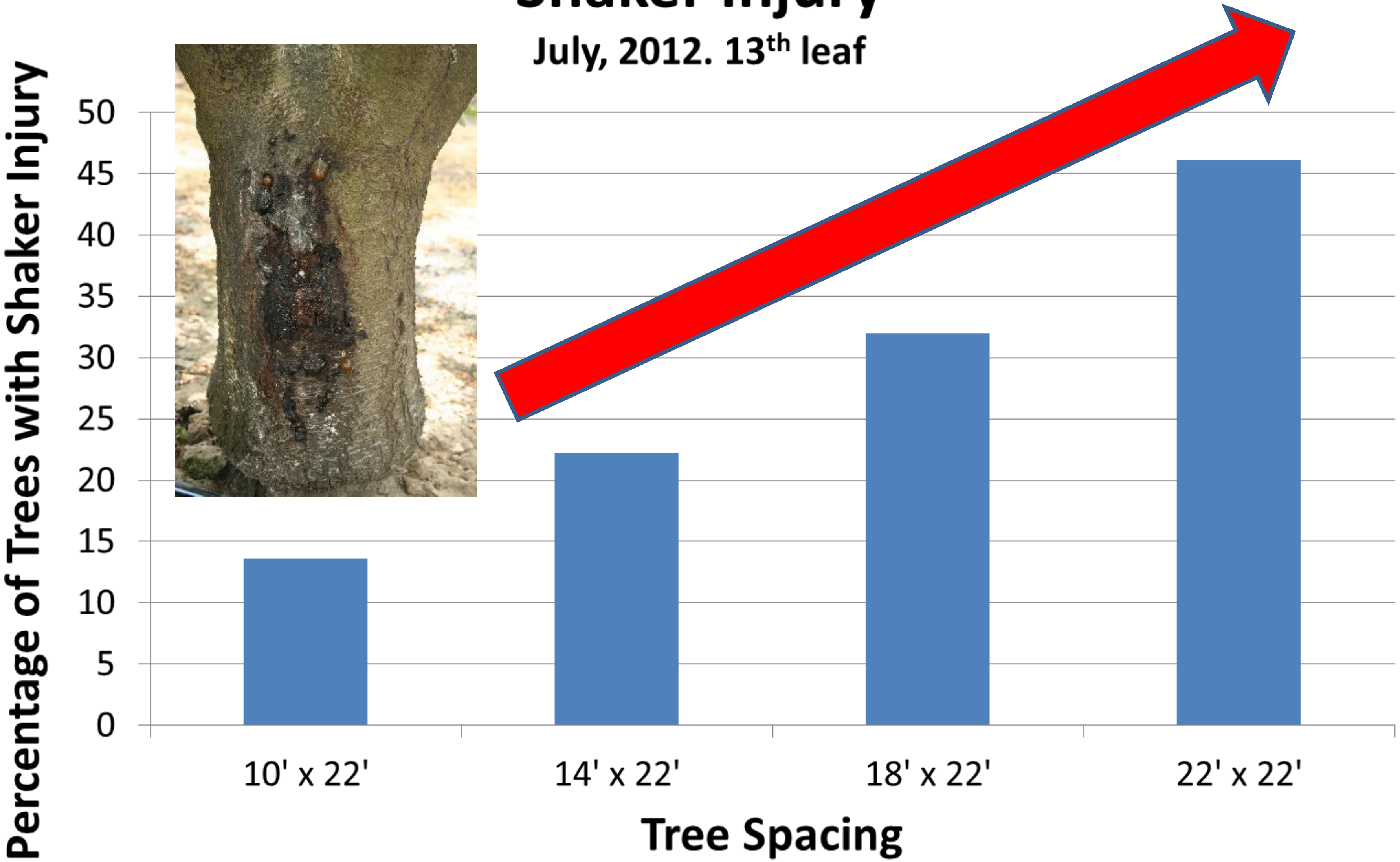
10’x22’: 46,355
14’x22’: 47,463
18’x22’: 49,329
22’x22’: 46,925

-2,974 lb (6.0%)

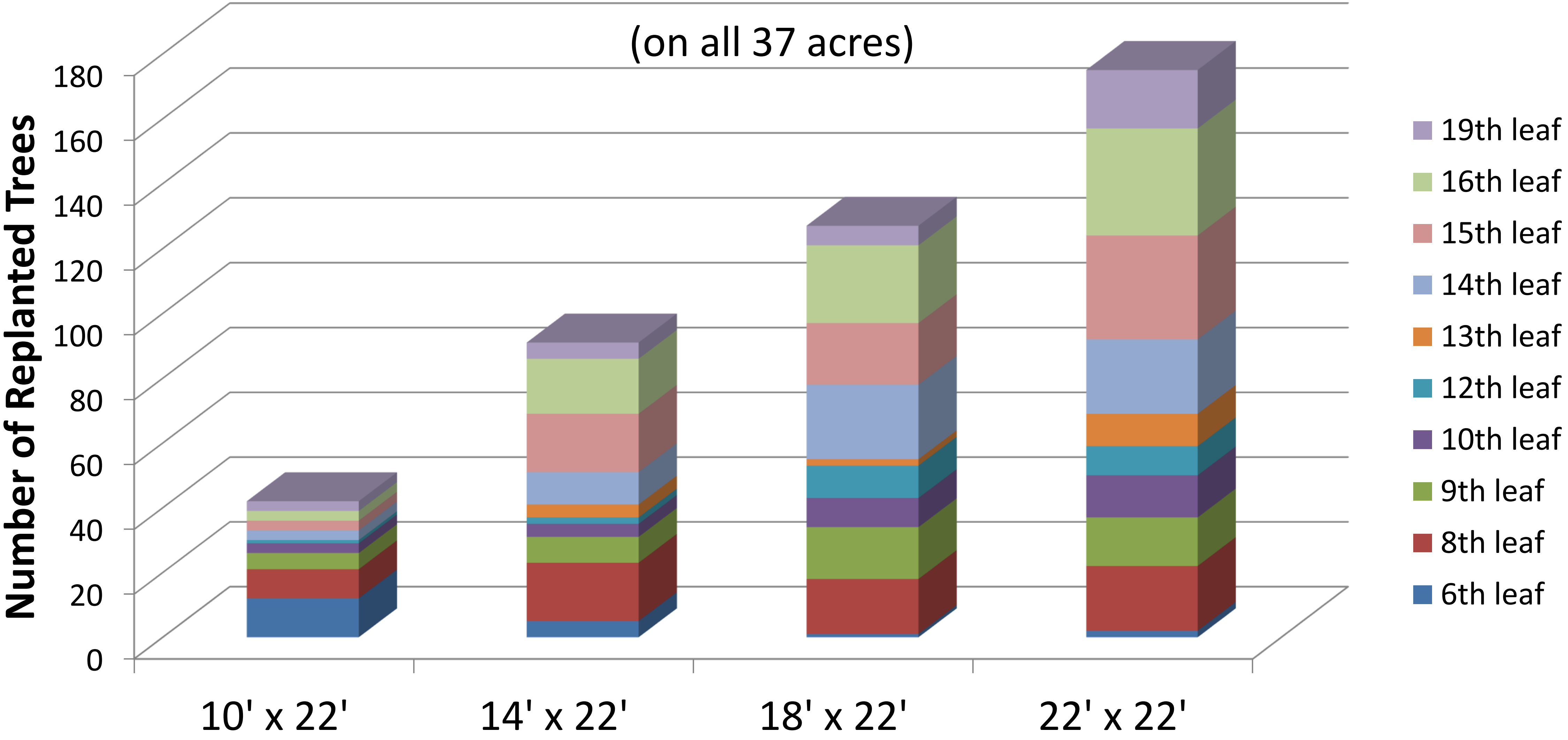
Moderate spacing may be best for large variety on vigorous rootstock.

The Effect of Tree Spacing on Trunk Shaker Injury

July, 2012. 13th leaf



The Influence of Tree Spacing on the Number of Replanted Trees



(on all 37 acres)

The Influence of Tree Spacing on Missing Canopy

	Cumulative Number of Replants	Square Footage of Missing Canopy
10 x 22	42	9,240
14 x 22	91	28,028
18 x 22	127	50,292
22 x 22	175	84,700

Through the 19th leaf

Effect of Tree Density on Yield to Date:

- Yield advantage to tighter spacing is highly dependent on inherent tree vigor
  - Smaller trees (varieties, rootstocks, etc.) will benefit most from tight spacing
  - Benefit may persist throughout orchard’s life
  - Vigorous trees may not have higher yields at higher density.
  - Photosynthetically active canopy is the goal, not the number of trunks per acre
- Advantages other than yield (smaller trees, fewer structural problems, less pruning, easier to shake, fewer mummies, etc.)
- Perhaps more risk of planting too wide than too close??

1) Standard trained, standard annual pruning

- 3 scaffolds
- medium annual pruning to maintain open centers

2) Standard trained, unpruned after 2^{nd} dormant

- 3 scaffolds
- unpruned after second dormant season

3) Minimally trained, “minimally” pruned

- 4-6 scaffolds
- 3 pruning cuts annually

4) Untrained & “unpruned" forever

- Limbs interfering with machinery removed

Standard trained & pruned vs. Untrained & unpruned.

End of 3^{rd} Season.

Untrained,
unpruned
Nonpareil
22’ x 22’

Year 19

The Effect of Pruning on 2018 (19th Leaf) & Cumulative Yield

	Nonpareil		Carmel	
	2018 Yield (lb. / a)	Cumulative	2018 Yield (lb. / a)	Cumulative
Training & Pruning Strategy				
Trained to 3 scaffolds; Annual, moderate pruning	2998 a	41,326	2461 b	38,851
Trained to 3 scaffolds; Unpruned after 2nd year	3080 a	42,237	2784 ab	41,732
Trained to multiple scaffolds; Three annual pruning cuts	2901 a	39,739	2591 ab	40,780
No scaffold selection; No annual pruning	3004 a	42,278	2801 a	43,274

The Effect of Pruning on 2018 (19th Leaf) Nonpareil Yield in High Density Trees (10’ x 22’) on Hansen Rootstock

	Nonpareil
	2018 Yield (lb. / a)
Training & Pruning Strategy	
Trained to 3 scaffolds; Annual, moderate pruning	3099 b
Trained to 3 scaffolds; Unpruned after 2nd year	3733 ab
Trained to multiple scaffolds; Three annual pruning cuts	3329 ab
No scaffold selection; No annual pruning	3873 a

Effect of Pruning on Yield to Date

- Pruning has not increased or even sustained yield in the short or long term. Pruning has either had no significant effect or has reduced yield.

- 19 years x $275 pruning / shredding costs = $5225

- Decrease in yield by about 1000 to 3500 pounds = loss of ~$2500 - $9000 / acre
  - Cumulative loss from annual pruning likely $7,500 - $14,000 / acre

Remarks on Pruning

- In every UC trial ever conducted, pruning has NEVER, EVER increased yield. That includes hand pruning, mechanical pruning, every year, every other year, topping, hedging, in the short term or over 25 years.
- Sometimes pruning is needed for safety, equipment access, removing broken and dead branches, limb cankers, etc.
- Best to train trees for good structure and then abandon pruning
- Reason to prune should justify expense, potential yield loss and your fengshui

Thank you for your Attention

See you at the posters 3:00 – 5:00

Roger Duncan
209-525-6800

raduncan@ucdavis.edu

University of California
Agriculture and Natural Resources

Almond Culture & Orchard Management

- **Farm Advisor**
- **Counties**
- **Poster #**

Project Objectives:

Significant Findings:

❖

❖

Five small projects conducted throughout state by farm advisors

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Yield Effects of Mechanically Topping 2nd Leaf Almonds

- Dani Lightle
- Orchard Systems Advisor
- UCCE Glenn, Butte & Tehama
- Poster #80

Project Objectives:

- Determine whether mechanical topping during 2nd dormant affect 3rd and 4th leaf almond yields
  - All trees had scaffold selection and balancing cuts performed by hand crews
  - Mechanically topped trees flat-topped at 9 ft. height in Nov. 2016

Mechanically topped tree (left)
Untopped tree (right)
April 2017

Yield Effects of Mechanically Topping 2nd Leaf Almonds

- **Dani Lightle**
- **Orchard Systems Advisor**
- **UCCE Glenn, Butte & Tehama**
- **Poster #80**

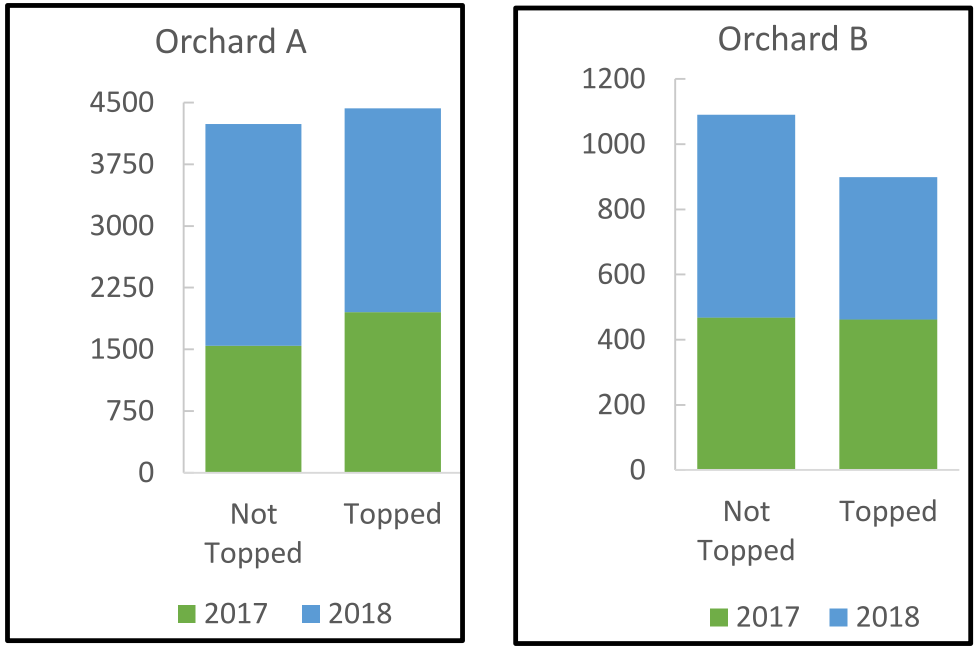
Project Objectives:

❖ **Determine whether mechanical topping during 2nd dormant affect 3rd and 4th leaf almond yields**

Significant Findings:

❖ **No yield benefit or loss observed in either year**

❖ **Treatments did not impact likelihood of getting band canker or losses from windthrow**



Nonpareil Yield / Acre

No Significant Yield Differences

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Tree Growth Response to Wood Mulch in a Newly Established Orchard

- **Mae Culumber**
- **Farm Advisor**
- **Fresno County**
- **Poster Location**

Project Objectives:

- Determine how a wood chip application rate of 85-90 tons/acre impacts establishment of young almond trees
- Monitor soil biological and chemical shifts to identify mechanisms of nutritional deficiencies in trees planted with wood chips or other agricultural waste products

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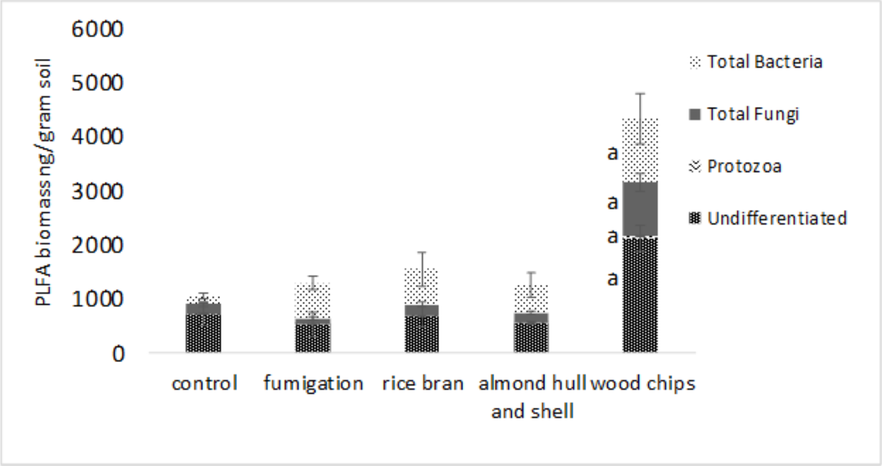
- Monitor soil biological and chemical shifts to identify mechanisms of nutritional deficiencies in trees planted with wood chips or other agricultural waste products

Significant Findings:

- Higher total soil microbial biomass and fungal to bacterial ratios in wood mulch suggests the carbon rich amendment is stimulating microbial activity and development of communities that can assimilate cellulose and lignin in wood
- Higher soil NH_4^+-N levels with wood mulch may indicate lower nitrification potential



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Does Fall Nitrogen Application Improve Almond Yields?

- **Franz Niederholzer**
- **Orchard Systems Farm Advisor**
- **UCCE Colusa, Yuba, Sutter**
- **Poster #105**

Project Objectives:

- **Determine the yield impacts of fall applications (Sept or Oct) of ammonium sulfate on productive, mature ‘Nonpareil’ and ‘Aldrich’ trees under micro-irrigation.**
  - **Applications applied September 14 (‘Nonpareil’ and ‘Aldrich’ or October 28, 2017 (‘Nonpareil’, only)**
  - **Rates examined = 0 and 30 lb N/acre**

Ammonium sulfate @ 30 lb N/a.
‘Nonpareil’ trees.
September 14, 2017

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Does Fall Nitrogen Application Improve Almond Yields?

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- Orchard Systems Farm Advisor
- UCCE Colusa, Yuba, Sutter
- Poster #105

Project Objectives:

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  - Applications applied September 14 ('Nonpareil' and 'Aldrich' or October 28, 2017 ('Nonpareil', only)
  - Rates examined = 0 and 30 lb N/acre

Significant Findings:

- Fall, 2017 N fertilization did not change 2018 yield in 'Nonpareil' or 'Aldrich' trees.
- These results are consistent with 'Nonpareil' findings in 2015/16 and 2016/17 studies with mid-October application timings.

Ammonium sulfate @ 30 lb N/a.
'Nonpareil' trees.
September 14, 2017

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Almond Bloom Disease Fungicide Efficacy Trial

- **Brent Holtz**
- **UC Farm Advisor**
- **San Joaquin County**
- **Poster #34**

Brown Rot, Shot Hole, Scab Bloom Diseases

- Fungicides are commonly sprayed on almond trees during bloom to prevent brown rot and scab disease.
- Treatments of Aproach, Fontelis, Abound, Bumper, Indar, Merivon, Quadris Top, Bravo, Tebuconazole, Pyraziflumid, and experimental products from Dow/DuPont, Syngenta, and Nichino, along with organic treatments Microthiol Disperse, Regalia and Serenade, were applied to almond trees during bloom to prevent disease.
- Most treatments significantly reduced the incidence and severity of scab.
- Not enough brown rot was observed to rate because of cold temperatures during bloom.


Scab symptoms

Effects of Rice Herbicide Drift on Almonds

- **Mariano Galla**
- **Weed Science Advisor**
- **UCCE Glenn, Butte and Tehama**
- **Poster # 24**

Project Objectives:

- **Evaluate the effects of bispyribac-sodium (Regiment®) drift on first-leaf almond growth and development**
- **Compare growth of trees exposed to drift only one year to that one of trees exposed to simulated drift two consecutive years**

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Effects of Rice Herbicide Drift on Almonds

- Mariano Galla
- Weed Science Advisor
- UCCE Glenn, Butte and Tehama
- Poster # 24

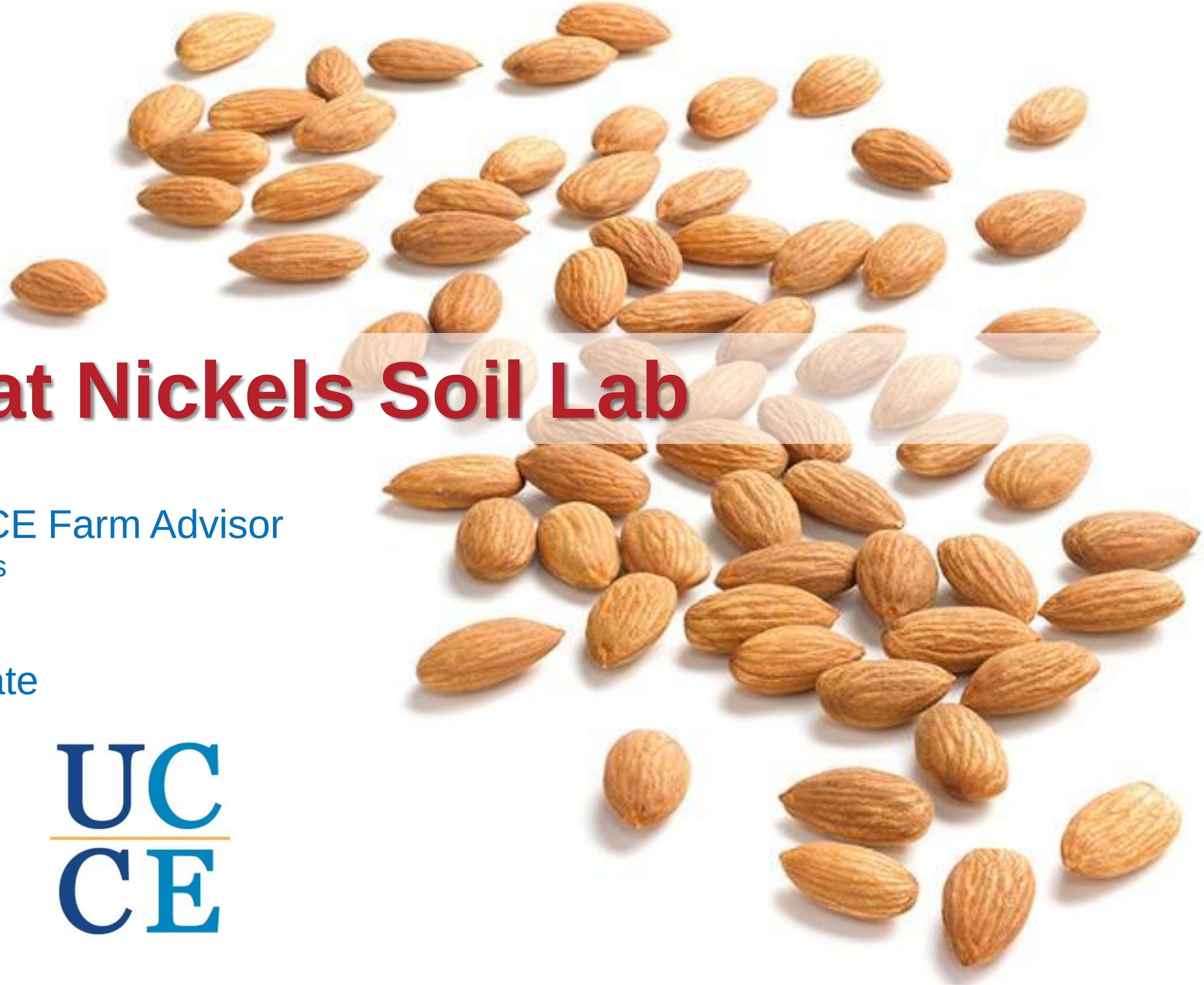
Project Objectives:

- Evaluate the effects of bispyribac-sodium (Regiment®) drift on first-leaf almond growth and development
- Compare growth of trees exposed to drift only one year to that one of trees exposed to simulated drift two consecutive years

Significant Findings:

- Simulated drift rates caused leaf yellowing, chlorotic spotting and internode length shortening, but almond trees started to recover in approximately 3 weeks
- Half of the treated trees will be exposed to simulated drift in summer 2019

Research at Nickels Soil Lab



Franz Niederholzer, UCCE Farm Advisor
Colusa and Sutter/Yuba Counties
@Hwy20Orchardoc

Stan Cutter, Nickels Estate
Farm Manager

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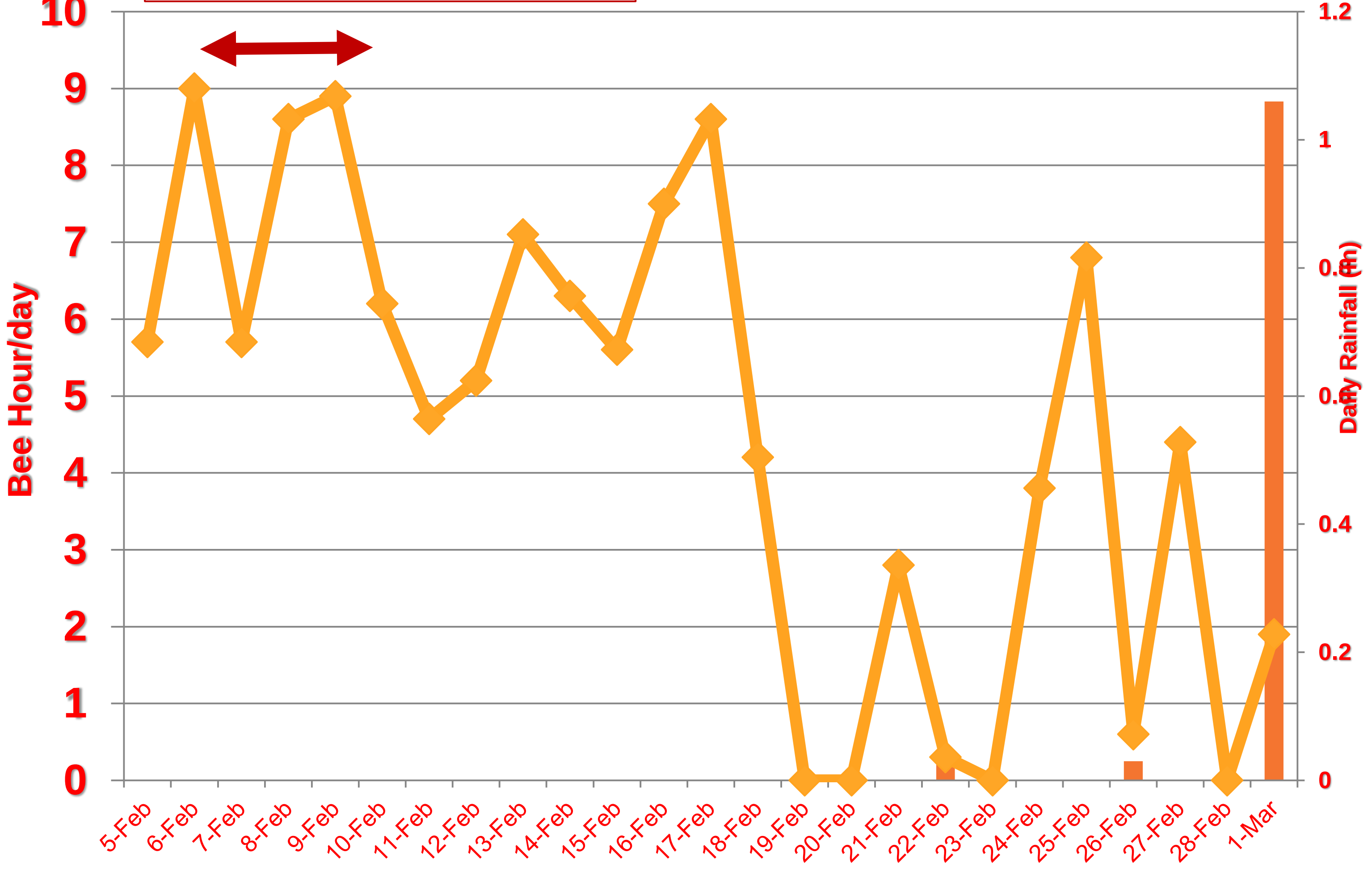
Major projects at Nickels & year planted

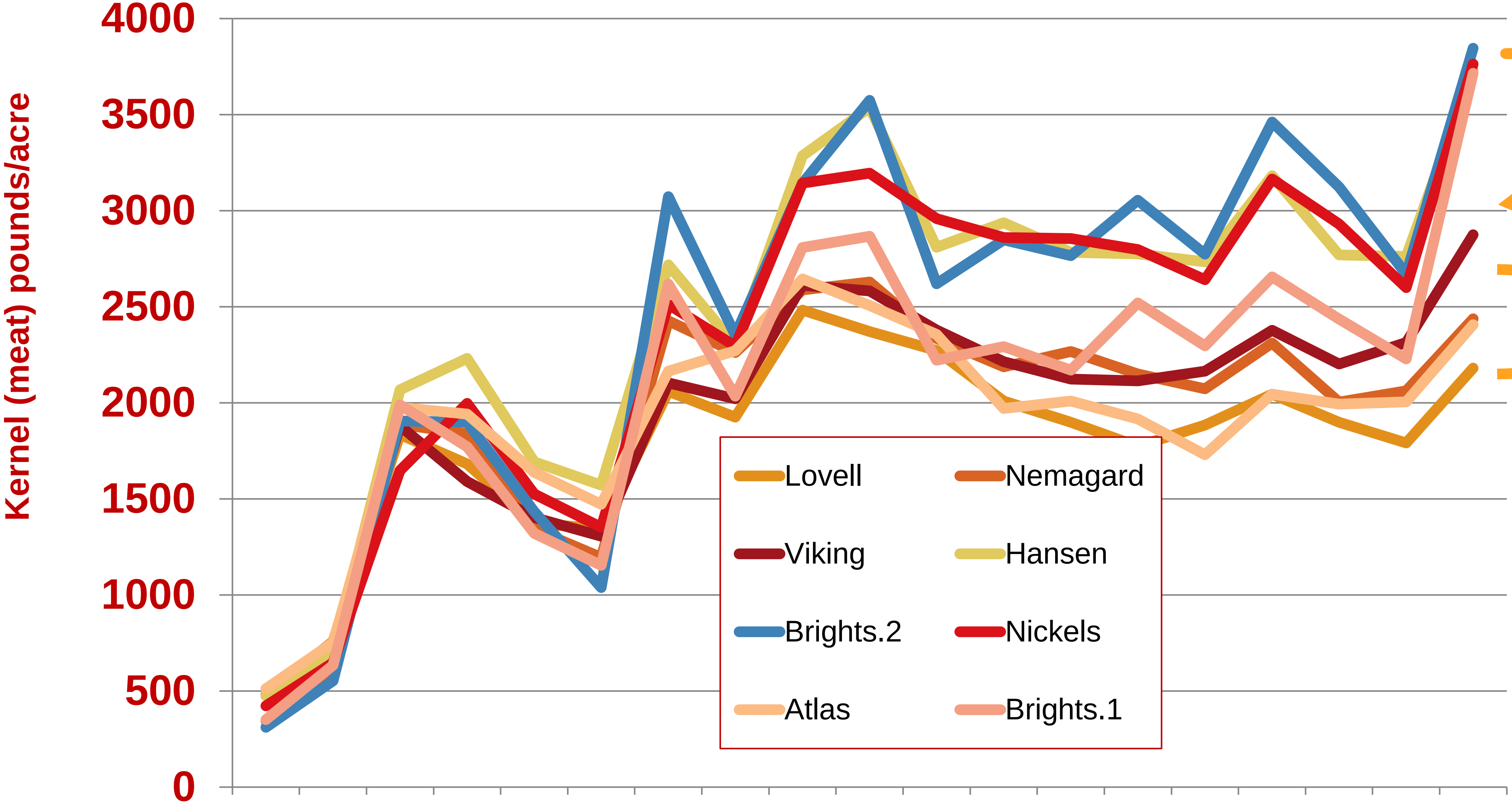
- Rootstocks: peach, peach/almond hybrids, plum and plum hybrids (1997, 2006, 2008)
- Pruning (1997)
- Nonpareil pollinator groups (2006)
- Organic demo (2006)
- Self-fertile vs high value NP planting (2013)
- Planting density down-the-row (2017)
- Orchard recycling, 2 rates ± fumigation (2019)

Warm, dry bloom followed by cold/freeze affected set.

Nonpareil bloom



Peach/almond hybrid rooted Nonpareil produced very well in perfect early bloom, 2018.

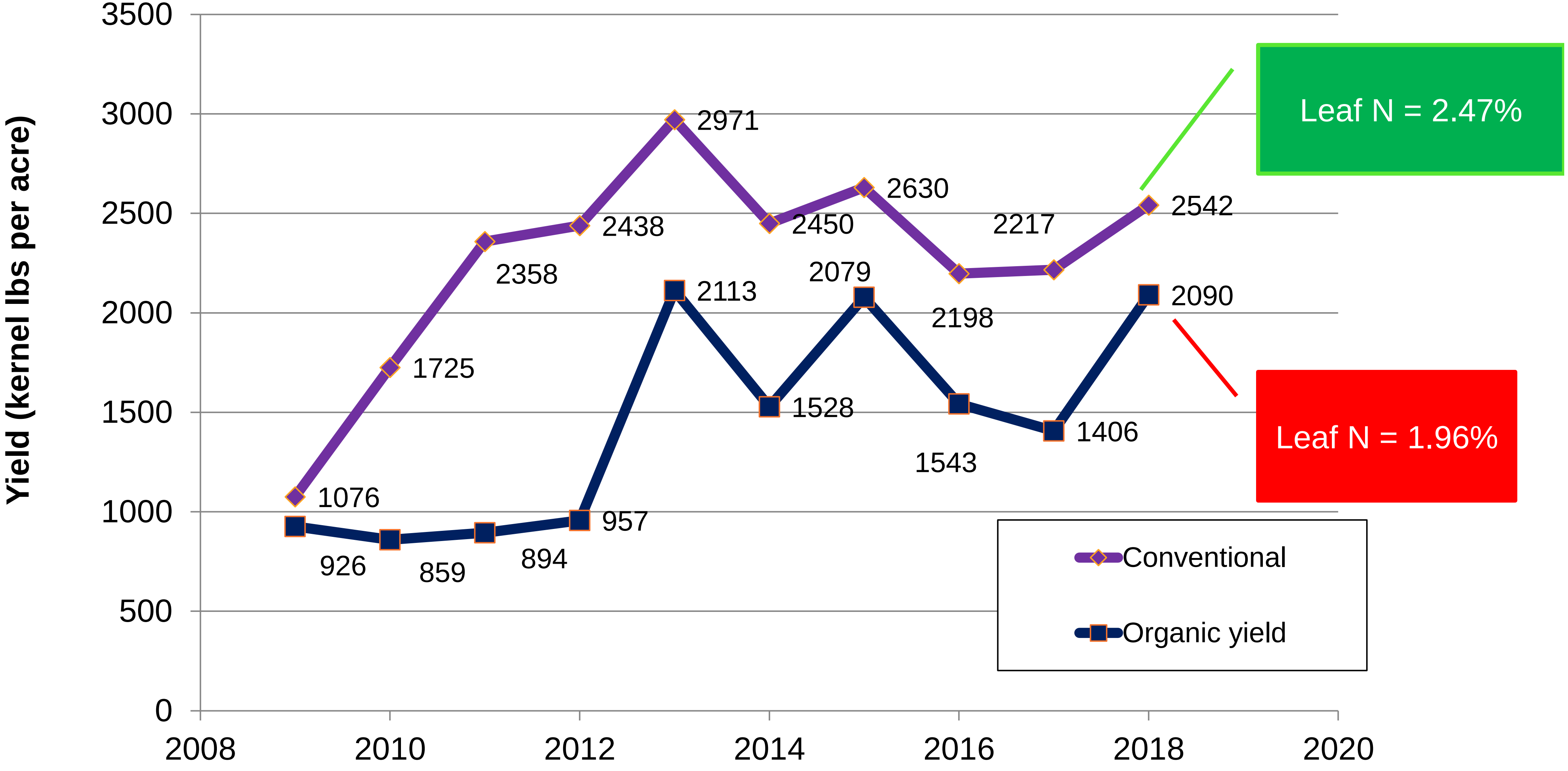


Hansen 536
Bright's
Nickels

Viking

Nemaguard
Atlas
Lovell

Average production, Organic/Conventional Demo block, 4-13th leaf



Leaf N = 2.47%

Leaf N = 1.96%

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Pollinizer selection did not influence Nonpareil yield, again.

Variety Group	Rep 1	Rep 2	Rep 3	Ave*
A.Fritz/Nonpareil/Monterey	2825	2861	2832	2839
B.Winters/Nonpareil/Aldrich	3320	3168	2836	3108
C.Winters/Nonpareil/Monterey	3007	3169	2785	2987

*No significant statistical difference at 5% (Duncan's HSD)

Thank you!

More info:

Poster 81

Carbohydrate Observatory

Physiology of carbohydrate management in trees

Maciej Zwieniecki (Dr. Who? Dr. ‘Z’)

Anna Davidson, Aude Tixier

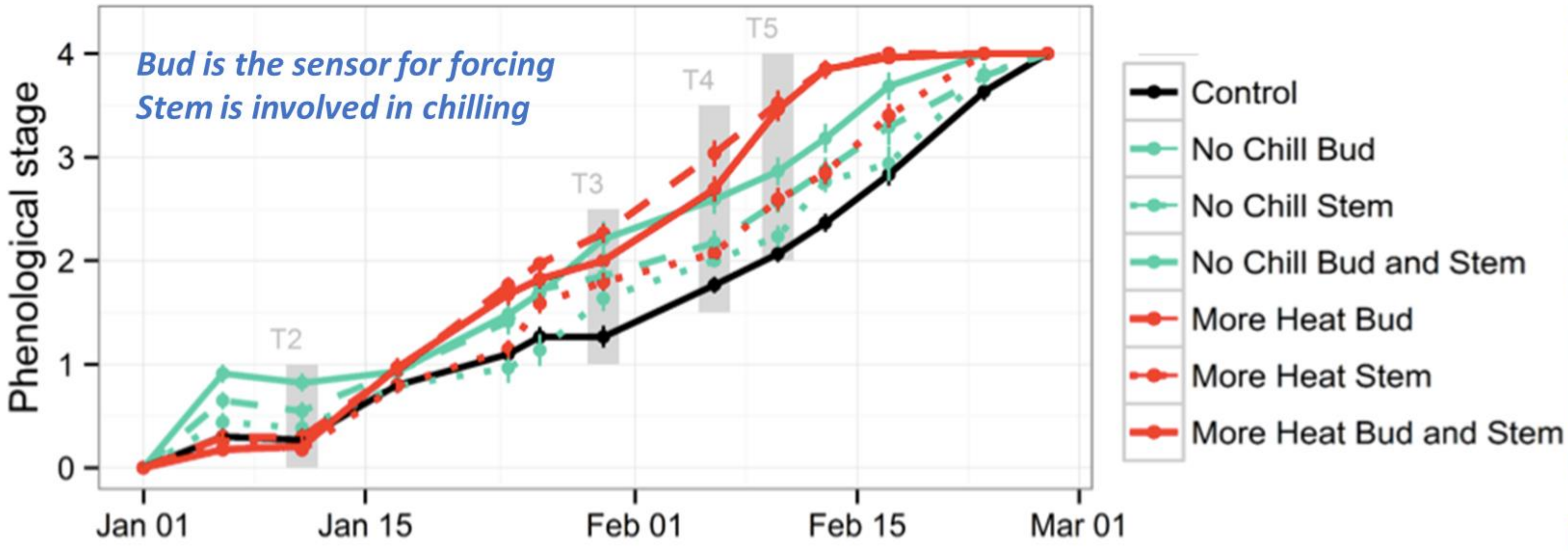
california almonds®
Almond Board of California

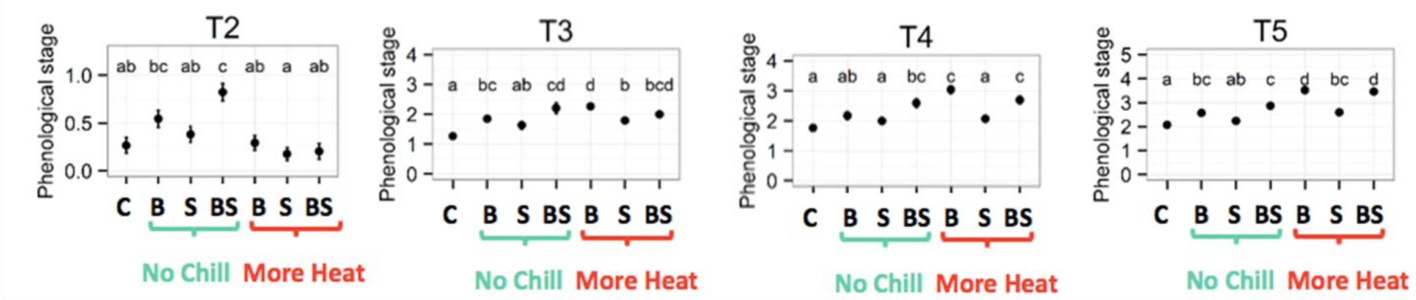
Lab

Three major research areas

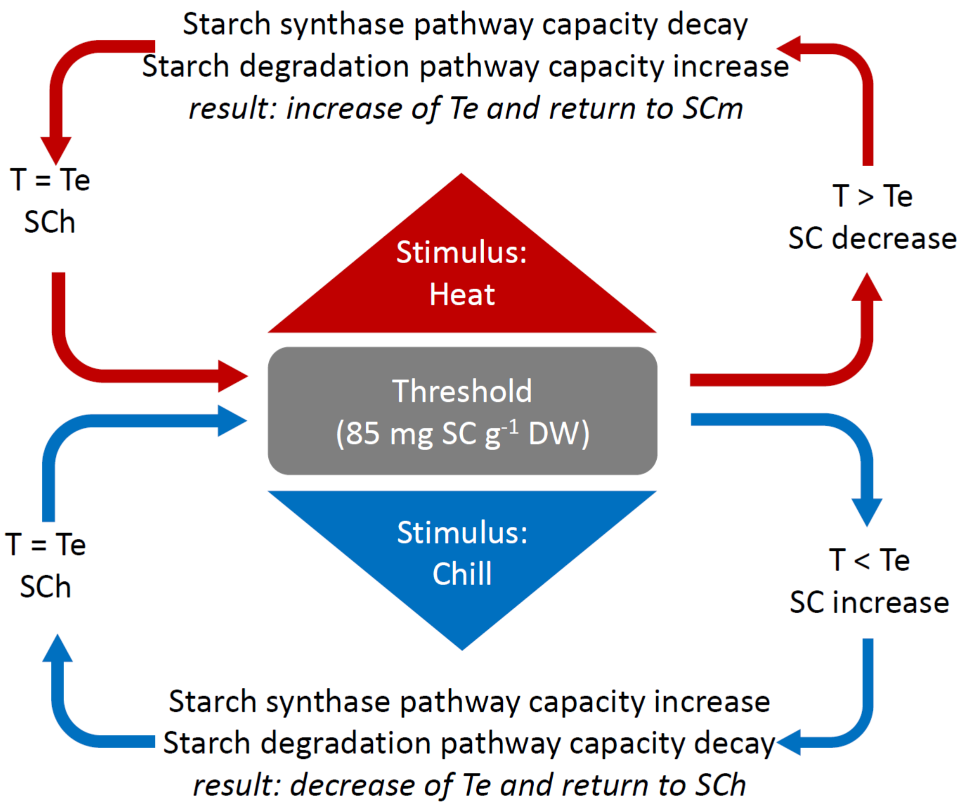
- Physiology and biology of dormancy
- Mechanistic (process based) modeling bloom time
- Analysis of seasonal pattern of NSC (sugars and starch) content in Almond trees (**Carbohydrate Observatory**)

Physiology and biology of dormancy


Bud is the sensor for forcing
Stem is involved in chilling



Mechanistic (process based) modeling bloom time



Starch synthase pathway capacity decay
Starch degradation pathway capacity increase
result: increase of Te and return to SCm

T = Te
SCh

T > Te
SC decrease

Stimulus: Heat

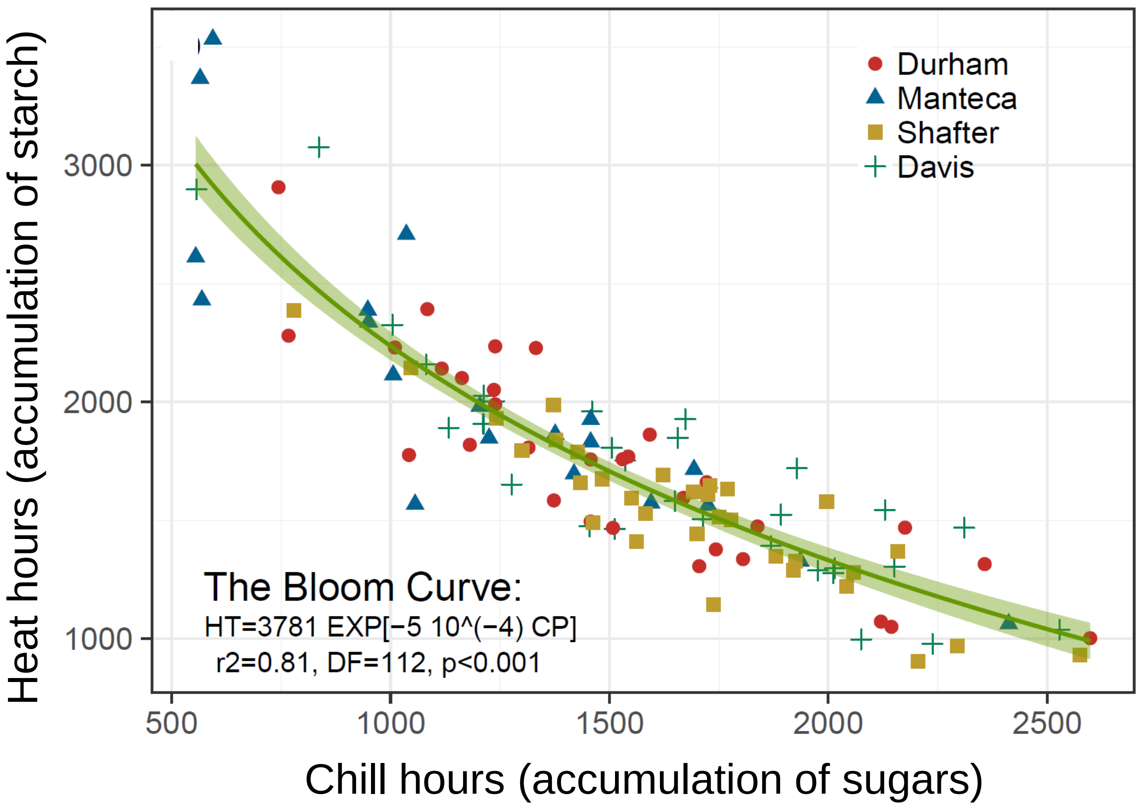
Threshold
(85 mg SC g^{-1} DW)

Stimulus: Chill

T = Te
SCh

T < Te
SC increase

Starch synthase pathway capacity increase
Starch degradation pathway capacity decay
result: decrease of Te and return to SCh



The Bloom Curve:
HT=3781 EXP[−5 10^(−4) CP]
r2=0.81, DF=112, p<0.001

Understanding dormancy – path forward

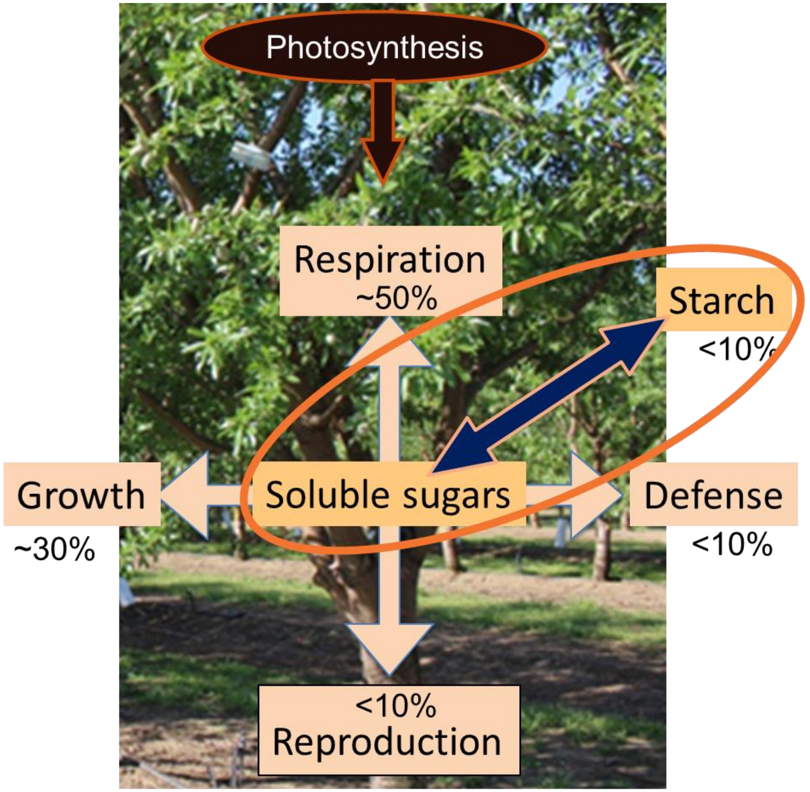
Science

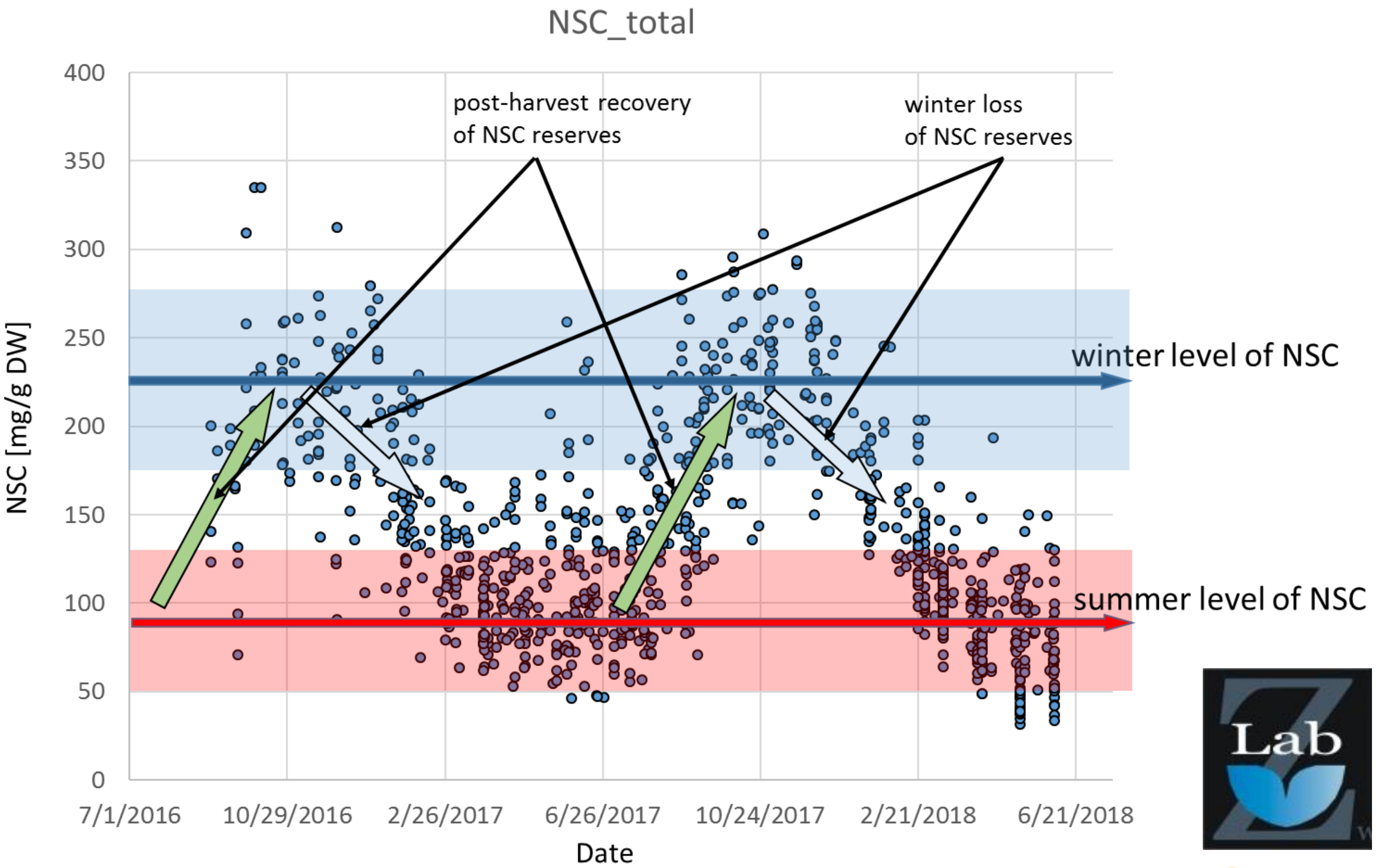
- Genetics of dormancy – discovery of signaling paths
- Metabolism of dormancy – discovery of metabolic thermal memory
- Physiology of dormancy – characterization of physiological parameters affecting dormancy

Applications

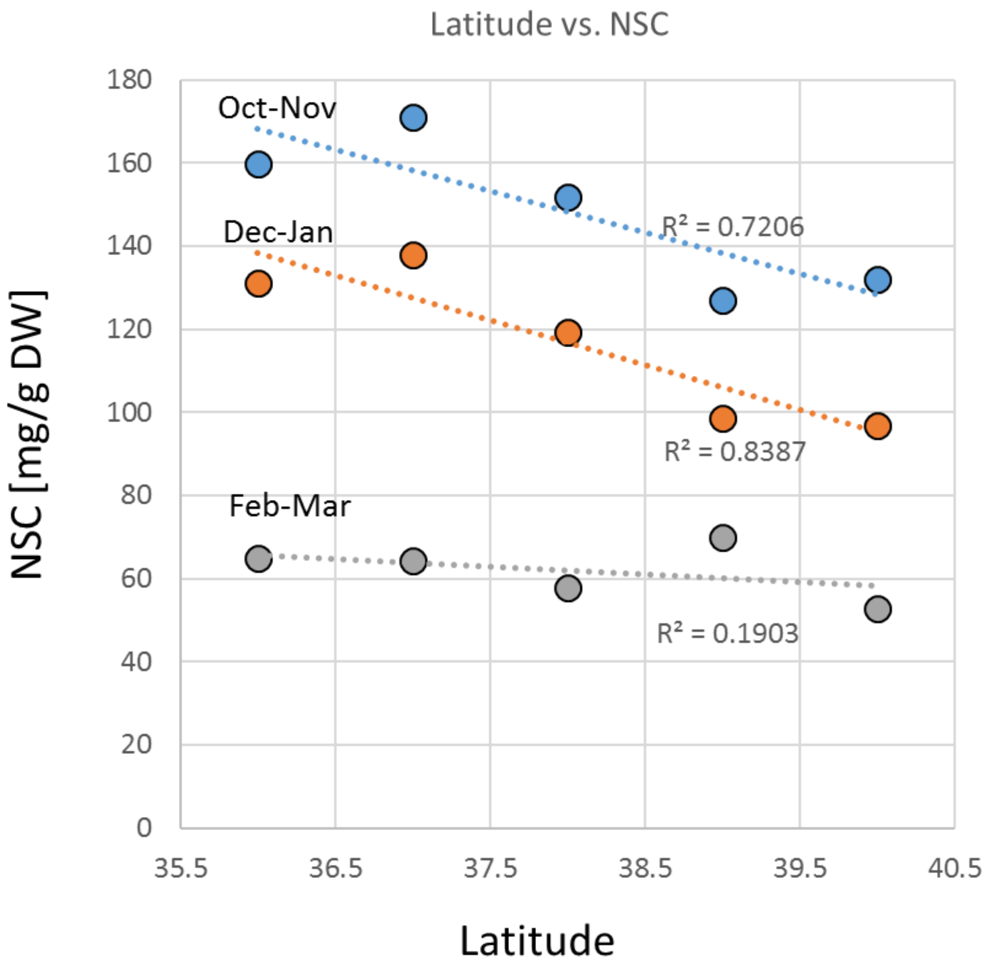
- Generation of dormancy progression models for predicting bloom time
- Designing genetic/metabolic tool kits for analysis of tree readiness for bloom
- Providing know-how for management based activity that affects dormancy length
- Specifying metabolic targets for breeding efforts to adapt to chilling requirements for specific areas

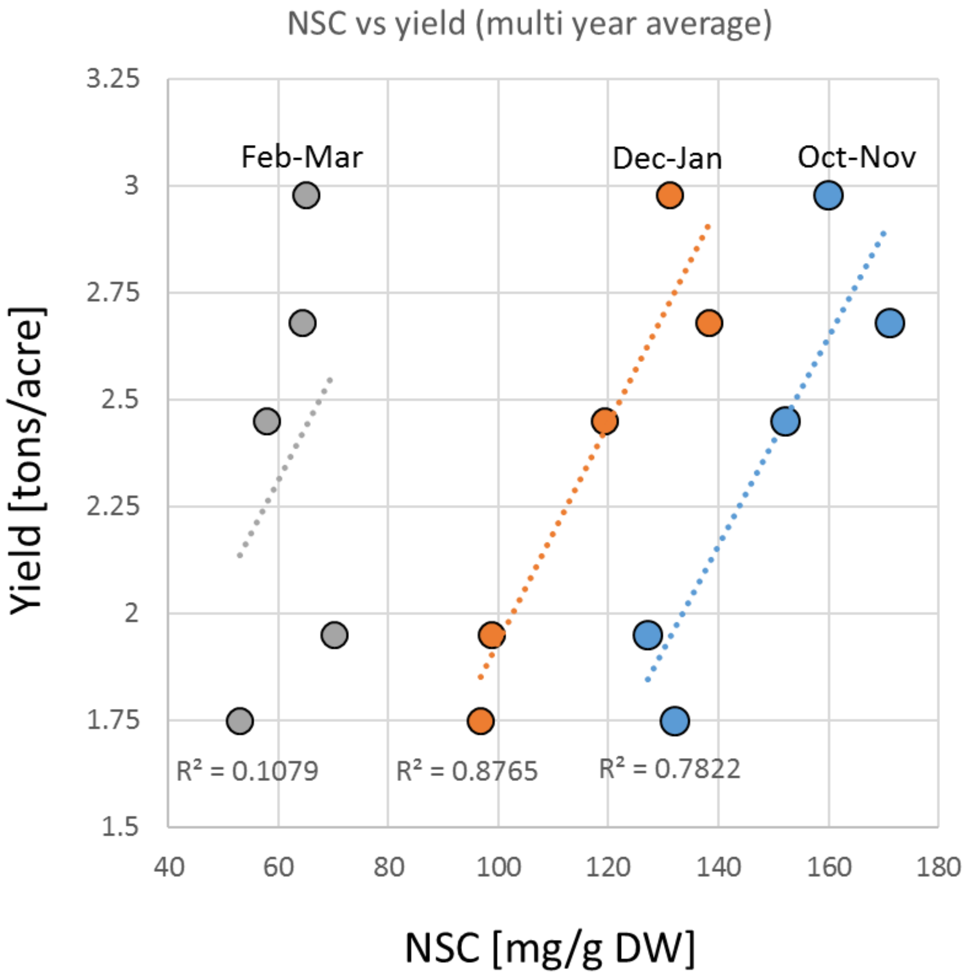
Carbohydrate Observatory Analysis of seasonal pattern of NSC (sugars and starch)





Carbohydrate Observatory Analysis of seasonal pattern of NSC (sugars and starch)





Carbohydrate Observatory

Science

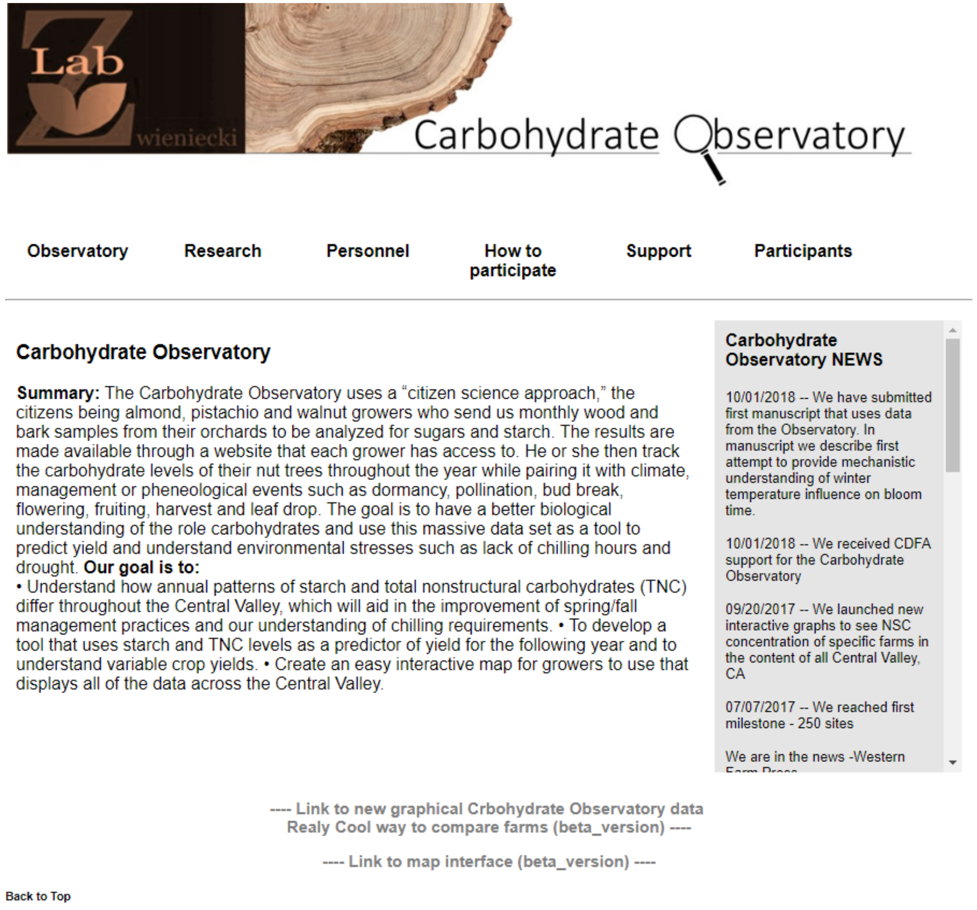
- Determination of management practices on carbohydrate metabolism and physiology General health of orchards
- Characterization of thermal/drought/biotic stresses on tree carbohydrate management/storage
- How to manage orchard for NSC?

Applications

- Characterizing specific varieties of NSC based performance (yield) in relation to environment, management, salinity etc.
- Near real-time information on NSC orchard status to assist in management especially during postharvest and dormancy periods
- Provide information for precision physiology based agriculture

https://zlab-carb-observatory.herokuapp.com/

Carbohydrate Observatory



Carbohydrate Observatory

Summary: The Carbohydrate Observatory uses a “citizen science approach,” the citizens being almond, pistachio and walnut growers who send us monthly wood and bark samples from their orchards to be analyzed for sugars and starch. The results are made available through a website that each grower has access to. He or she then track the carbohydrate levels of their nut trees throughout the year while pairing it with climate, management or pheneological events such as dormancy, pollination, bud break, flowering, fruiting, harvest and leaf drop. The goal is to have a better biological understanding of the role carbohydrates and use this massive data set as a tool to predict yield and understand environmental stresses such as lack of chilling hours and drought. **Our goal is to:**
• Understand how annual patterns of starch and total nonstructural carbohydrates (TNC) differ throughout the Central Valley, which will aid in the improvement of spring/fall management practices and our understanding of chilling requirements. • To develop a tool that uses starch and TNC levels as a predictor of yield for the following year and to understand variable crop yields. • Create an easy interactive map for growers to use that displays all of the data across the Central Valley.

Carbohydrate Observatory NEWS

10/01/2018 -- We have submitted first manuscript that uses data from the Observatory. In manuscript we describe first attempt to provide mechanistic understanding of winter temperature influence on bloom time.

10/01/2018 -- We received CDFA support for the Carbohydrate Observatory

09/20/2017 -- We launched new interactive graphs to see NSC concentration of specific farms in the content of all Central Valley, CA

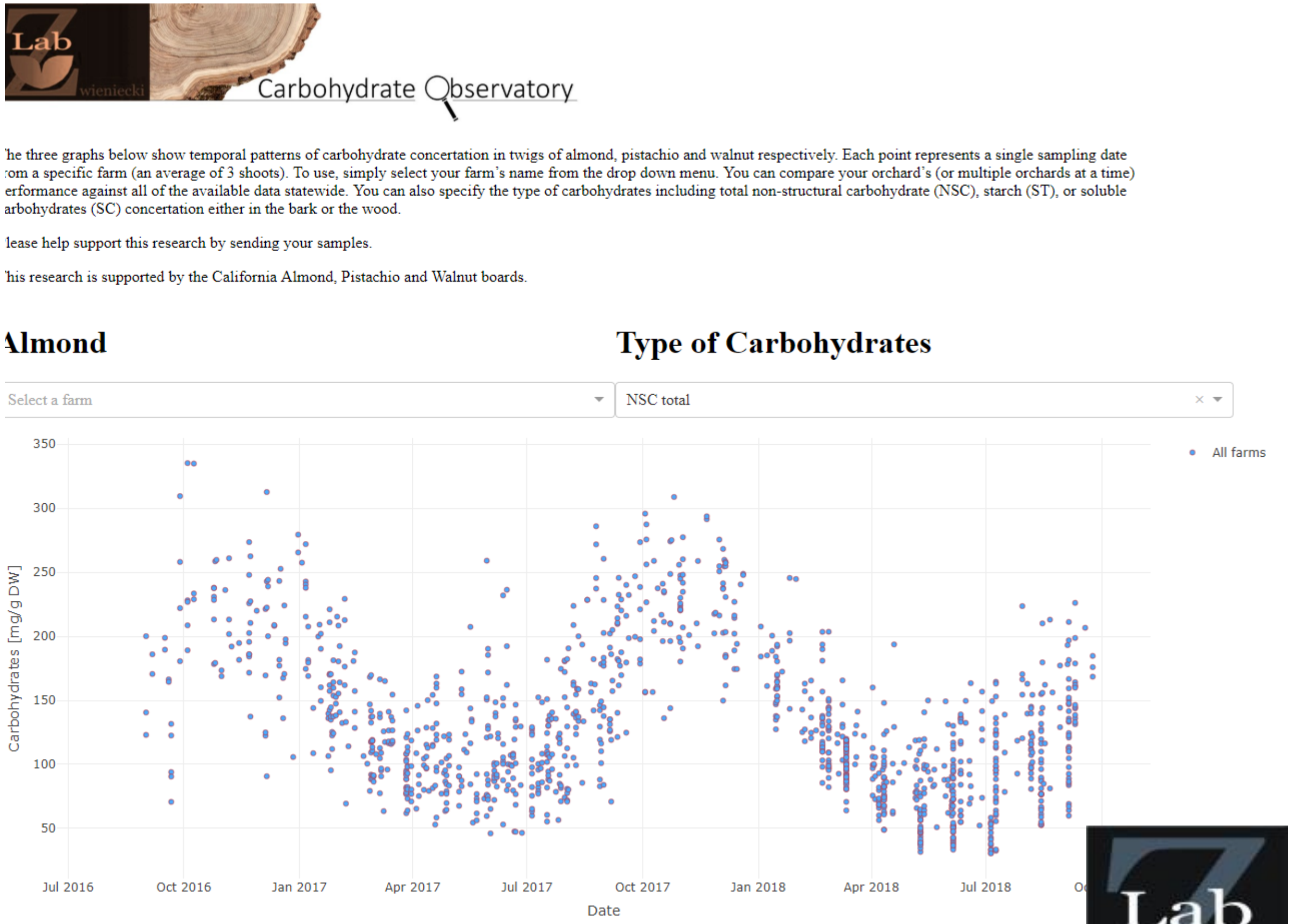
07/07/2017 -- We reached first milestone - 250 sites

We are in the news -Western

---- Link to new graphical Crbohydrate Observatory data
Realy Cool way to compare farms (beta_version) ----

---- Link to map interface (beta_version) ----

Back to Top



he three graphs below show temporal patterns of carbohydrate concertation in twigs of almond, pistachio and walnut respectively. Each point represents a single sampling date rom a specific farm (an average of 3 shoots). To use, simply select your farm’s name from the drop down menu. You can compare your orchard’s (or multiple orchards at a time) erformance against all of the available data statewide. You can also specify the type of carbohydrates including total non-structural carbohydrate (NSC), starch (ST), or soluble arbohydrates (SC) concertation either in the bark or the wood.

lease help support this research by sending your samples.

his research is supported by the California Almond, Pistachio and Walnut boards.

lmond

Type of Carbohydrates

Select a farm

NSC total

https://psfaculty.plantsciences.ucdavis.edu/plantsciences_faculty/zwieniecki/CR/cr.html

Carbohydrate observatory

Please Participate

Send samples – use your $$$ contribution to the Almond Board

Contact Anna Davidson

Email: adavidson@ucdavis.edu

Phone: (815) 212-4409

Thank you!

Impact of Irrigation Patterns and Canopy Management on Root Development

Astrid Volder, Paul Martinez & Bruce Lampinen

Department of Plant Sciences, UC Davis, UC ANR Cooperative Extension

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Almond Board of California

Importance of fine roots

- Primarily responsible for nutrient and water uptake
- High respiration and costly for plant to maintain
- Form depletion zones in soil – need to keep renewing and exploring new zones to acquire nutrients
- Lose N uptake capacity with age

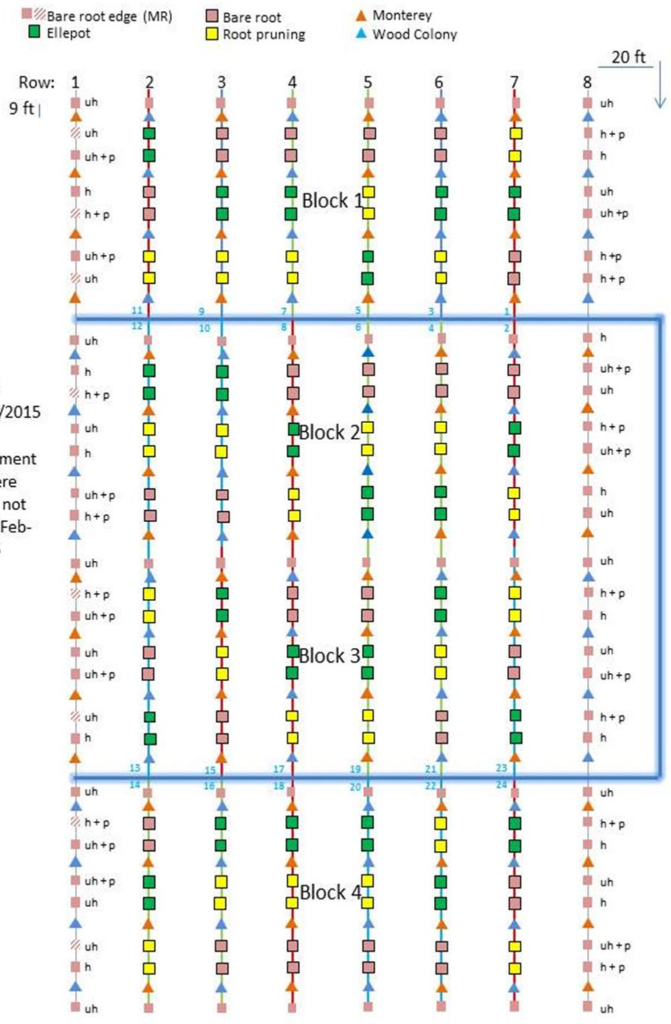
➢ So, when planting, is a “finer” root system a “better” root system?

Questions

- How does heading/pruning at planting affect initial root system establishment?
- Establishment success after transplanting from bare root versus pot grown
  - tree water status & growth
  - do we see more roots in pot grown trees?
- How does canopy pruning affect root production, lifespan and depth distribution?
- Impact of irrigation

Design

- Nonpareil almond on Krymsk 86 rootstock planted Feb 2015
    - Bare root versus root pruning pot versus ellepot – rootstocks produced from cuttings, grafted in nursery
    - Pairs of trees, one pruned, one unpruned – pruning treatment start spring 2016, pruning maintained spring 2017 and spring 2018
    - Three irrigation treatments started May 2016 – well watered (100%), 85% and 70%
- Interspersed with either Wood Colony or Monterey as pollinizer, all on Krymsk 86
- Each pot x irrigation x pruning treatment replicated twice within four blocks (8 trees total)
- Edge trees used to test impact of heading & pruning at planting versus no management (bare root trees)



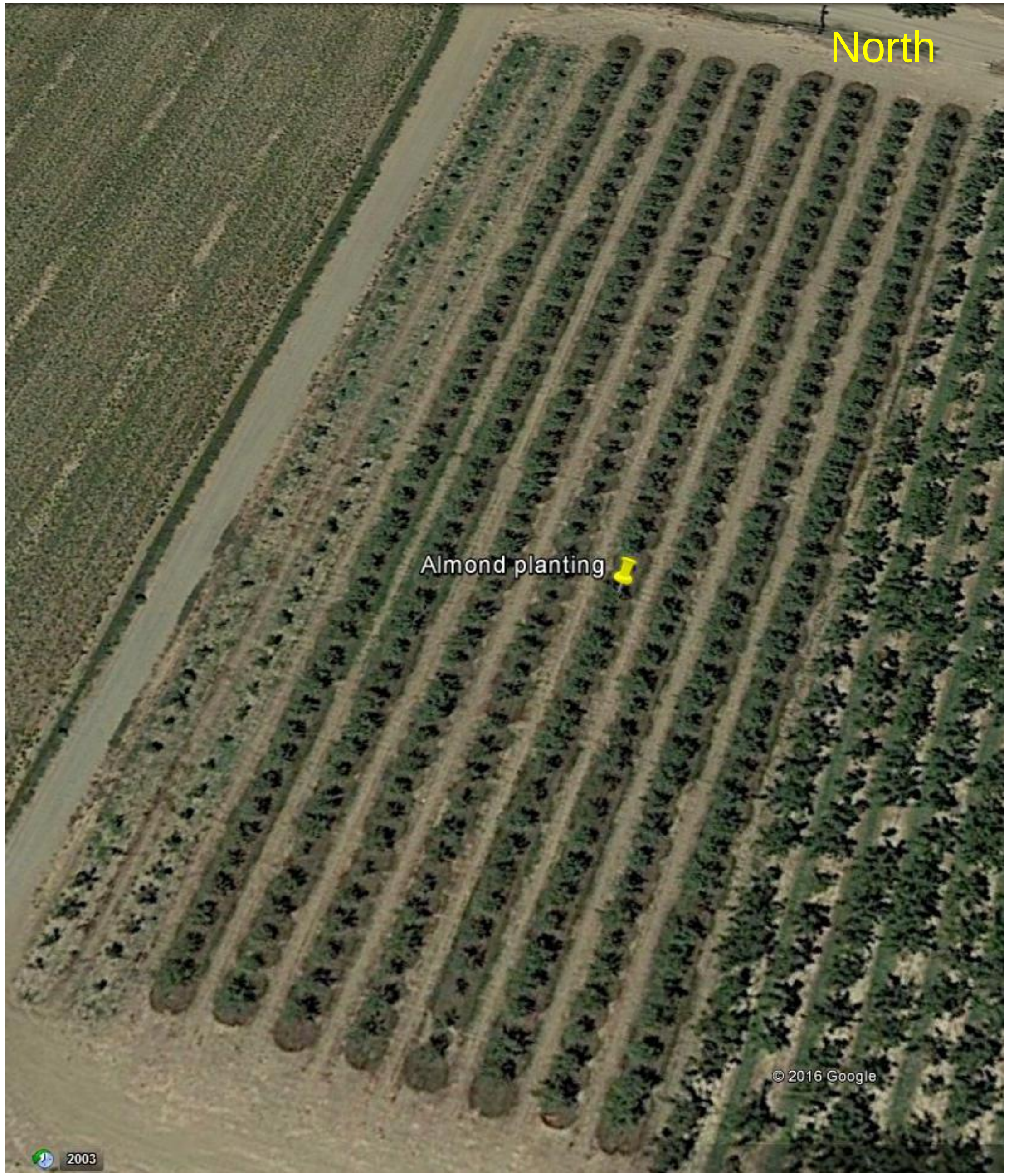
Planted Feb/2-3/2015

All treatment rows were pruned, not headed Feb-14-2015

h = headed @ 32"
p = all branches removed

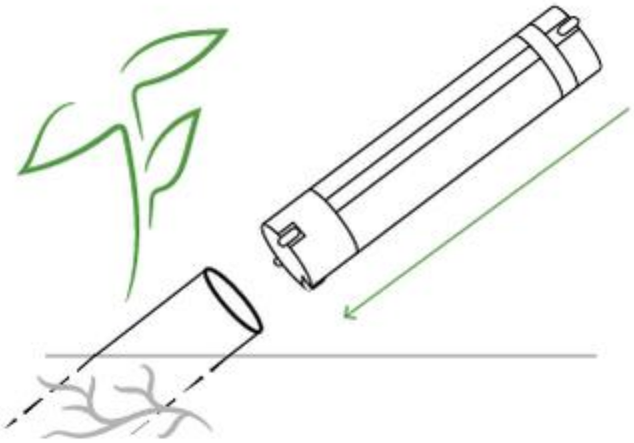
Headed / pruned
Feb-14-2015

Rows 15 ft wide, trees spaced at 9 ft within row

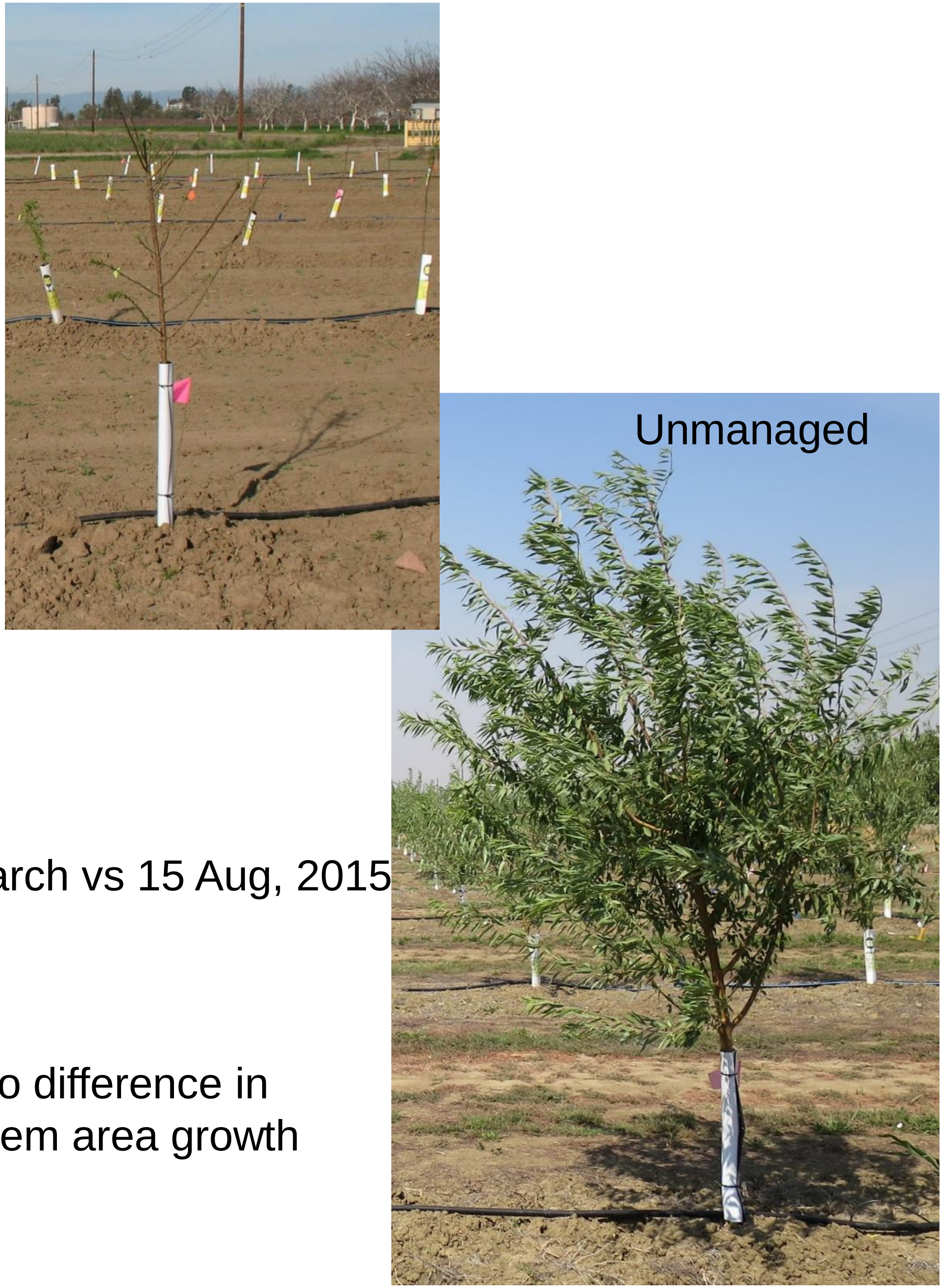


Expt 1 – impact of heading & pruning at planting

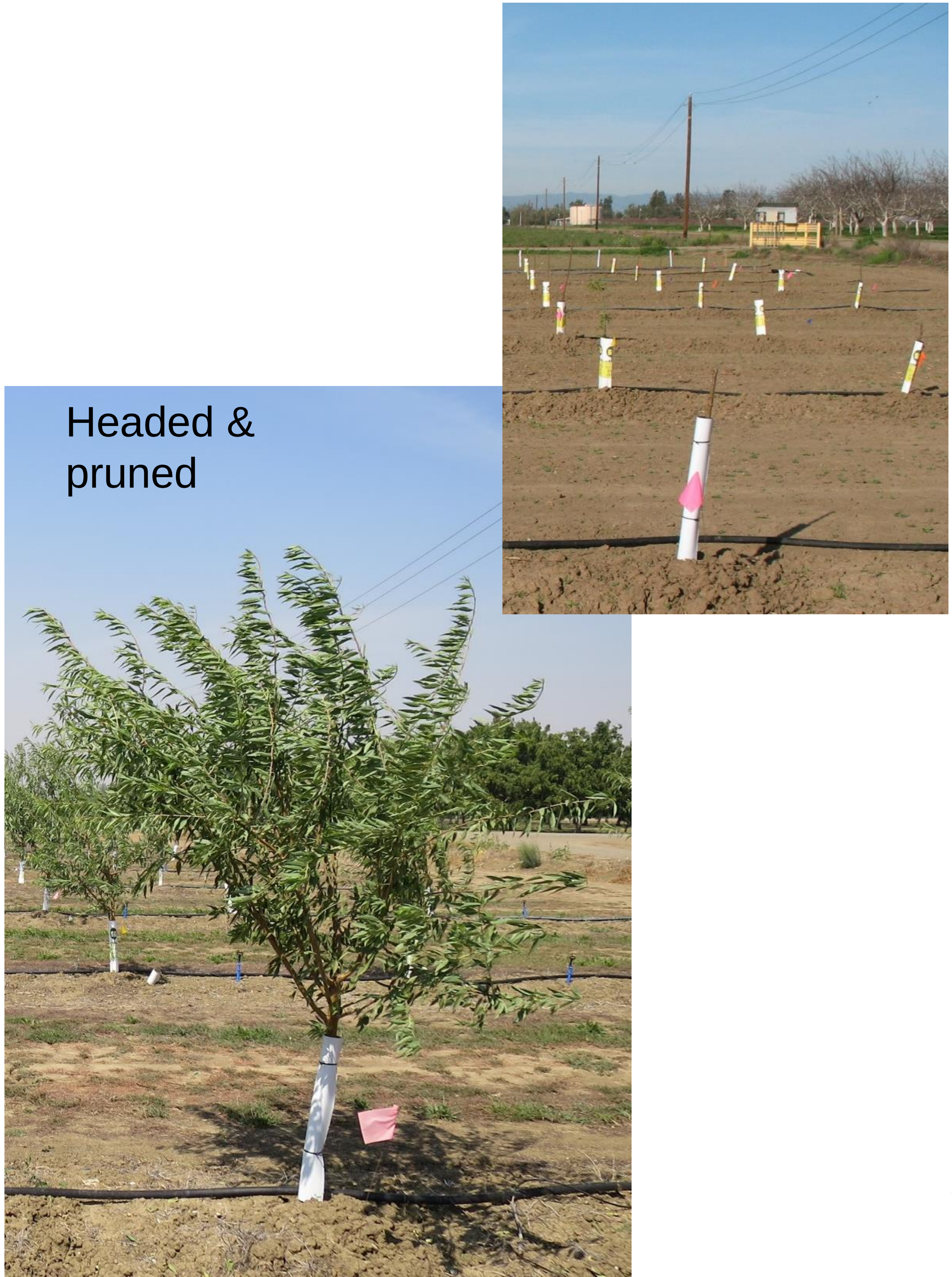
- Planted Feb 2-3, 2015
- Headed and pruned Feb 14, 2015
- Root observation tubes installed March 2015
- Observations started May 2015 – images collected weekly until Nov 2015



CID bioscience root scanner



Unmanaged



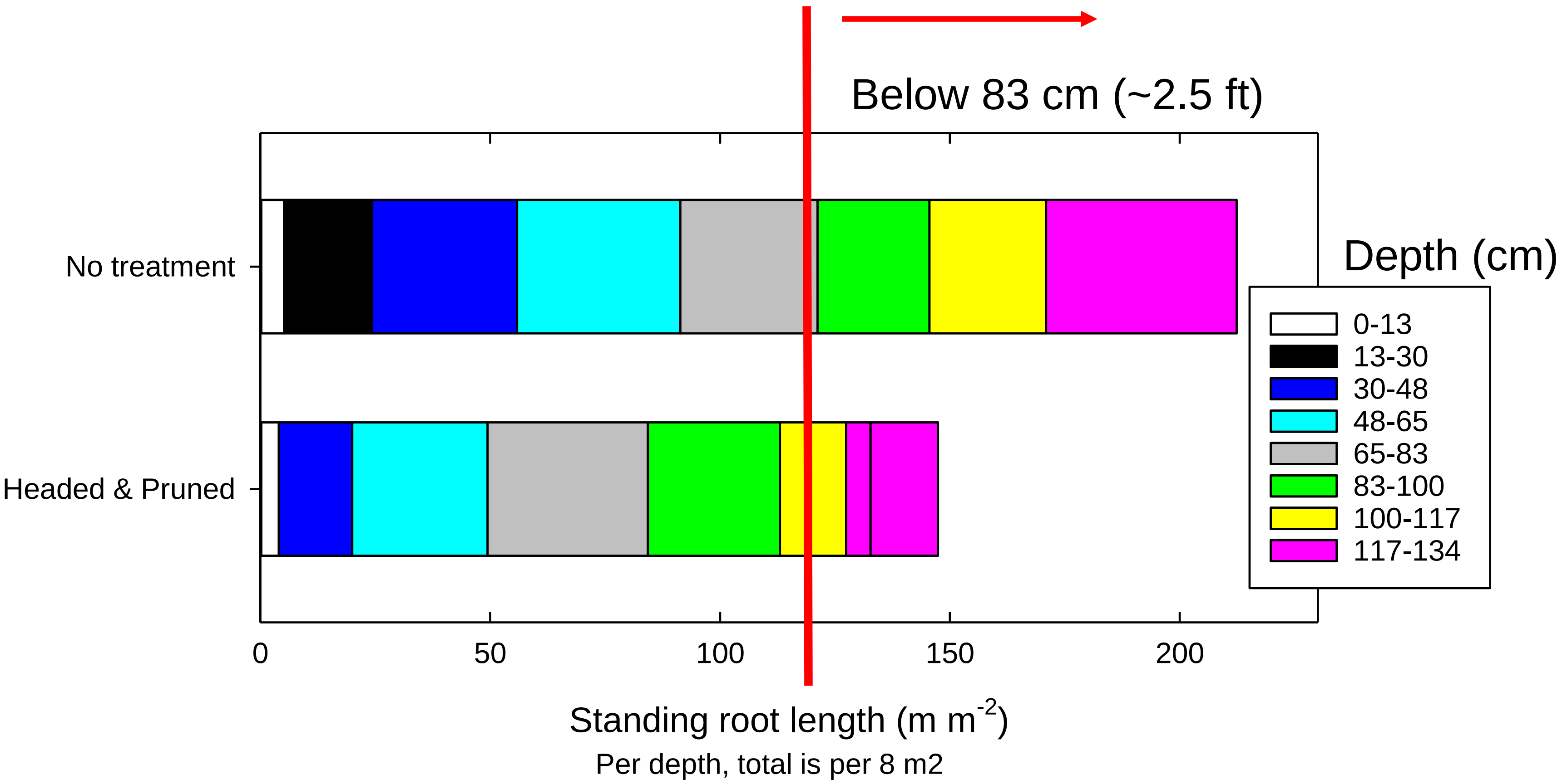
Headed &
pruned

8 March vs 15 Aug, 2015

No difference in
stem area growth

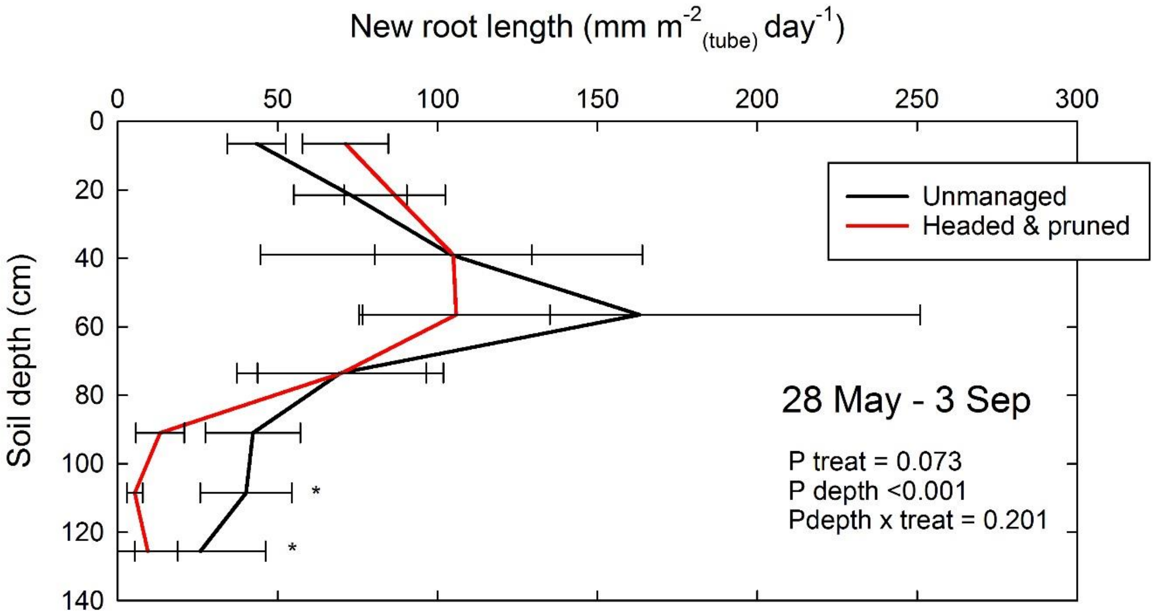
Root growth immediately after planting

Trees planted Feb 3
Treatments imposed Feb 14

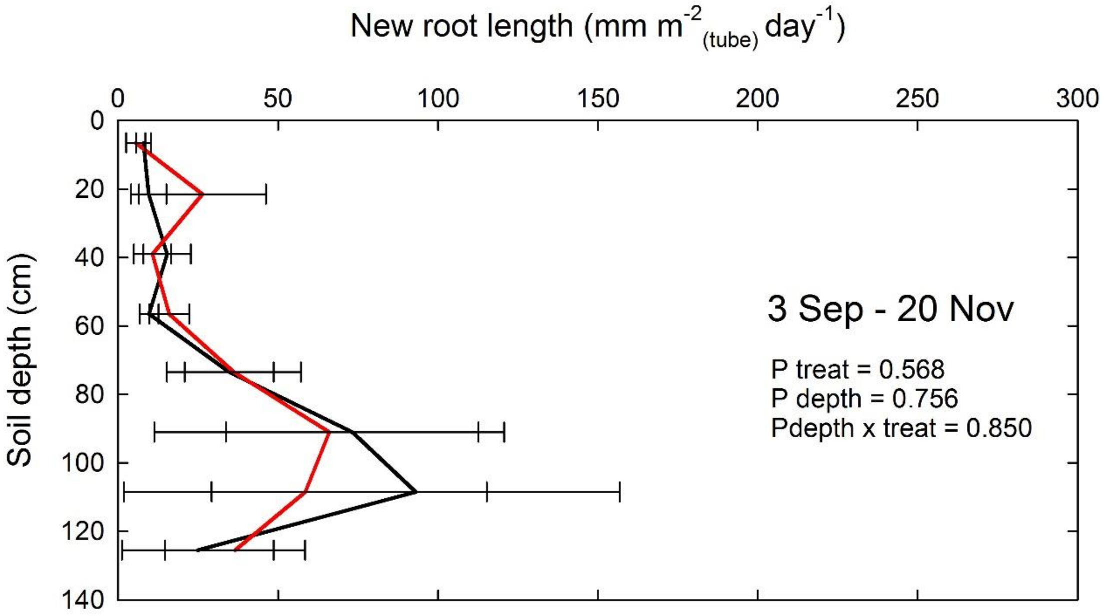


114 days after planting (May 28, 2015), standing root length was less at depth in the headed/pruned trees

Summer:
Peak root length production 0-75 cm (approximate depth of irrigation)



Fall:
Peak root length production below 75 cm (warmer?)



Trees that were not headed had greater root production at depth in the 8 months after establishment

Main expt – irrigation, pruning, production method

- How do irrigation, pruning and production affect plant water status and aboveground growth
- How do irrigation, pruning and production affect fine root production patterns
  - New roots
  - Root death
  - Root lifespan
  - Seasonality
  - Depth distribution

bare root

Switch from bare root production to pot grown trees
“Better” root system?

Does pruning reduce root production or accelerate root death?

Mar 2015

(no heading)

Sep 2015

pruning

April 2016

Sep 2016

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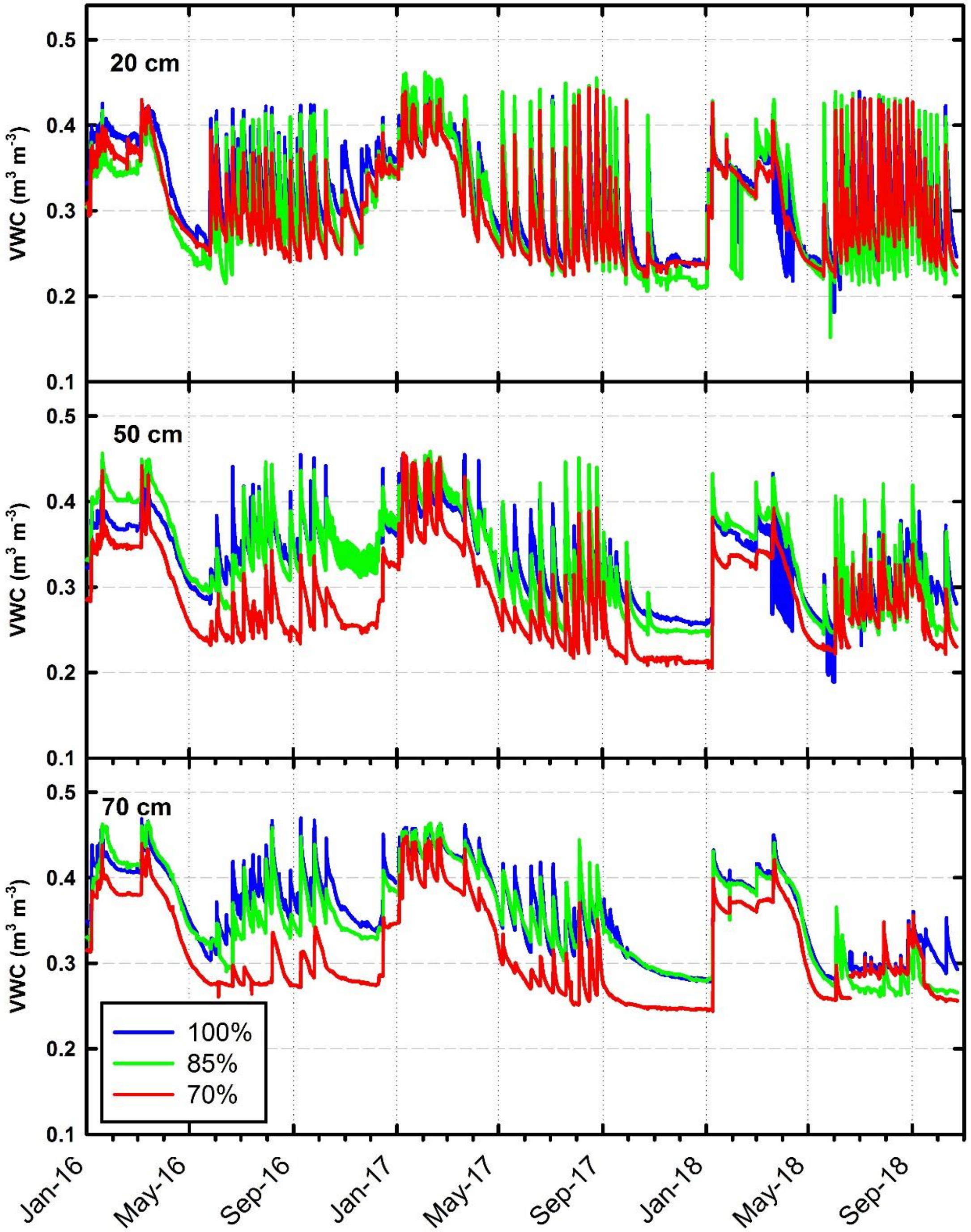
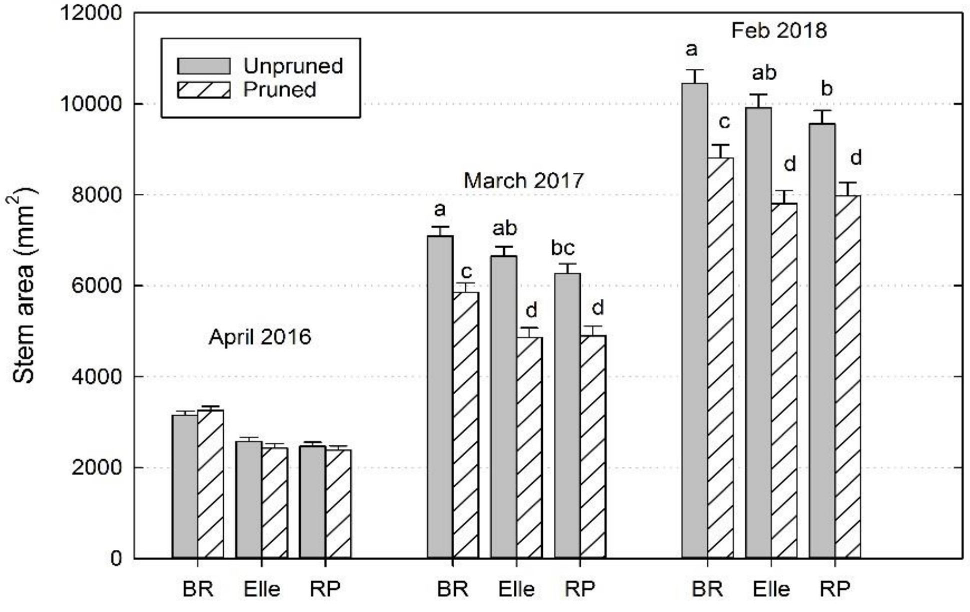
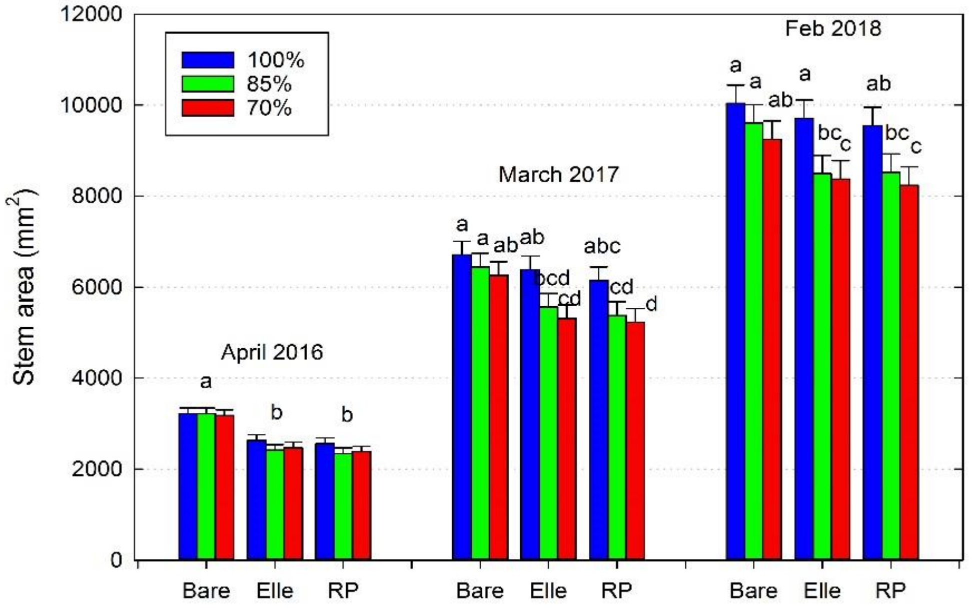
Mar 2017
(after
pruning
again)



Reducing irrigation by 30% led to significantly reduced soil water content at 50 an d70 cm depth



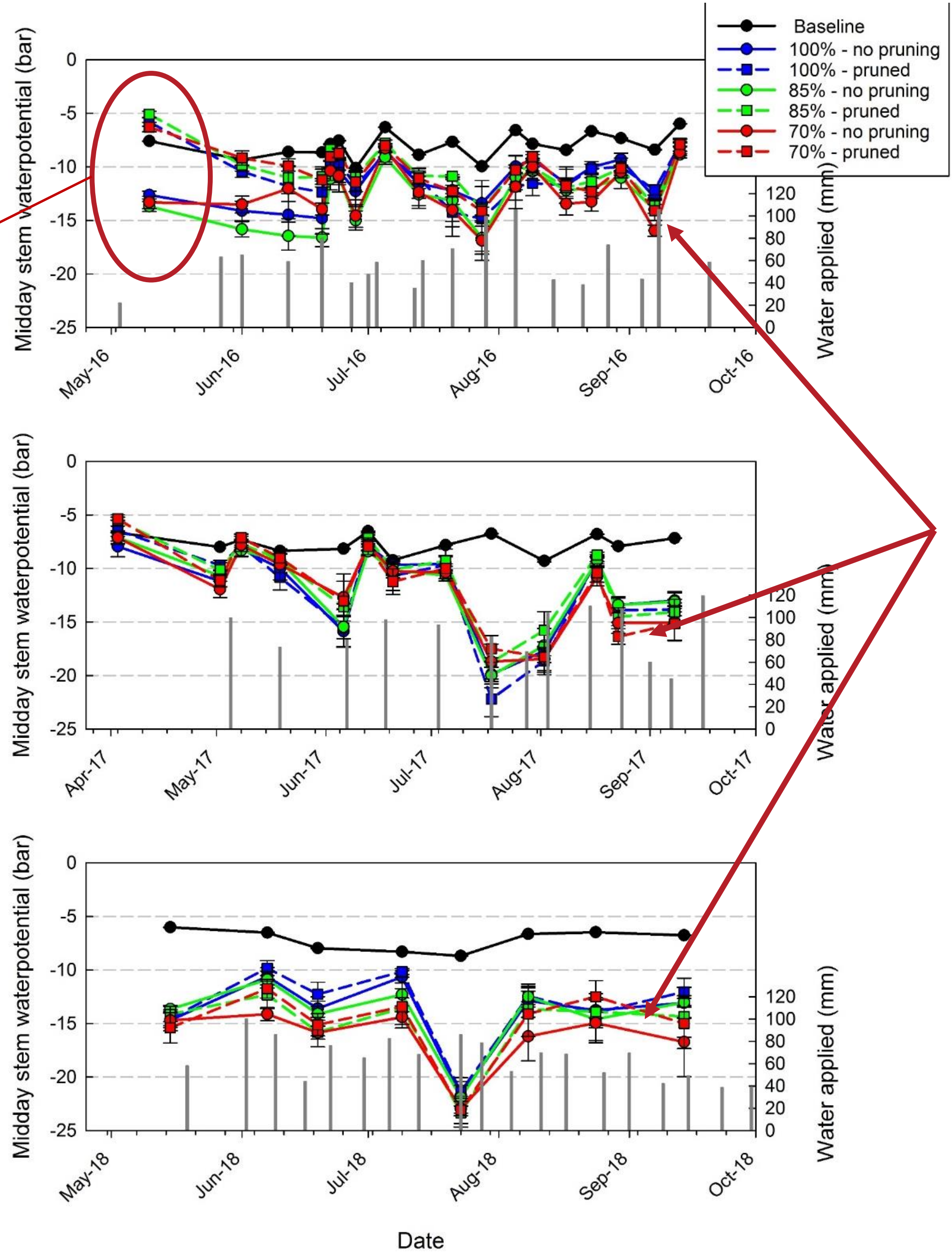


Potted trees grew faster, consistent across irrigation treatments (they were smaller to begin with). There were no interactions between the effects of pruning, irrigation or nursery treatment.

Pruning had a greater negative impact on stem area growth than reducing irrigation by 30%, particularly in the first year

In the first year after planting, pruned trees had a less negative water potential than unpruned trees early in the season

This effect was reversed later in the summer



Trees receiving 70% of fully watered generally had a more negative stem water potential later in the season, but not so much early on when they may have been depleting deeper soil layers

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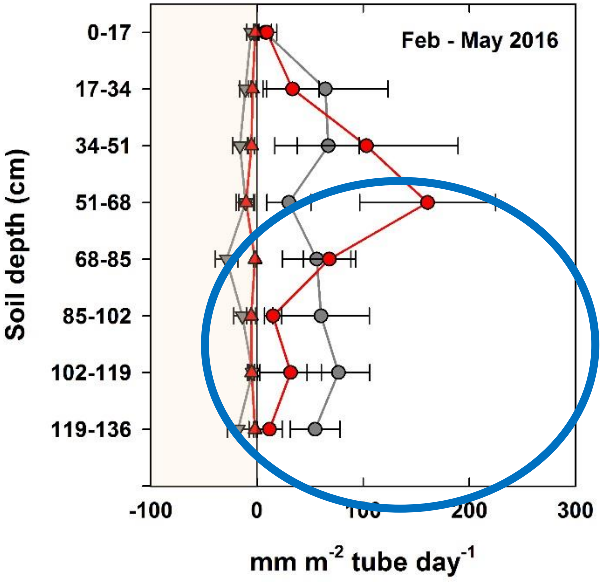
Bare root trees

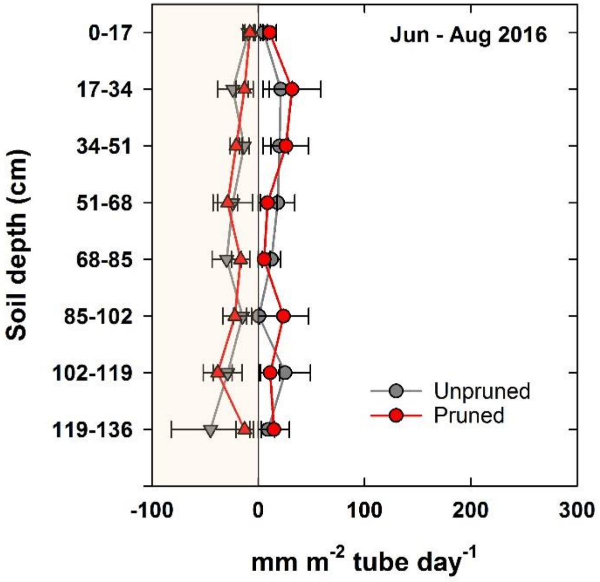
Red lines are pruned trees

Spring - soil T increasing 12-20 ^oC

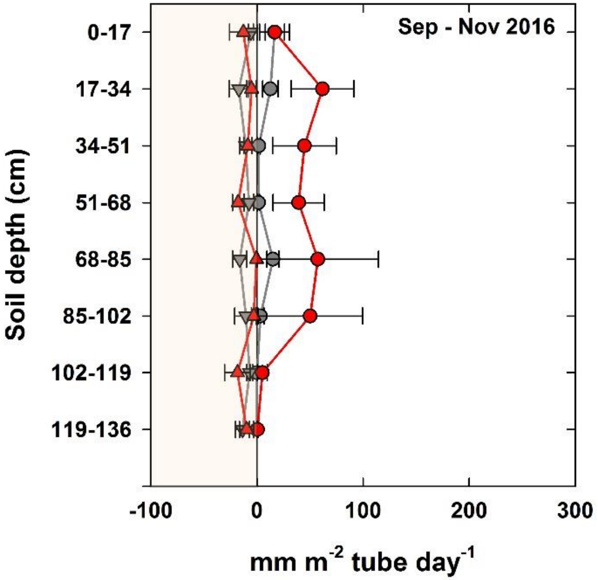
Spring 16: pruned has less deep root production – lack of deep roots may explain greater summer water stress



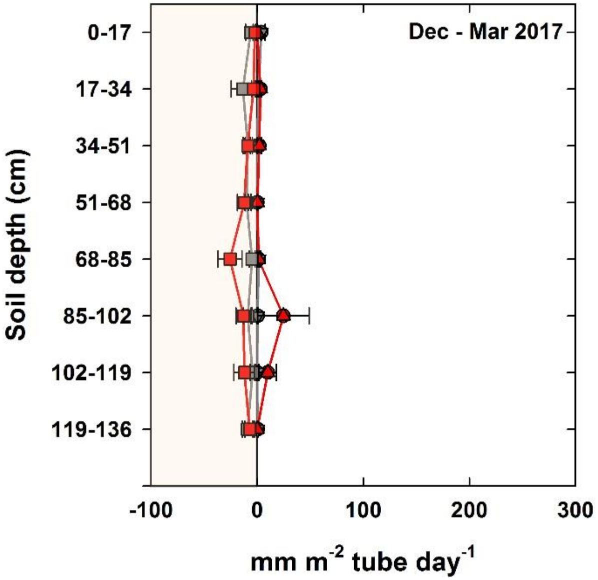
Summer - soil T > 25 ^oC



Negative scale in yellow shade zone indicates root death



Fall - soil T decreasing rapidly 20-12 ^oC

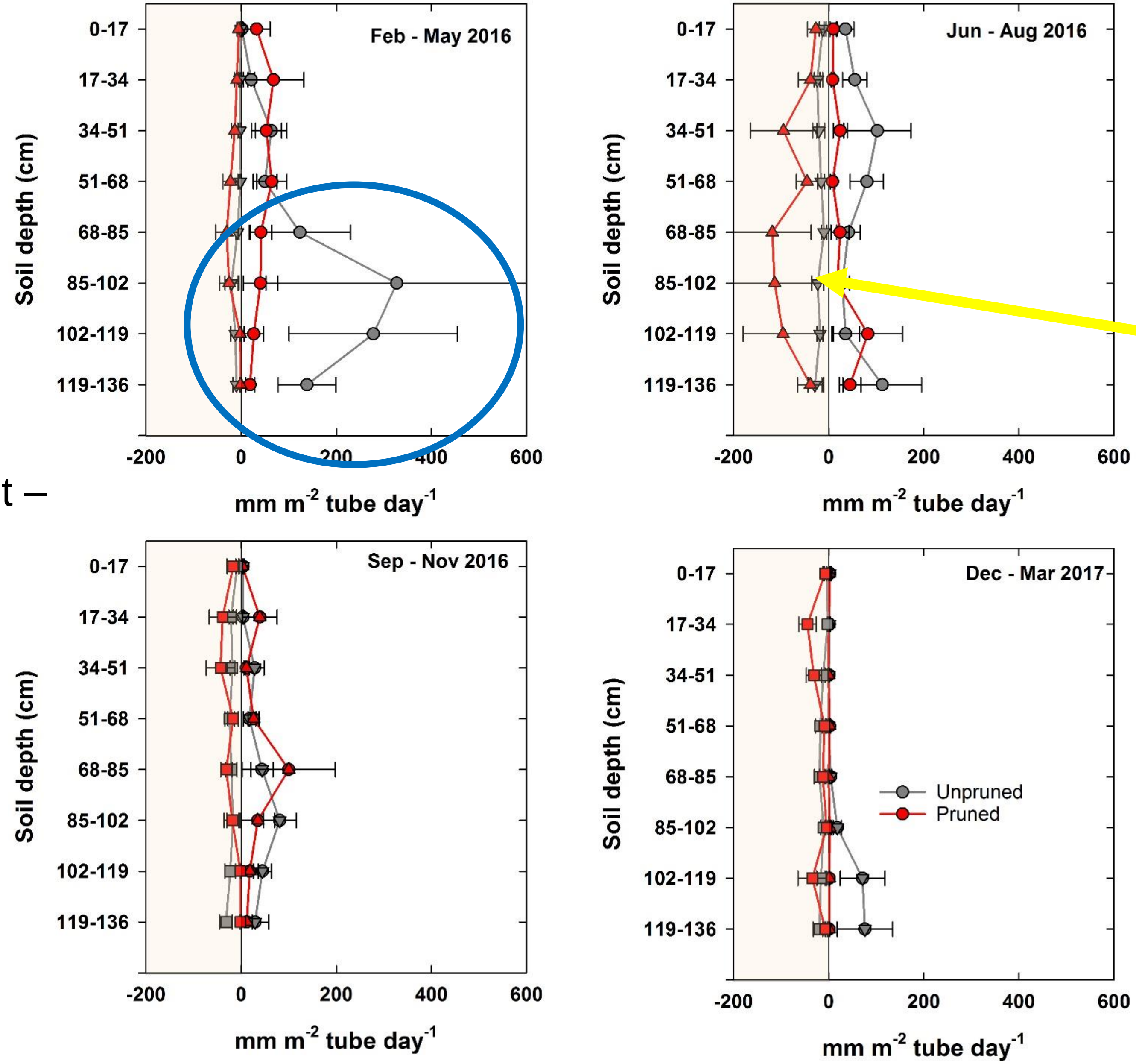


Winter - soil T ~12 ^oC

Although root production is seasonal, root death is fairly stable throughout the seasons

Ellepot trees

Red lines are pruned trees

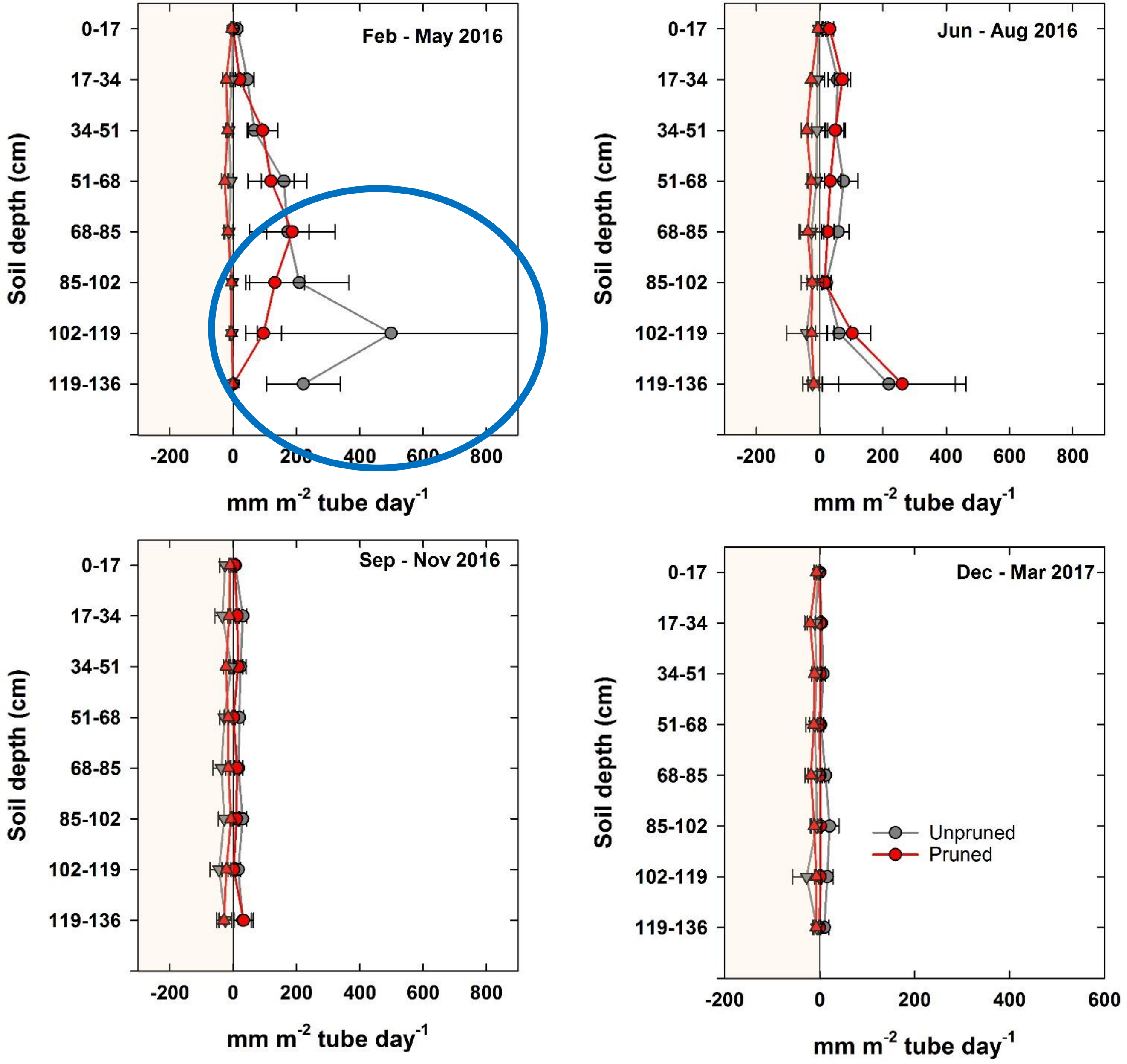


Scale doubled compared to bare root – much more fine root production

Note significant summer death at all depths, no net increase in standing root length

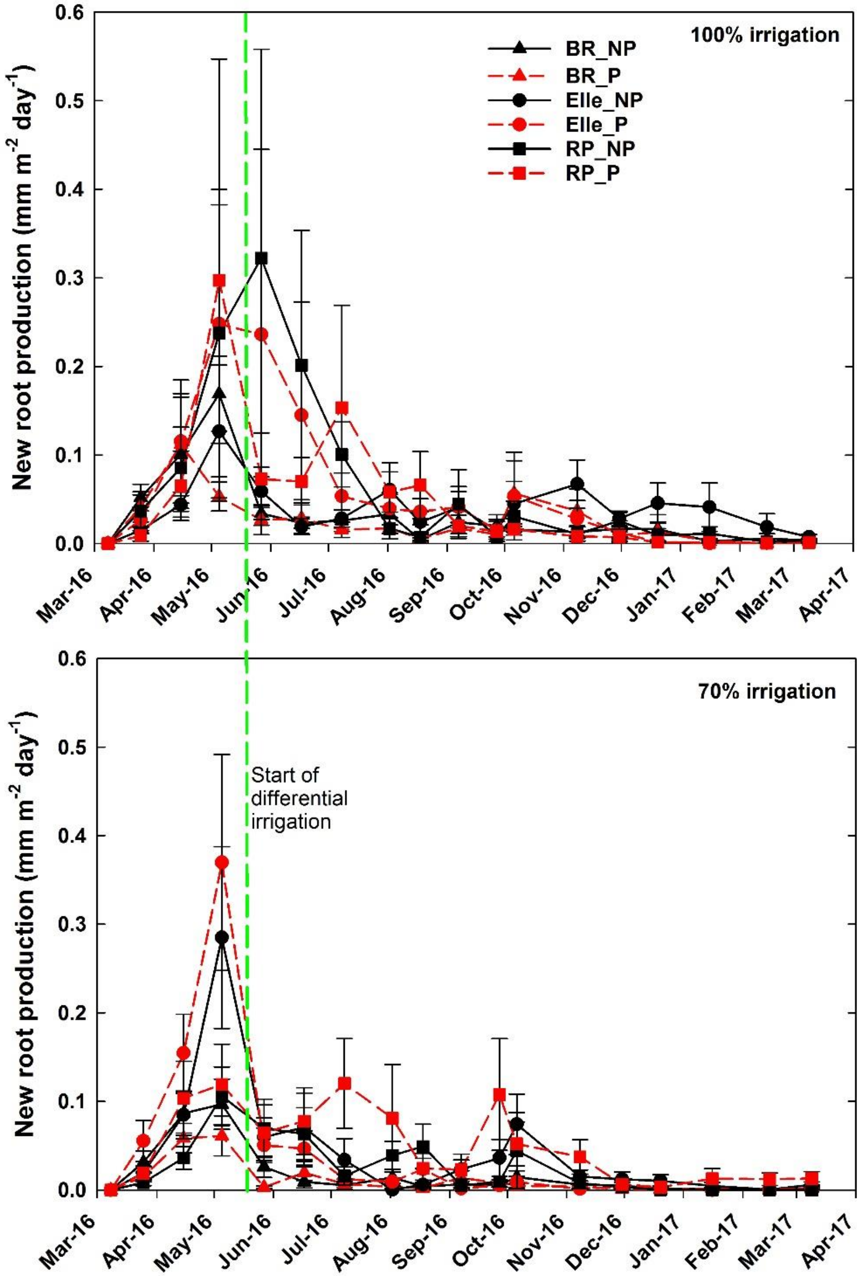
Root pruning pot trees

Red lines are pruned trees

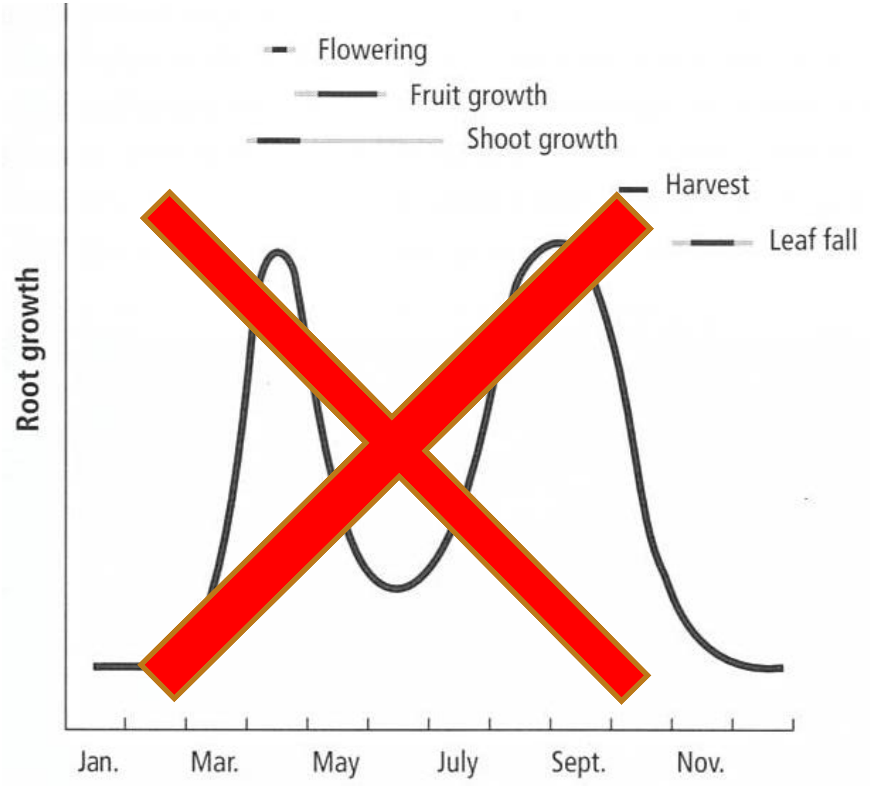


Almost no Fall or Winter production

New root production



First year new root production was reduced by reducing irrigation 30%, but timing did not shift



Note absence of Fall peak

Preliminary conclusions

- Trees produced in pots initially grew faster than bare root trees (as expected, growth is size dependent)
- Pruning of these young trees had a more negative impact on aboveground growth than reducing irrigation to 70%
- The data suggest that heading & pruning at planting delays early deep root production
    - No evidence that canopy pruning reduced root lifespan
- Trees from pots had greater fine root production one year after planting – this did not affect their stem water potential
    - It may be that for bare root trees most roots have grown past the tube position
- Much more information on the posters, including impact of scion, irrigation and pruning on carbohydrate content of root & shoot

Acknowledgements

UCDAVIS
DEPARTMENT OF PLANT SCIENCES
College of Agricultural and Environmental Sciences

- UC Davis pomology farm staff
- Sierra Gold nursery for donating the trees

Funding provided by:
- Almond Board of California
- Department of Plant Sciences at UC Davis

Feb 2018 – unpruned (left) vs pruned (right)

University of California
Agriculture and Natural Resources

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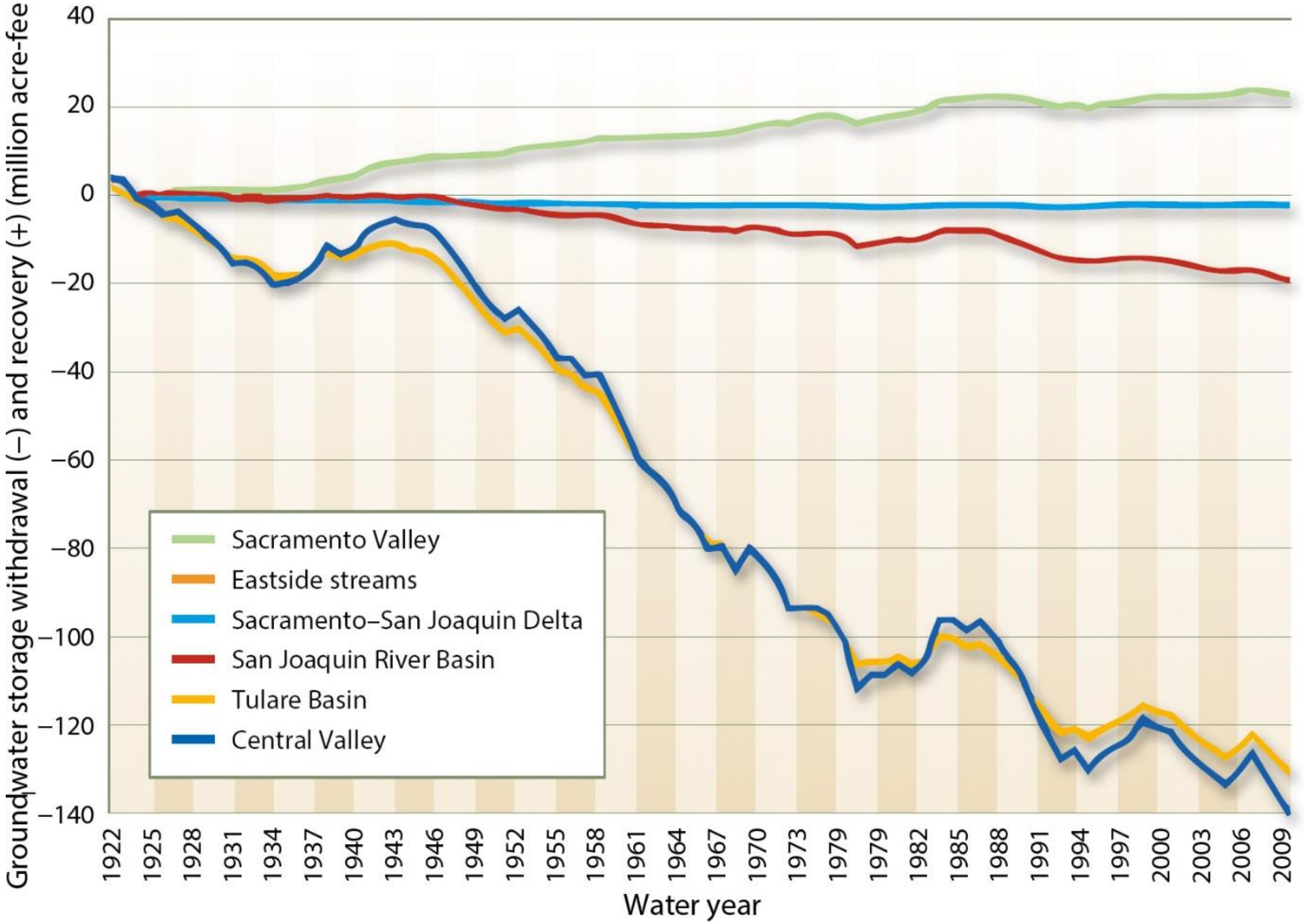
The *Science* and Practice of Intentional Recharge in Almond Orchards

Helen E. Dahlke, Astrid Volder, Ken Shackel, Bruce Lampinen

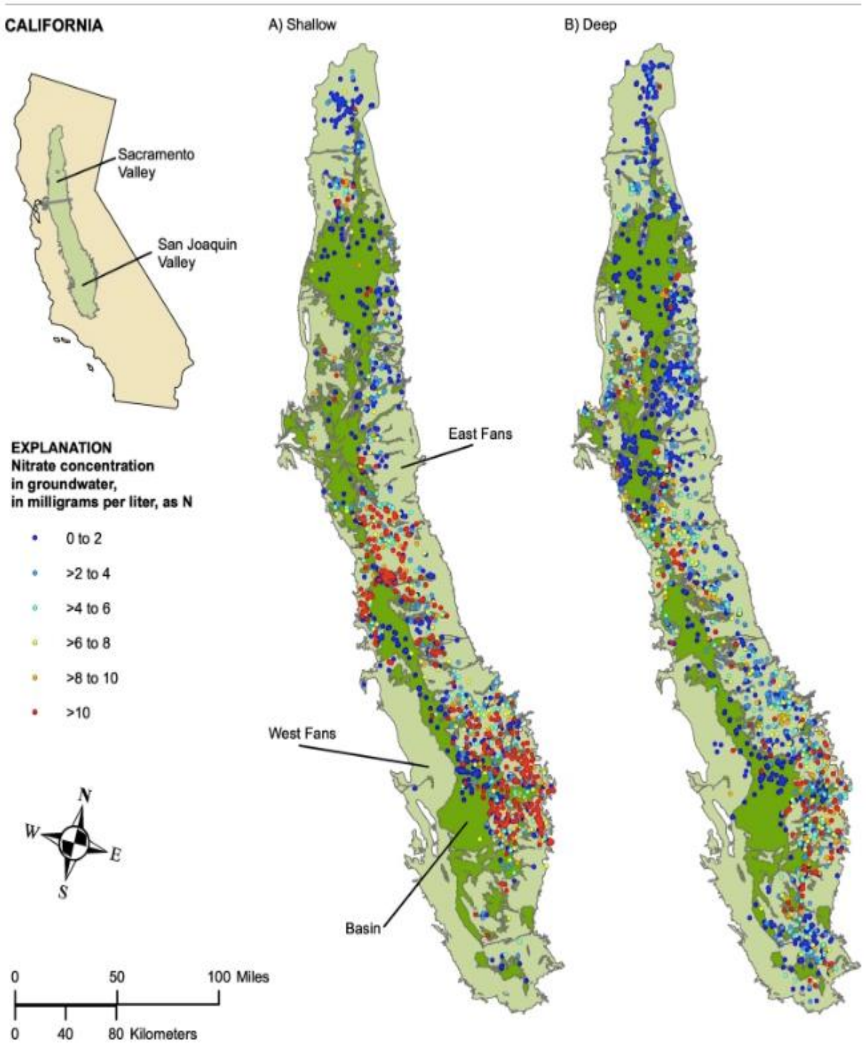
Groundwater Overdraft

- 2 Million Acre Feet per Year
- 5 fold increase in overdraft during the last drought



Consequences of Groundwater Overdraft

- ↑ Land Subsidence
- ↓ Water Quality
- ↓ Water Tables
- ↑ Seawater Intrusion



Ransom et al. 2017

Usgs.gov

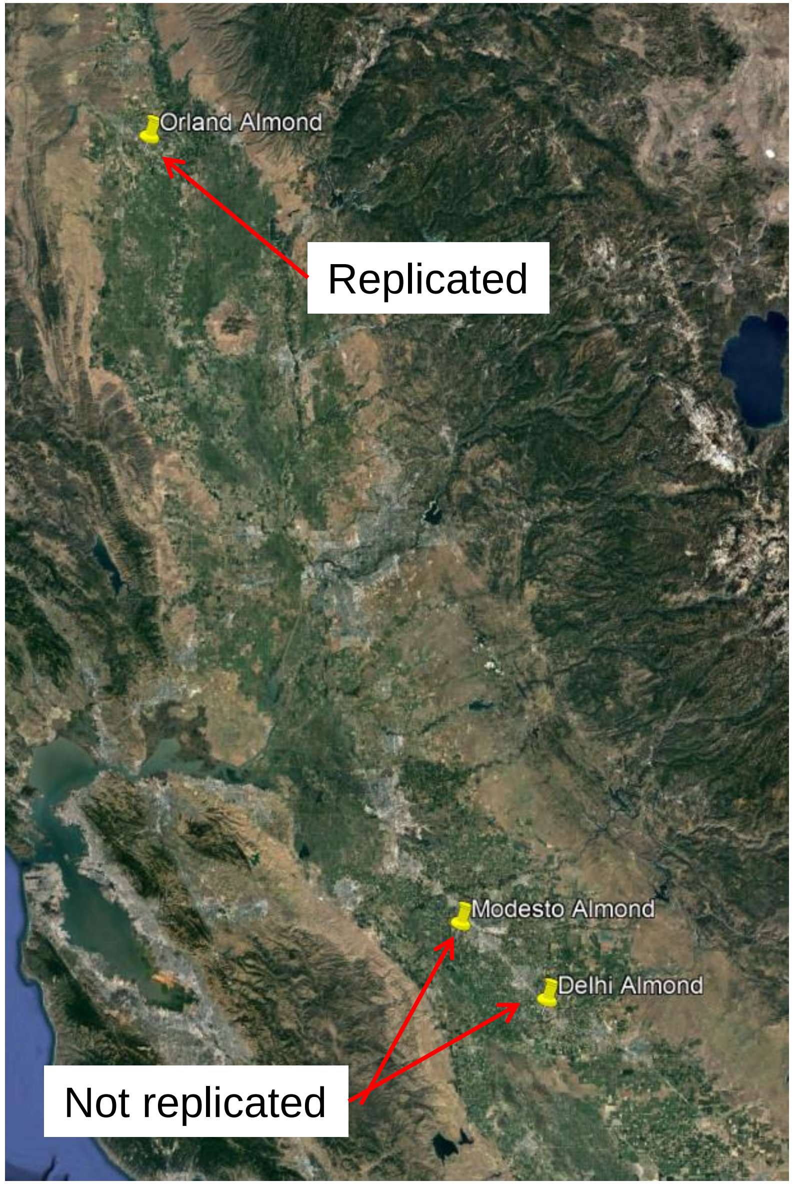
What is Agricultural Managed Aquifer Recharge?

- ↑ Drought Resilience
- ↓ Downstream Flood Risk
- ↑ Water Tables
- ↓ Mitigating Subsidence

https://californiawaterblog.com/2015/10/13/capturing-el-nino-for-the-underground/

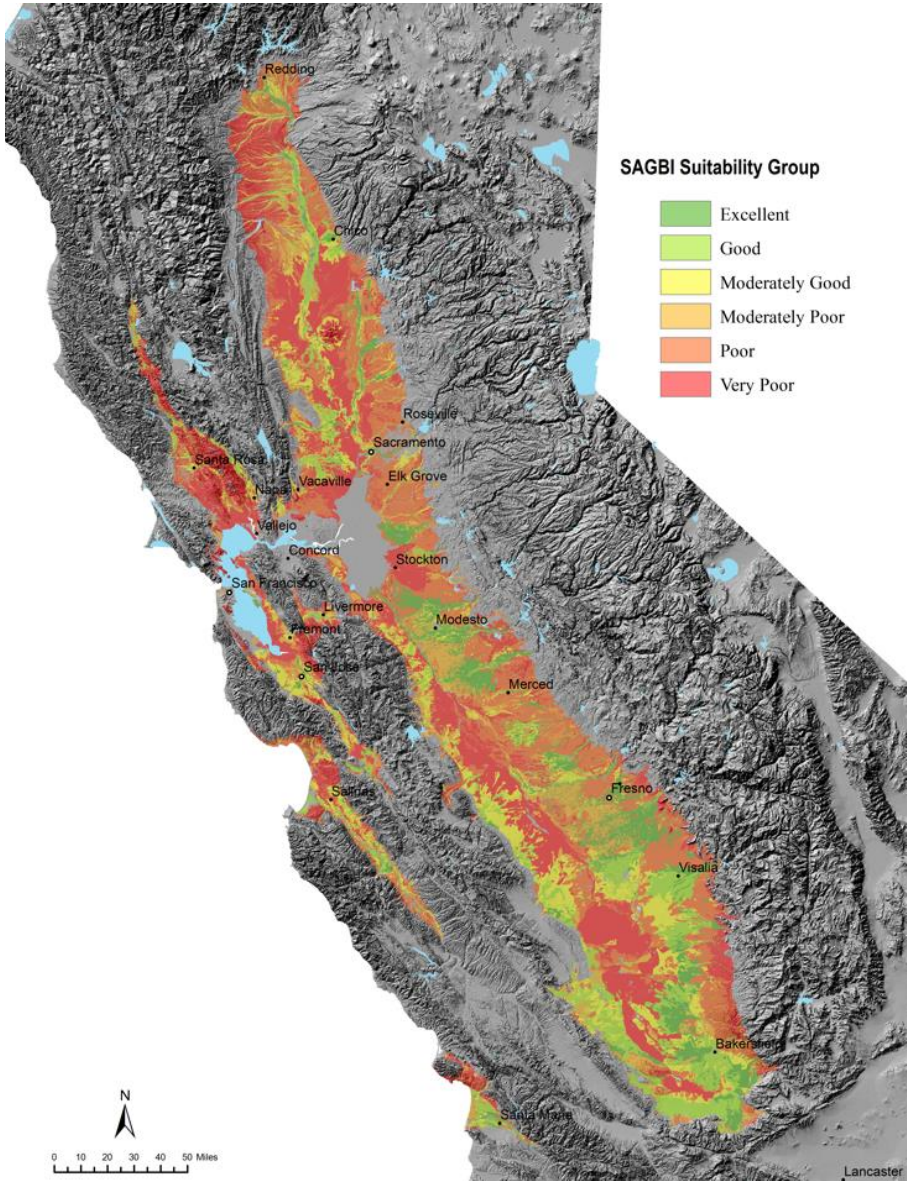
Site Information

- **Modesto:**
  - Nonpareil, Monterey
  - Stand age: 20 years
  - Flood irrigated
  - Dinuba, fine sandy loam
  - SAGBI: moderately good
- **Delhi:**
  - Butte, Padre, Nemaguard
  - Sprinkler irrigated
  - Stand age: 14 years
  - Dune land, sand
  - SAGBI: excellent
- **Orland:**
  - Butte, Padre, Mission
  - Stand age: 25 years
  - Flood irrigated
  - Jacinto, fine sandy loam
  - SAGBI: moderately poor



Replicated

Not replicated



Deep Percolation

Site	Applied Water (inches)	Deep Percolation (inches)	Deep Percolation (%)
Delhi (2015/2016)	26.15	24.30	93%
Delhi (2016/2017)	25.80	25.60	99%
Modesto (2015/2016)	24.00	19.35	81%
Modesto (2016/ 2017)	24.00	23.16	96%
Orland (2016/ 2017)	4.76	3.65	77%

Yield Data

		Year		
Site	**Treatment**	**2015**	**2016**	**2017**
		(pre-treatment)		
Modesto	Grower	3220	3090	3900
	(Dry Winter)	3360	3290	2980
	Recharge	3430	3130	2990
Delhi	Grower	1230	1250	2200
	(Dry Winter)	1190	1140	2640
	Recharge	1410	1200	3110
Orland	Grower	**DROUGHT**		1640 ± 190
	Recharge			1520 ± 140

Benefit

Underline = Max. yield per year

Soil Nitrate Leaching – Modesto – 2015/16 and 2016/17

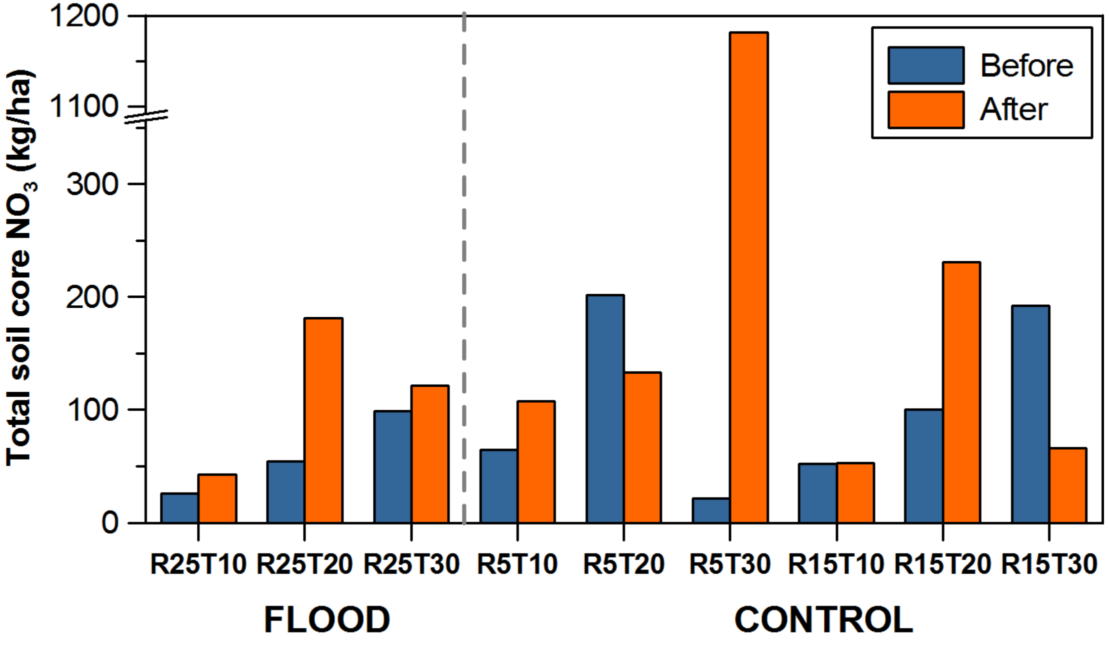
- **2015/16:** 53 % ***increase*** in NO_3^- across treatments, 107% ***increase*** in Flood treatment

➢ Most of the increase in soil nitrate occurred in the root zone as the result of nitrification

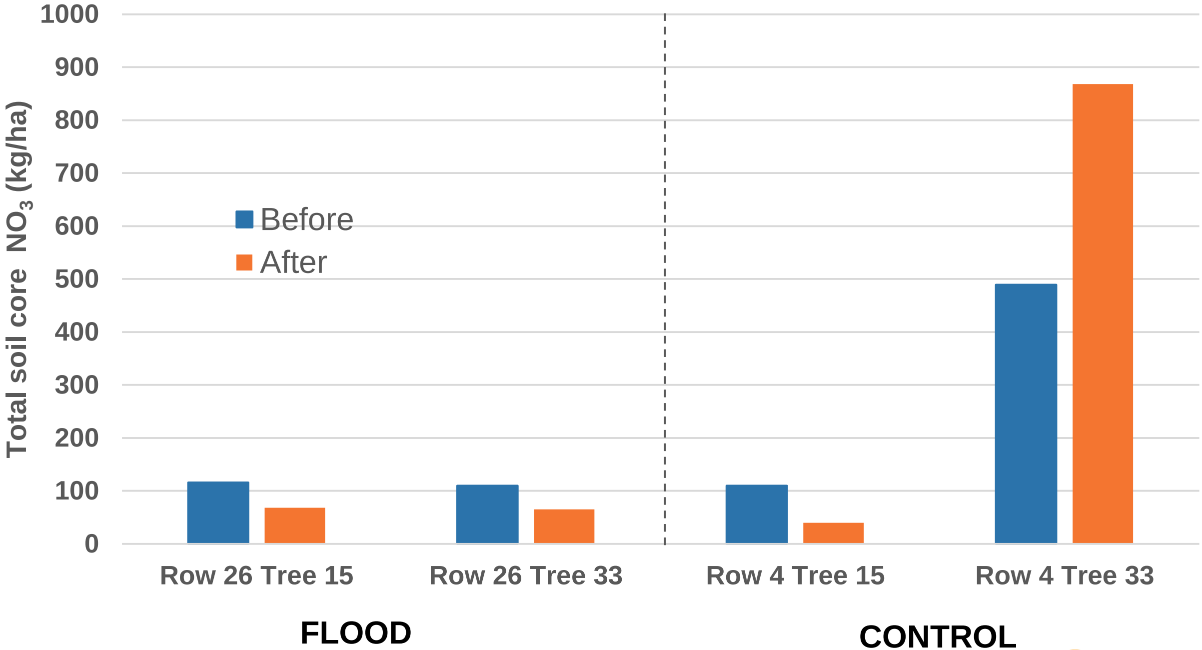
- **2016/17:** 18 % ***decrease*** in NO_3^- across treatments, 41% ***decrease*** in Flood treatment

➢ Wet year! Recharge combined with precipitation caused leaching

2015/2016



2016/2017



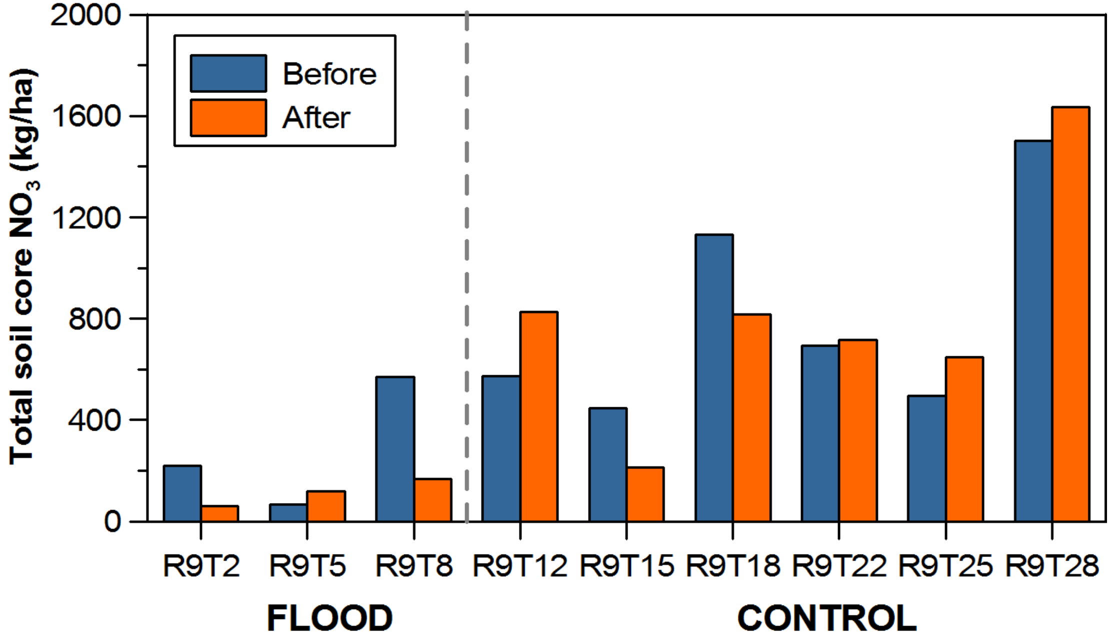
Soil Nitrate: 1 kg/ha = 0.89 lb/acre

Soil Nitrate Leaching – Delhi – 2015/16 and 2016/17

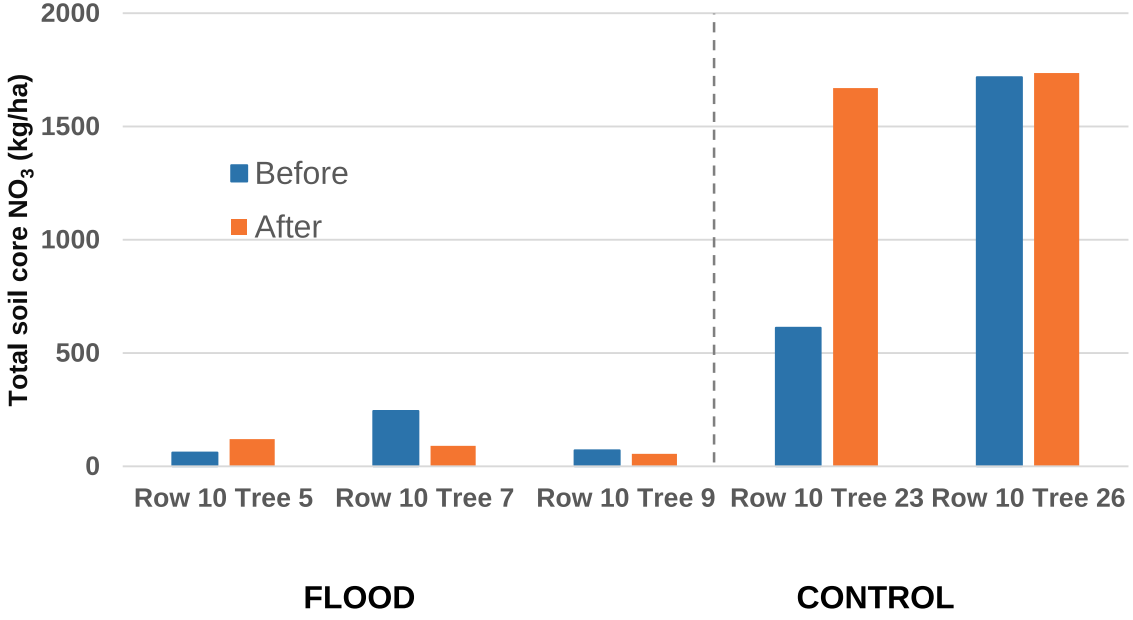
- **2015/16:** 7% ***decrease*** across treatments, 23% ***decrease*** in Flood treatment
  - ➢ Obvious decrease in NO_3- within the root zone in the flood treatment as result of recharge

- **2016/17:** 37 % ***increase*** in NO_3^- across treatments, 4% ***increase*** in Flood treatment
  - ➢ Wet year! Very low NO_3- load in the flood treatment (leaching), high load in loamier control treatment (lateral transport?)

2015/2016



2016/2017



Soil Nitrate: 1 kg/ha = 0.89 lb/acre

Conclusions

Plant Physiology and Yield

- Yield, stem water potential, canopy light interception and new root production were not affected by winter recharge
- **Take away:**
  - No obvious warning signs that winter irrigation for groundwater recharge affects tree health or production.

Conclusions

Groundwater Recharge

- Deep percolation in sites with SAGBI ratings of Excellent and Moderately Good ranged from 19.35 inches to 25.60 inches - 81% to 99% of water applied going to deep percolation
- The rate of infiltration and recharge is a function of soil water storage and saturated hydraulic conductivity – finer textured soils (lower SAGBI rated soils) may reduce infiltration and create surface runoff conditions

Water Quality

- Sandy soils – clear nitrate loss from recharge
- Silt loams and complex soils with impeding layers – recharge might increase soil nitrate through mineralization and nitrification

Nitrate Leaching Under Agricultural Managed Aquifer Recharge

Hannah Waterhouse, Helen Dahlke, Peter Nico,
Nicolas Spycher, William Horwath

california almonds
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Which Crops and on Which Soils?

- Cores drilled to 30 ft (9m)
- Almonds, Grapes, Tomatoes
- High Permeability (“A”) vs Low Permeability Soils (“C/D”)

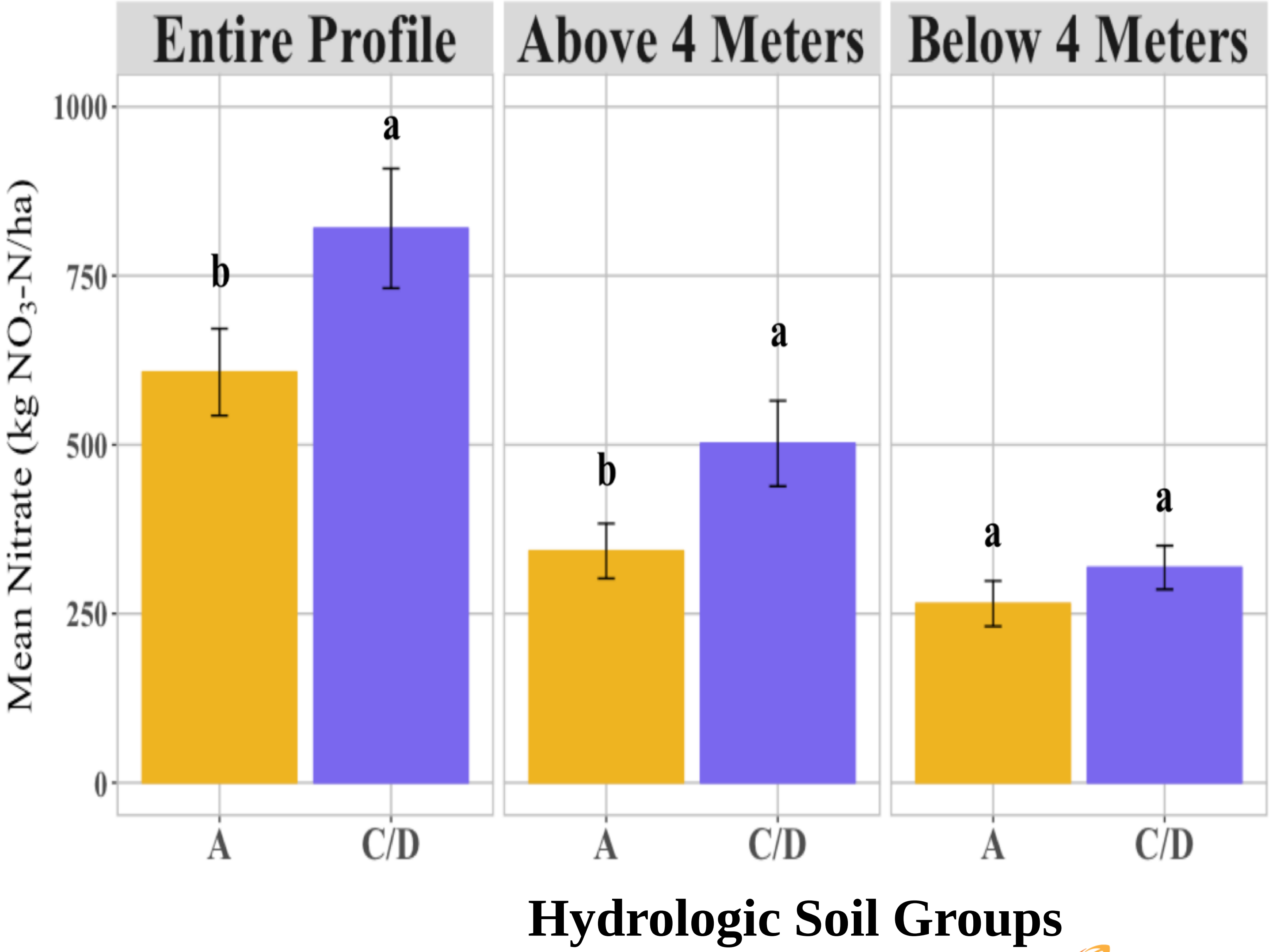
Which Crops and on Which Soils?

A= Very Permeable Soil
C/D = Low Permeable Soil

- Grapes had the lowest “Nitrate Footprint”
- Dedicated recharge sites could allow for dilution of nitrate in groundwater by large additions of clean surface water

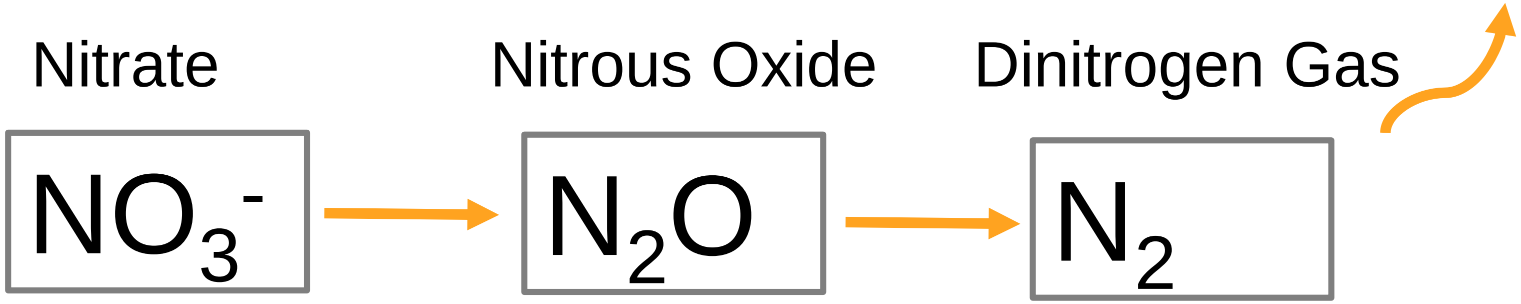
1 kg/ha = 0.9 lbs/acre

***Different Letters signify statistically significant differences**



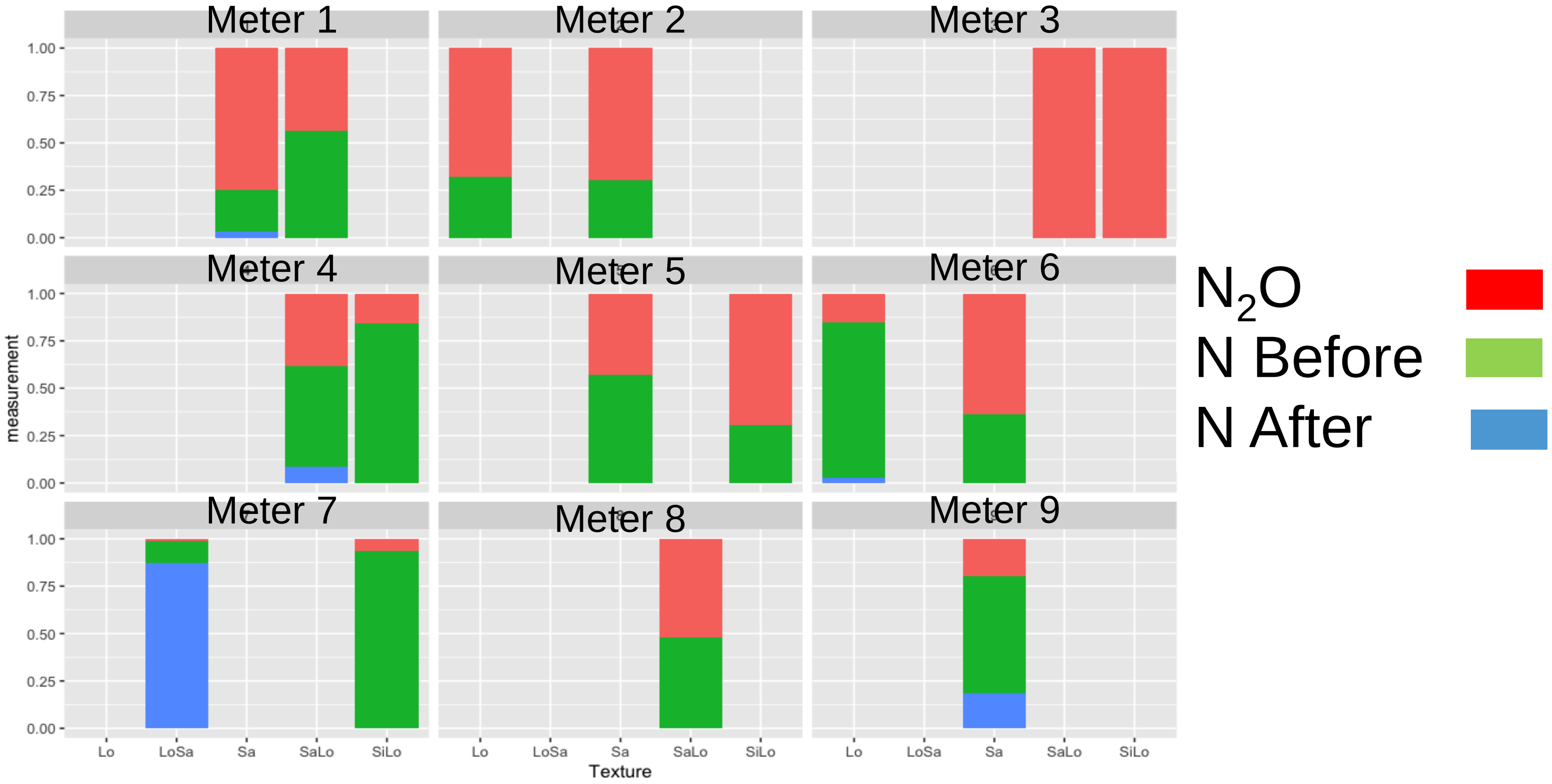
AgMAR and Denitrification

- Denitrification can occur in the deep vadose zone
- 75% of Nitrate was converted to N_2



Nitrate | Nitrous Oxide | Dinitrogen Gas

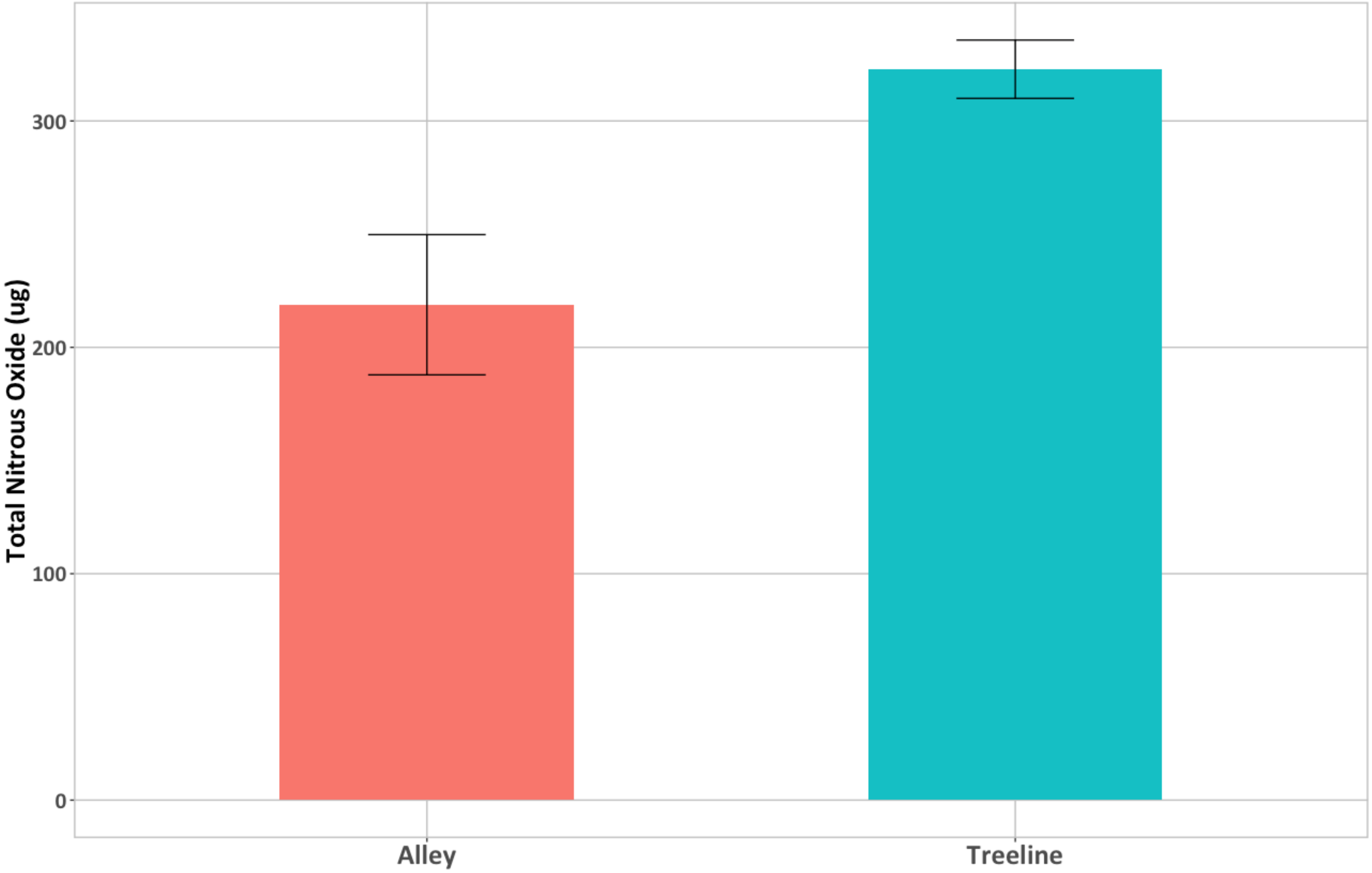
$NO_3^- \rightarrow N_2O \rightarrow N_2$



AgMAR and Denitrification

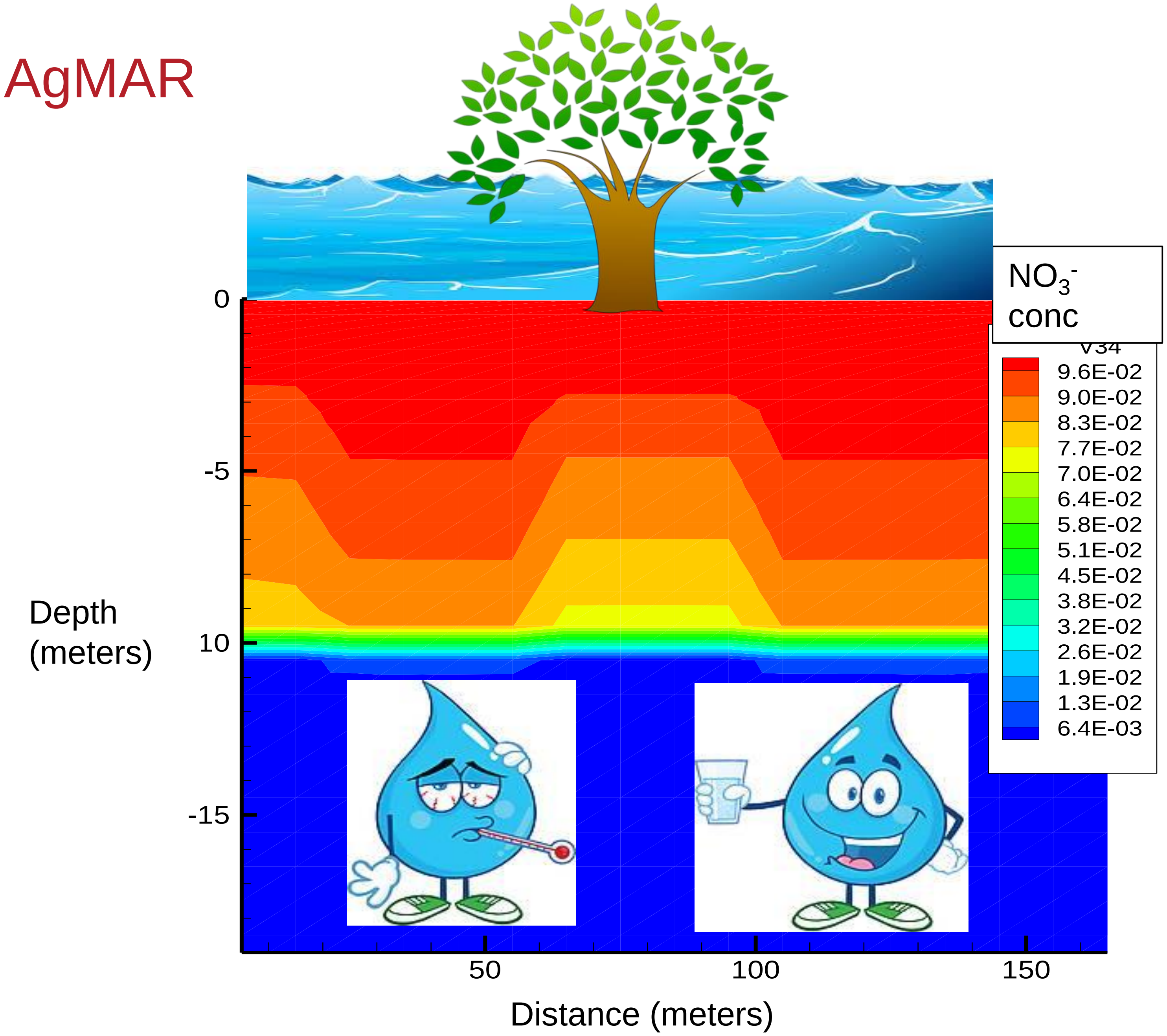
- Management at the land surface affects the deep vadose zone

- My research shows the potential for AgMAR to reduce NO_3^- leaching to groundwater by converting it to gaseous forms



Future Work: Modeling AgMAR

- Data collected from lab and field work will be used to parameterize a model to assess AgMAR's effect on water quantity and quality



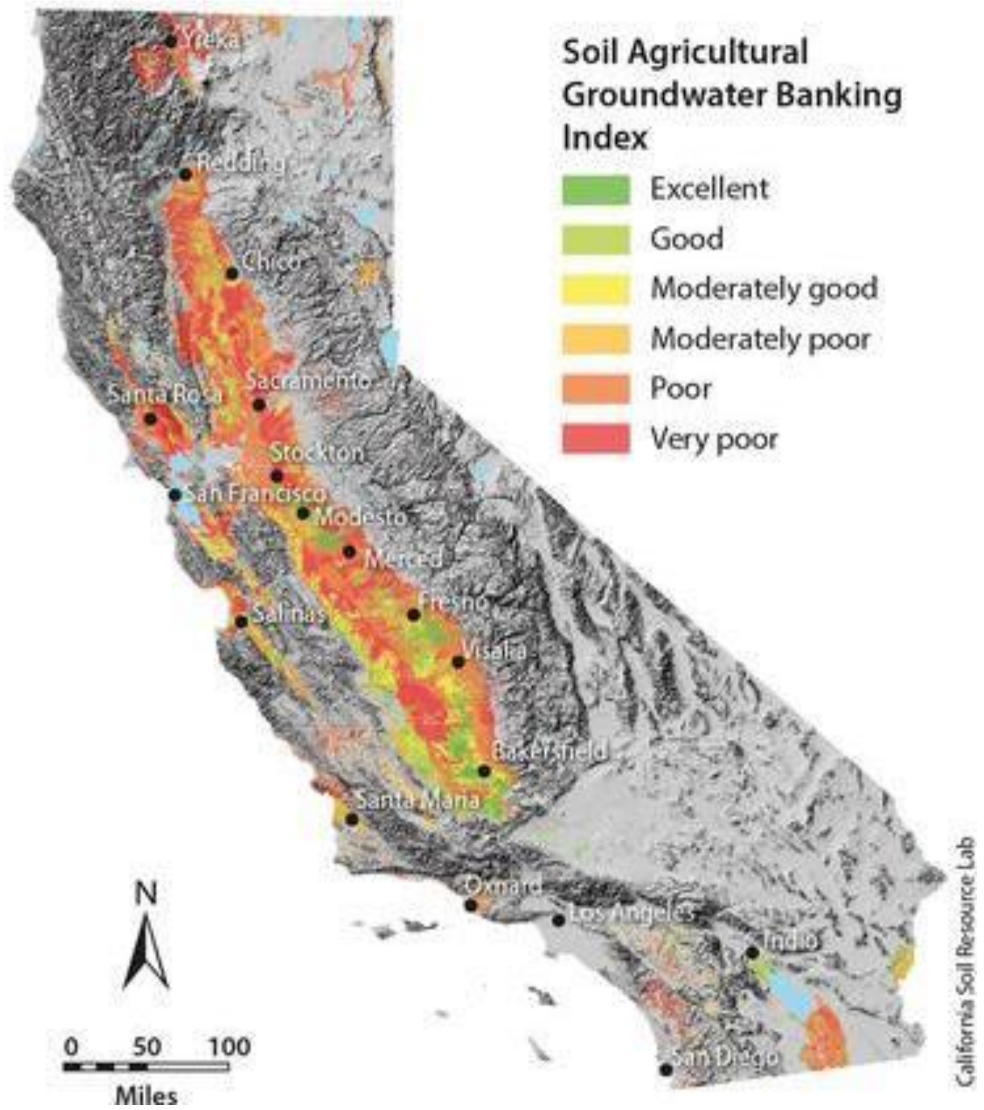
Importance of Subsurface Sediments on Water Movement

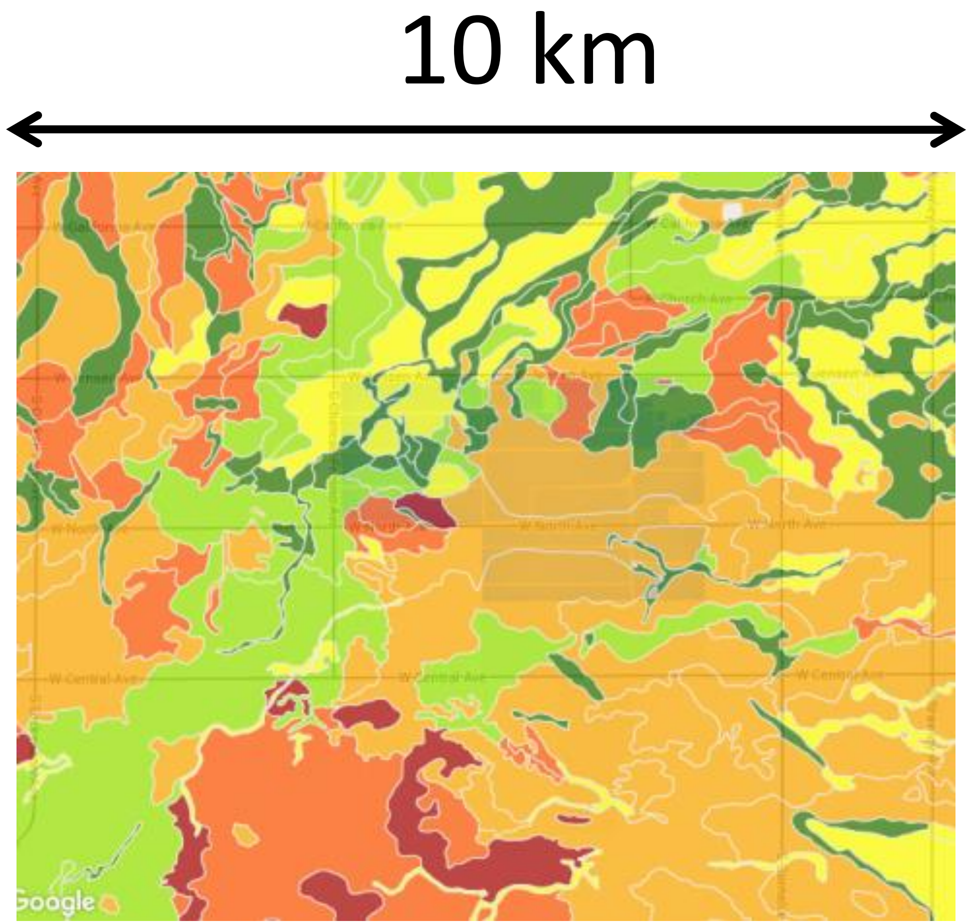
Peter S. Nico, Craig Ulrich, Yuxin Wu, Mark Conrad, Don Vasco, Greg Newman,
William Stringfellow, Christine Doughty and Yingqi Zhang
Lawrence Berkeley National Laboratory

Hannah Waterhouse, Helen Dahlke, William Horwath
University of California, Davis

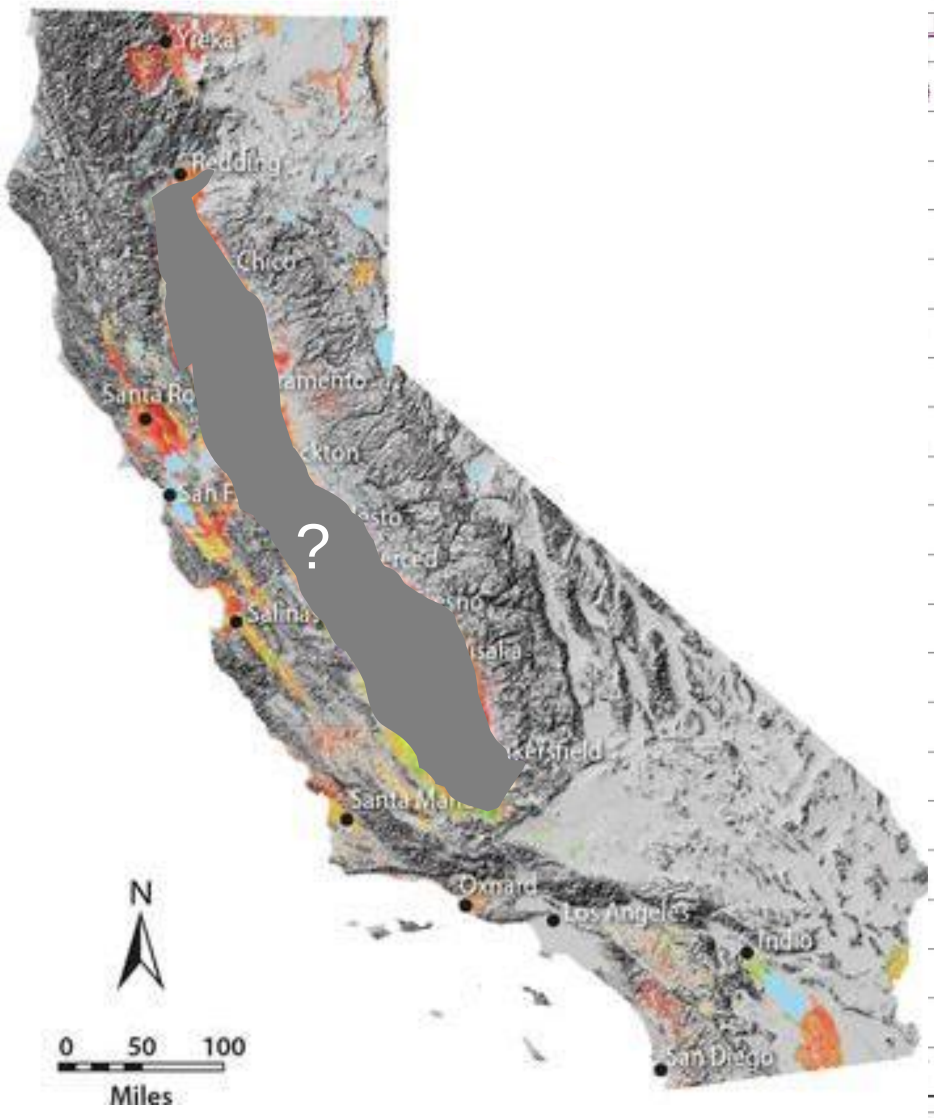
Nick Blom
The Arnold Farms
Roger Duncan and David Doll of UC ANR

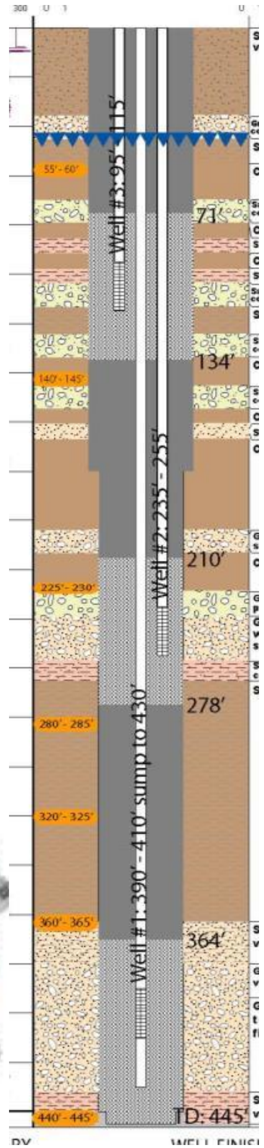
Surface Soils are Complex

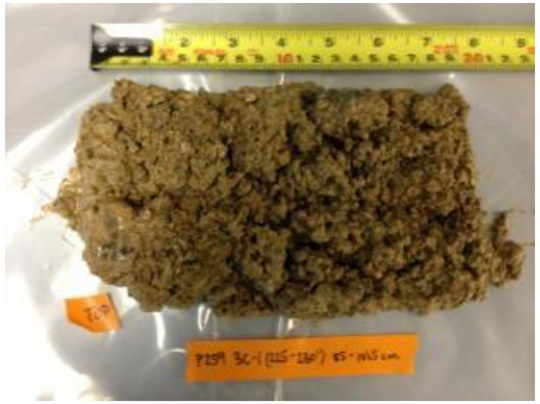


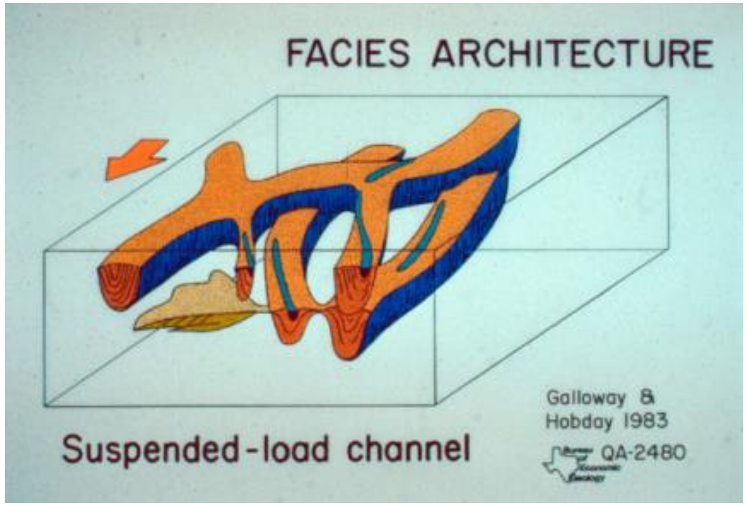


Subsurface as Complex as Surface Soil but Less Well Known

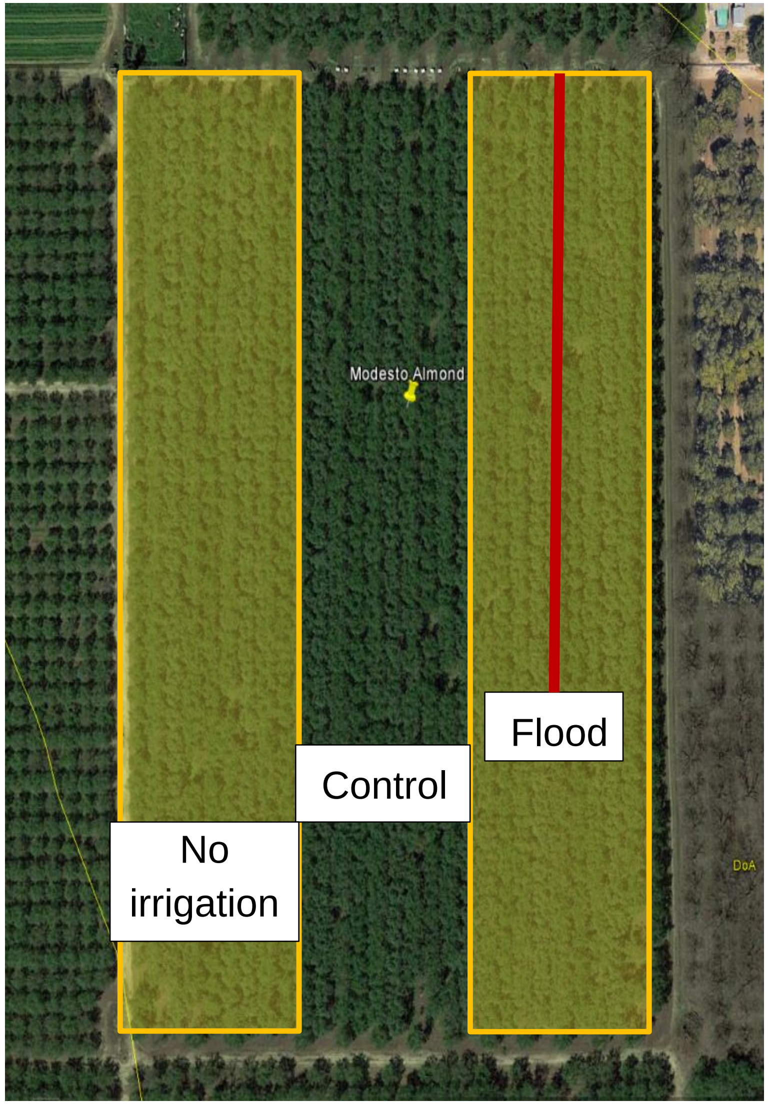


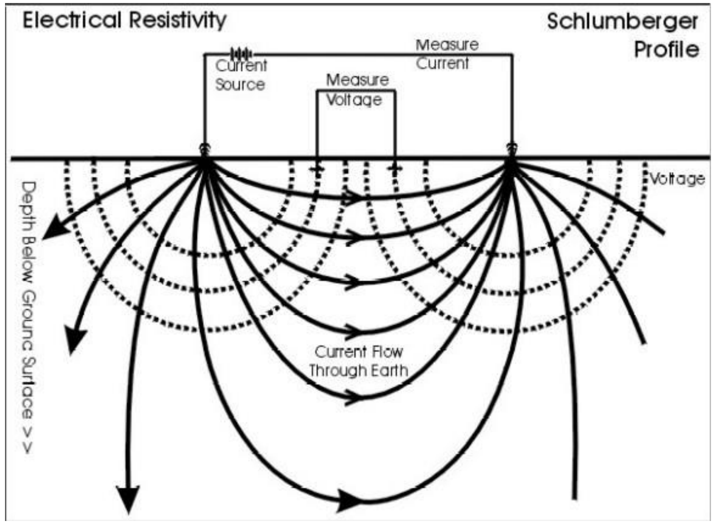




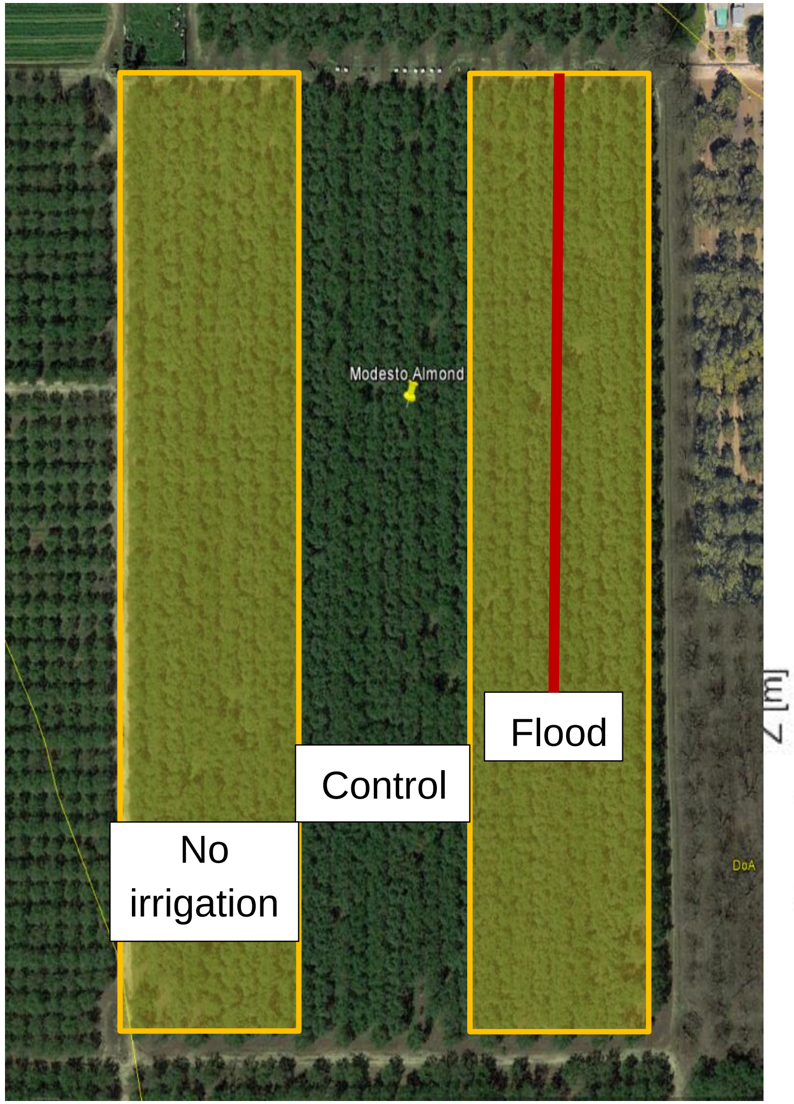


We Can Image What’s Below Ground

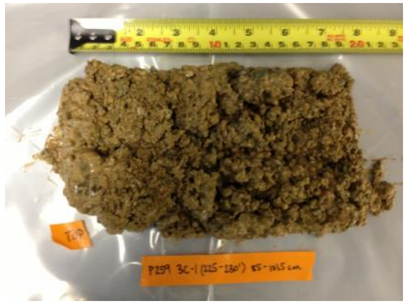




We Can Image What’s Below Ground



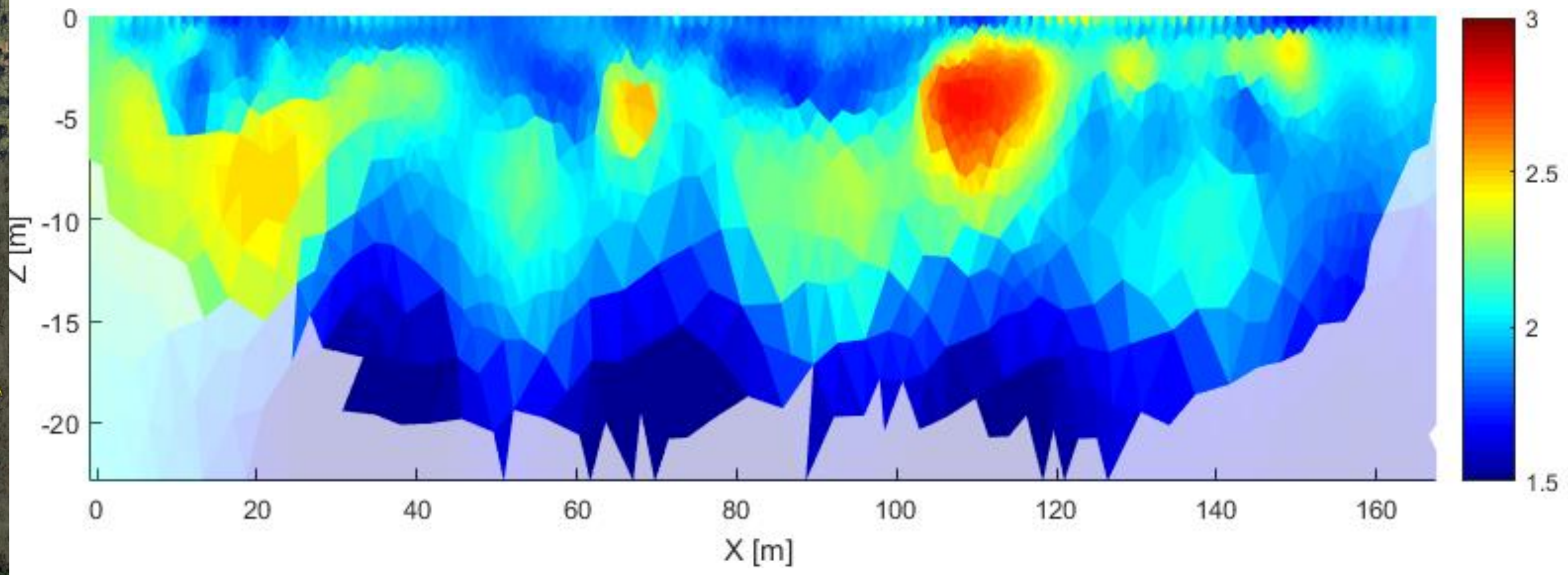
Coarser



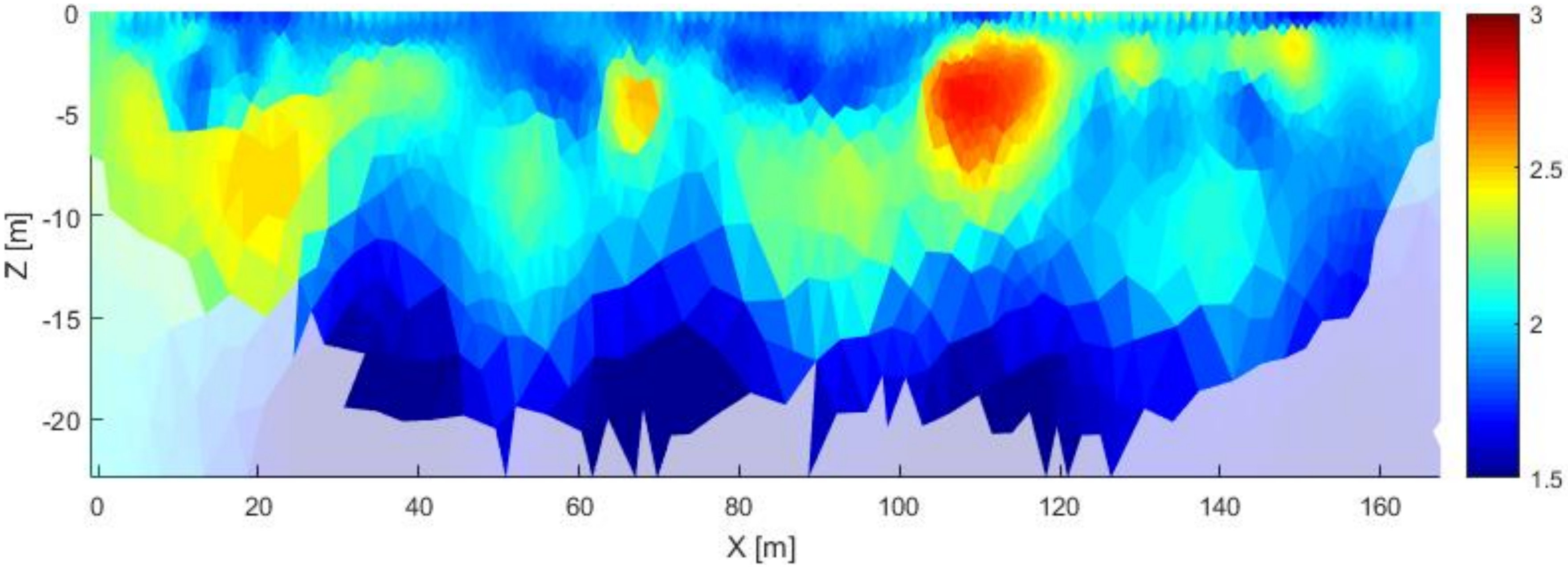
High Electrical Resistivity

Finer

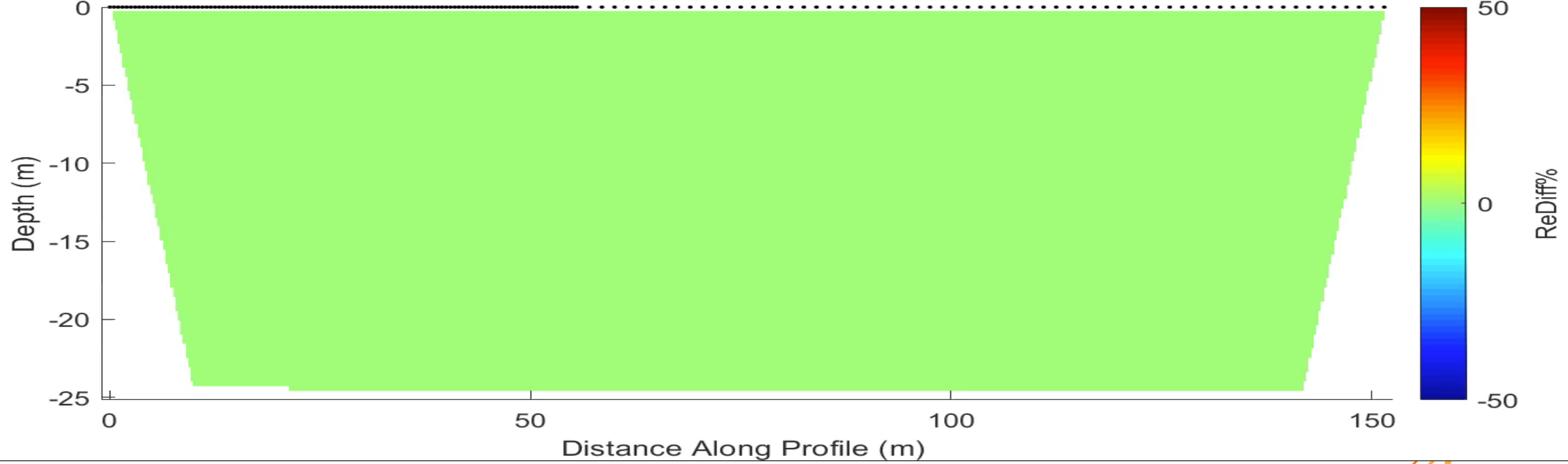
Low Electrical Resistivity



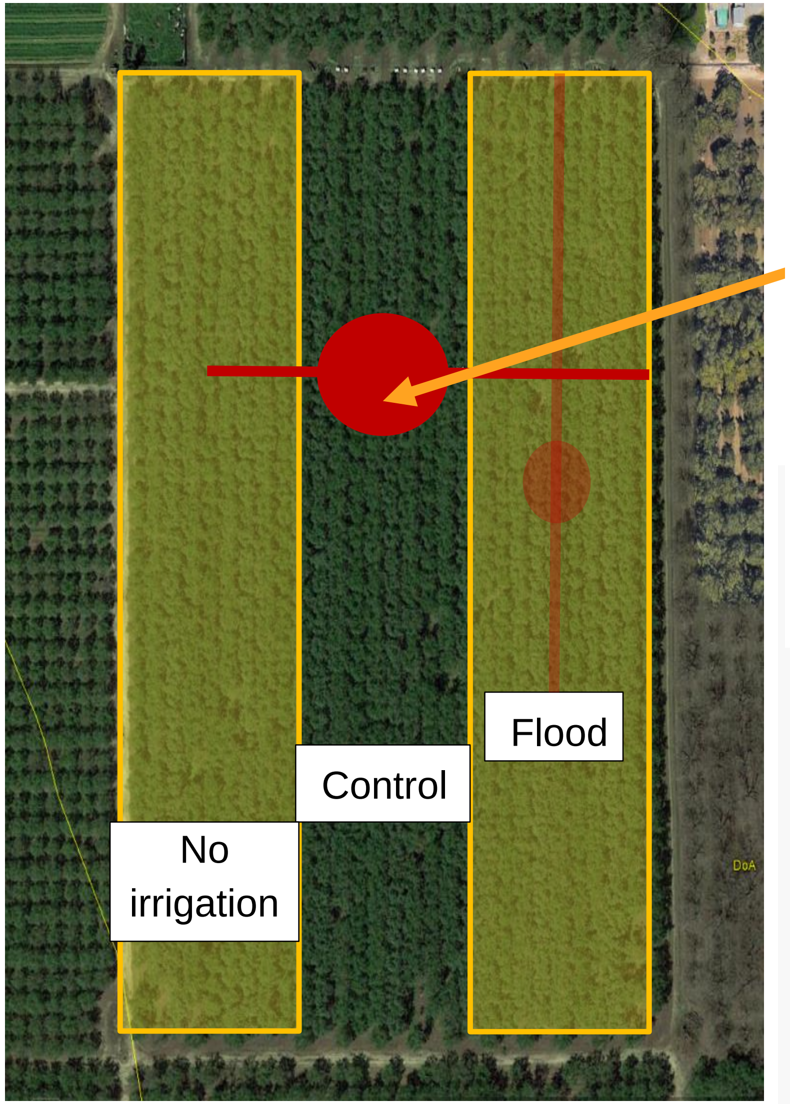
We Can Watch Water Move

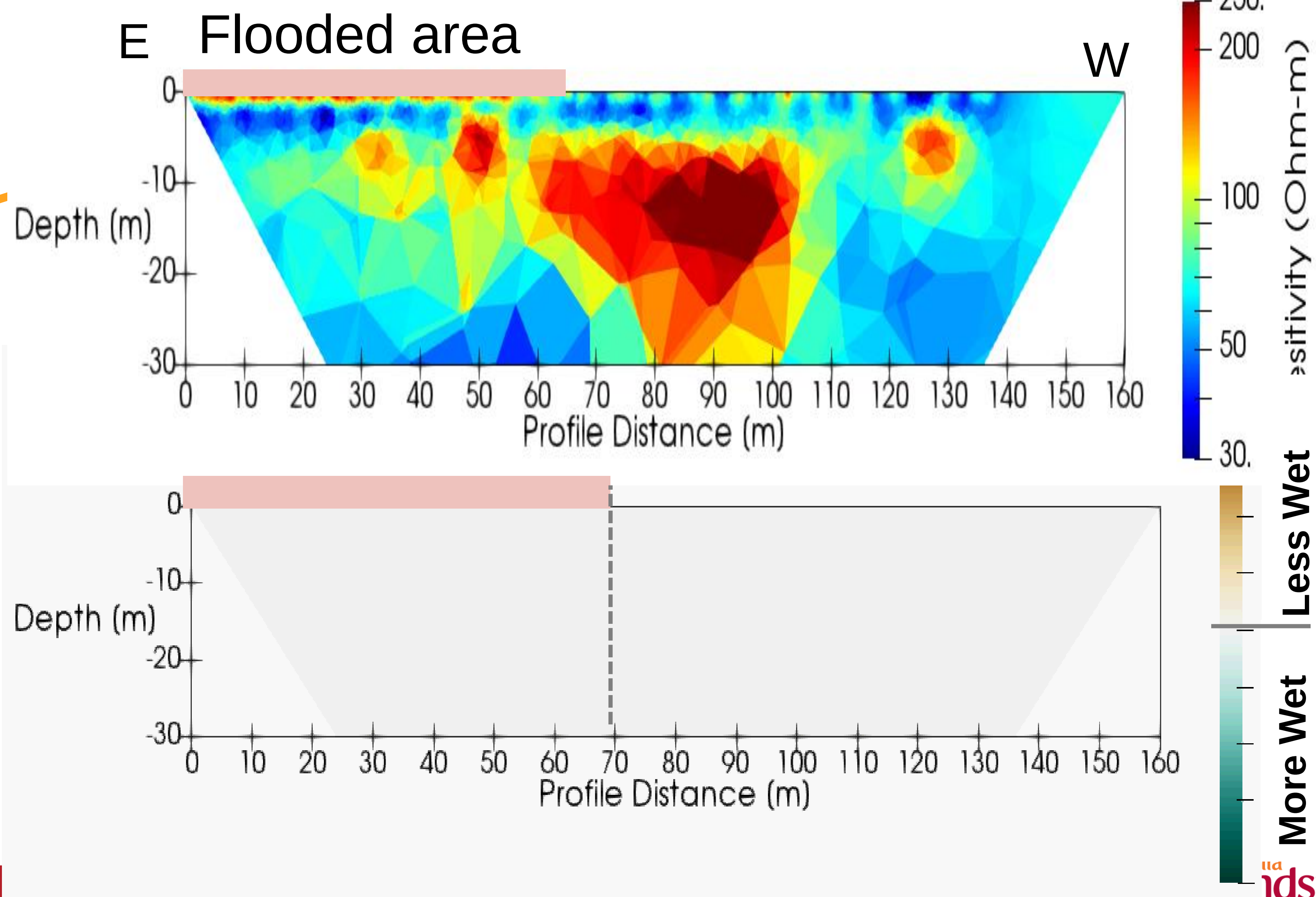


DD176-31-Jan-2017 19:24:00



Water Doesn’t Stay Where It is Put





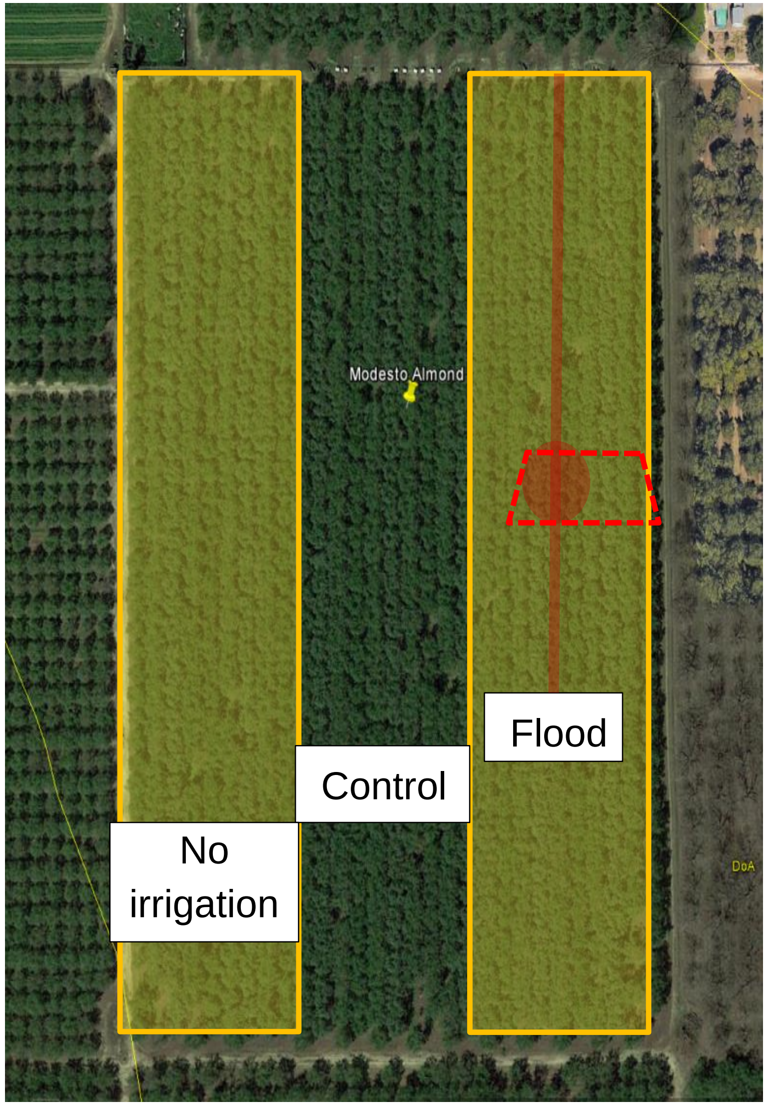
Infiltration Varies a Lot Over Small Distances

D = deuterium, isotope of H

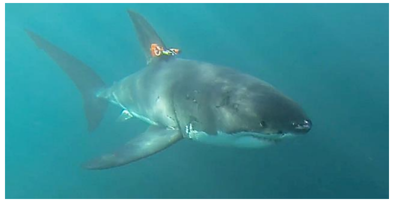
$D_2O = H_2O$

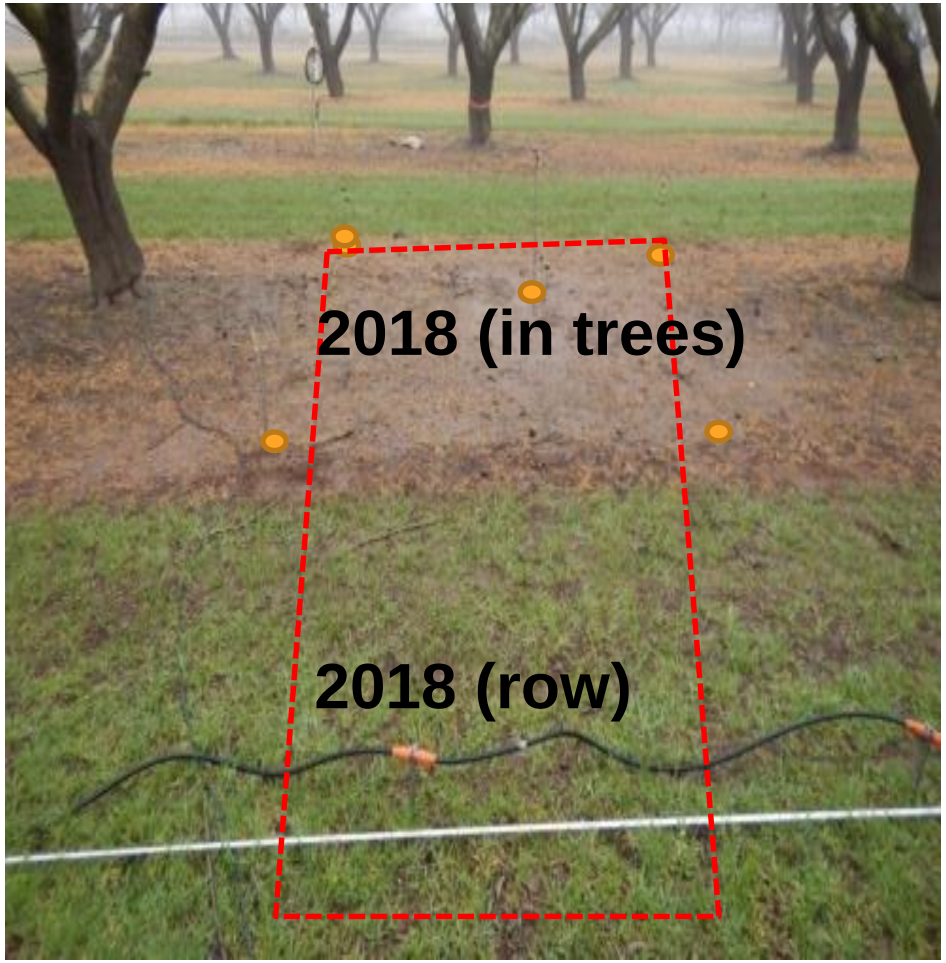
But we can follow it.

Infiltration Varies a Lot Over Small Distances

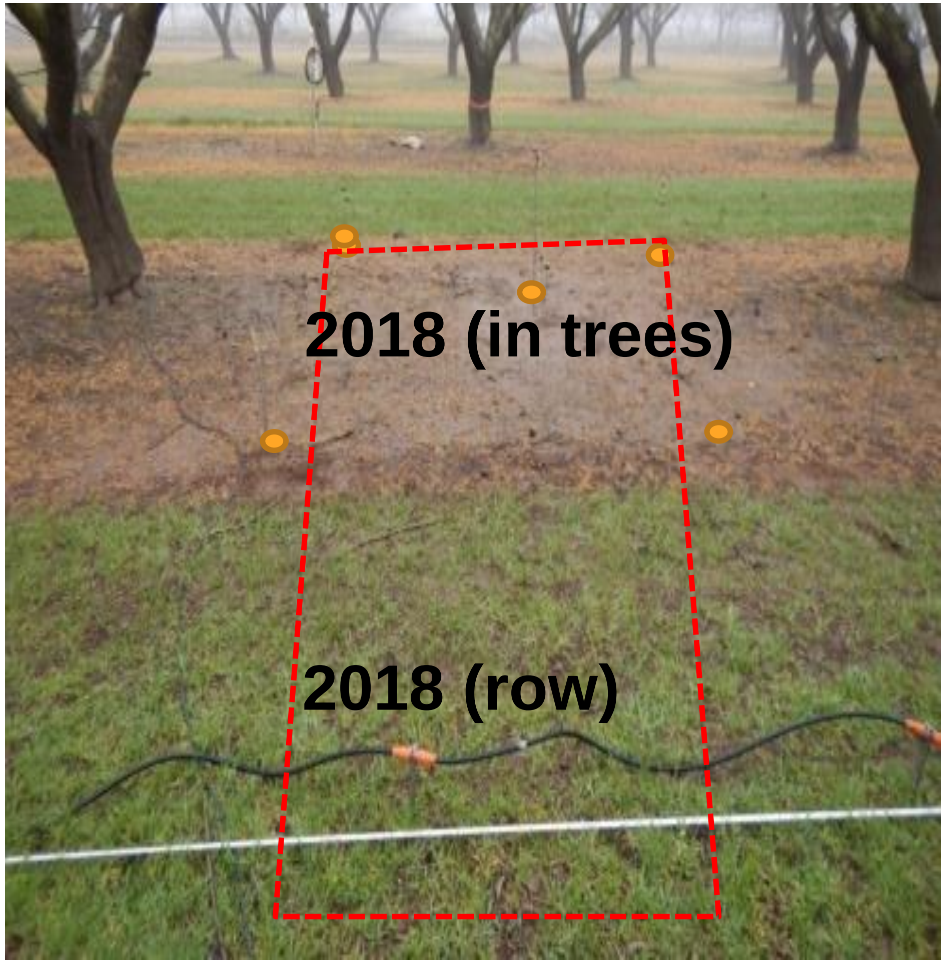


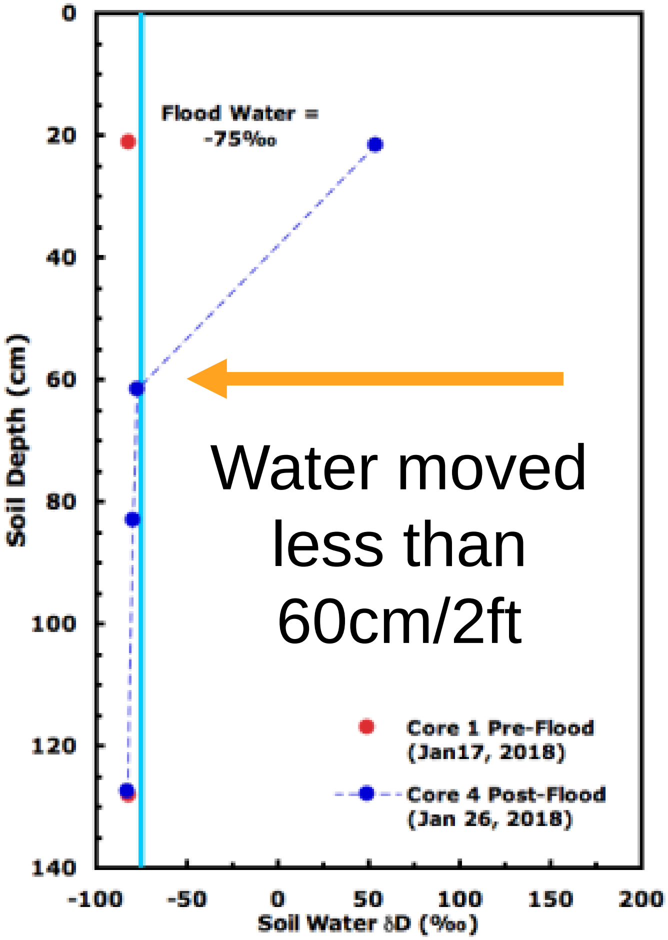
Apply D_2O before flood





Infiltration Varies a Lot Over Small Distances

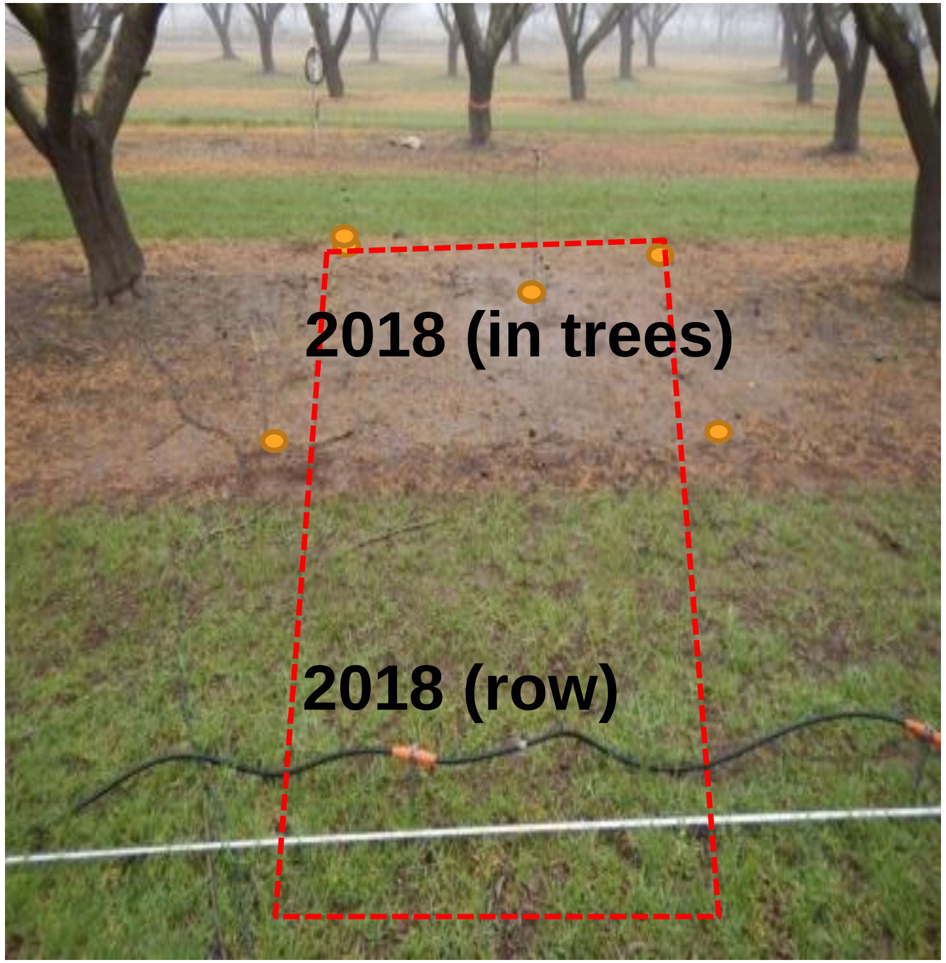


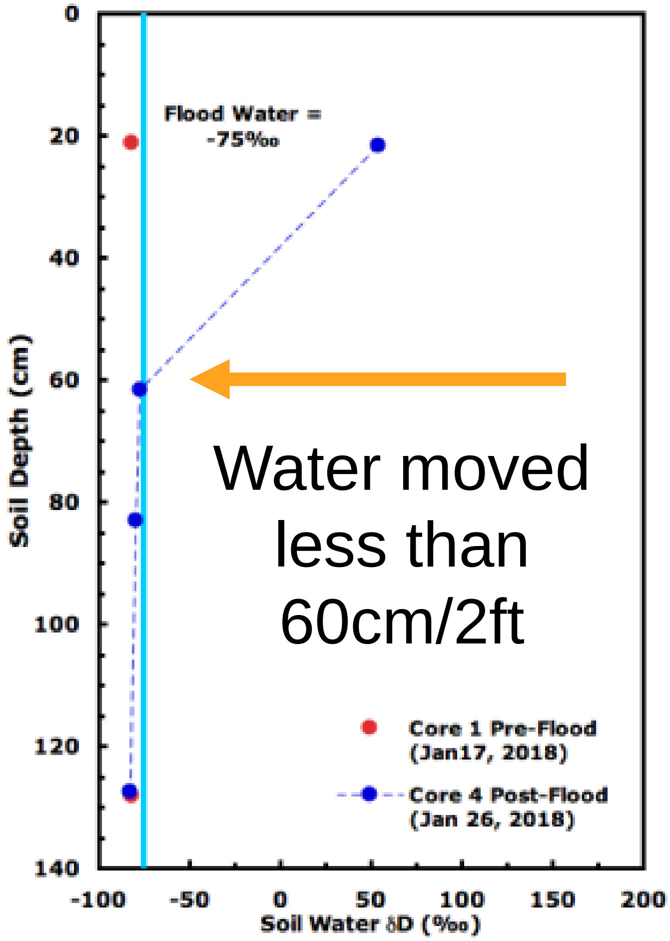


Water moved less than 60cm/2ft

2018 (in trees)

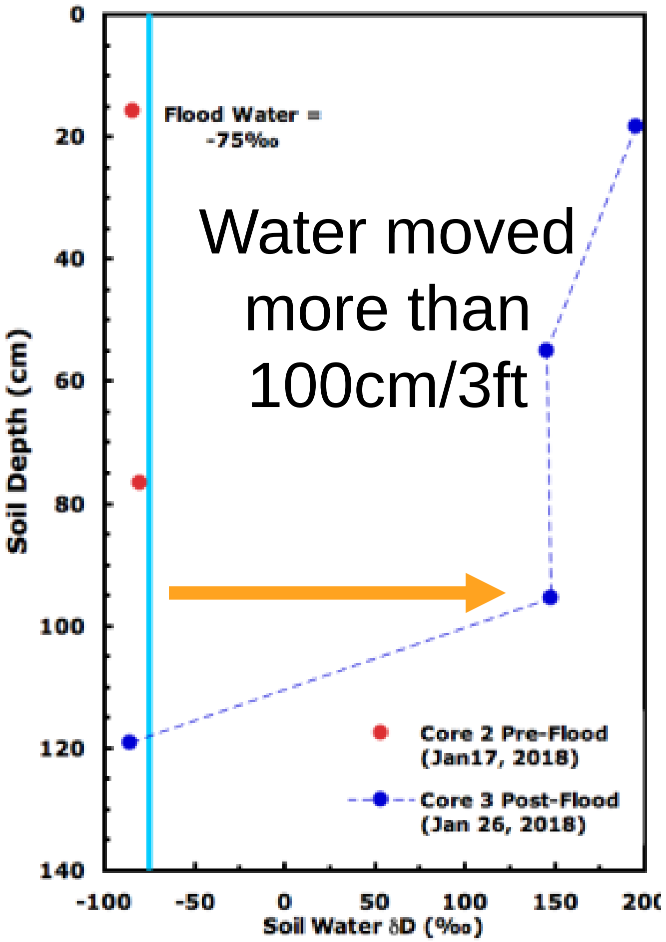
Infiltration Varies a Lot Over Small Distances





Water moved less than 60cm/2ft

2018 (in trees)



Water moved more than 100cm/3ft

2018 (row)

Parting Thoughts

- Optimizing On-Farm Recharge
  - Land Use, Land management, and Water Management
- Predicting and Protecting Water Quality
  - Protect Water Resources, Prevent Problems Before They Occur
  - e.g. Hannah Waterhouse Presentation
- Management and Monitoring at Scale by Satellite and New Techniques
  - Provide Methods for Monitoring Both at Field Scale and at Management Scale

Thank You!

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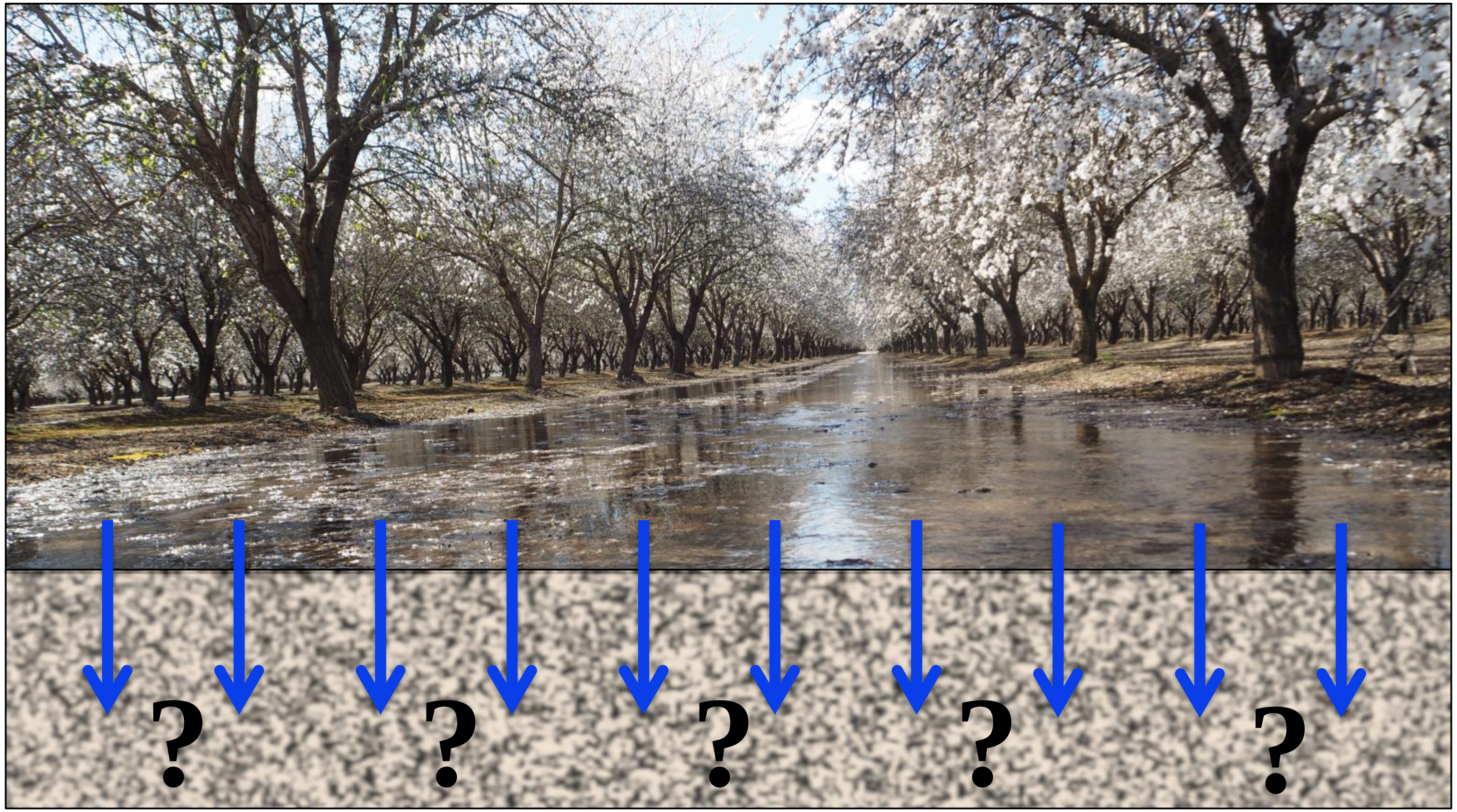
Almond Board of California

Geophysical Imaging of Sediment Texture

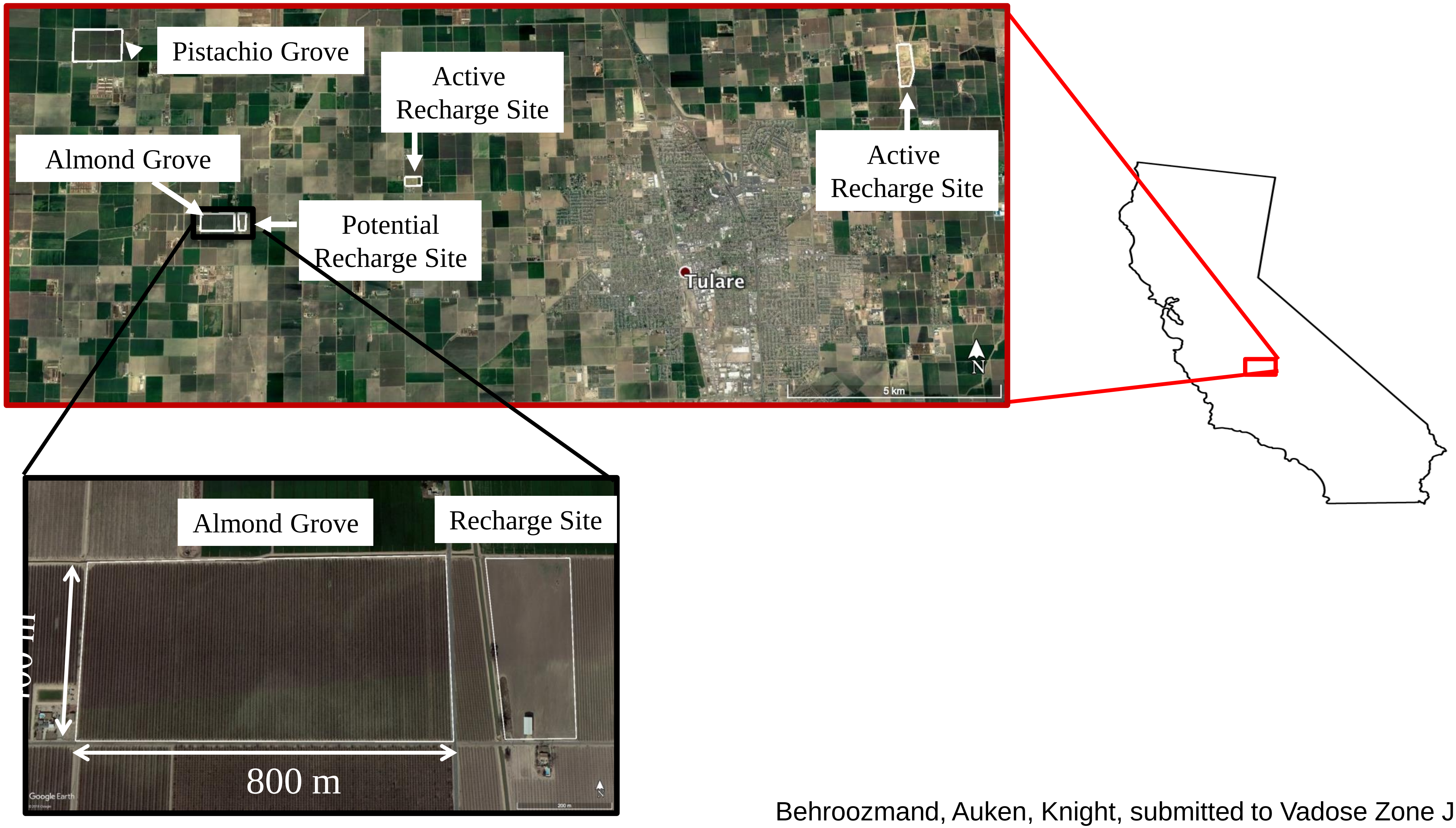
Rosemary Knight & Meredith Goebel
rknight@stanford.edu mgoebel@stanford.edu

Motivation: Assessment of sites for on-farm recharge



Sediment texture controls where the water goes, and how quickly.
Sediment texture needs to be accounted for in modeling changes in water quality.

Study Area: Sites in Tulare Irrigation District



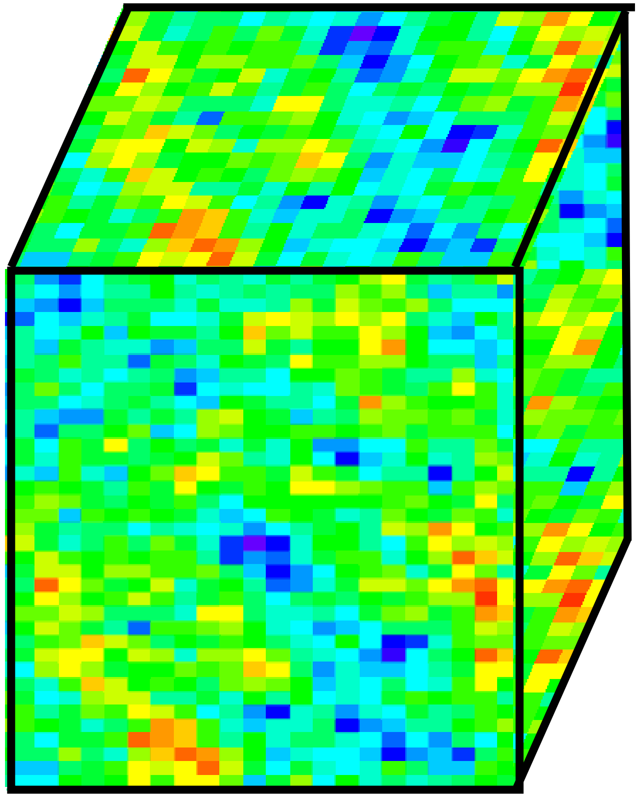
Behroozmand, Auken, Knight, submitted to Vadose Zone Journal, 2018

towTEM: A geophysical imaging method

moves at 10-15 km/hr, imaging depth 50-80 m
horizontal resolution: ~15 m vertical: 1m to 8 m
dense spatial sampling

Behroozmand, Auken, Knight, submitted to Vadose Zone Journal, 2018

The Challenge



geophysical property that we measure: electrical resistivity

↓

subsurface information that we want: sediment texture

From Electrical Resistivity to Sediment Texture

low resistivity:
clay

high resistivity:
sand and gravel

From Electrical Resistivity to Sediment Texture

but increasing water content

Resistivity [ohm-m]

low resistivity:
clay

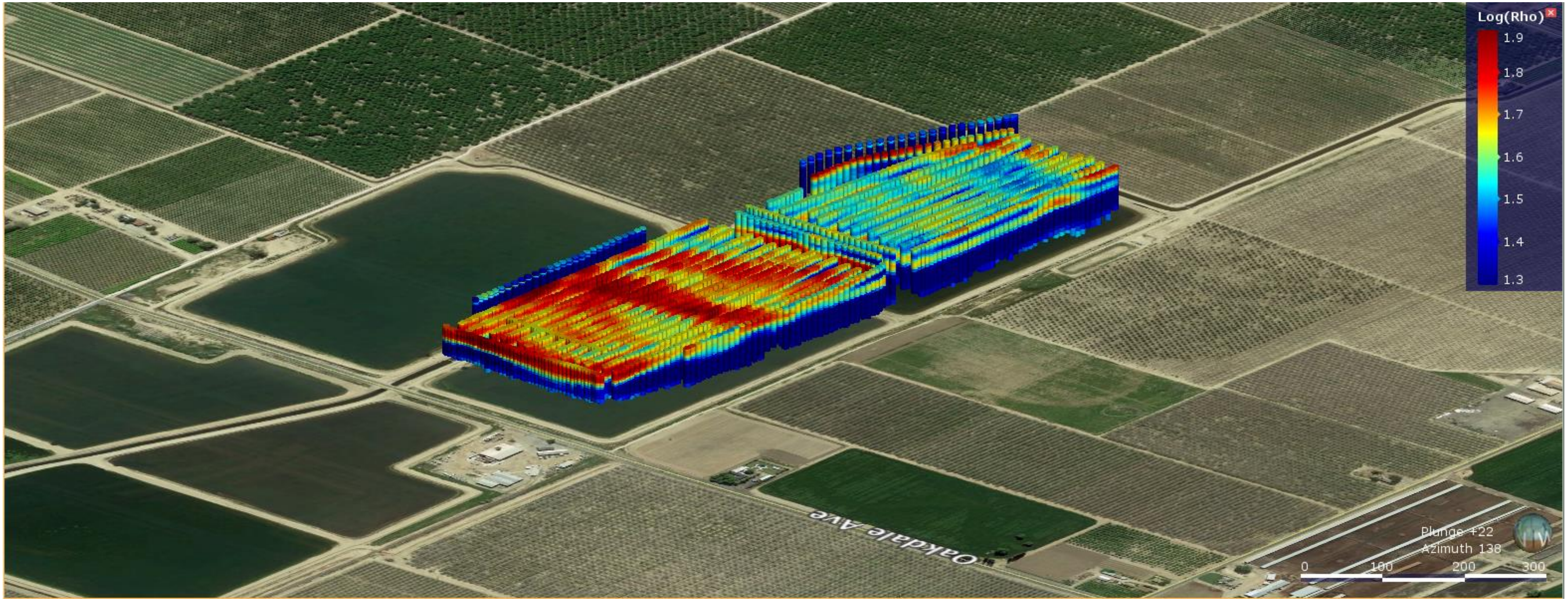
high resistivity:
sand and gravel

INSERT VIDEO PLEASE SCALED SO THAT TEXT BELOW SHOWS

Thanks to Aaron Fukuda for the drone footage.

Behroozmand, Auken, Knight, submitted to Vadose Zone Journal, 2018

Upcoming Research Activities



1) Cone Penetrometer Testing to aid in the resistivity to sediment texture transform.
2) Drone TEM as a new way to monitor during recharge.

What’s Next

Research Poster Session at 3:00 p.m.

Almond Stage Presentation at 3:00 p.m.

- Electronic Sensing of Larvae and Adult Insect Moths, presented by Sensor Development Corporation

Sensor
Development
Corporation

3:30 p.m. – 5:30 p.m. Social Hour is sponsored by Mulch Master

MulchMaster
Conserving Water Beautifully

What’s Next

Almond Stage Presentation at 3:30 p.m.

- Best Practices in Nut Butter Milling, presented by AC Horn

Almond Stage Presentation at 4:00 p.m.

- In-Canopy Sensors & Micro-Climate Models for Navel Orangeworm Management, presented by Semios

Almond Stage Presentation at 4:30 p.m.

- Smart Pest and Disease Scouting for Almond Trees, presented by Aerobotics