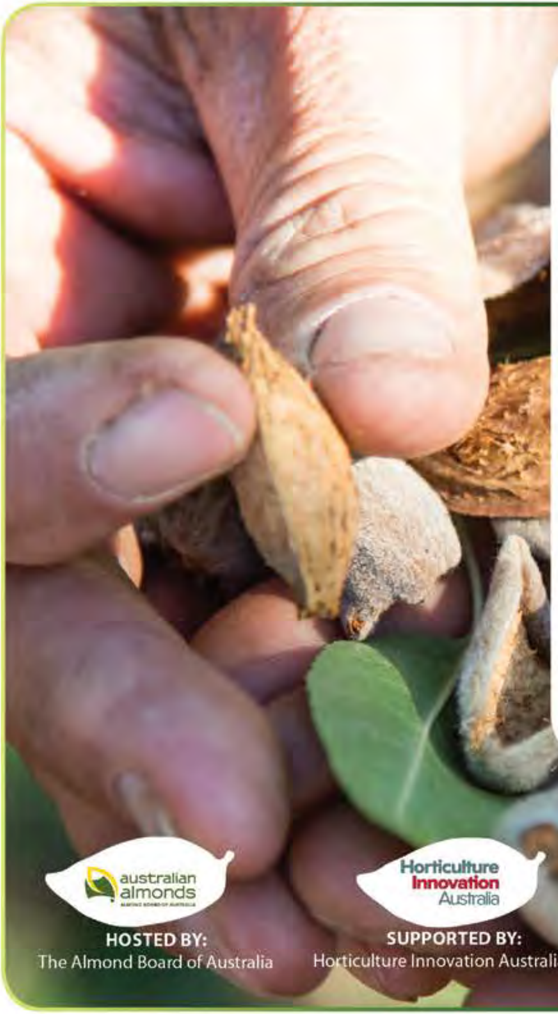


# Yield as a function of evapotranspiration and irrigation

(Original title: Correlation of individual tree nut yield, evapotranspiration, tree stem water potential, total soil salinity and chloride in a high production almond orchard)


**Blake Sanden –**

**Irrigation/Soils Advisor, University of California, Kern County**



17th Australian Almond Conference

HOSTED BY:
The Almond Board of Australia

SUPPORTED BY:
Horticulture Innovation Australia Ltd

Pullman Hotel Melbourne, Albert Park, Victoria

November 8th - 10th, 2016

# Blake Sanden

17th Australian Almond Conference
November 8th - 10th, 2016

## Irrigation & Agronomy Farm Advisor, University of California Cooperative Extension

Blake Sanden is the Irrigation and Agronomy Farm Advisor with the University of California Cooperative Extension, stationed in Kern County at the southern end of the San Joaquin Valley. He conducts county-based, applied research and extension programs focusing on irrigation system management, salinity/fertility management for all crops, and agronomic field crop production of alfalfa, dry beans and oil crops.

Blake has a BS in International Agricultural Development & Agronomy and MS in Irrigation and Drainage from UC Davis and 35 years of experience in production ag, international ag development and extension. Significant projects include: development of salt tolerance thresholds for pistachios in the San Joaquin Valley, soil moisture monitoring and irrigation efficiency assessment on 12,000 acres in Kern County, deficit irrigation in early citrus navels and almond water use/fertilizer management for optimal yield.

UNIVERSITY of CALIFORNIA
COOPERATIVE EXTENSION

<u>Co-investigators</u>

S. Muhammad – UC Davis, Pakistan Agricultural Extension

P.H. Brown – UC Davis, Pomology/Fertilitly

K.A. Shackel – UC Davis, Pomology/Plant-Water Relations

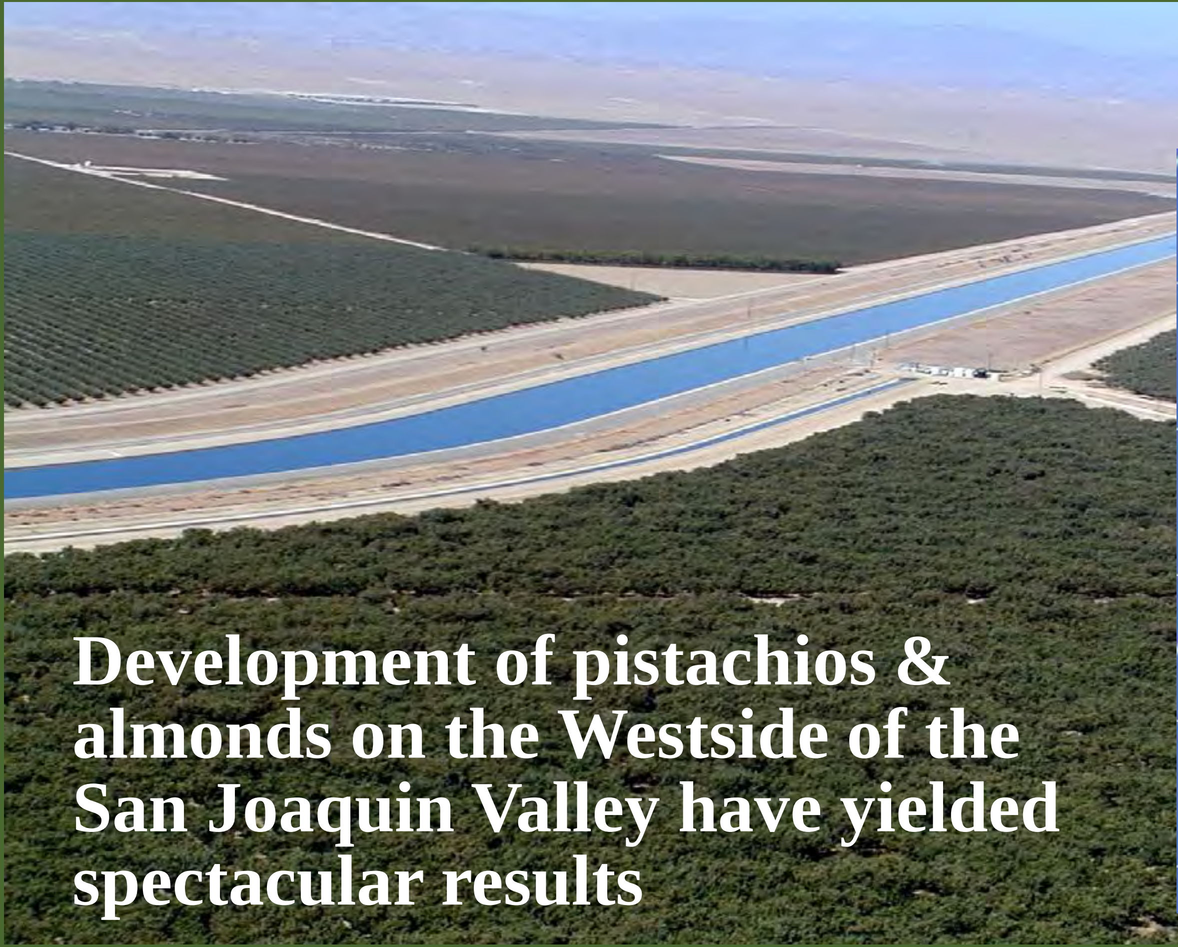
R.L. Snyder – UC Davis, Extension Specialist Biometeorolgy

<u>Cooperators</u>

Paramount Farming Company / Roll International

Kern County farmers and almond growers

<u>Funding:</u> Almond Board of California



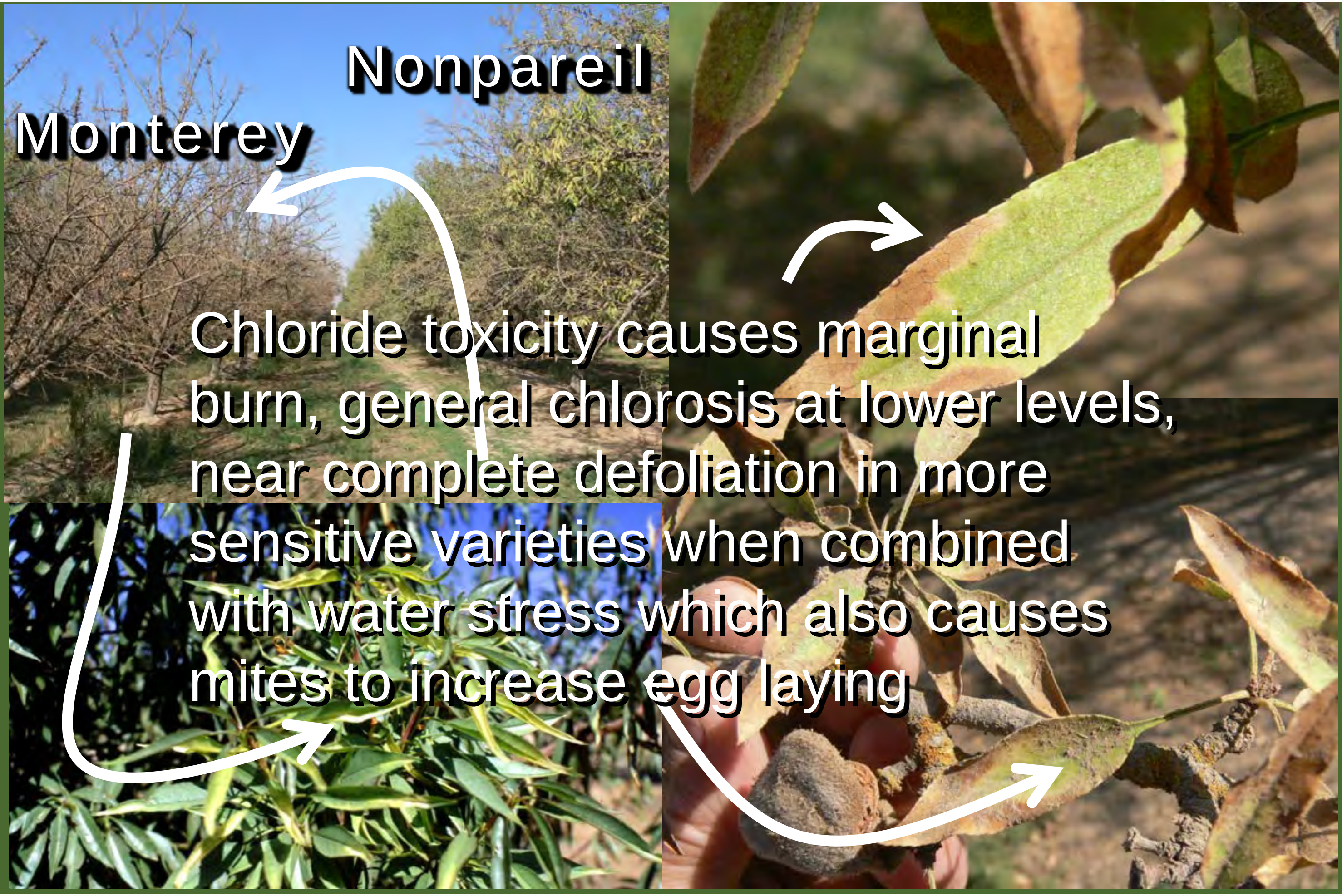
Development of pistachios & almonds on the Westside of the San Joaquin Valley have yielded spectacular results

Much former flood irrigated cotton ground prone to water logging and salinity problems has been converted to pistachios on drip irrigation.  Better ground has been planted to almonds – but this is no guarantee of escaping salt problems.

**Boron, chloride and sodium accumulation killing marginal leaf areas at end of season.**

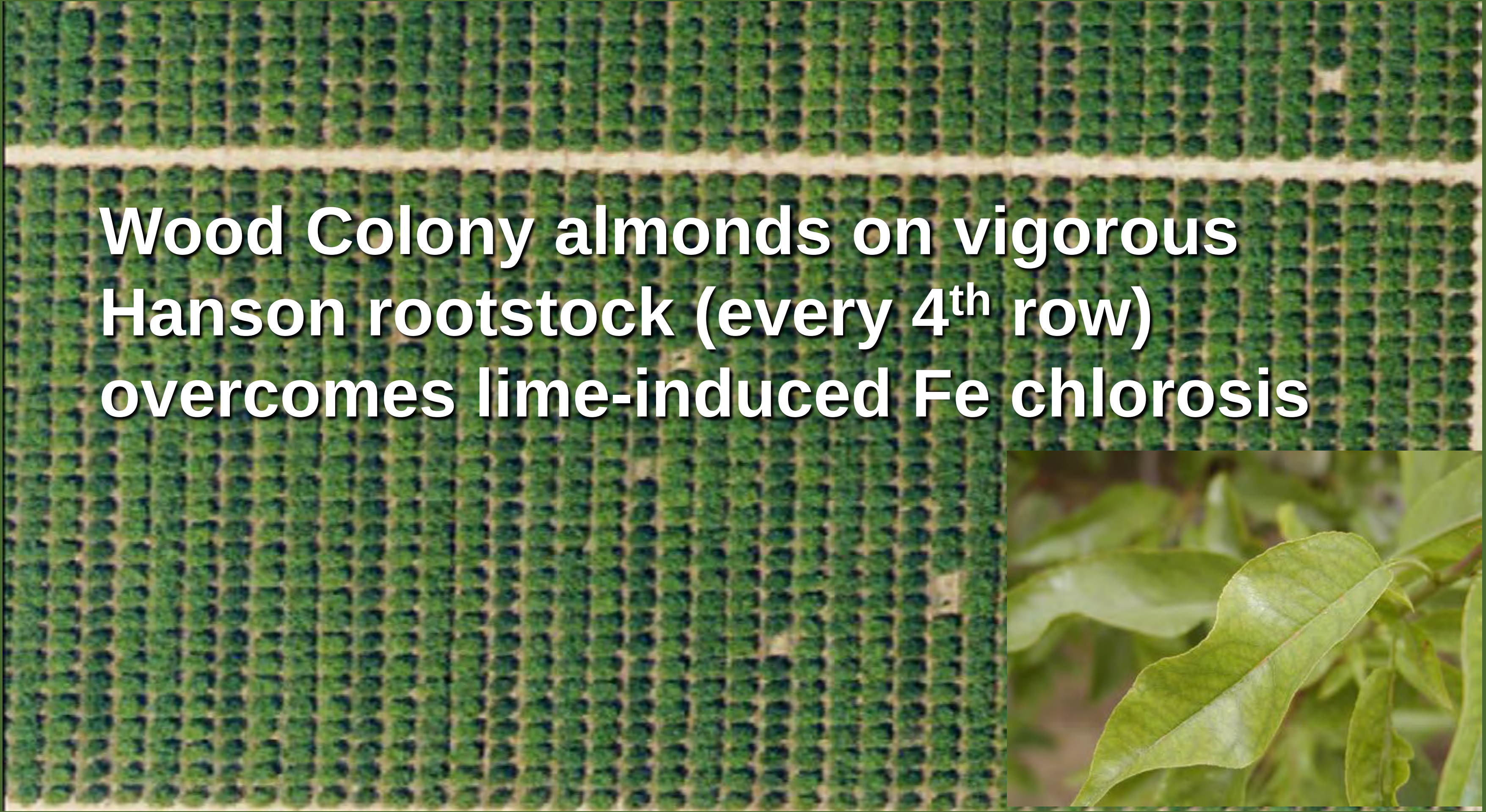
# Excessive Na, Cl and especially B can burn and desiccate almonds.

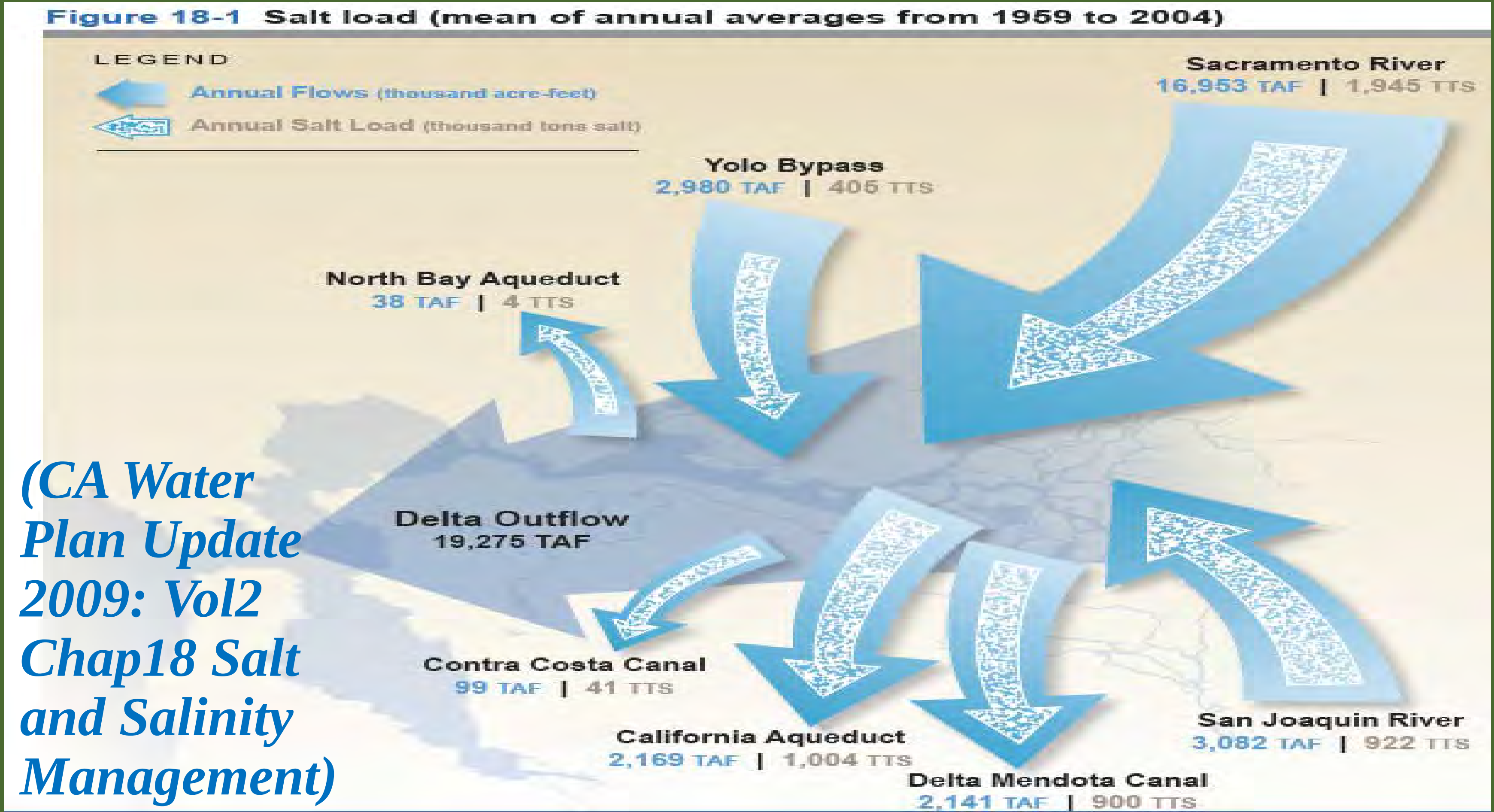

Observation: Many orchards would stress and exhibit some defoliation as early as July on through harvest.


Nonpareil
Monterey
Chloride toxicity causes marginal burn, general chlorosis at lower levels, near complete defoliation in more sensitive varieties when combined with water stress which also causes mites to increase egg laying

# Lime-induced Iron Chlorosis in Almonds

# Wood Colony almonds on vigorous Hanson rootstock (every 4th row) overcomes lime-induced Fe chlorosis






*(CA Water Plan Update 2009: Vol2 Chap18 Salt and Salinity Management)*

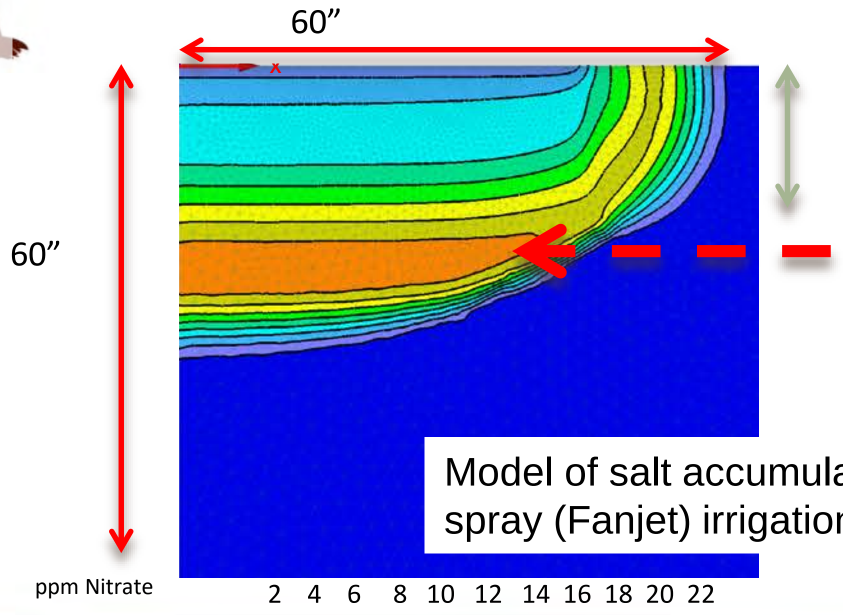
# What about salinity buildup under super efficient irrigation when the salt load is ~ ½ mt/ML?

# Micro-irrigation system capable of injecting fertilizer and applying 0.6 to 1.5 inches/day

# What Next:



- Salinity is the greatest threat to orchard production in California
- Our understanding is still limited
- Considerable potential to improve management strategies particularly irrigation and leaching strategies.
- Without mitigation (leaching and/or improved water quality), it can only get worse.




18 “ Effective Root Zone

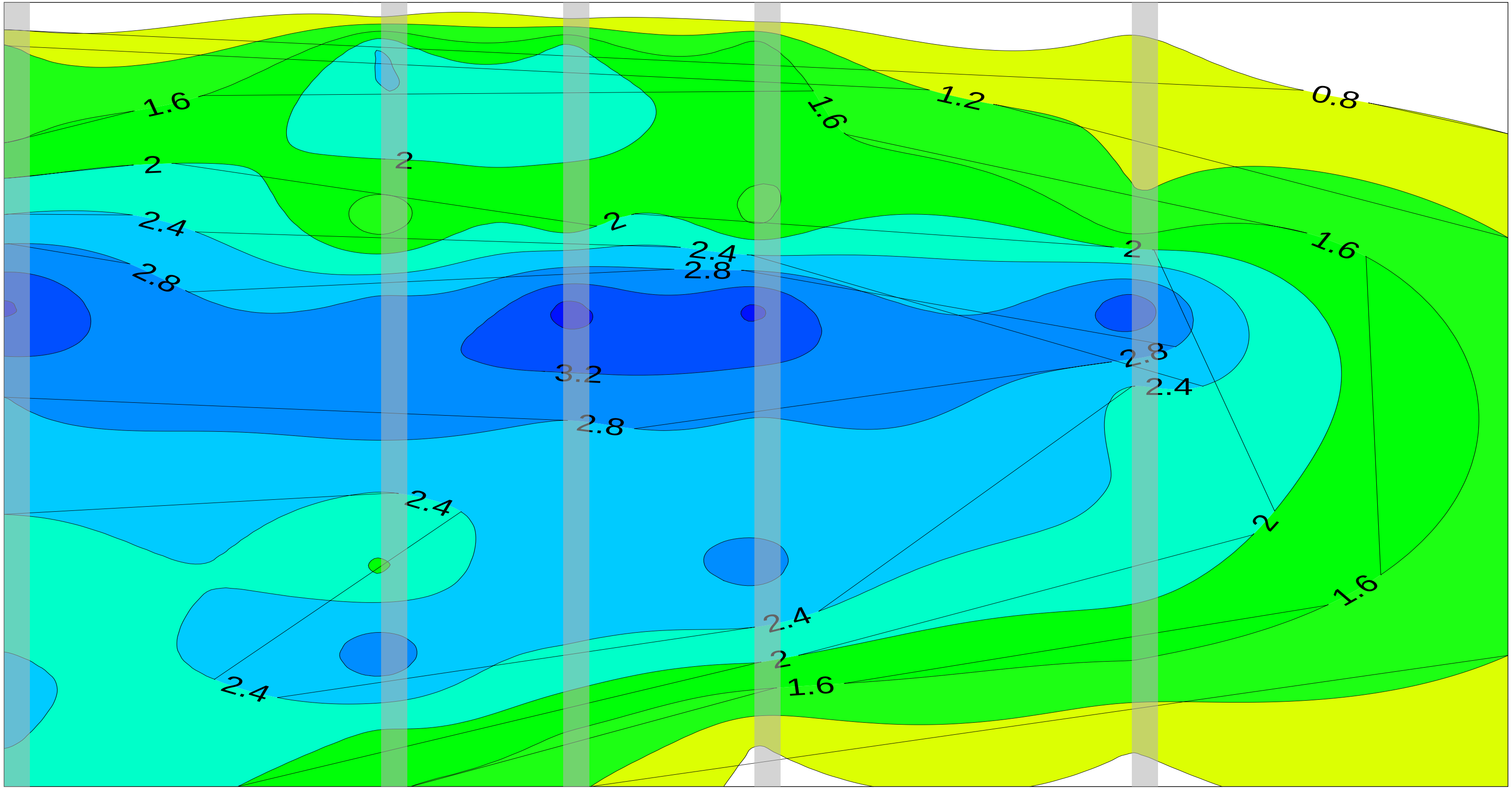
Salinity and Nitrate can accumulate below effective root zone.

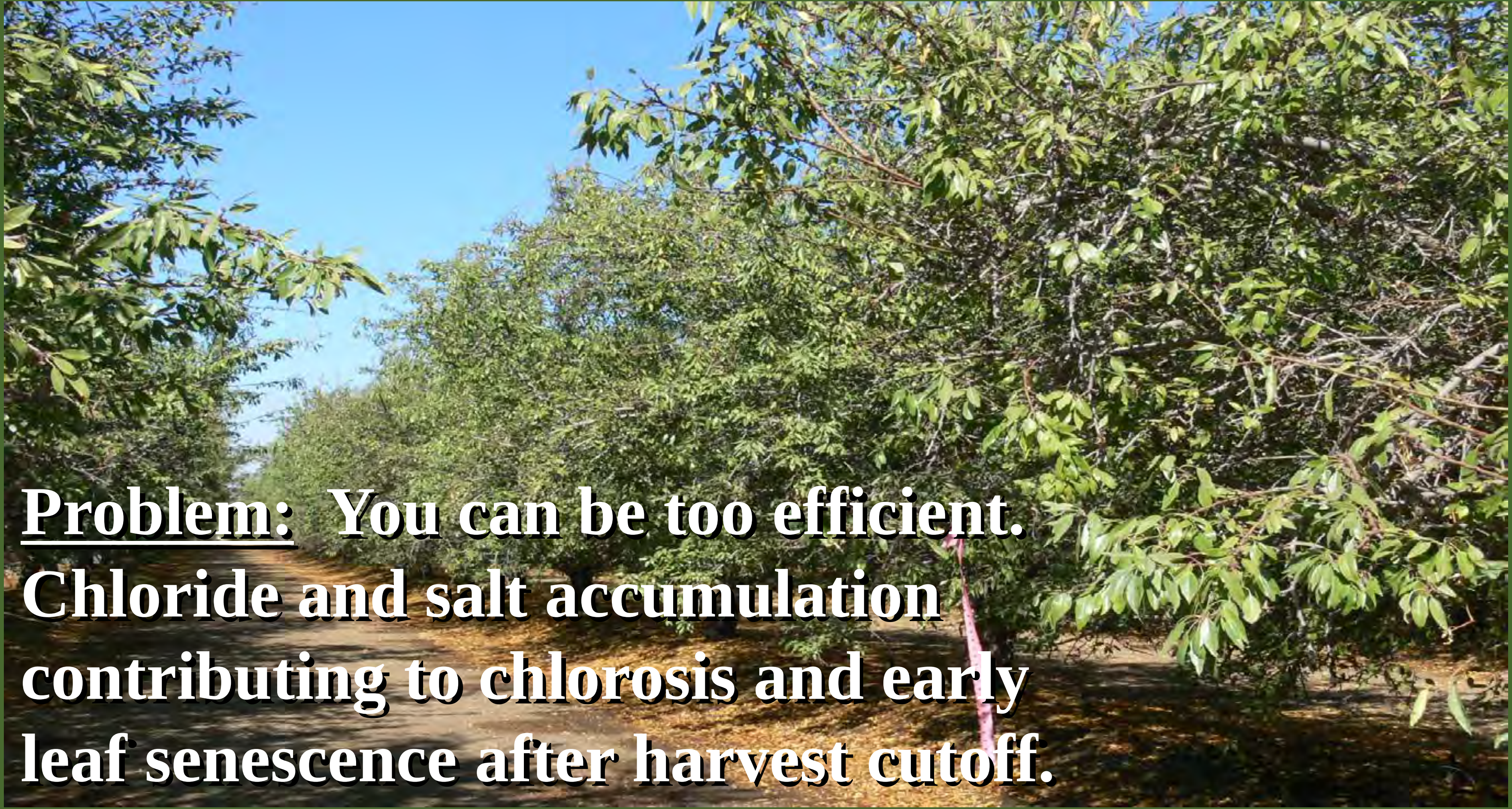
Kandelous, Unpublished


… or account for
“subbing” in a
double-line drip?

TREE

**DRIP HOSE**




Problem: You can be too efficient.
Chloride and salt accumulation contributing to chlorosis and early leaf senescence after harvest cutoff.

# *CA Water Plan 2009*
# *Salinity accumulation over time*

***<u>CA Aqueduct (or borehole) water salinity</u>***

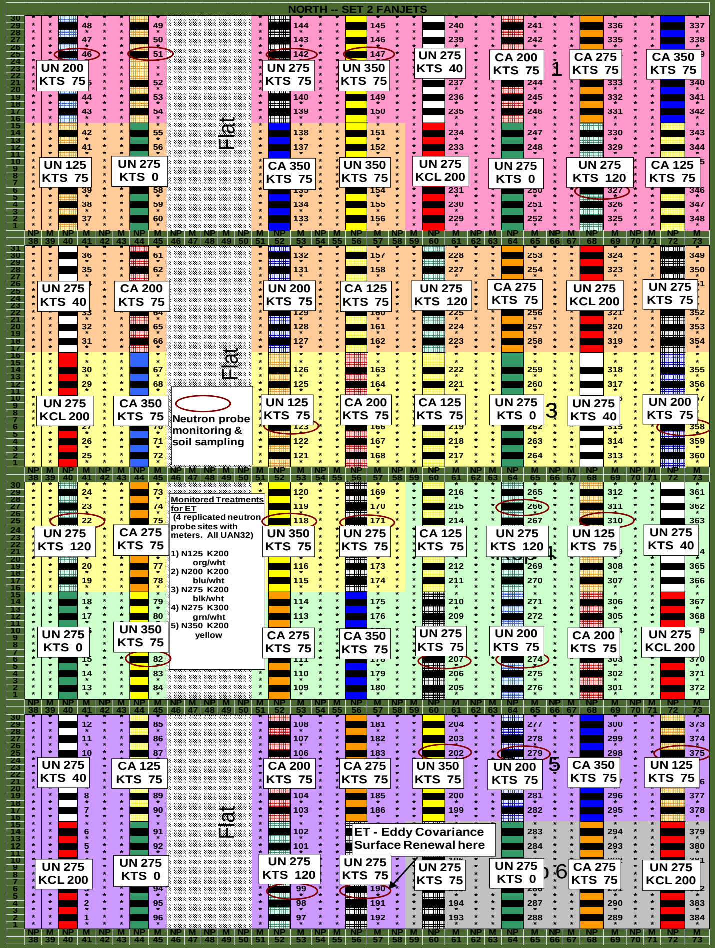
***= 0.41 mt / ML (0.46 t/ac-ft, 0.53 ds/m EC, 339 ppm tds)***

***=1.6 dS/m EC increase to 3 m depth of soil over 20 years @ 14 ML/ha/yr (55.1 inches)***

***=8.0 dS/m increase for 40% drip volume to 1.5m***

*1 ML/ha =100 mm depth water*
*(CA Water Plan Update 2009: Vol2 Chap18: Salt and Salinity Management)*


FANJET
S
DOUBLE-
LINE DRIP
Intensive monitoring site with 5 neutron probe access tubes, Watermark/Irrometer logger, Surface Renewal and Sonic Anemometer heat flux estimates of ET.
Possible PureSense Probe
1
6
7
11
12
13
14
18
LERDO HWY
Map center: 6067425, 2374681




# Patrick Brown fertility trial 2008-2012

## 12 treatments total

- 4 N levels, 2 sources
  125, 200, 275, 350 lb/ac
- 3 K levels, 3 sources
  100, 200, 300 lb/ac

# Comparison of University of California Almond ET/Kc Curves

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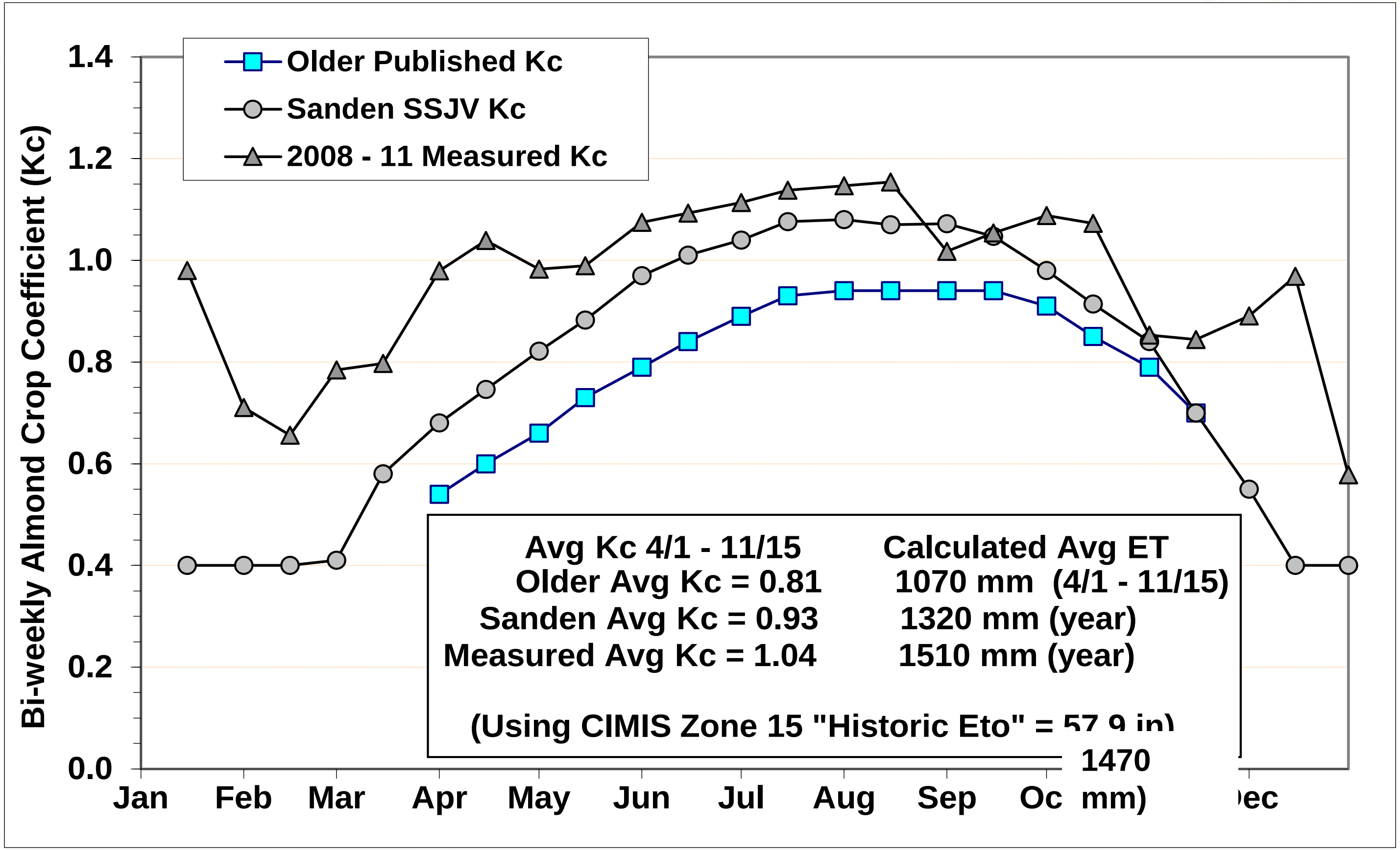
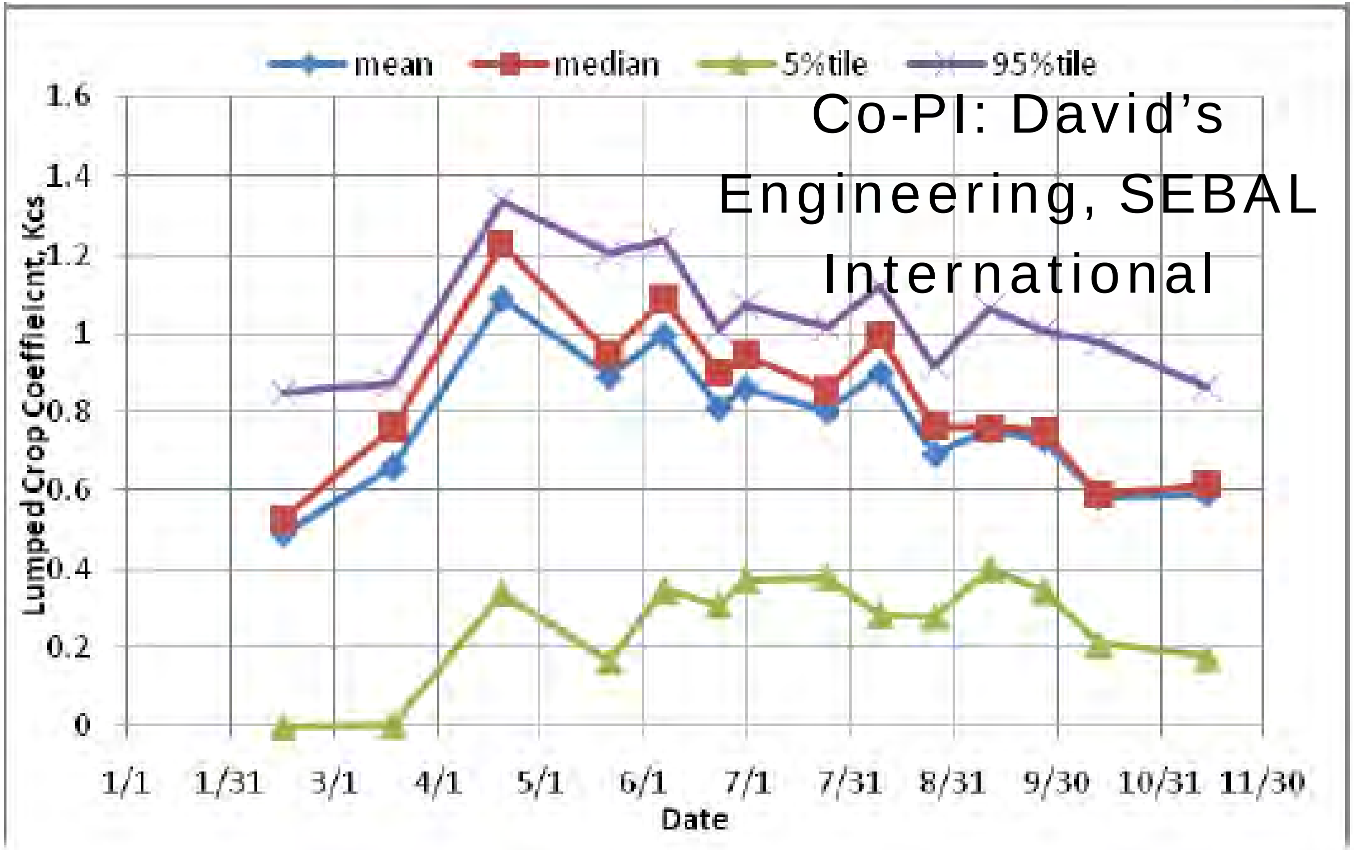


# 2008 Kern Almond Crop Coefficients (Kc) Using Satelites & SEBAL 156 Fields






Co-PI: David's Engineering, SEBAL International

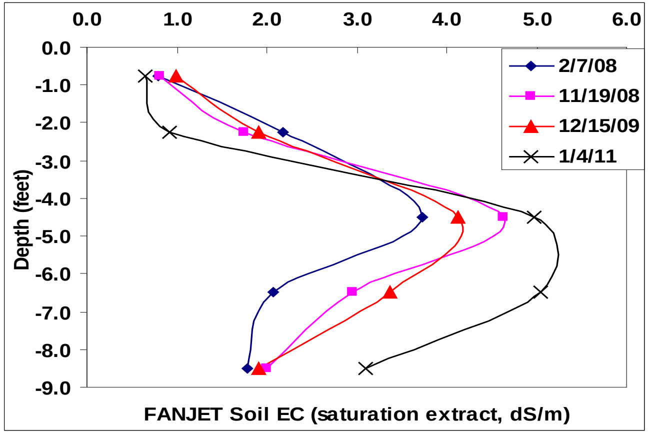
# Differential N rates affected yield but had no effect on individual tree SWP or ET

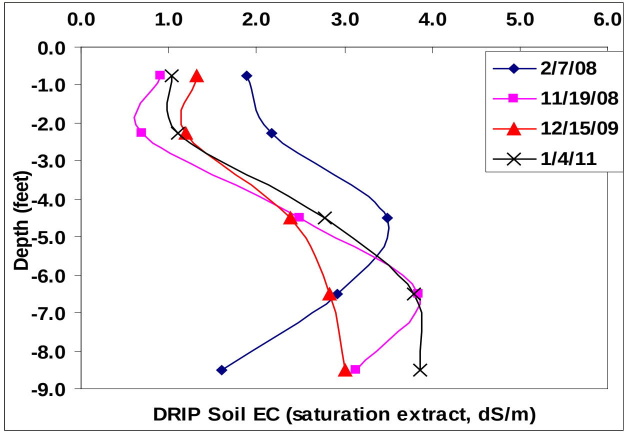
| **2010** Treatment (N-K lb/ac) | Stem Water Potential (MPa) | | Soil Water to 2.7 m (%) | | Total Neutron Probe ET (in) | | SWP-NP Tree Kernel Yield (kg/ha) | |
|---|---|---|---|---|---|---|---|---|
| | Drip | Fanjet | Drip | Fanjet | Drip | Fanjet | Drip | Fanjet |
| **125-200** | -0.98 a | -1.11 a | 14.7 ab | 13.3 a | 1443 a | 1409 a | 3996 a | 3676 a |
| **200-200** | -0.97 a | -1.19 b | 15.9 b | 13.9 a | 1448 a | 1382 a | 4235 ab | 4025 ab |
| **275-200** | -0.97 a | -1.25 b | 16.4 b | 15.0 a | 1439 a | 1396 a | 4781 cd | 4387 bc |
| **275-300** | -1.01 a | -1.21 b | 15.5 ab | 13.5 a | 1461 a | 1400 a | 4560 bc | 4264 bc |
| **350-200** | -0.97 a | -1.19 b | 13.6 a | 14.2 a | 1433 a | 1397 a | 5287 d | 4668 c |
| **AVERAGE** | **-0.98** | **-1.19** | **15.2** | **14.0** | **1445** | **1397** | **4572** | **4204** |
| *LSD 0.05* | *0.05* | *0.06* | *2.3* | *2.6* | *93.0* | *82.6* | *512* | *465* |

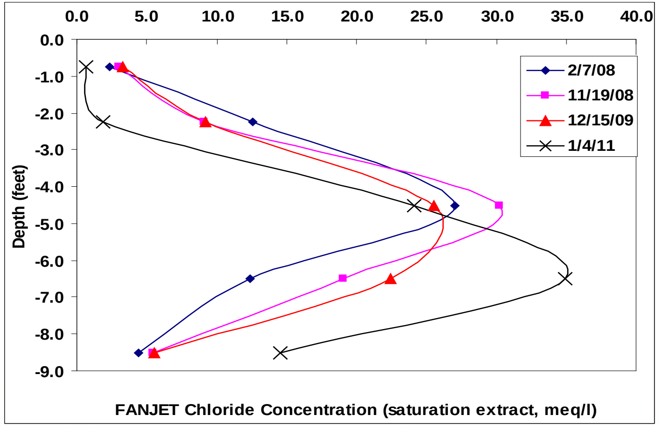
| **2011** Treatment (N-K lb/ac) | Stem Water Potential (MPa) | | Soil Water to 2.7 m (%) | | Total Neutron Probe ET (in) | | SWP-NP Tree Kernel Yield (kg/ha) | |
|---|---|---|---|---|---|---|---|---|
| | Drip | Fanjet | Drip | Fanjet | Drip | Fanjet | Drip | Fanjet |
| **125-200** | -0.93 b | -1.03 a | 15.8 ab | 14.3 a | 1366 a | 1390 a | 4391 a | 4101 a |
| **200-200** | -0.95 a | -1.04 a | 16.2 ab | 14.4 a | 1364 a | 1356 a | 4522 a | 4429 ab |
| **275-200** | -0.93 b | -1.05 a | 18.0 b | 16.7 a | 1373 a | 1377 a | 5180 b | 4893 bc |
| **275-300** | -0.93 b | -1.04 a | 16.3 ab | 14.9 a | 1388 a | 1364 a | 5141 b | 5270 c |
| **350-200** | -0.90 c | -1.05 a | 14.2 a | 15.3 a | 1402 a | 1340 a | 5152 b | 4790 bc |
| **AVERAGE** | **-0.93** | **-1.04** | **16.1** | **15.1** | **1379** | **1366** | **4877** | **4696** |
| *LSD 0.05* | *0.02* | *0.02* | *2.5* | *2.7* | *100.8* | *73.7* | *604* | *529* |

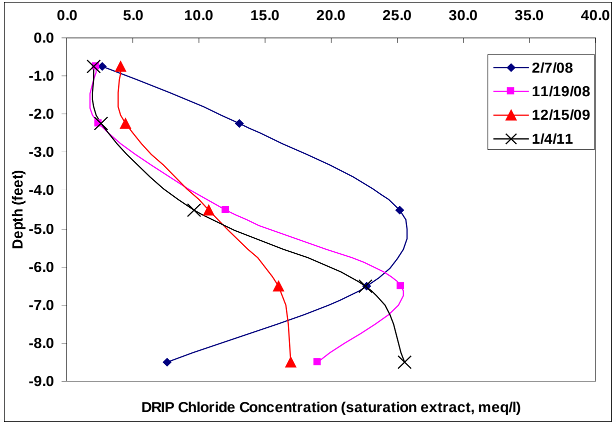
# Rootzone salinity profiles with depth





# FAO 29 Ayers & Westcott Salt Tolerance Curves Compared

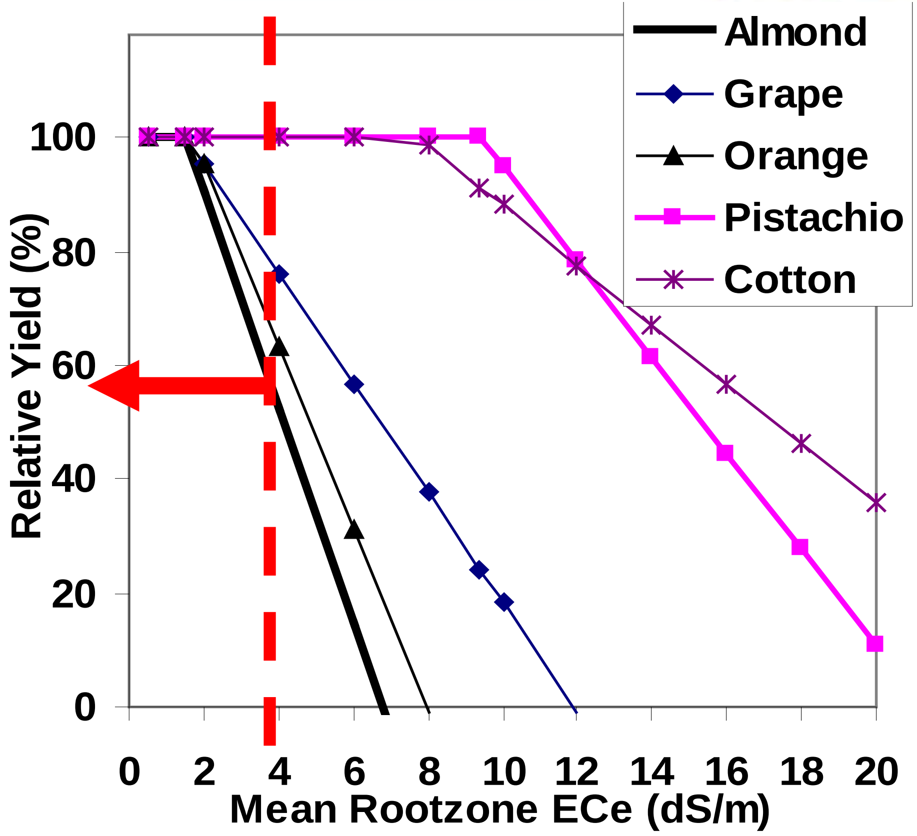


Almond Relative Yield (%) =
100 – 19*(Soil $EC_e$ – 1.5)

= 52.5%

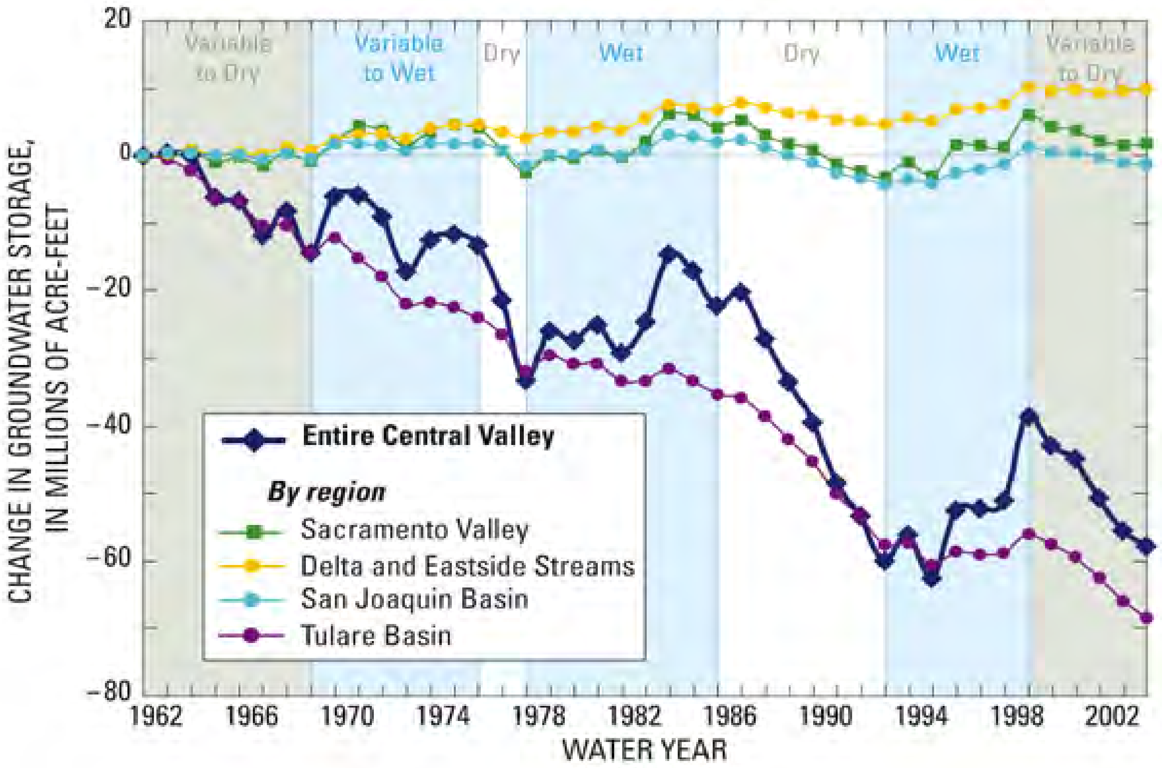
@ ECrz = 4 dS/m

Ayers, R.S., and D.W. Westcot. (1985). Water Quality for Agriculture. FAO Irrigation and Drainage Paper 29 Rev.1, Food and Agriculture Organization of the United Nations, Rome. 174 pp.



# CA groundwater depletion:  1962-2003

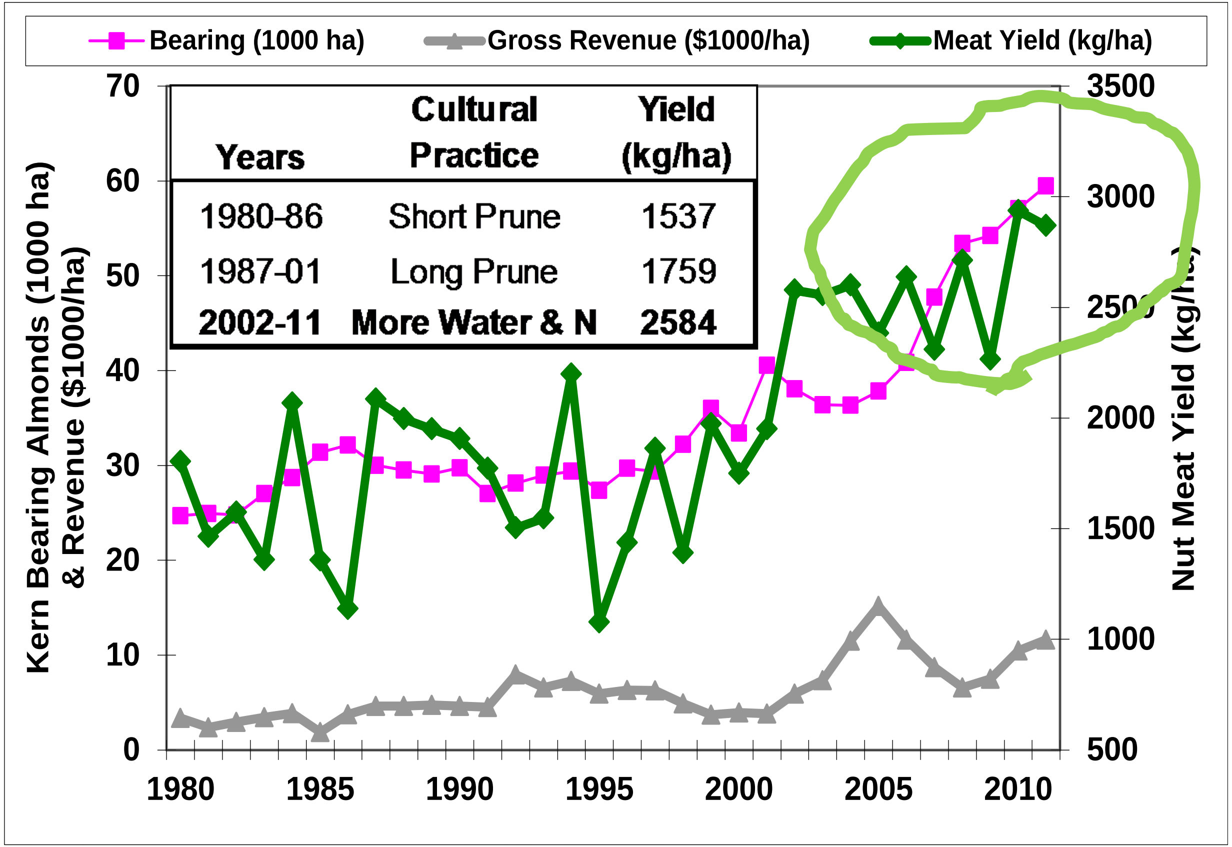





Faunt, C.C. ed., 2009, Groundwater Availability of the Central Valley Aquifer: U.S. Geo-logical Survey Professional Paper 1766, 225 p.
http://pubs.usgs.gov/pp/1766/

# Trends in Kern County Almonds






| Years | Cultural Practice | Yield (kg/ha) |
| --- | --- | --- |
| 1980-86 | Short Prune | 1537 |
| 1987-01 | Long Prune | 1759 |
| **2002-11** | **More Water & N** | **2584** |

# Trends in individual tree salinity and almond kernel yield

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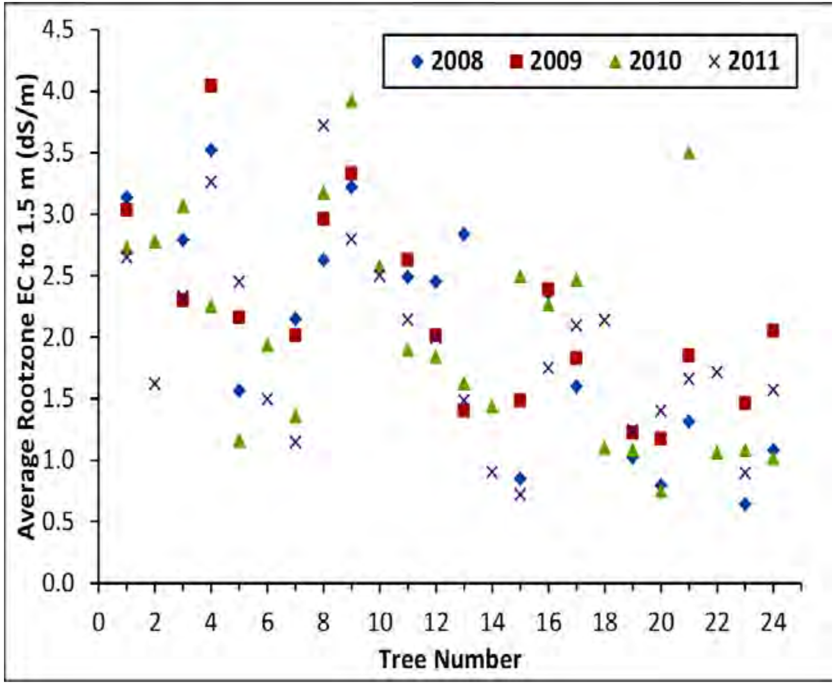


Fig. 2.a. All years average rootzone ECe to 1.5 m by tree number approximately west to east.

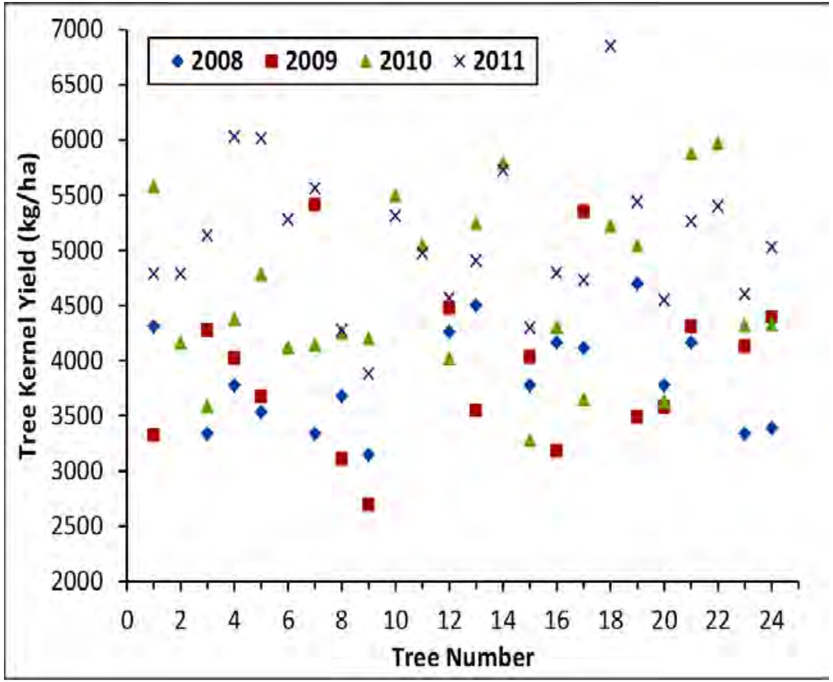


Fig. 2.b. All years tree kernel yield by tree number approximately west to east.

# Pearson Product "R" Correlation Values of Various Salinity, Water and Almond Yield Characteristics

| | Chloride | SWP | NP-ET | Yield | Previous Year EC |
|---|---|---|---|---|---|
| 2008 EC | 0.970* | -0.451 | 0.189 | 0.014 | -- |
| 2009 EC | 0.926* | -0.571* | -0.188 | -0.294 | 0.786* |
| 2010 EC | 0.899* | -0.306 | -0.045 | -0.120 | 0.550* |
| 2011 EC | 0.866* | -0.454* | 0.170 | -0.007 | 0.507* |
| All Years Avg | 0.920* | -0.533* | 0.063 | -0.266 | -- |

(*Probability < 0.05)

# Comparison of "relative yield" as a function of salinity for a 0.9 m and 1.5 m rootzone

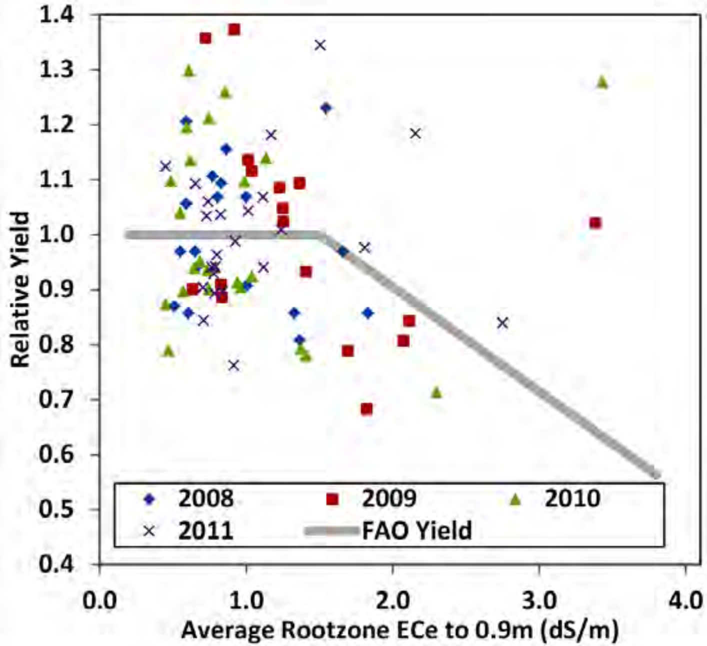


Fig. 3.a. Relative kernel yield as a function of average rootzone salinity (0-0.9 m) for all years and the "classic" almond salt tolerance curve (Ayers and Westcott, 1985).

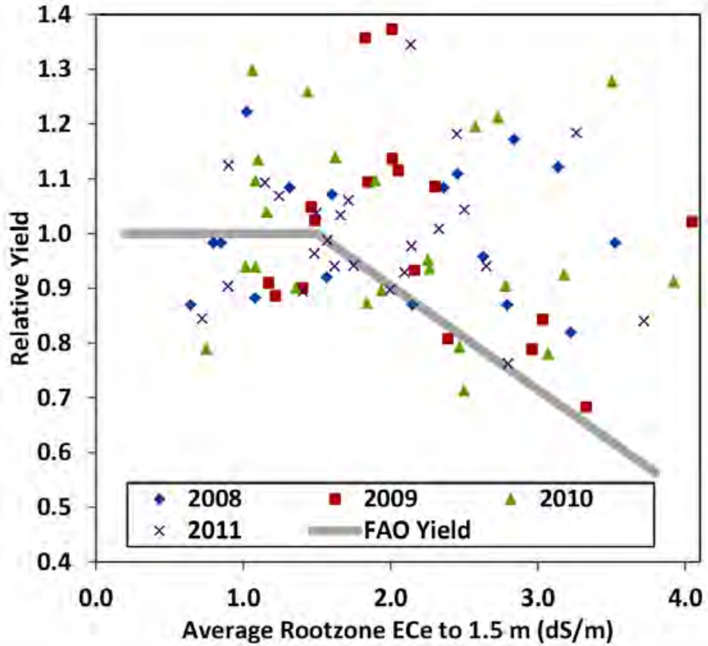


Fig. 3.b. Relative kernel yield as a function of average rootzone salinity to 1.5 m for all years and the "classic" almond salt tolerance curve (Ayers and Westcott, 1985).

# Growth and Salt Tolerance of Nonpareil on Different Rootstocks

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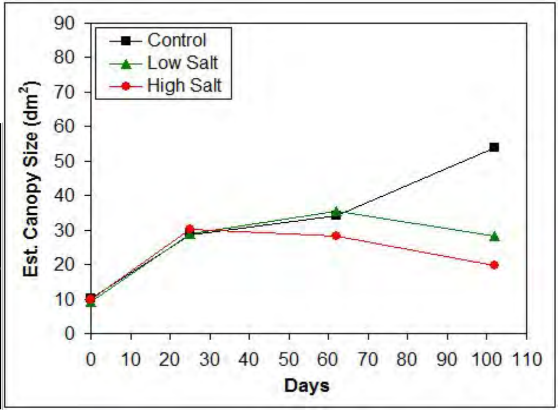
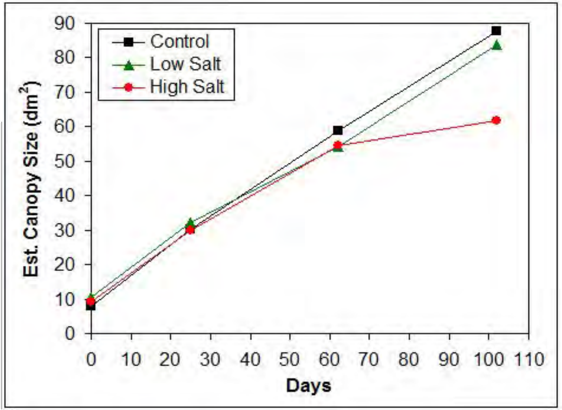
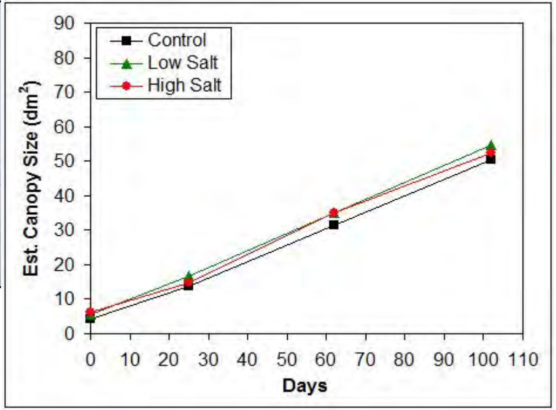
Nemaguard



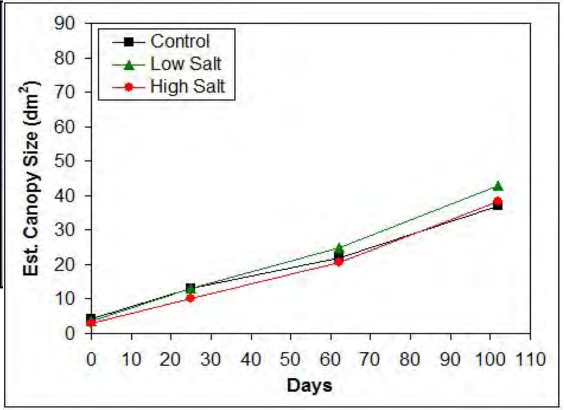

Hansen 536




Empryean-1




Viking

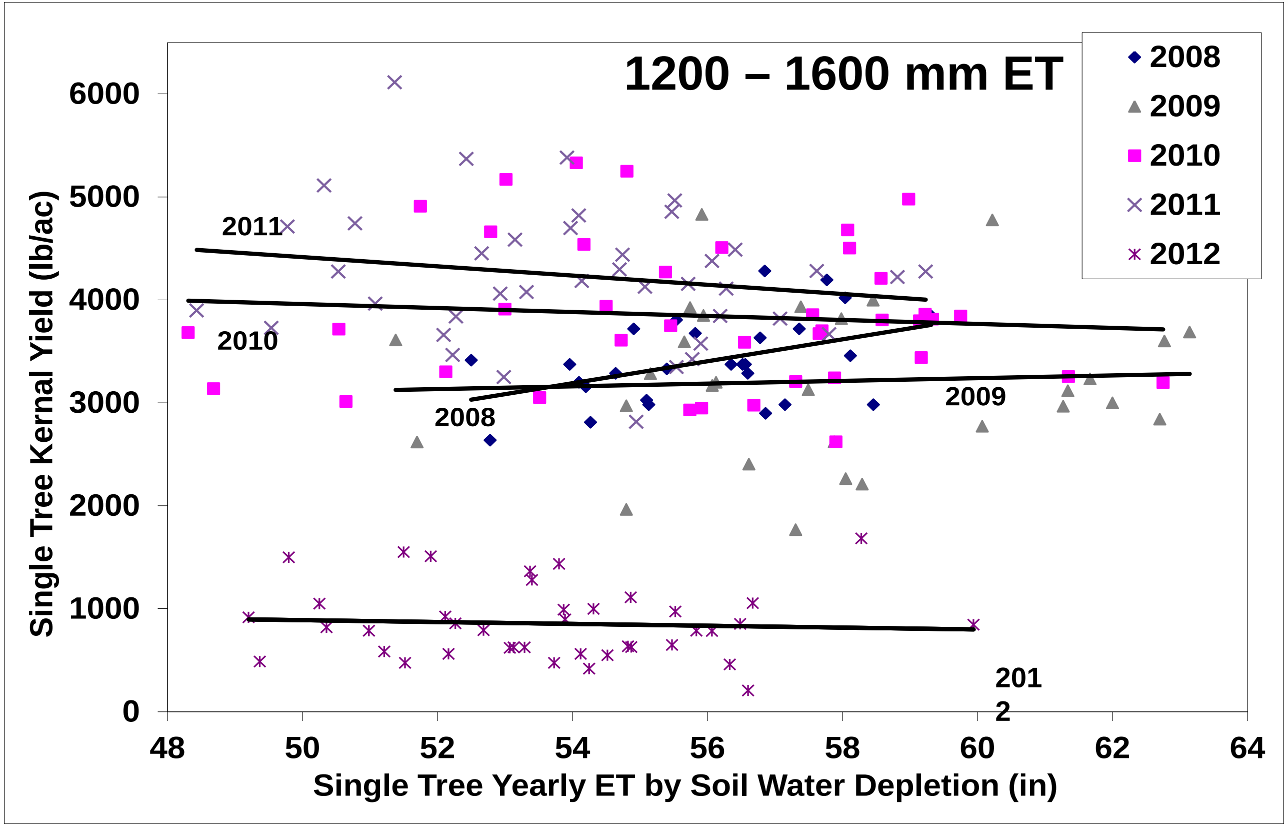



Current Patrick Brown salinity trials at UC Davis

# So how consistent is yield as a function of applied water and ET?

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





# Yield by applied water, Murray-Darling R. Valley Australia

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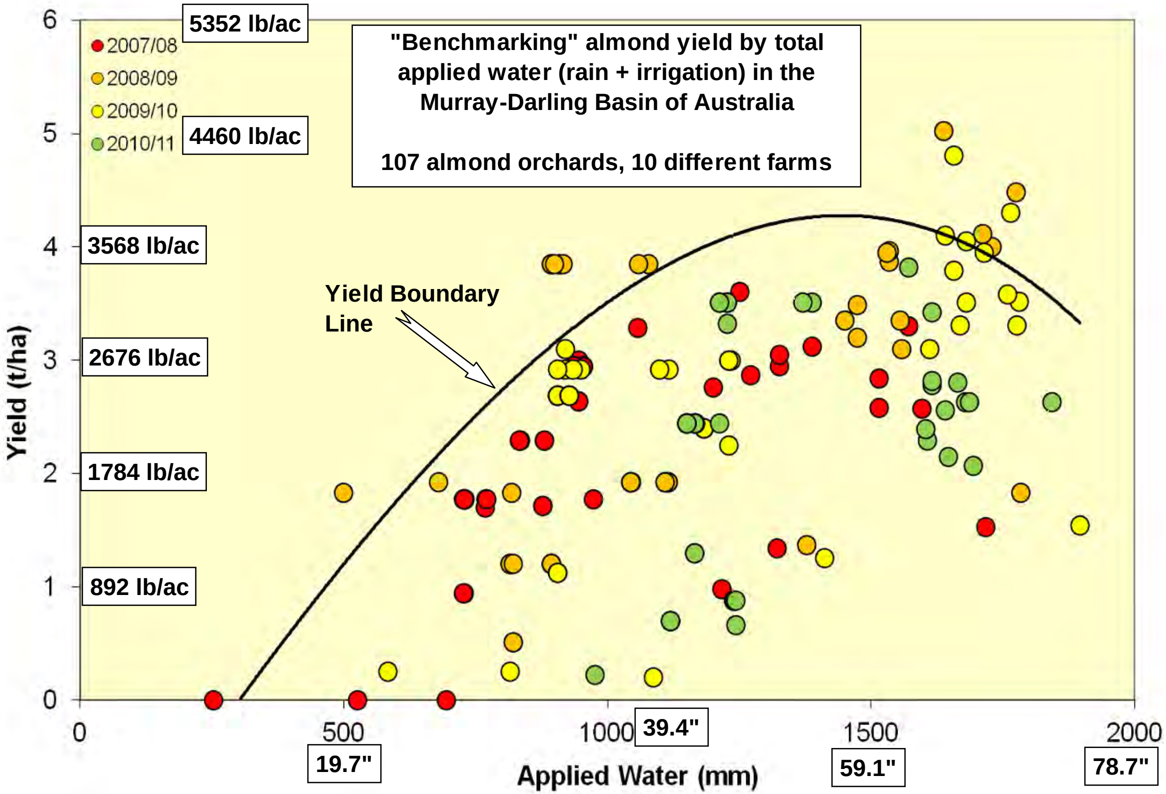
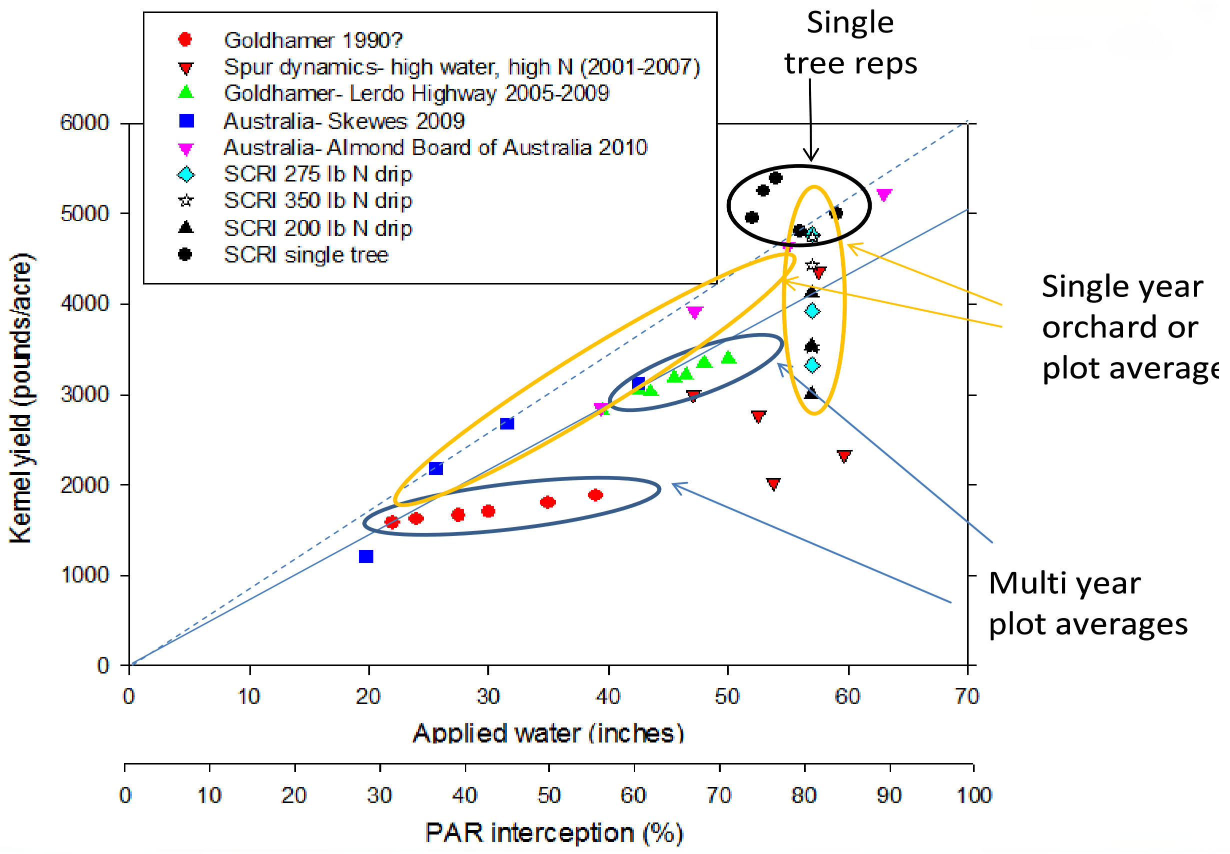
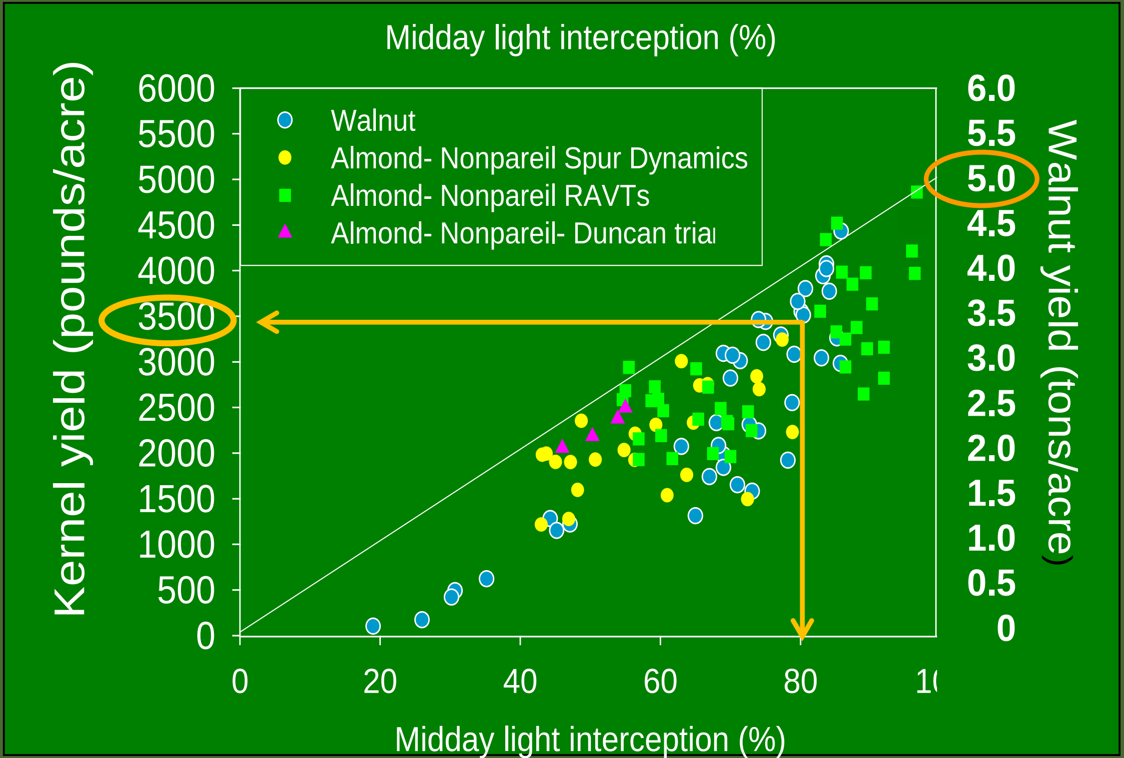


# Almond yield by light (PAR) & water



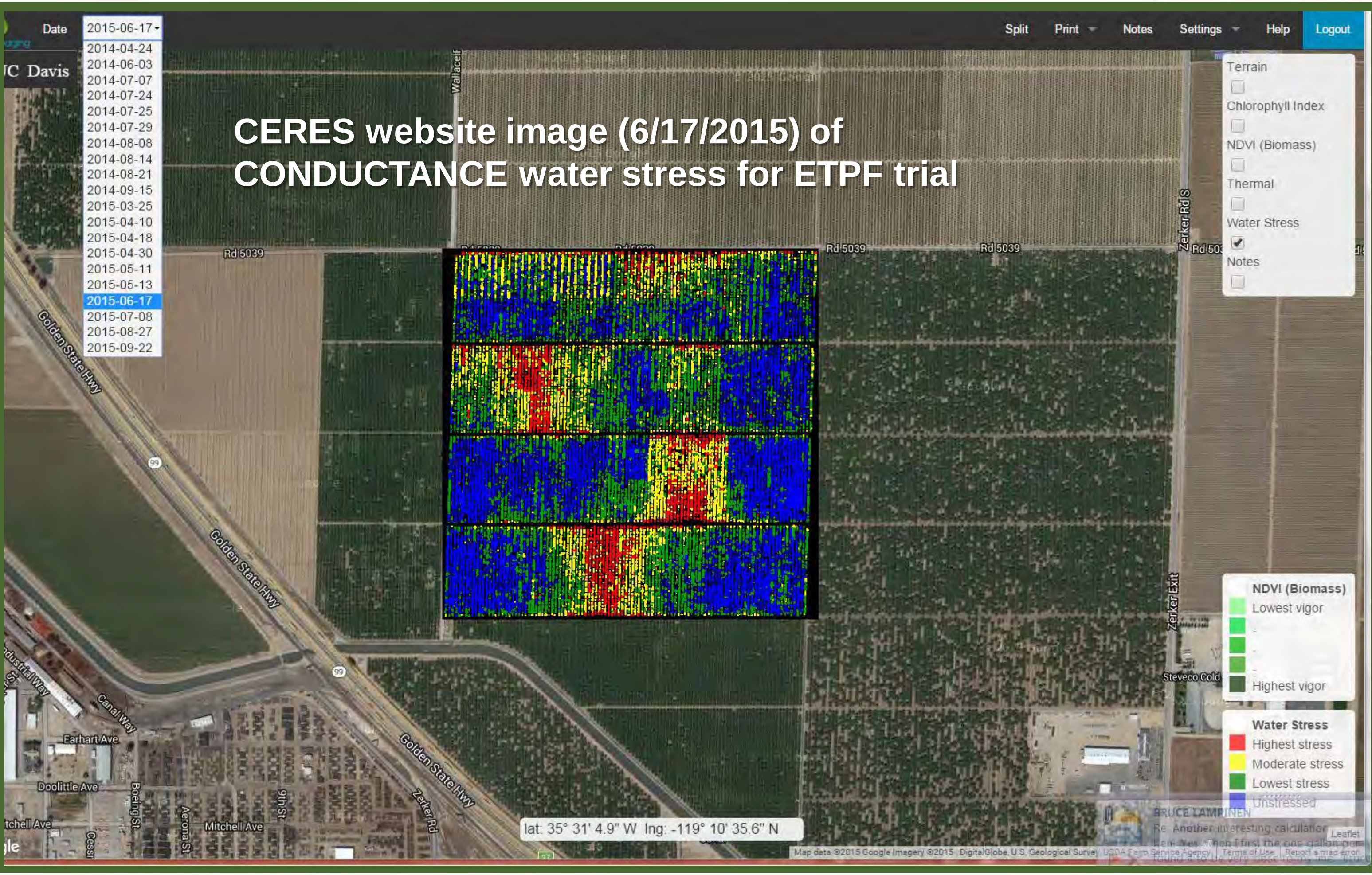


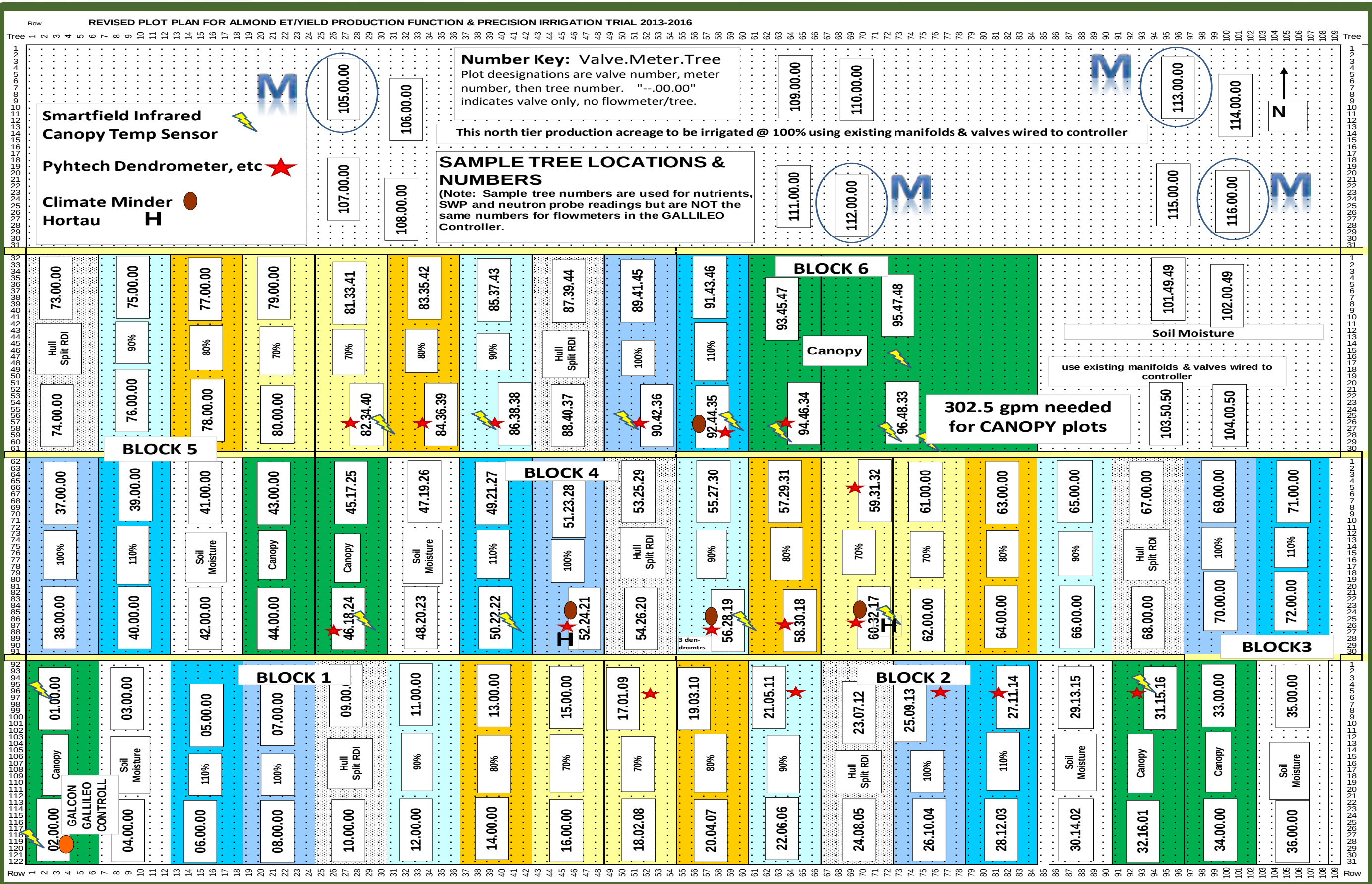



The white line is the maximum potential yield. Any number of factors can decrease your orchard yield relative to it's potential including water stress (excess or deficit), disease pressure, poor bloom weather, poor nutrient management etc.

Production potential is about 50 kernel pounds/ac of almond for every 1% of incoming light intercepted- so to produce 4000 kernel pounds per acre you need to intercept ~80% of the incoming PAR (Bruce Lampenin data for California).

# CERES website image (6/17/2015) of CONDUCTANCE water stress for ETPF trial






# Irrig. Treatments

**70%**

**80%**

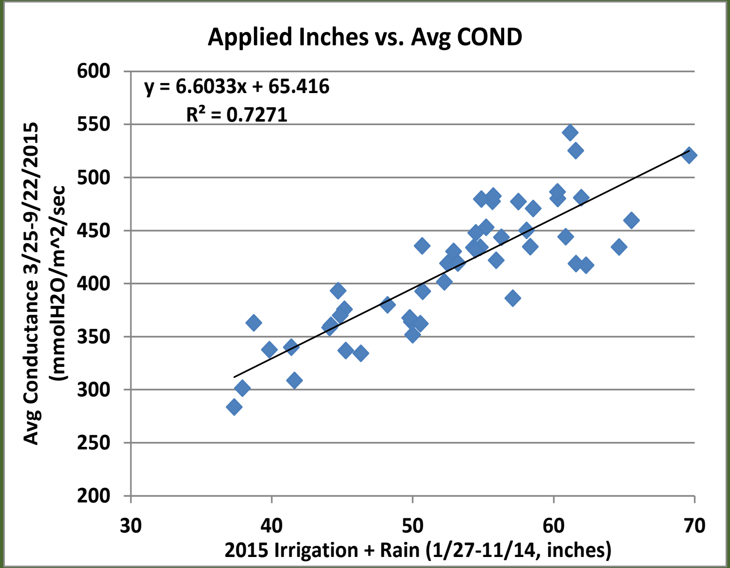
**90%**

**Hull Split RDI**

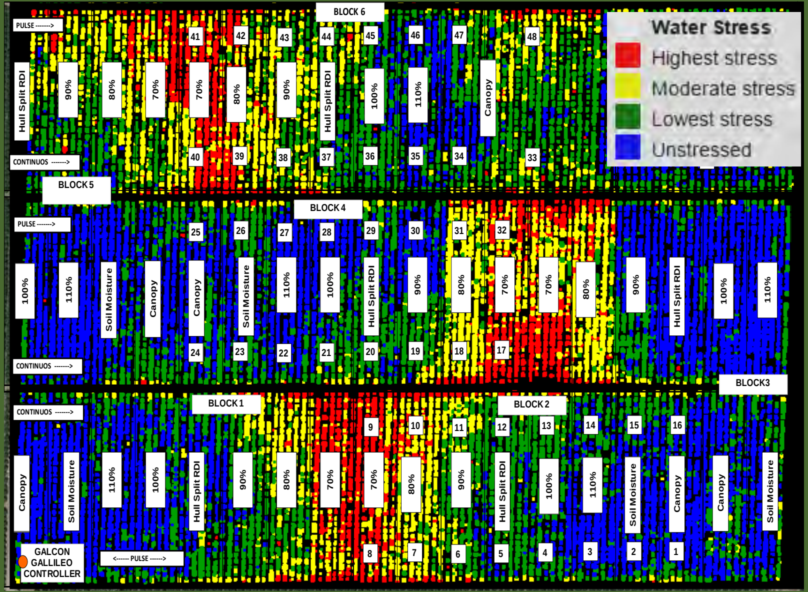
**100%**

**110%**

## Statewide Almond Water Production Function Trial – Kern County Site




# AERIAL IMAGERY CAN IDENTIFY IRRIGATION/STRESS NON-UNIFORMITY

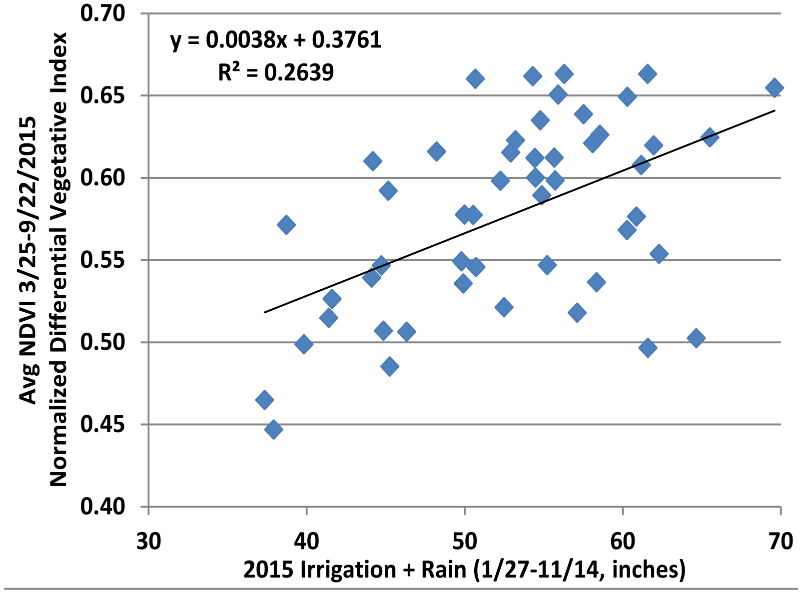



3/25-9/22/2015 average almond plot CONDUCTANCE by 2015 applied irrigation (10 flyovers)

**Canopy Temp/Water Stress by Irrigation Treatment**

**(CERES Spectral Imaging 6/17/2015)**

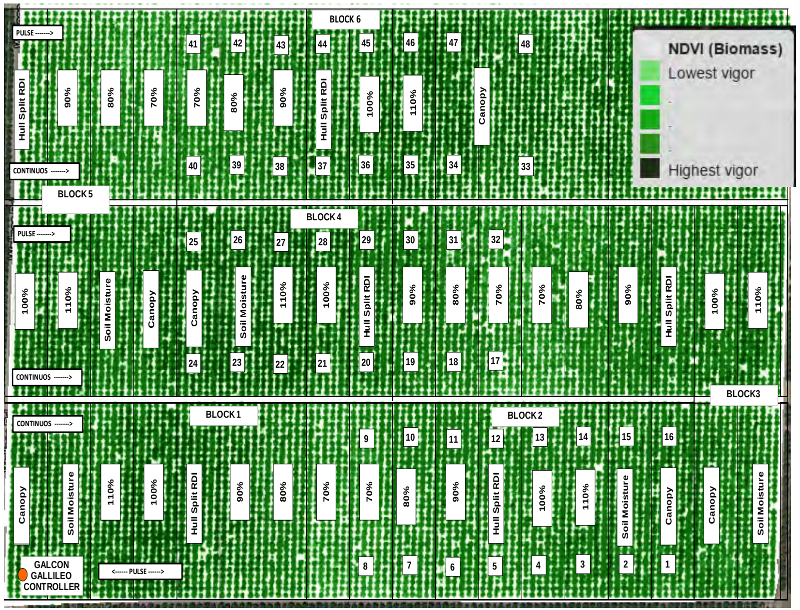
# NDVI (vigor/biomass) not as strongly correlated with applied water



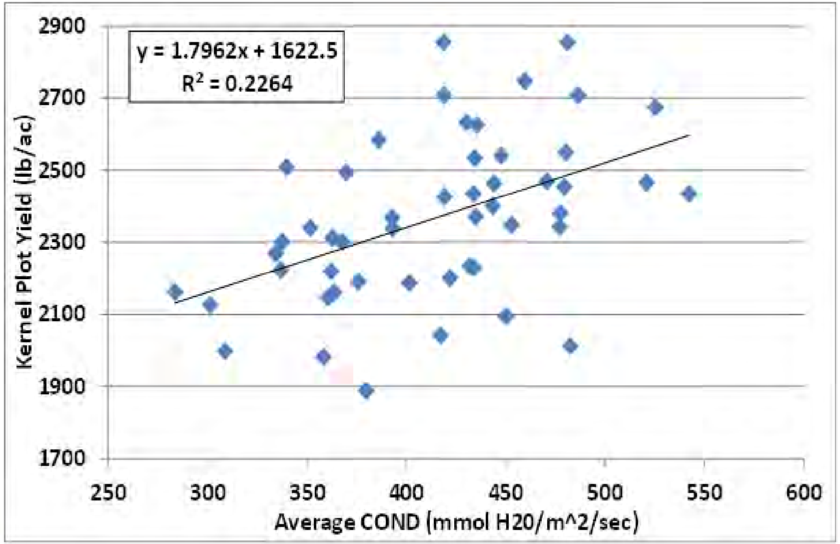

3/25-9/22/2015 average almond plot NDVI by 2015 applied irrigation (10 flyovers)

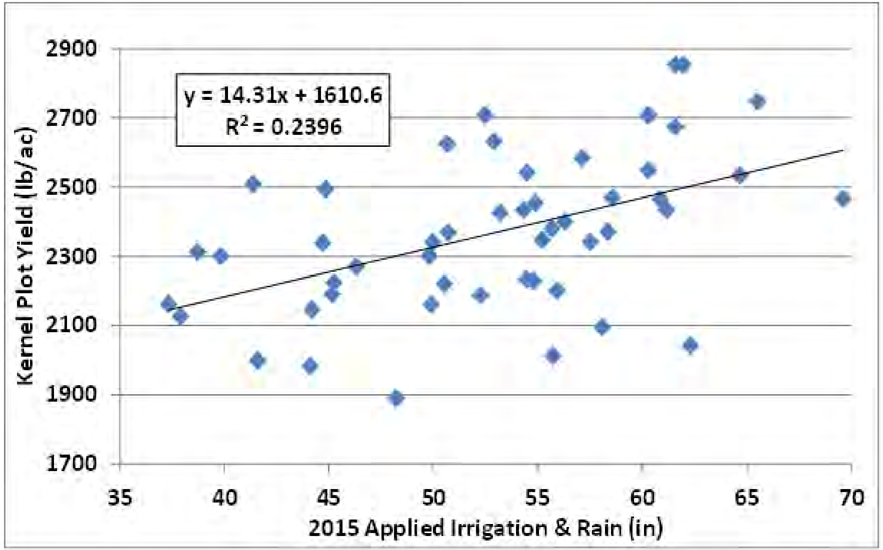
## NDVI/Biomass by Irrigation Treatment

(CERES Spectral Imaging 6/17/2015,
Shackel, et al. Yield Production Function Trial)



**Both CONDUCTANCE & APPLIED WATER were poorly correlated to final kernel yield. Bloom density and other factors can be just as important as stress on your final yield.**



# Conclusions



- Almonds are capable of much higher yields under even more saline conditions than old published standards.
- The presence of clay exchange sites, good to high levels of free Ca in the field soil and better attention to optimal irrigation help overcome toxicity problems documented in earlier sand tank and field studies.
- Development of new almond salinity thresholds should somehow include these variables.

# The Global Perspective: Paul Ehrlich's "Population Bomb" has not disappeared

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November 8th - 10th, 2016

- Global food production will need to increase by 38% by 2025 and 57% by 2050.
- It is estimated that about 15% of the total land area of the world has been degraded by soil erosion and physical and chemical degradation, including soil salinization.

*(Wild A. 2003. Soils, land and food: managing the land during the twenty-first century. Cambridge, UK: Cambridge University Press.)*