UNIVERSITY of CALIFORNIA COOPERATIVE EXTENSION

Crop & Irrigation Management with Marginal Water Quality

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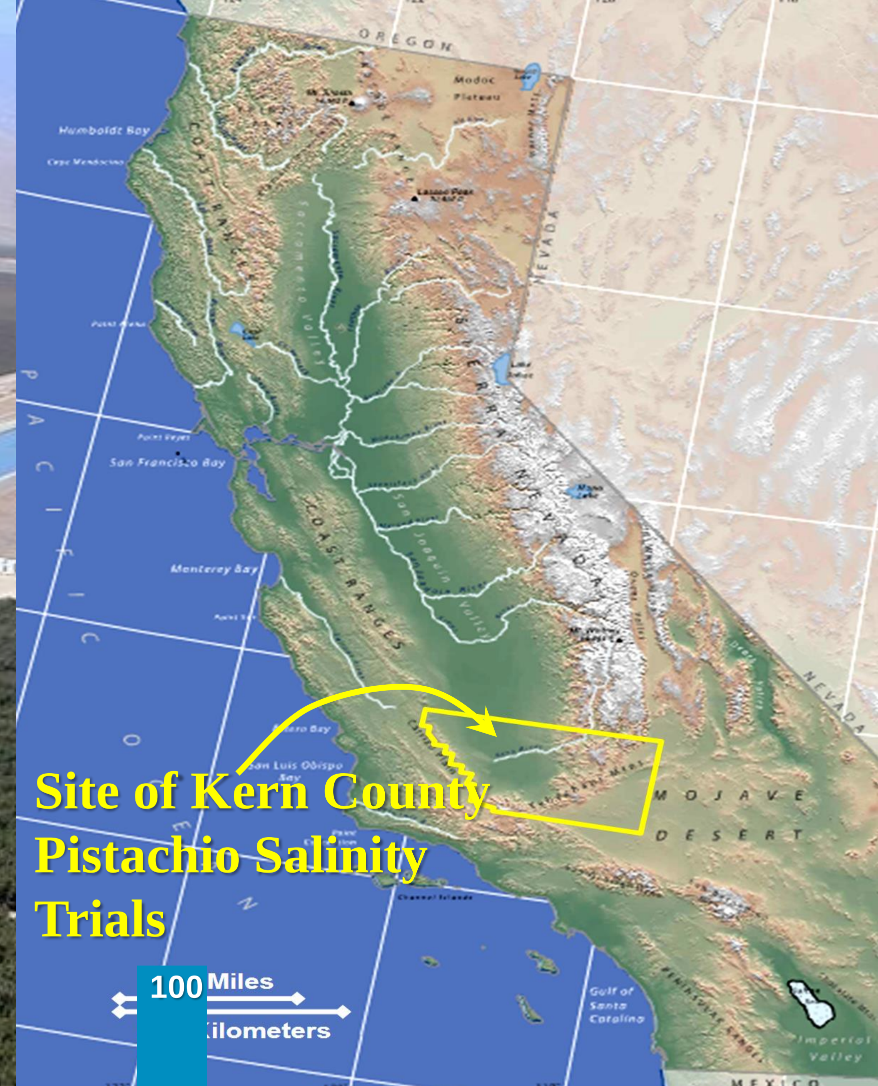
2014 Fluid Fertilizer Marketing & Technology Workshop
Sacramento,CA   Dec 9-10, 2014



Development of pistachio plantings 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.

FIRST A PUBLIC SERVICE / SAFETY ANNOUNCEMENT…

Trees are wonderful things… but they eventually need pruning… which is what I was doing when I was perched up here

But if you insist on doing your own pruning tell the "y" chromosome that the physics of gravity is reality and be sure to wear a safety harness so you don't end up here!

Remember Joe Machado:

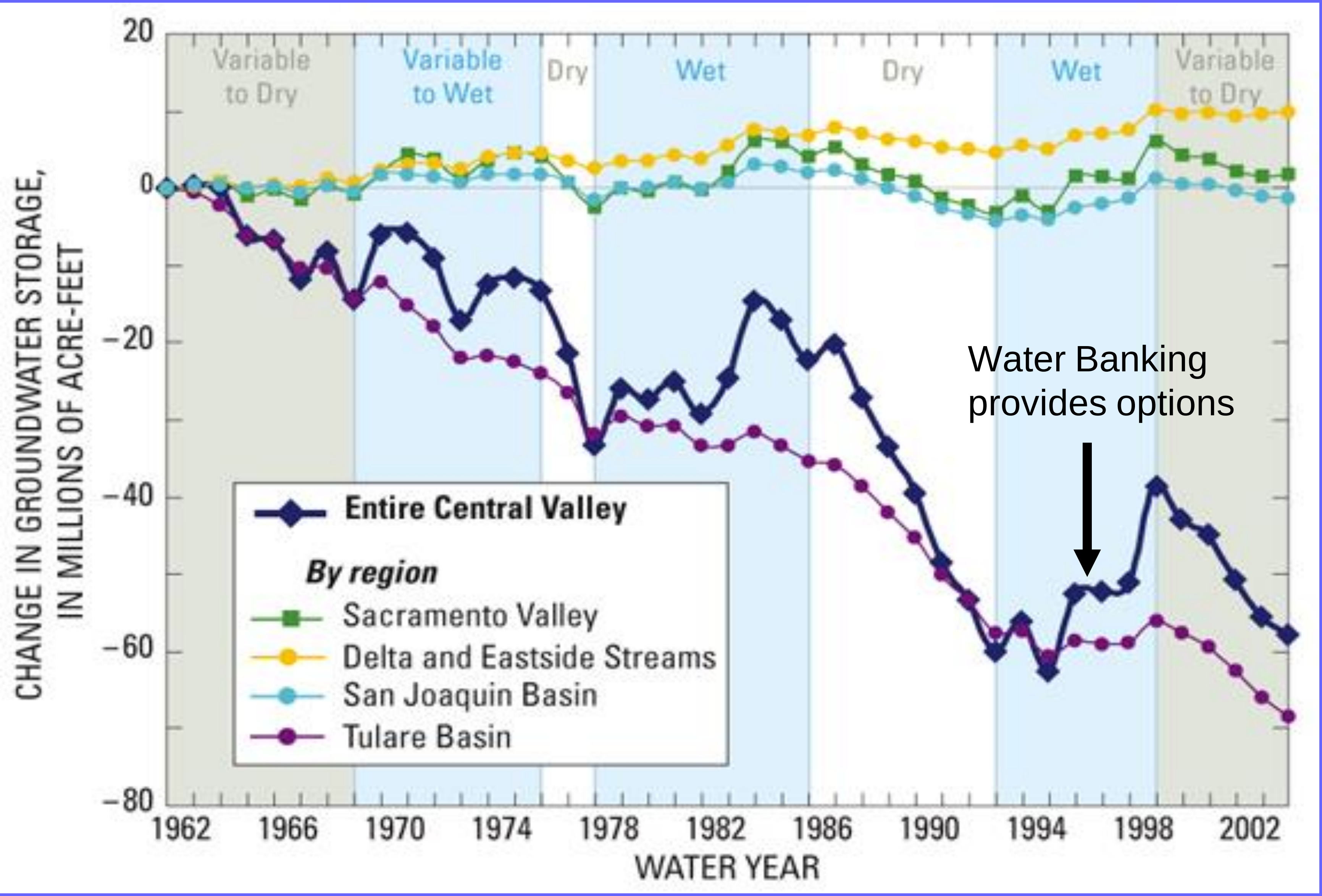
"How you doing?"

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

- 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.

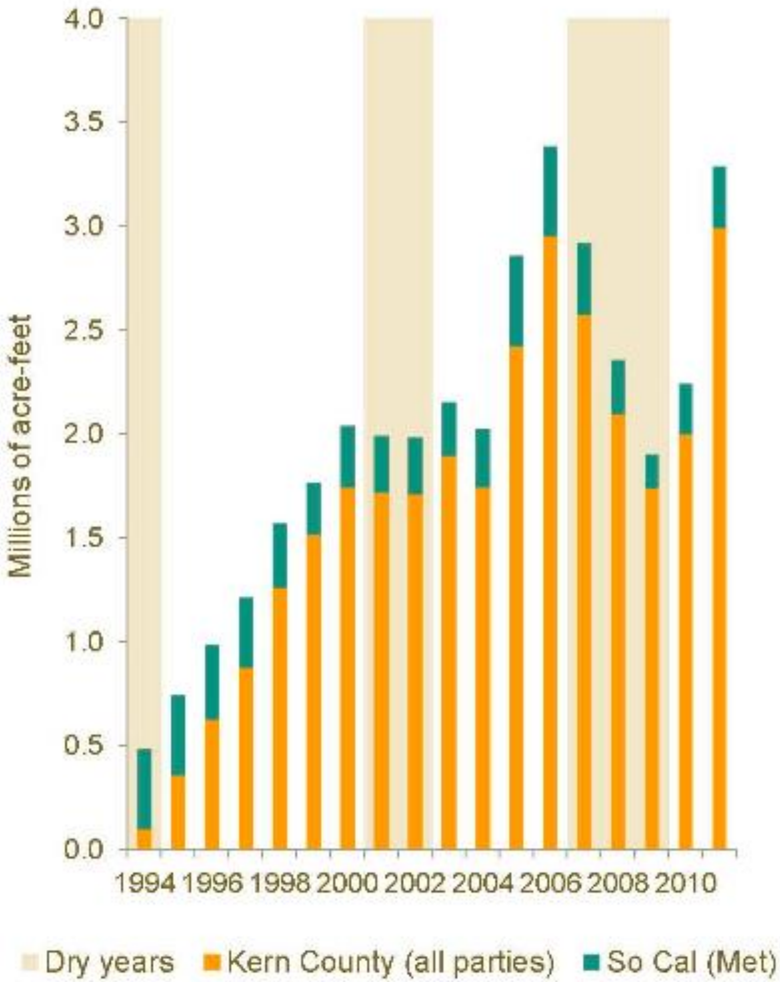
(Wild A. 2003. Soils, land and food: managing the land during the twenty-first century. Cambridge, UK: Cambridge University Press.)

CA groundwater depletion: 1962-2003



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

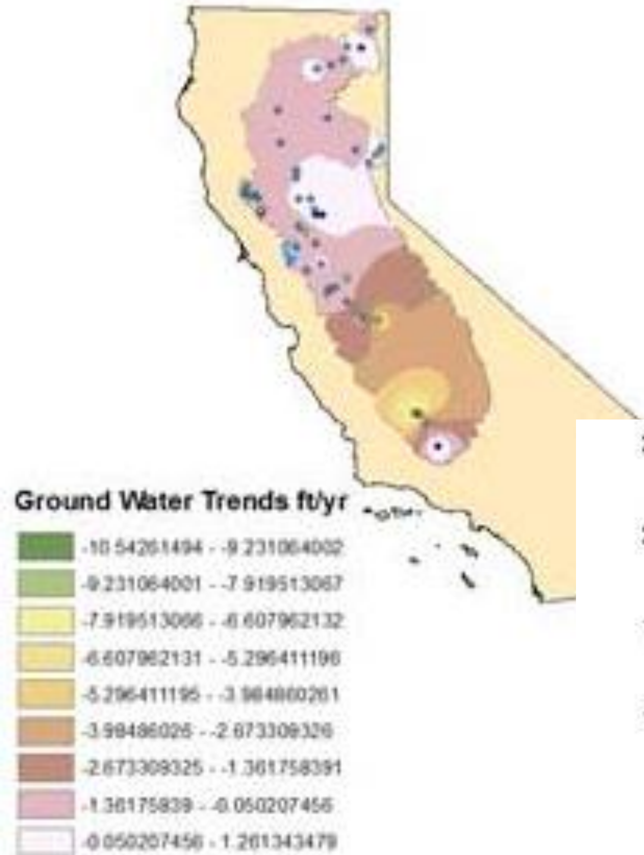
New Groundwater Banks Were Very Useful During Recent Drought

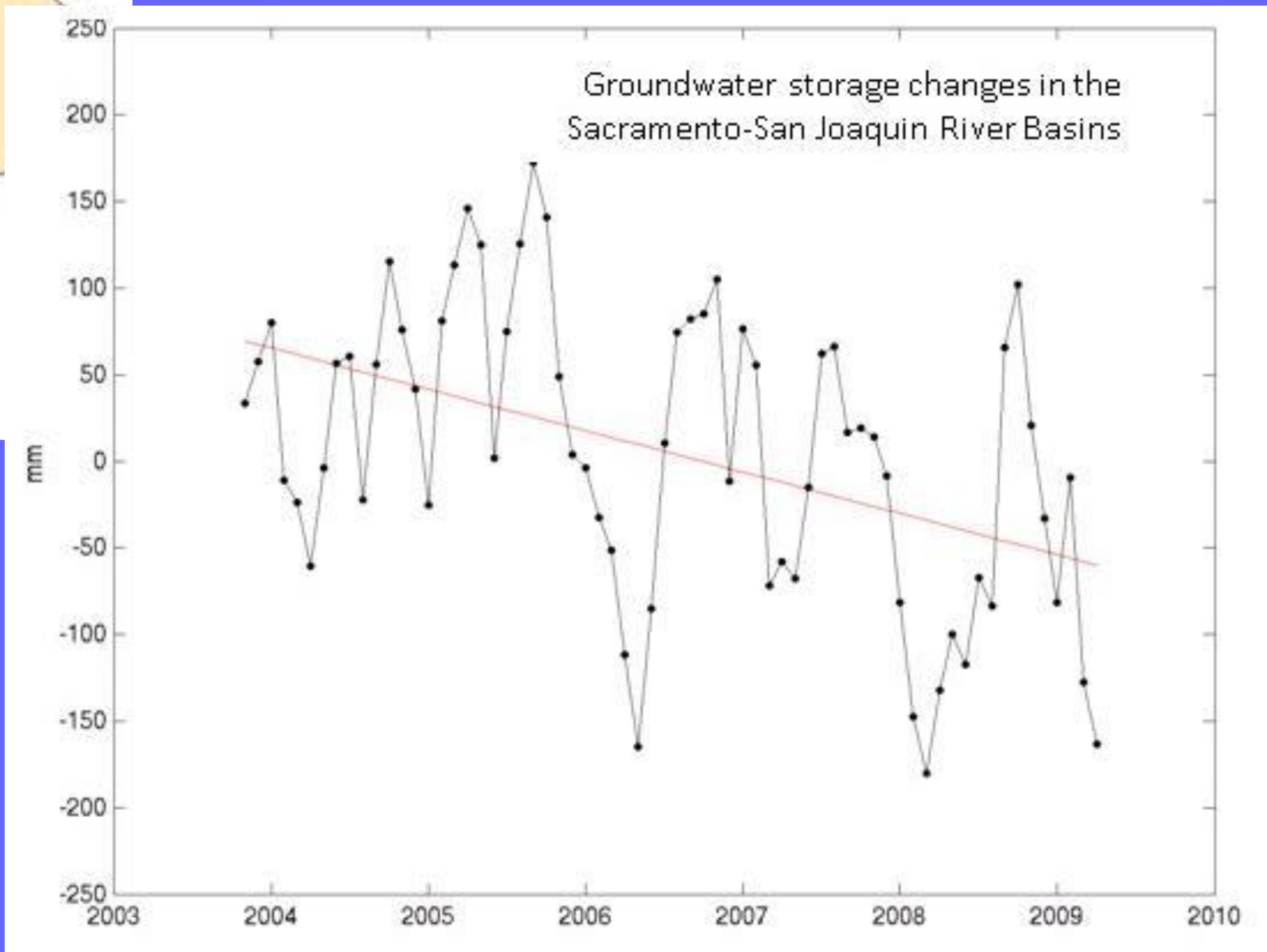


- Total withdrawals 2007–10: 1.9 maf (3x more than water market)
- Rapid recharge thanks to very wet 2011
- But some conflicts over falling groundwater tables
- Questions:
  - How to strengthen groundwater management in banking areas?
  - How to ensure recharge abilities given Delta pumping restrictions?

Source: Hanak and Stryjewski. 2012. *California's Water Market, By the Numbers*. PPIC.

NASA JPL Grace satellite groundwater estimate for SJV Oct’03-Mar’09: loss = 31 km3 = 25.13 MAF = Lake Mead

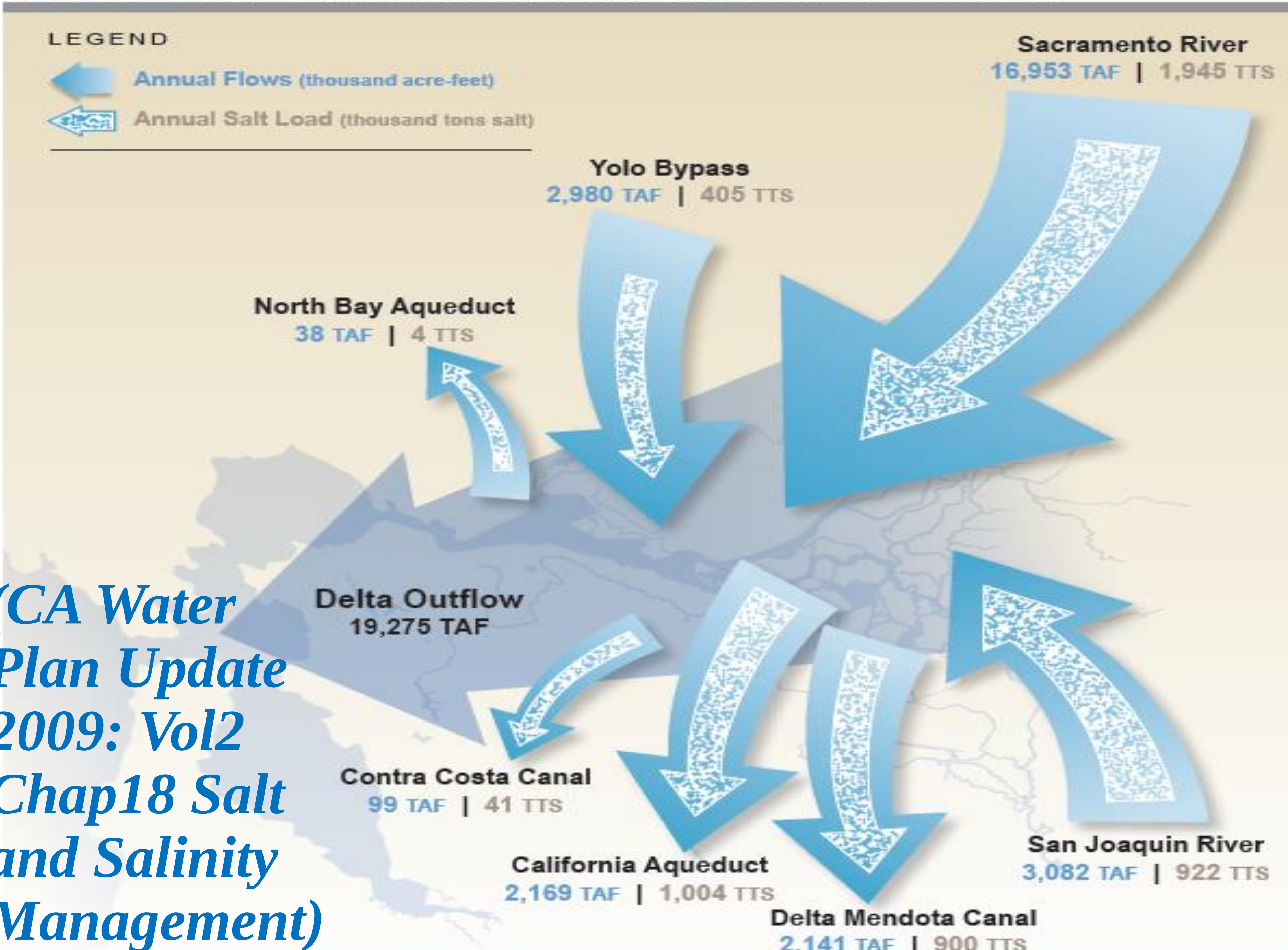




- http://www.jpl.nasa.gov/images/earth/agu/20091214/slide11-640.jpg

Subsidence is still a reality in many areas of the San Joaquin Valley – especially the Mendota area.

Figure 18-1 Salt load (mean of annual averages from 1959 to 2004)



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

CA Water Plan 2009
Salt and Salinity Management

Sacramento River water salinity
= 0.11 ton / ac-ft (0.13 ds/m EC, 83 ppm tds)

CA Aqueduct water salinity
= 0.46 ton / ac-ft (0.53 ds/m EC, 339 ppm tds
=73.6 t/ac @ 4 ac-ft/yr * 40 years
=2.87 dS/m increase in EC over 10 ft depth of soil)

Friant-Kern water salinity (Kern County data)
= 0.06 ton / ac-ft (0.07 ds/m EC, 45 ppm tds)

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

CA Water Plan 2009:
RESEARCH for salinity management

Salt storage and other research and implementation

10. Additional options for salt collection, salt treatment, salt disposal and long-term storage of salt should be developed. University researchers should work with regulatory agencies and stakeholders to identify environmentally acceptable and economically feasible methods of closing the loop on salt for areas of the state that do not currently have sustainable salt management options. Funding for this sort of research should be prioritized to ensure that areas with the greatest needs (i.e. high salt and few or no feasible management options) are targeted first. (See also Recommendations 2 through 7, 11 and 12.)

What happened to the UC Salinity-Drainage taskforce?

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

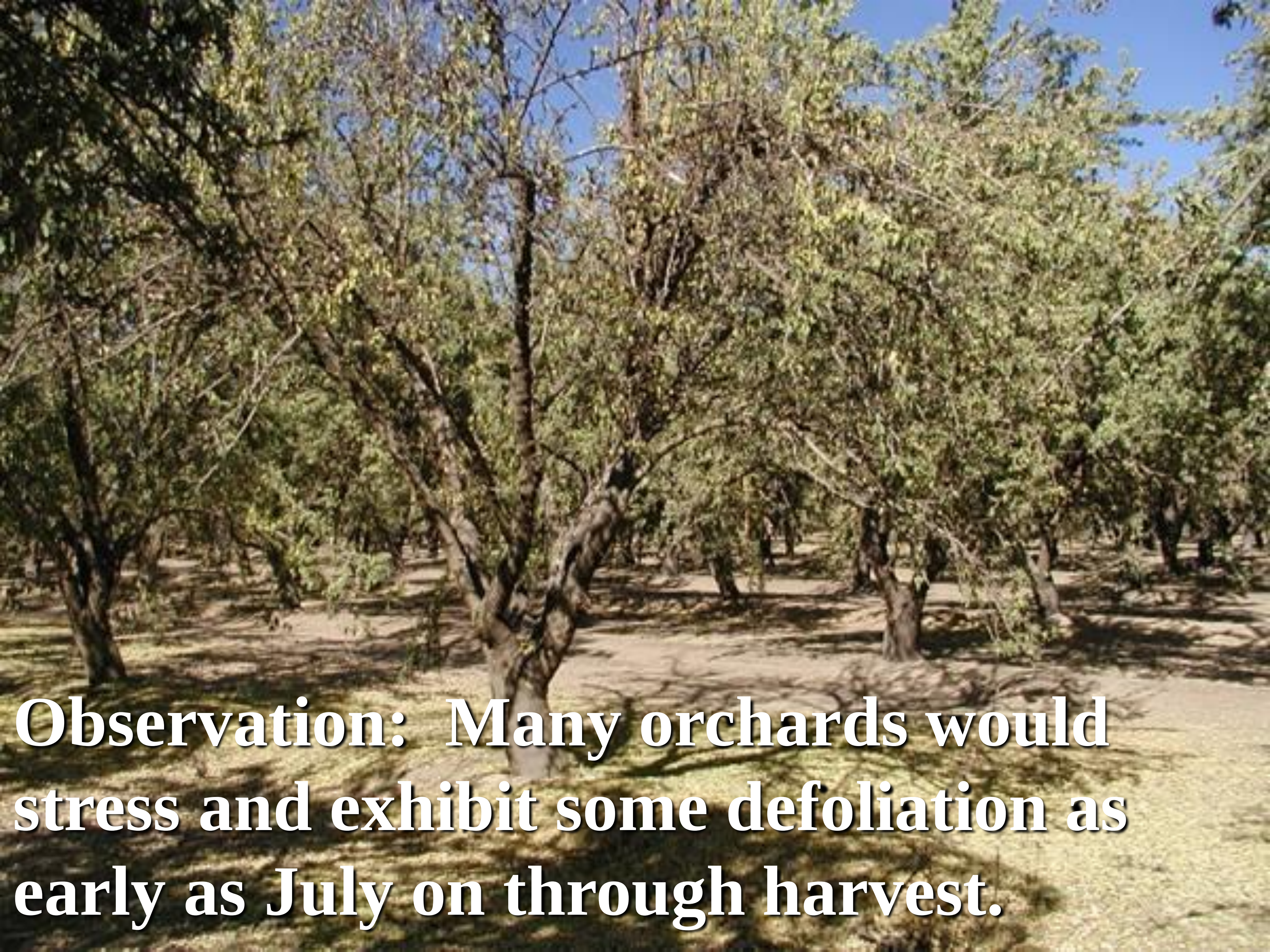
Excessive Na, Cl and especially B can burn and desicate almonds.





Lime-induced Iron
Chlorosis in Almonds

Wood Colony almonds on vigorous Hanson rootstock overcomes lime-induced Fe chlorosis

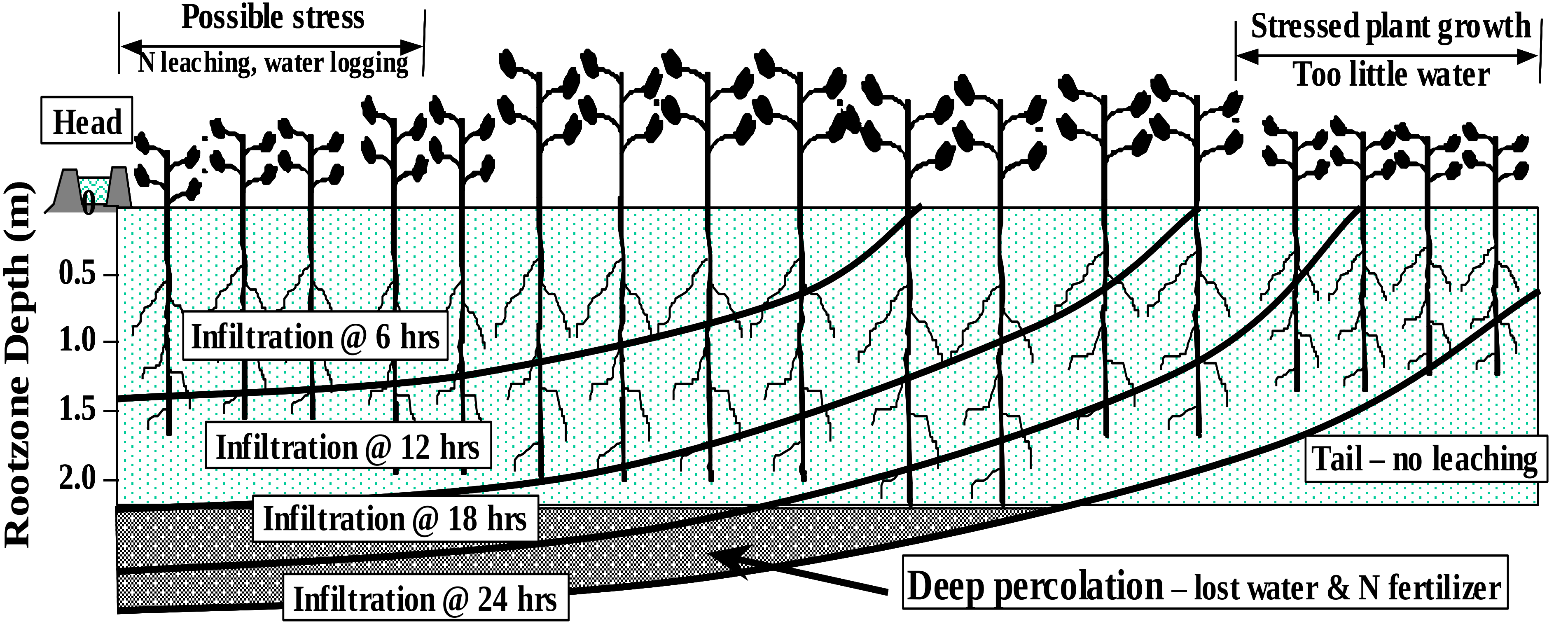

Observation: Many orchards would stress and exhibit some defoliation as early as July on through harvest.

Irrigation uniformity…

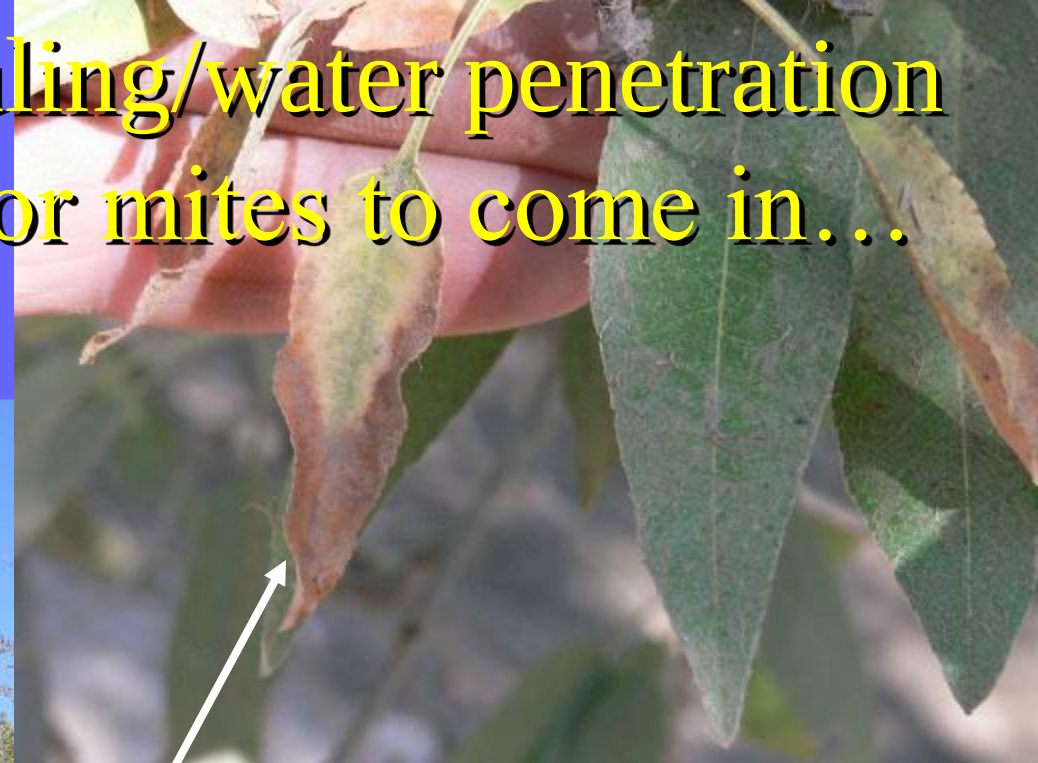
Has a big impact on water use and yield. Measure your distribution uniformity and improve it!

Irrigation distribution uniformity (DU) in surface irrigation is determined by soil infiltration rate, flow down the check and set duration.

$$DU\ (\%) = 100 * \frac{\text{“low quarter” infiltration}}{\text{Average field infiltration}}$$



At best poor scheduling/water penetration creates conditions for mites to come in…



At worst, individual leaves show marginal burn and can lead to severe defoliation

"Head" end of same rows – adequate depth of irrigation for ET, more leaching

DU in micro systems is determined by emitter flow variation across the orchard.


Causes of micro irrigation non-uniformity: algae, slime, debris plugging hose screens and/or emitters
Trash from pipe break after repair and system restart
Thin coating of algae. No system chlorination.

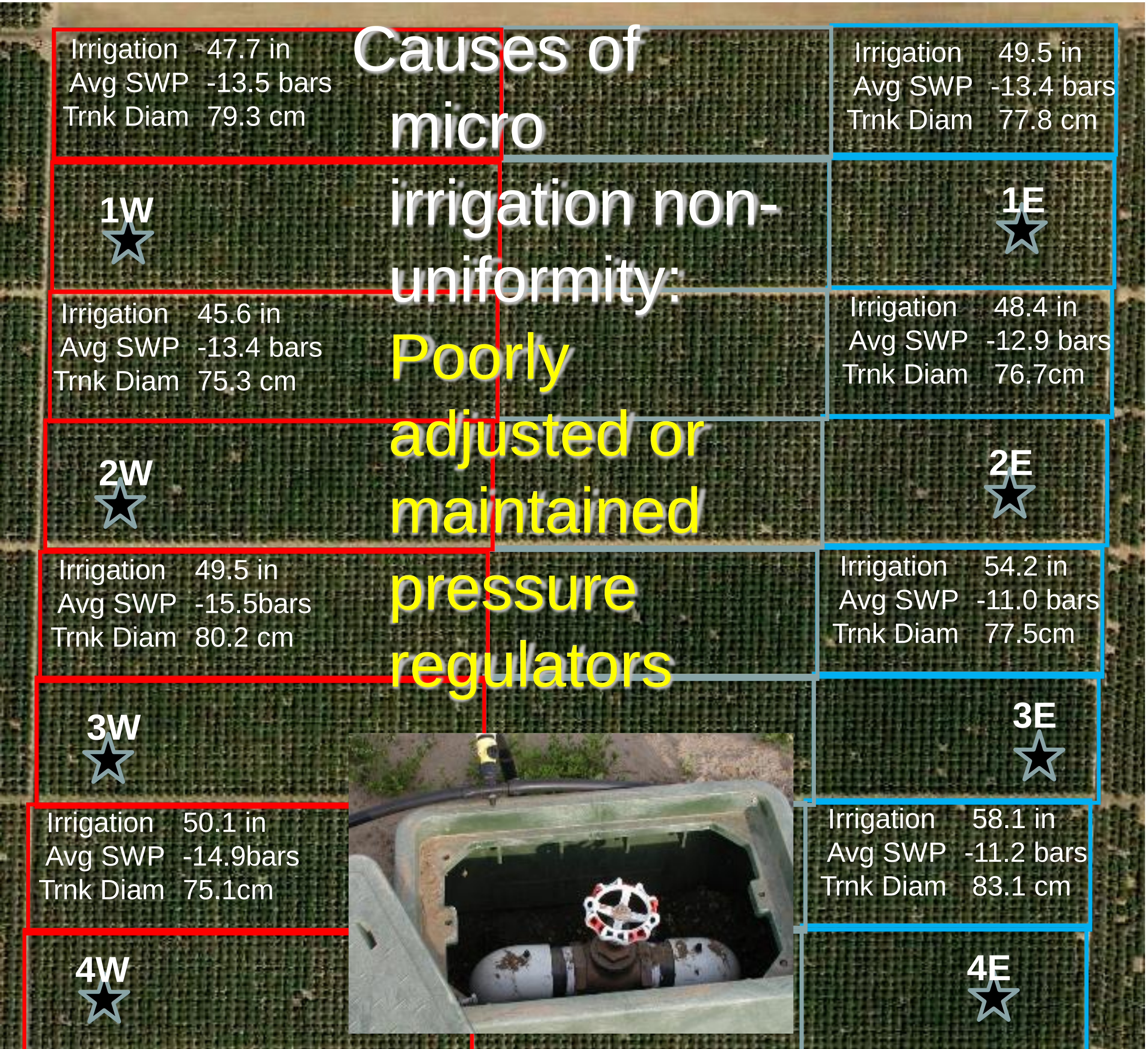
Causes of micro irrigation non-uniformity:

chemical precipitates clogging drippers or altering flow rates. Check fertilizer mixes, gypsum injection, maybe use acid.

Microsprinklers may show precipitation but rarely lose flow.


Causes of micro irrigation non-uniformity:
Use of non-pressure-compensating emitters in orchards with rolling topography

Causes of micro irrigation non-uniformity: Poorly adjusted or maintained pressure regulators

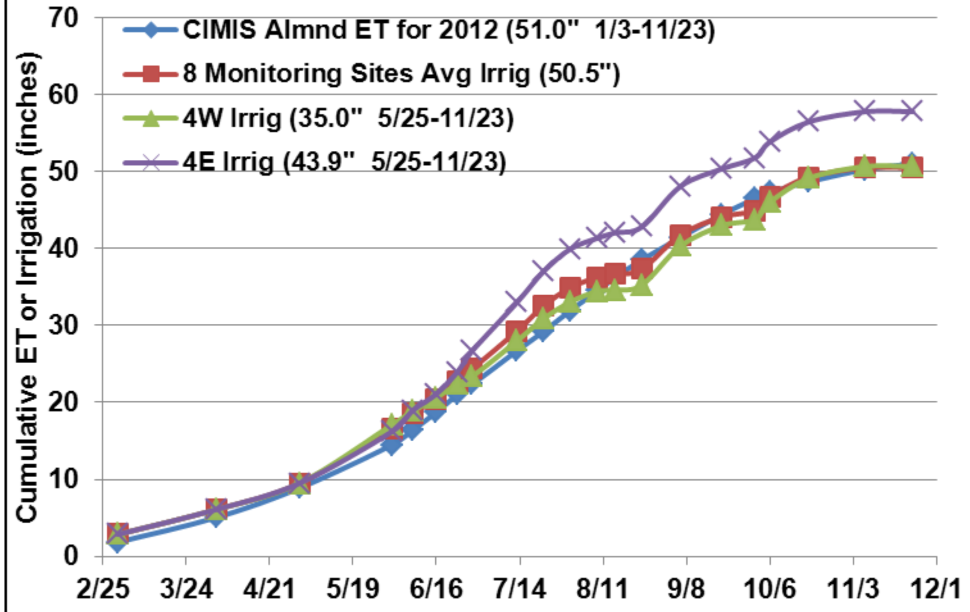


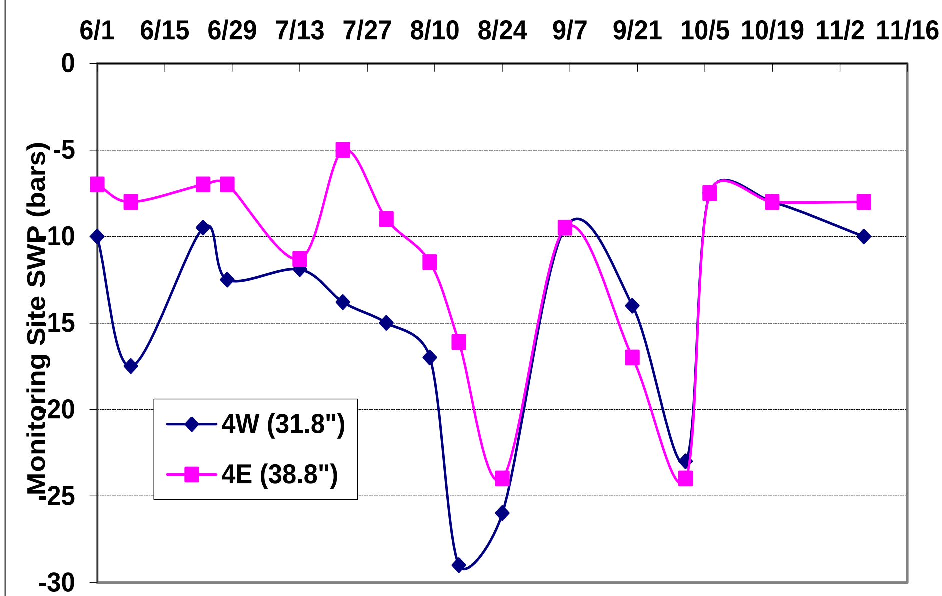
PFC Ranch 3061
Block 10-2

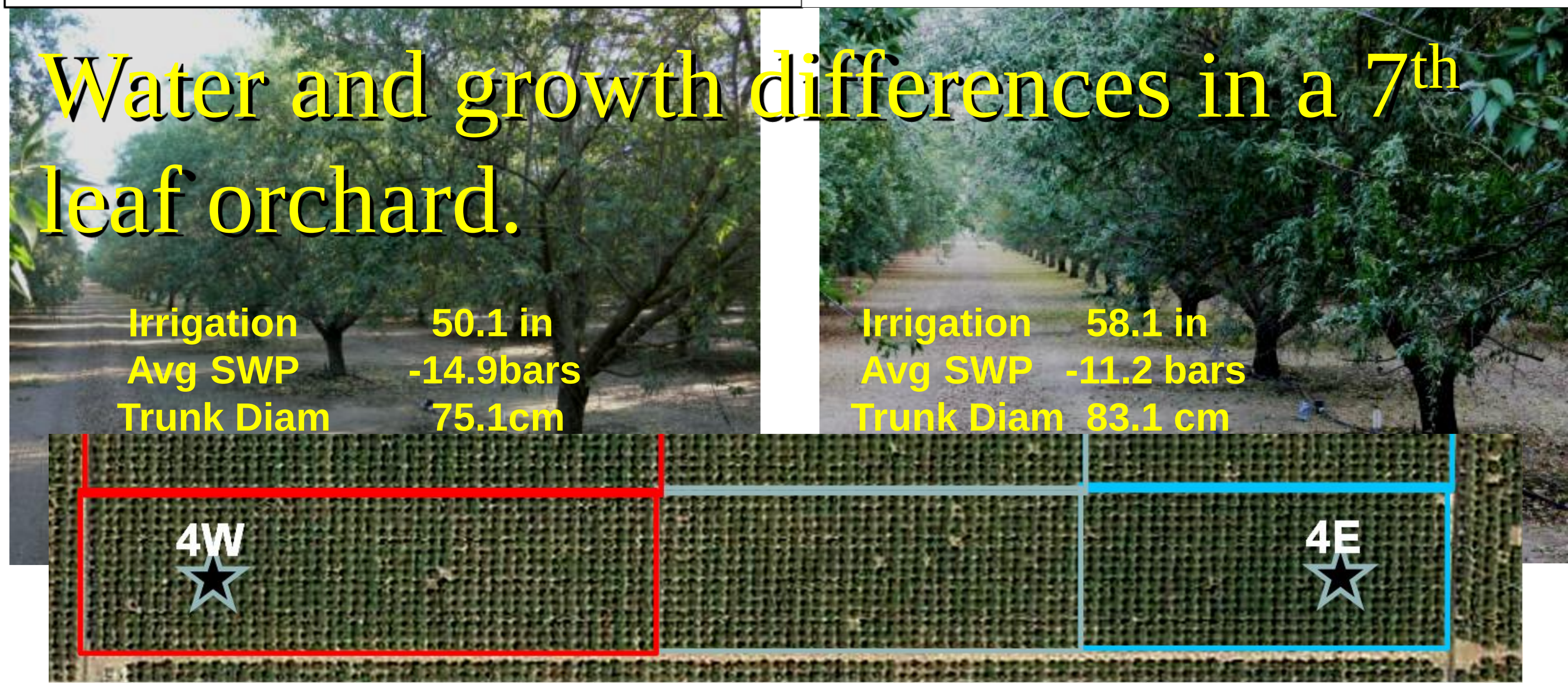
08/27/2012

Relatively small pressure differentials in irrigation subunits (+/- 4 psi) produced different amounts of applied water, canopy cover and leaf retension by the end of August

Water and growth differences in a 7th leaf orchard.





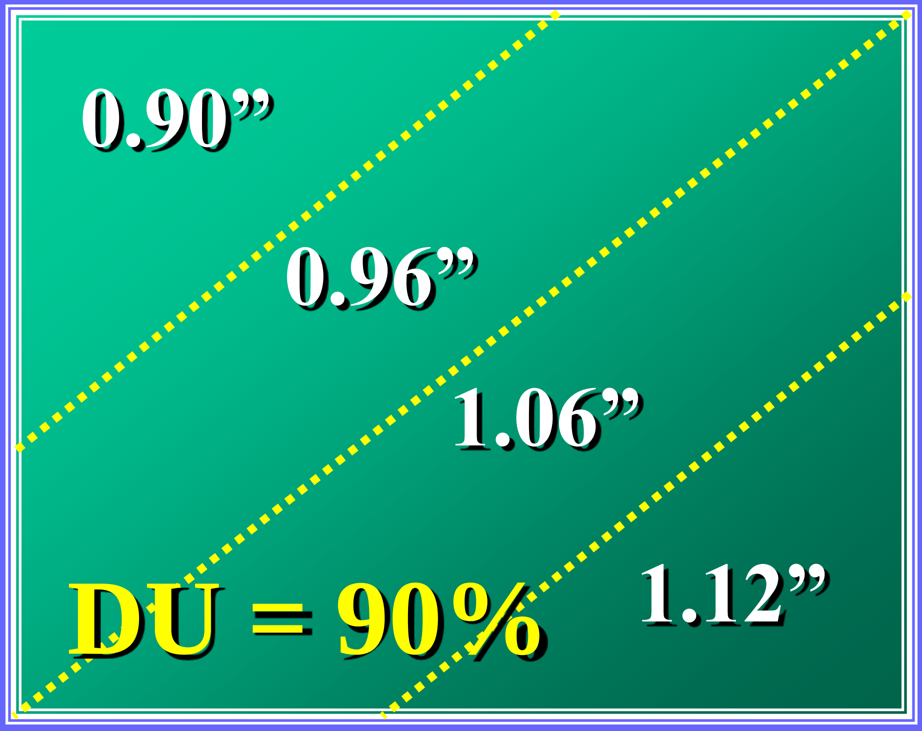


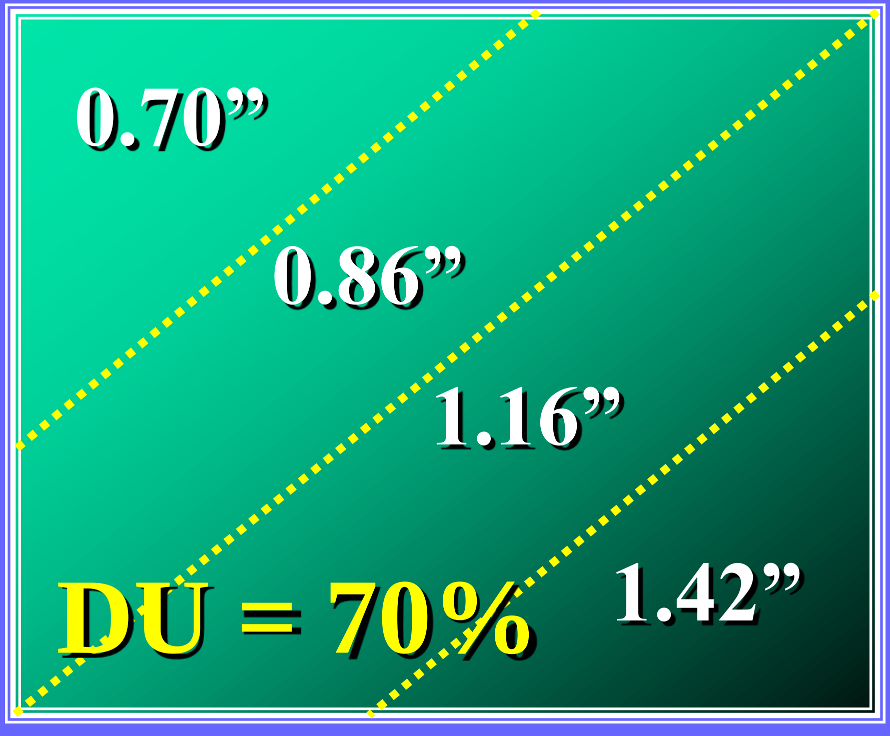
Irrigation: Getting It Uniform

- **Check Field Distribution Uniformity:**

$$DU = \frac{\text{Average of low 1/4}}{\text{All Field Average}}$$

Target Application = 1.0 inch





What about salinity buildup under super efficient irrigation?

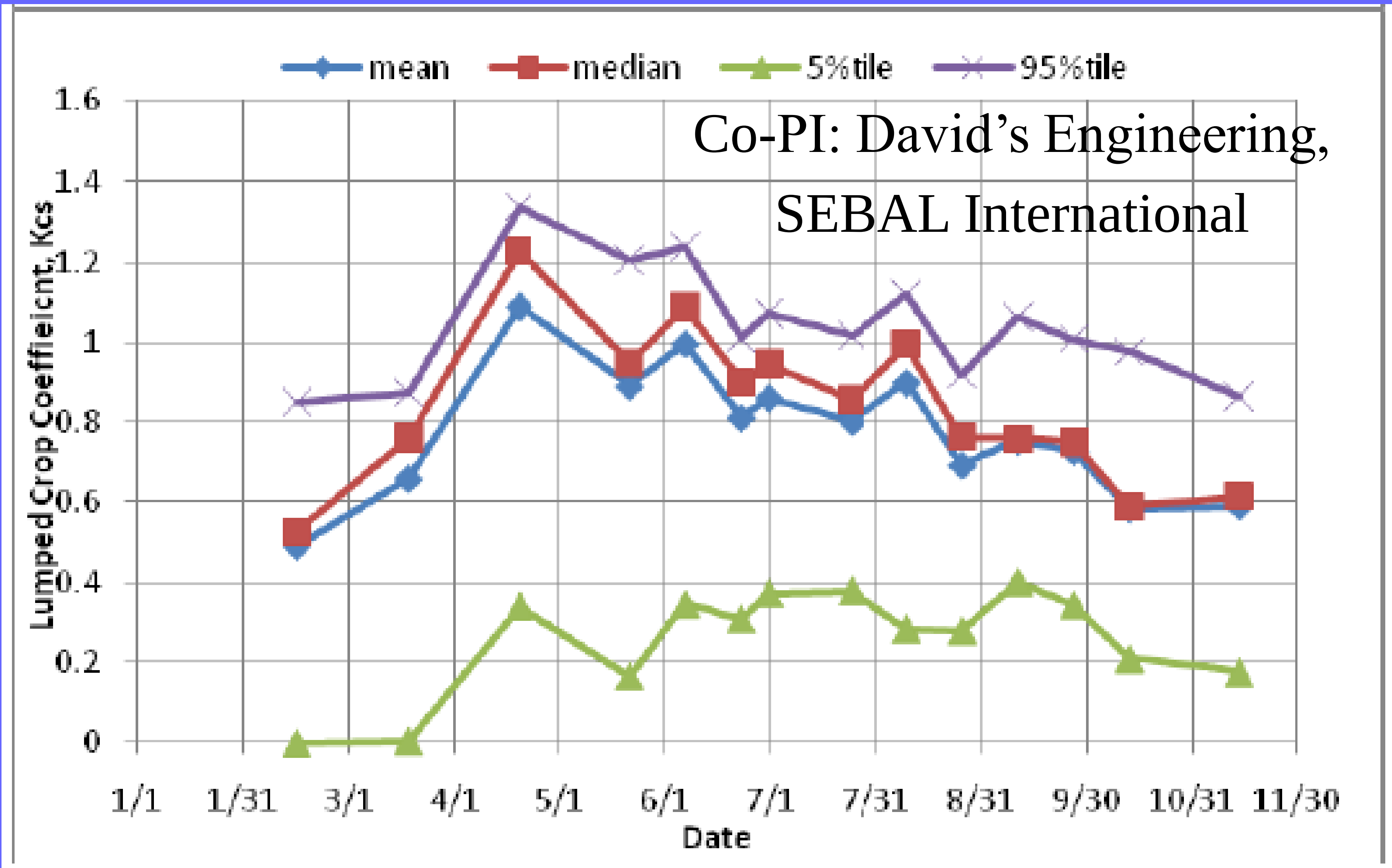
Micro-sprinkler or double-line drip systems capable of injecting fertilizer and applying 0.6 to 1.5 inches/day

Sanden Almond ET/Kc schedule for Kern County (published 2002)

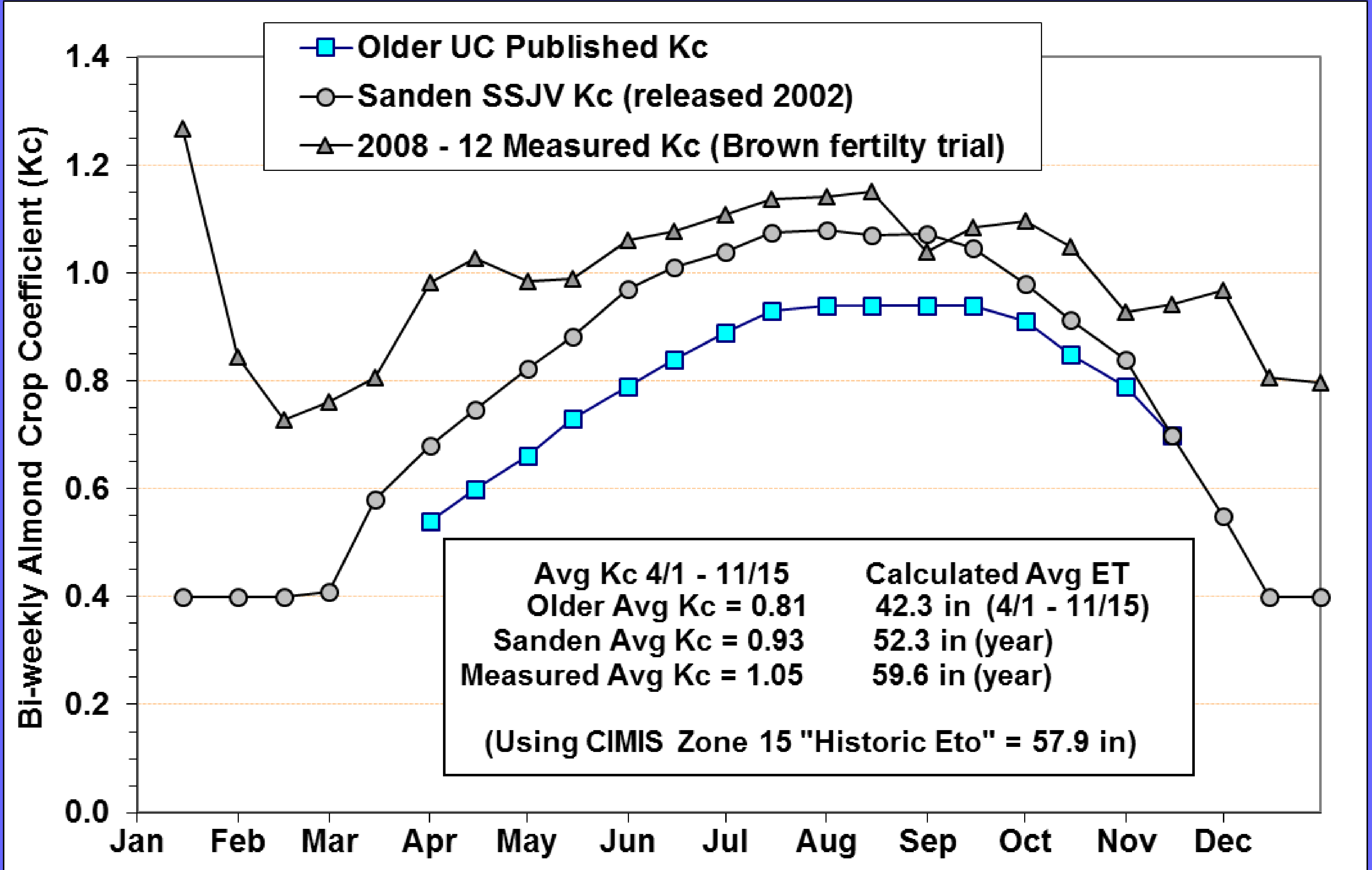
ET Estimates Using CIMIS Zone 15 Southern SJV "Historic" ETo (1st published 2002)

Week	Normal Year Grass ETo (in)	Mature Crop Coef-ficient (Kc)	Almond ET -- Minimal Cover Crop, MIcrosprinkler (inches, S. San Joaquin Valley)				
			1st Leaf @ 40%	2nd Leaf @ 55%	3rd Leaf @ 75%	4th Leaf @ 90%	Mature
1/6	0.21	0.40	0.03	0.05	0.06	0.08	**0.09**
1/13	0.28	0.40	0.04	0.06	0.08	0.10	**0.11**
1/20	0.30	0.40	0.05	0.07	0.09	0.11	**0.12**
1/27	0.36	0.40	0.06	0.08	0.11	0.13	**0.14**
2/3	0.42	0.40	0.07	0.09	0.13	0.15	**0.17**
2/10	0.47	0.40	0.08	0.10	0.14	0.17	**0.19**
2/17	0.54	0.40	0.09	0.12	0.16	0.19	**0.22**
2/24	0.61	0.40	0.10	0.13	0.18	0.22	**0.24**
3/3	0.69	0.42	0.12	0.16	0.22	0.26	**0.29**
3/10	0.79	0.61	0.19	0.27	0.36	0.43	**0.48**
3/17	0.89	0.64	0.23	0.31	0.43	0.51	**0.57**
3/24	0.98	0.67	0.26	0.36	0.49	0.59	**0.65**
3/31	1.09	0.72	0.31	0.43	0.59	0.70	**0.78**
4/7	1.19	0.74	0.35	0.48	0.66	0.79	**0.88**
4/14	1.32	0.75	0.40	0.55	0.74	0.89	**0.99**
4/21	1.41	0.81	0.46	0.63	0.85	1.03	**1.14**
4/28	1.49	0.83	0.50	0.68	0.93	1.12	**1.24**
5/5	1.59	0.86	0.55	0.75	1.03	1.23	**1.37**
11/3	0.67	0.78	0.21	0.29	0.39	0.47	**0.53**
11/10	0.57	0.71	0.16	0.22	0.31	0.37	**0.41**
11/17	0.48	0.68	0.13	0.18	0.25	0.30	**0.33**
11/24	0.42	0.60	0.10	0.14	0.19	0.22	**0.25**
12/1	0.36	0.50	0.07	0.10	0.13	0.16	**0.18**
12/8	0.31	0.40	0.05	0.07	0.09	0.11	**0.12**
12/15	0.29	0.40	0.05	0.06	0.09	0.10	**0.11**
12/22	0.25	0.40	0.04	0.06	0.08	0.09	**0.10**
12/29	0.21	0.40	0.03	0.05	0.06	0.08	**0.09**
Total	**57.90**		**20.91**	**28.75**	**39.20**	**47.05**	**52.27**

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

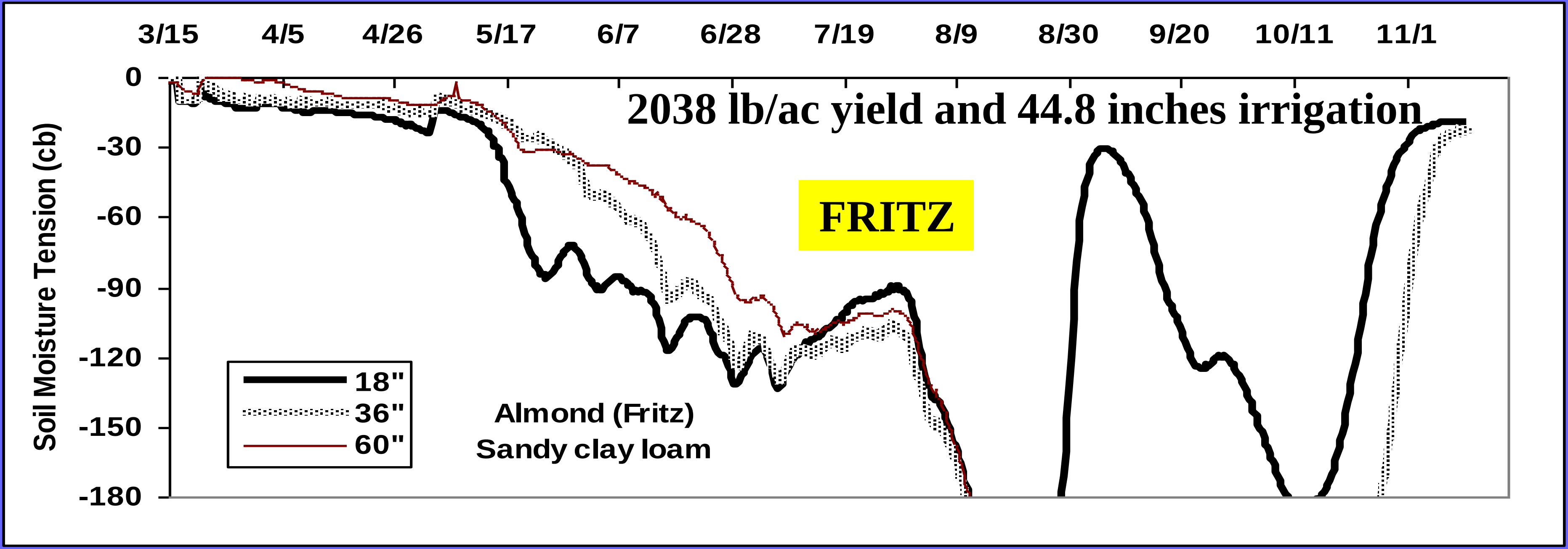


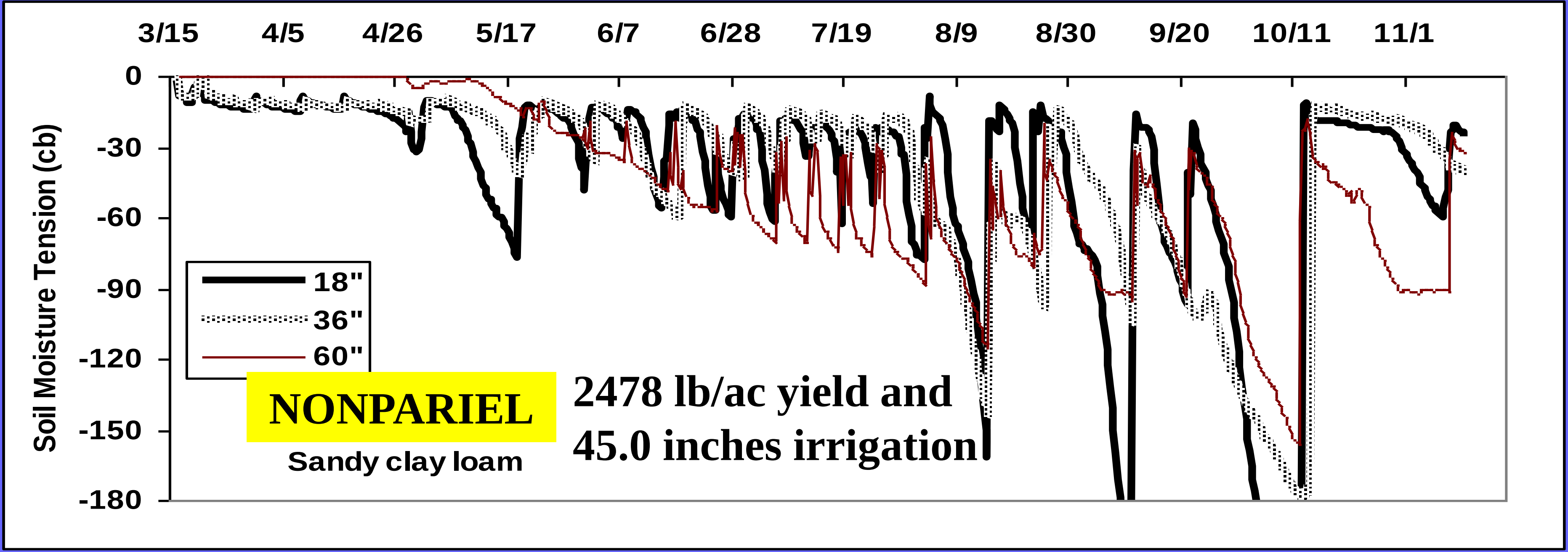
Measured Brown Fertility ET compared to 2002 Sanden & 1968 UC Almond ET



Siting logger and soil moisture monitoring equipment near micro sprinkler and tree in 5th leaf almonds. (Chart @ 18" depth.)

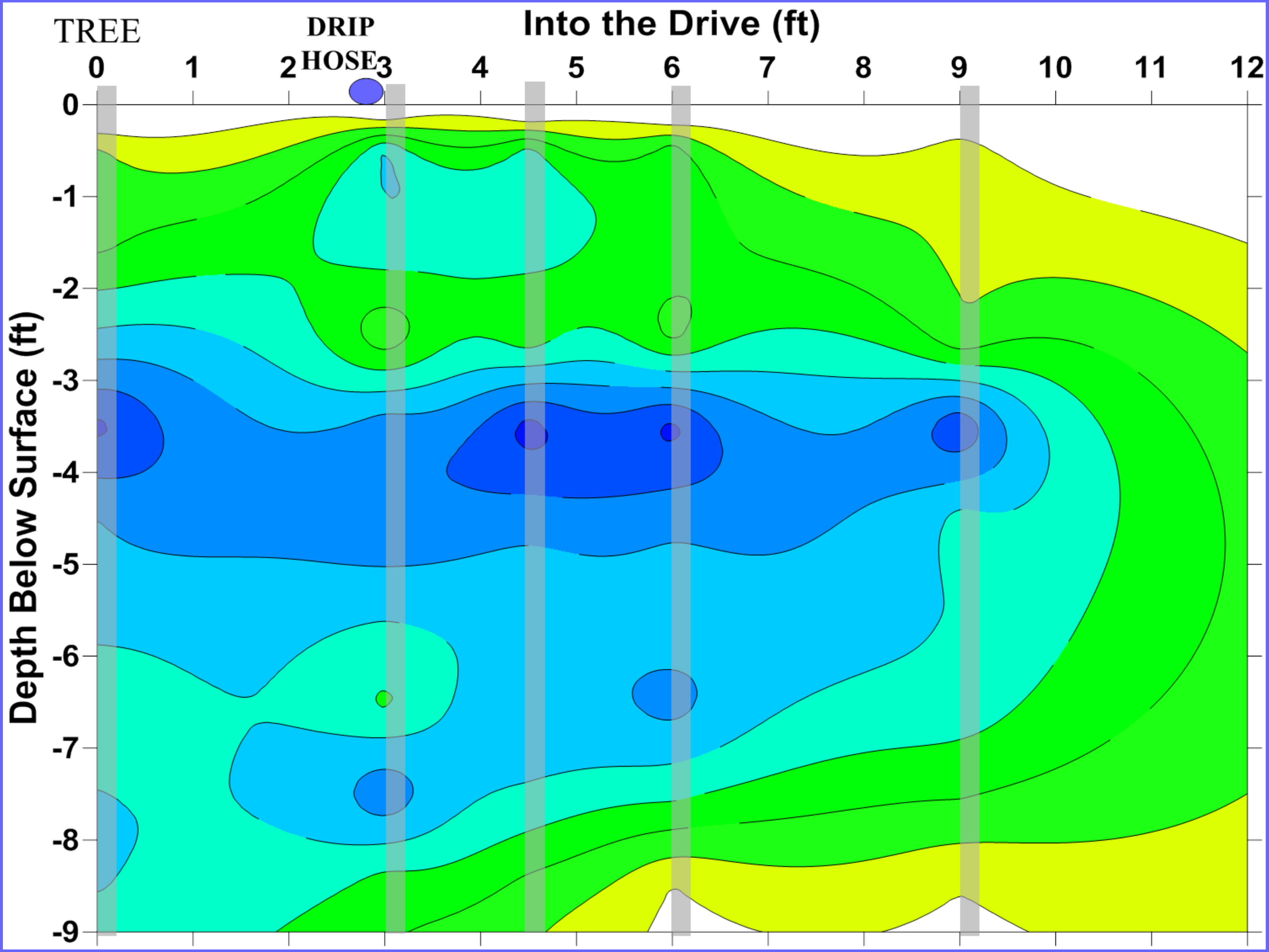
Watermark Readings from AM400 logger, reading 3x/day






How do I calculate
total available water
with microsprinklers
@ 1.5 in/day…


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


TREE
DRIP HOSE
Into the Drive (ft)
0 1 2 3 4 5 6 7 8 9 10 11 12
Depth Below Surface (ft)
0 -1 -2 -3 -4 -5 -6 -7 -8 -9

Estimating Water Holding Capacity & Microirrigation Set Times for Orchards

Refill Times for Different Soil Textures and Micro Systems

[1]Irrigation Time to Refill & Moisture Reserve of 4 Foot Wetted Rootzone @ 50% to 100% Available

ALMONDS 0.28 inch/day ET

Soil Texture	Available Soil Moisture (in/ft)	Avg Drip Subbing Diameter from 1 to 4' Depth (ft)	Dble-Line Drip 1-gph, 10 per tree (irrig hrs)	Moisture Reserve @ 0.28"/day (days)	10 gph Fanjet, 1 per tree (irrig hrs)	Moisture Reserve @ 0.28"/day (days)	14 gph Fanjet, 1 per tree (irrig hrs)	Moisture Reserve @ 0.28"/day (days)
Sand	0.7	2	2.2	0.3	11.6	1.6	12.5	2.4
Loamy Sand	1.1	3	7.8	1.0	19.6	2.7	20.9	4.0
Sandy Loam	1.4	4	17.5	2.4	26.9	3.6	28.3	5.4
Loam	1.8	5	35.9	4.9	37.1	5.0	38.6	7.3
Silt Loam	1.8	6	43.1	5.8	39.7	5.4	40.8	7.7
Sandy Clay Loam	1.3	6	31.1	4.2	28.6	3.9	29.5	5.6
Sandy Clay	1.6	7	44.7	6.0	37.6	5.1	38.3	7.2
Clay Loam	1.7	8	54.3	7.3	42.6	5.8	42.9	8.1
Silty Clay Loam	1.9	9	68.2	9.2	50.6	6.8	50.5	9.6
Silty Clay	2.4	9	86.2	11.6	64.0	8.6	63.8	12.1
Clay	2.2	10	87.8	11.9	62.3	8.4	61.5	11.6

[1]Based on a tree spacing of 20 x 22'. Drip hoses 6' apart. 10 gph fanjet wets 12' diameter. 14 gph fanjet @ 15' diameter.

Note: Peak water use @ 0.28"/day and 20 x 22' spacing = 74 gallons/day/tree. 0.20"/day = 55 gallons/day/tree.

Table takes into account merging water patterns below soil surface for drip irrigation.

So how much salt comes in with my irrigation water?

Kern 10-year Pistachio Salt Tolerance Trial Average Water Quality 2004-2013

2004-2013 AVERAGE TREATMENT WATER QUALITY

TREATMENT	pH	EC (dS/m)	SAR	Ca (meq/l)	Mg (meq/l)	Na (meq/l)	Cl (meq/l)	B (ppm)	HCO3 (meq/l)	CO3 (meq/l)	NO3-N (ppm)	SO4 (meq/l)
Aqueduct	7.9	0.49	2.4	1.1	1.0	2.4	2.1	0.2	1.3	<0.1	0.5	0.7
Blend	7.7	3.48	4.5	14.1	7.6	14.8	19.6	7.6	1.5	<0.1	1.7	9.9
Well	7.6	5.32	5.4	23.2	12.9	22.8	34.1	11.6	1.6	<0.1	5.7	19.6
Well 9-3 high EC	*7.8*	*8.89*	*7.0*	*40.3*	*19.1*	*37.7*	*66.3*	*19.2*	*2.0*	*<0.1*	*12.0*	

Salt tonnage by water quality calculations:

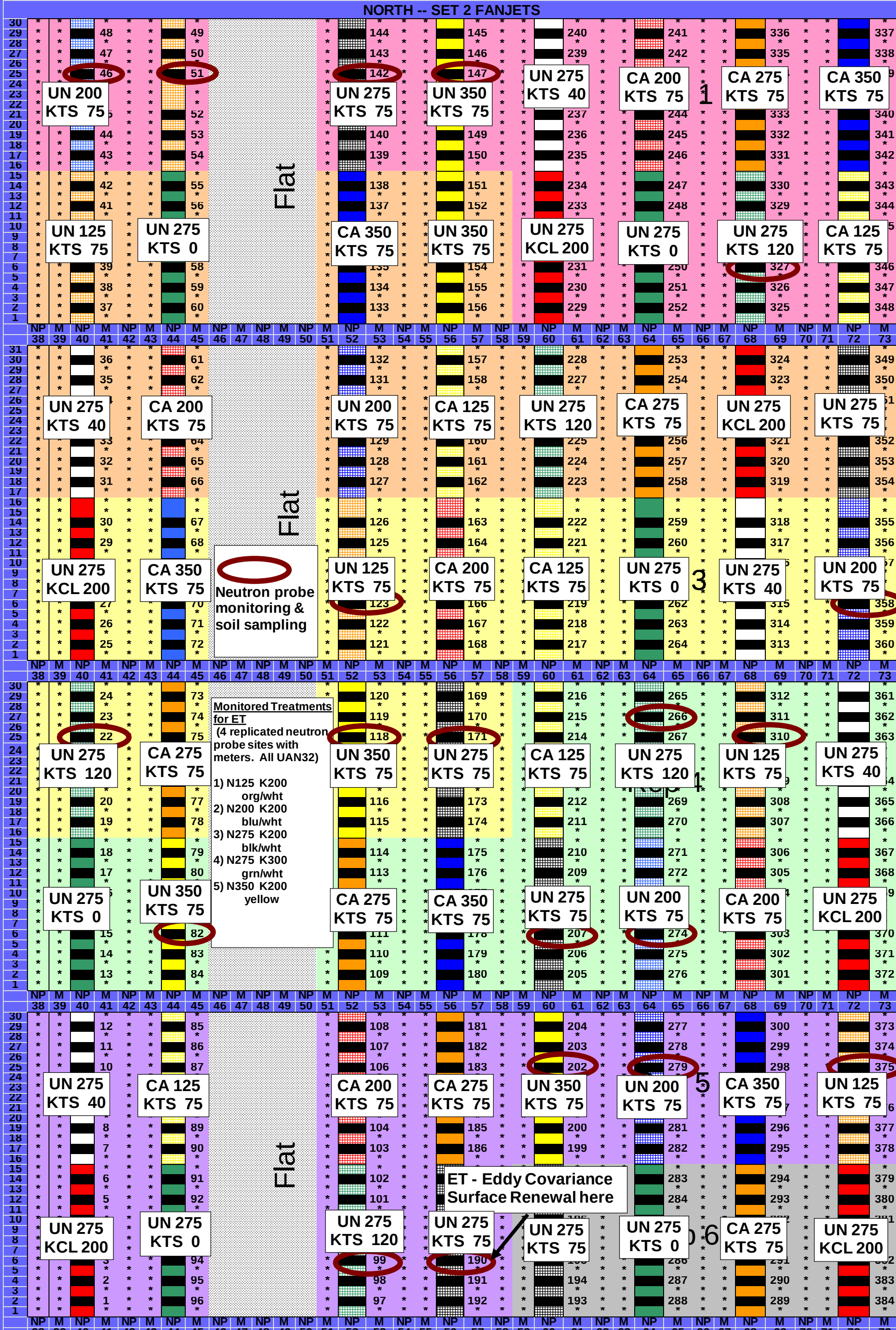
2004-2013 AVERAGE TREATMENT WATER QUALITY (TDS/PPM values)

Water Source	pH	EC (TDS)	SAR	**Ca (ppm)**	Mg (ppm)	**Na (ppm)**	**Cl (ppm)**	B (ppm)	HCO3 (ppm)	NO3-N (ppm)	SO4 (ppm)
Aqueduct	7.9	312	2.4	**22**	48	**55**	**73**	2	79	0.5	63
Blend	7.7	2228	4.5	**282**	372	**341**	**675**	82	89	1.7	948
Well	7.6	3405	5.4	**465**	627	**525**	**1176**	125	97	5.7	1877
Well high EC	7.8	5690	7.0	**807**	929	**867**	**2284**	207	124	12.0	*Not tested*

MASS (lbs/4 ac-ft) **1 Acre-Foot of Water = 2.719 million pounds**

Water Source	pH	EC	***EC Increase**	SAR	**Ca**	Mg	**Na**	**Cl**	B	HCO3	NO3-N	SO4
Aqueduct	7.9	3397	**0.27**	2.4	**239**	523	**601**	**791**	25	854	4.9	684
Blend	7.7	24236	**1.89**	4.5	**3065**	4043	**3707**	**7342**	890	964	18.4	10317
Well	7.6	37033	**2.89**	5.4	**5057**	6822	**5713**	**12792**	1357	1050	62.0	20414
Well high EC	7.8	61885	**4.83**	7.0	**8777**	10103	**9435**	**24844**	2250	1344	130.1	*Not tested*

Maximum increase in rootzone soil ECe if salt is spread evenly throughout a 5 foot rootzone.



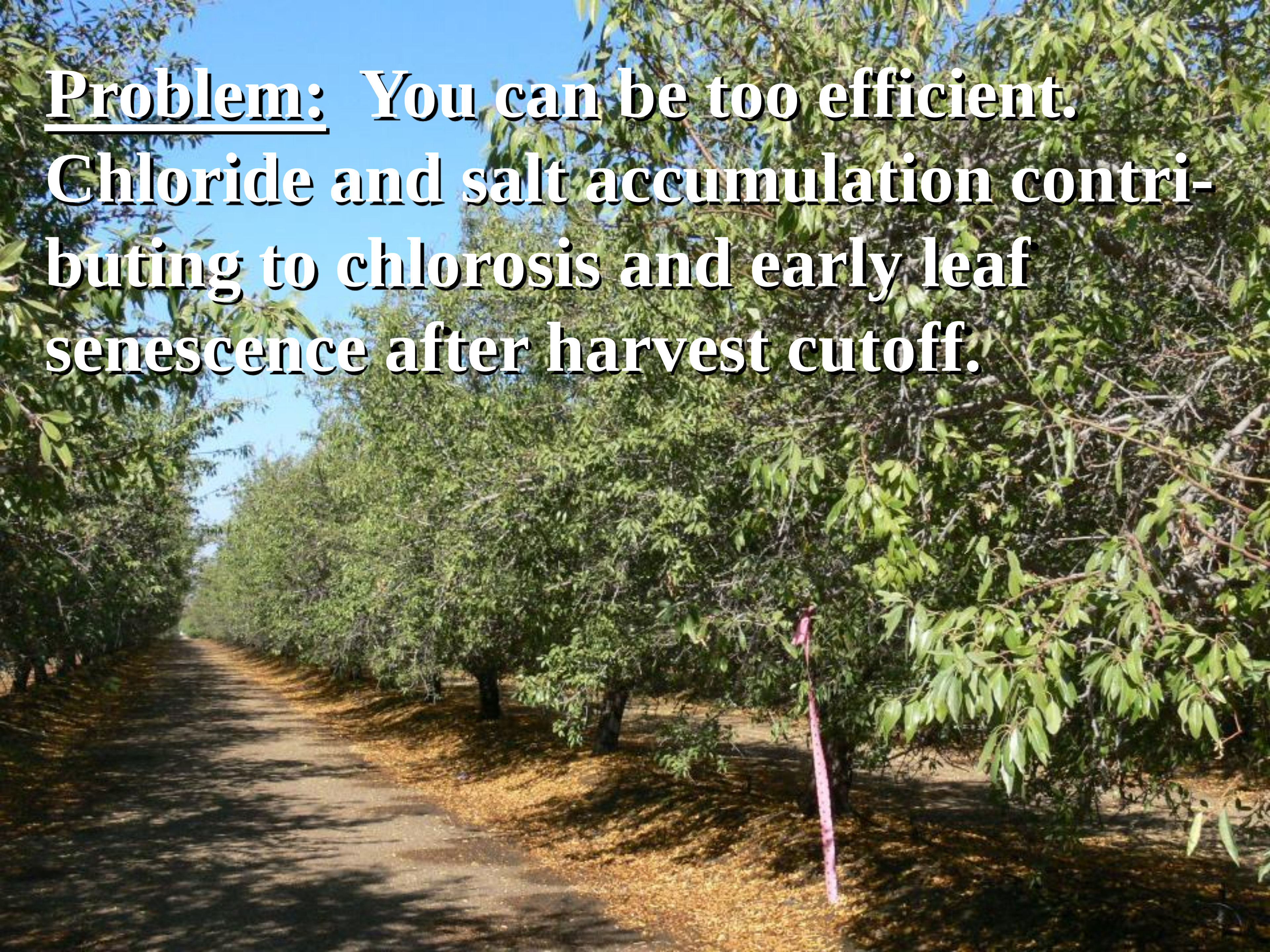
Patrick Brown fertility trial 2008-2012

12 treatments total

- **4 N levels:**
  125, 200, 275, 350 lb/ac
  2 sources: UAN32, CAN17

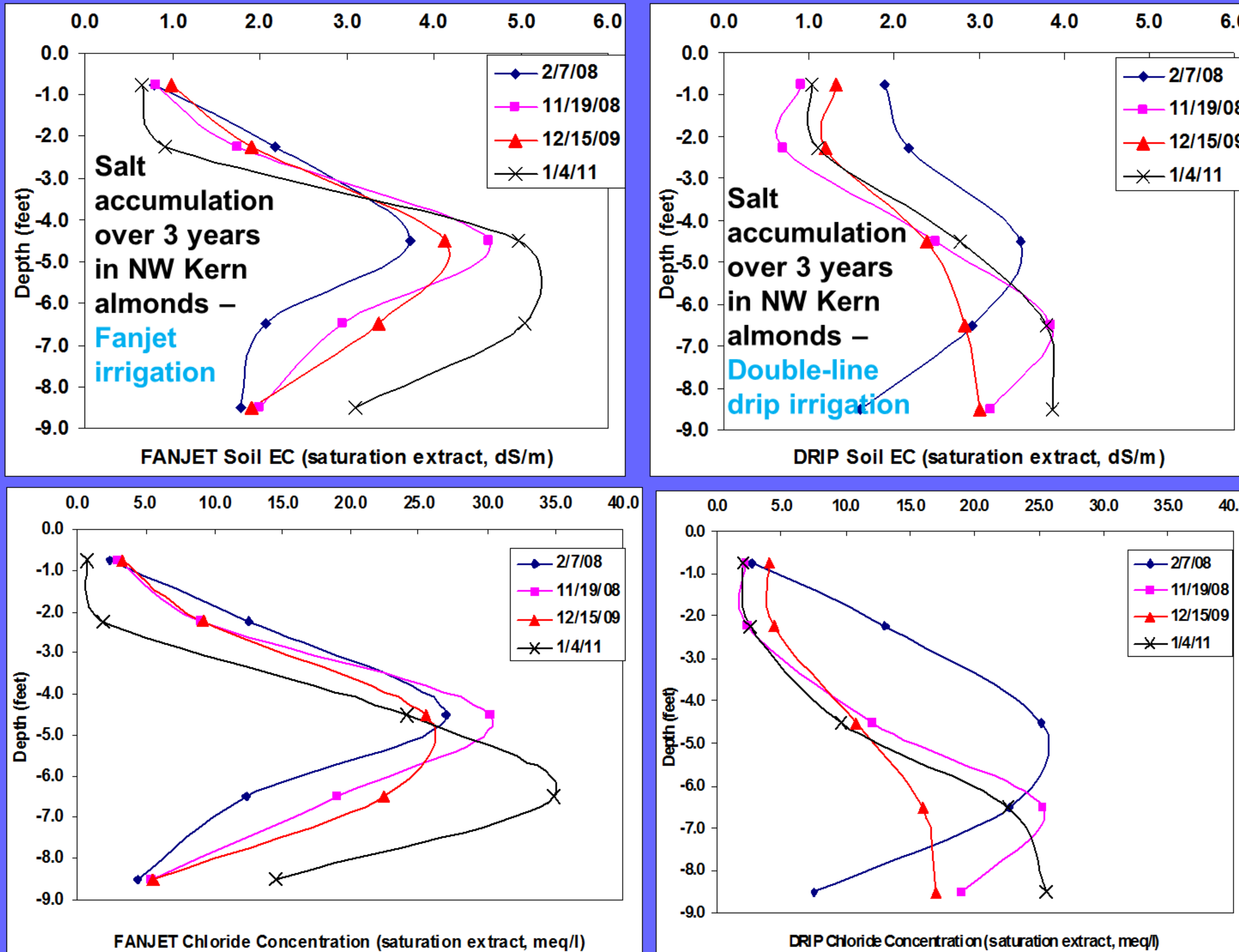
- **3 K levels:**
  100, 200, 300 lb/ac
  3 sources: K2SO4, KCl, K thiosulfate

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



Defoliation in Nonpareil and Monterey 10/1/11

Canopy condition after late Nonpareil shake (9/6/12)



0.0
1.0
2.0
3.0
4.0
5.0
6.0
-1.0
-2.0
-3.0
-4.0
-5.0
-6.0
-7.0
-8.0
-9.0
Depth (feet)
2/7/08
11/19/08
12/15/09
1/4/11
Salt accumulation over 3 years in NW Kern almonds –
Fanjet irrigation
FANJET Soil EC (saturation extract, dS/m)
Salt accumulation over 3 years in NW Kern almonds –
Double-line drip irrigation
DRIP Soil EC (saturation extract, dS/m)
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
FANJET Chloride Concentration (saturation extract, meq/l)
DRIP Chloride Concentration (saturation extract, meq/l)

Salt tonnage by water quality calculations:

Table 1. Salt Index values for some K Sources from the Jackson and Rader methods and those being reported in Crop Protection Handbook and Western Fertilizer Handbook. (After: Clapp, J.G. Currently Used Salt Index Tables are Misleading. 2007 Indiana CCA Conference Proceedings)

K-Source	Rader (1944)	Jackson (1958)	Crop Protection Handbook (2006)	Western Fertilizer Handbook (2002)
KCl	116.3	149.6	116.2	116.3
K2SO4	46.1	111.2	42.6	46.1
KNO3	73.6	97.6	69.5	73.6
S of Potash-magnesia	43.2	64.8	43.4	43.4
Thiosulfate	--	63.2	68	64

Note: The current standard salinity hazard index number is the osmotic potential of the fertiizer compared to the osmotic potential of sodium nitrate which is standardized at 100. Thus KCl @ 116.3 creates 16% more osmotic potential per pound of fertilzer compared to NaNO3.

Salt tonnage by soil & water salinity calculations:

200 lb/ac K application from KCl

= 200 lb K + 182 lb Cl = 382 lb KCL

Average soil saturation extract Cl=12 meq/l=420 ppm

With extract SP at 0.33 =~ 2790 lb Cl

down to 5 foot deep

Possible Cl increase from FERTILIZER

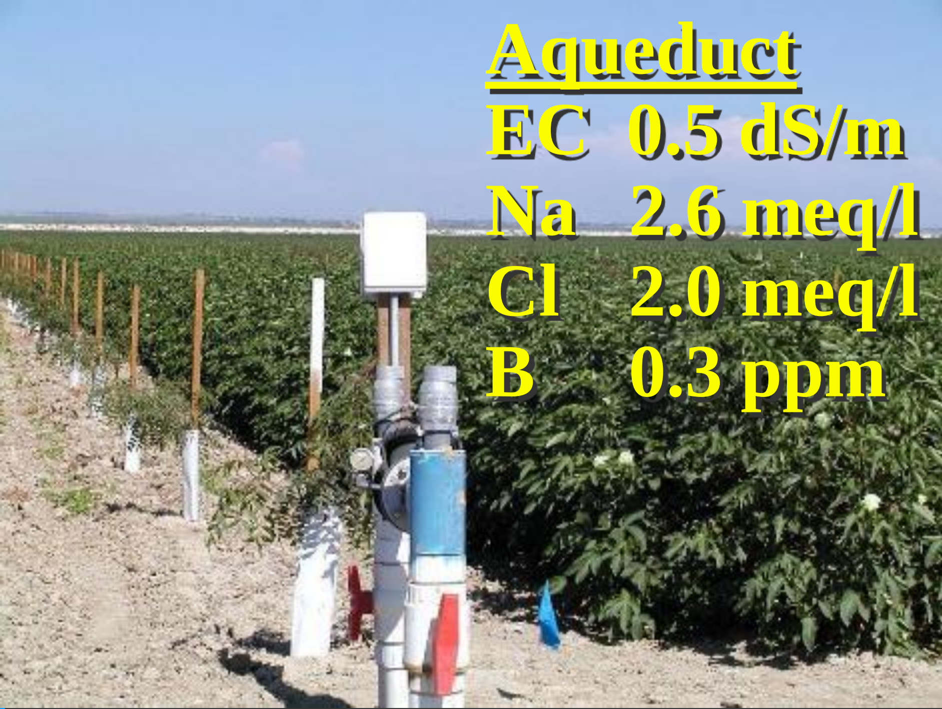
= 182 / 2790 = 6.7%

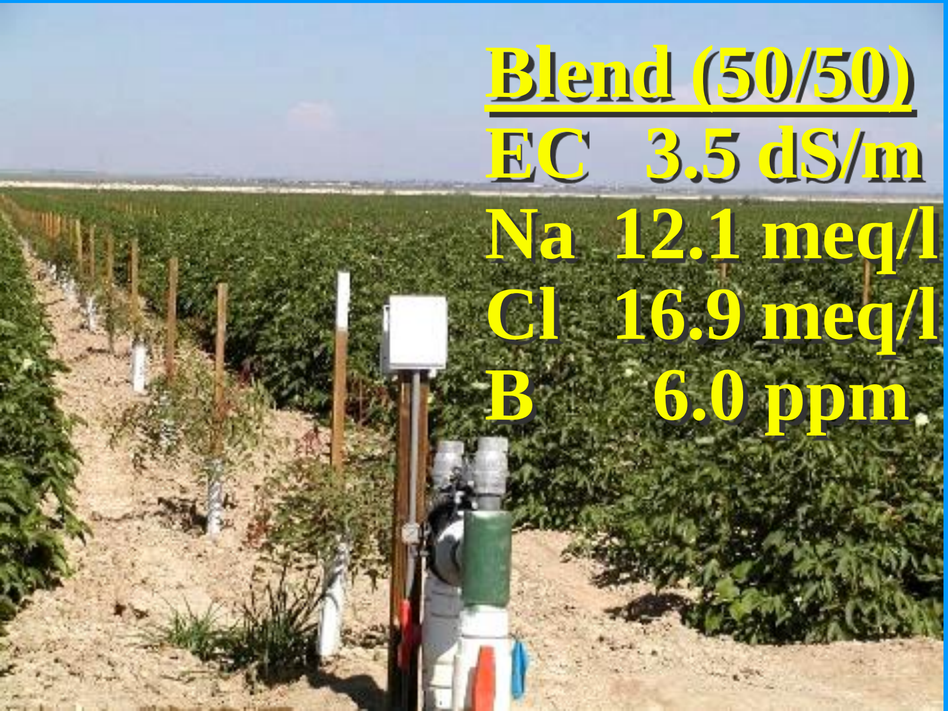
Possible Cl increase from WATER

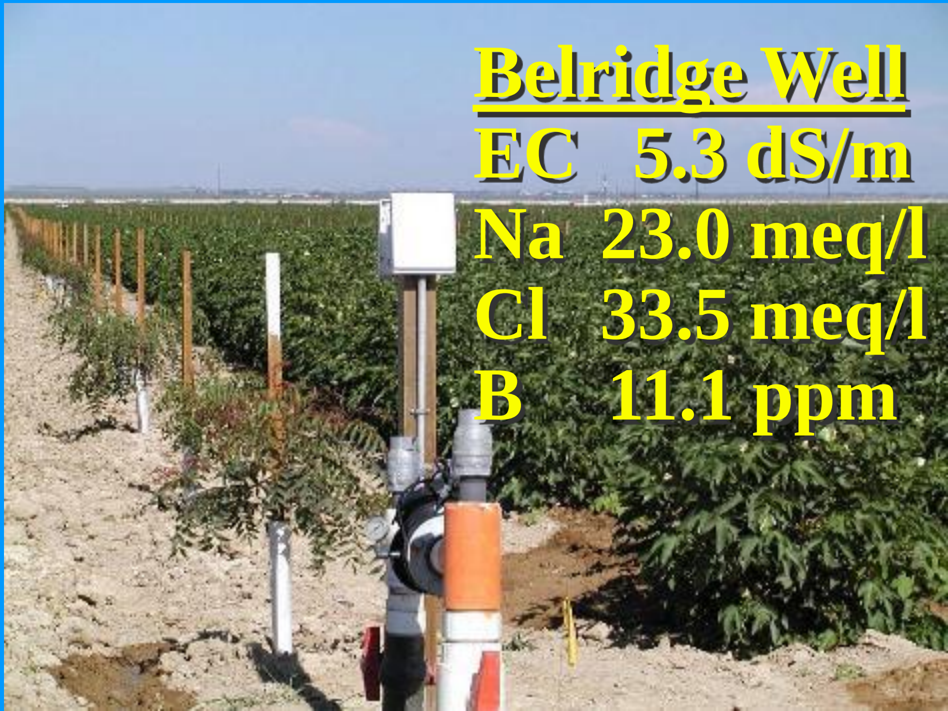
= 791 / 2790 = 28.4%

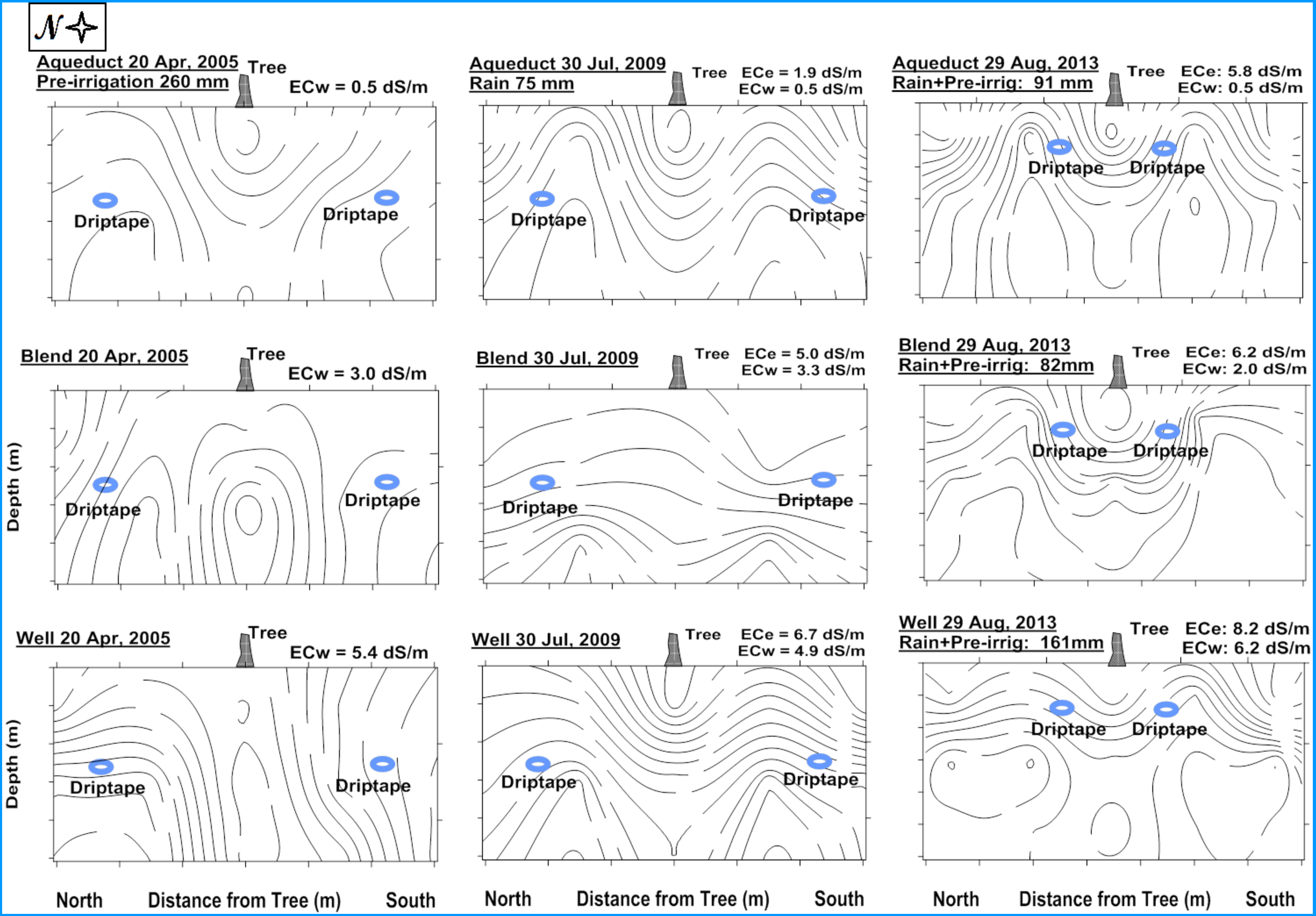
Establishing pistachios interplanted in Pima cotton using drip tape and saline water.

(1st leaf, 8/2/05)





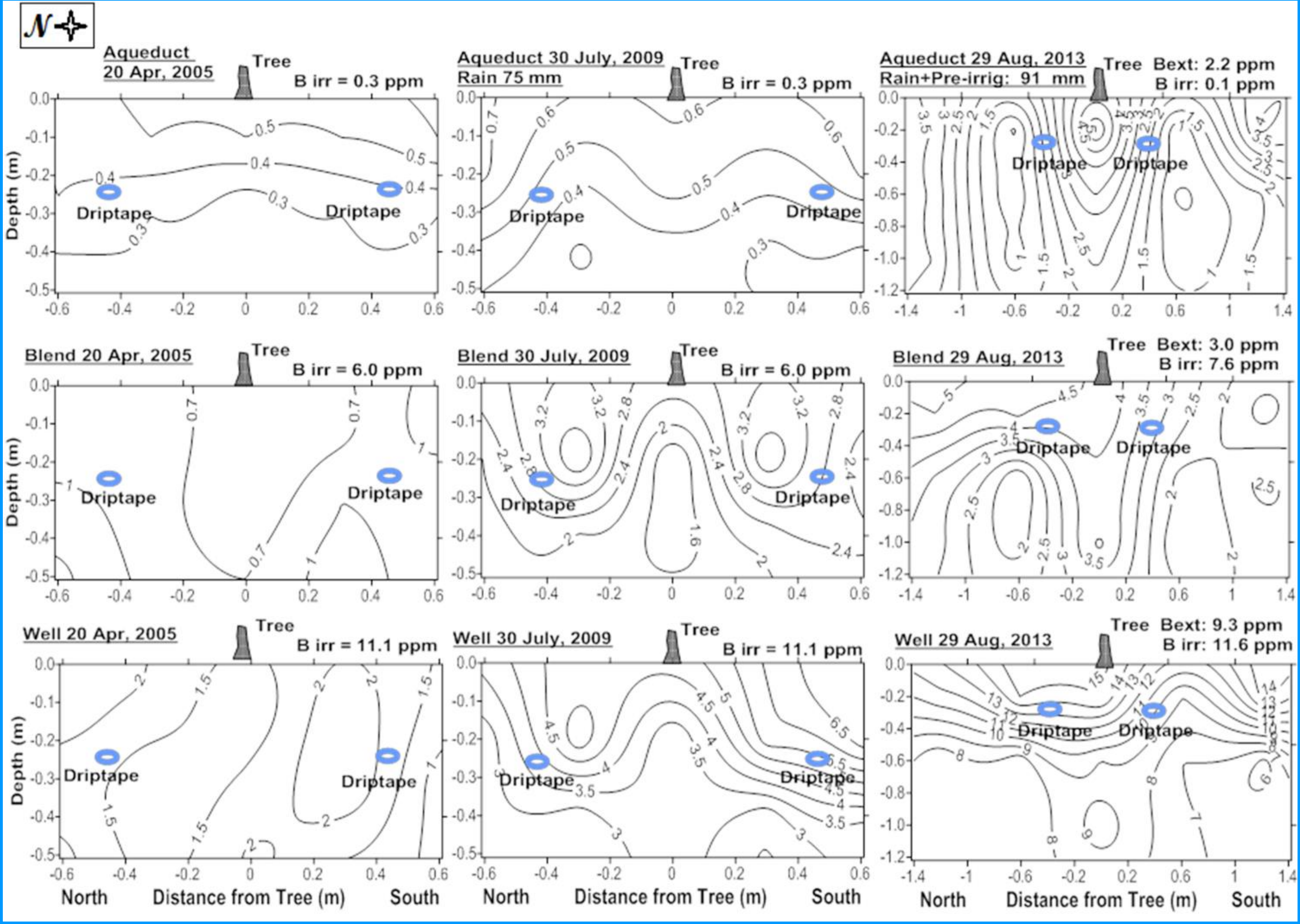




Contours of soil salinity (ECe, dS/m) in pistachio rows, 2005-2013

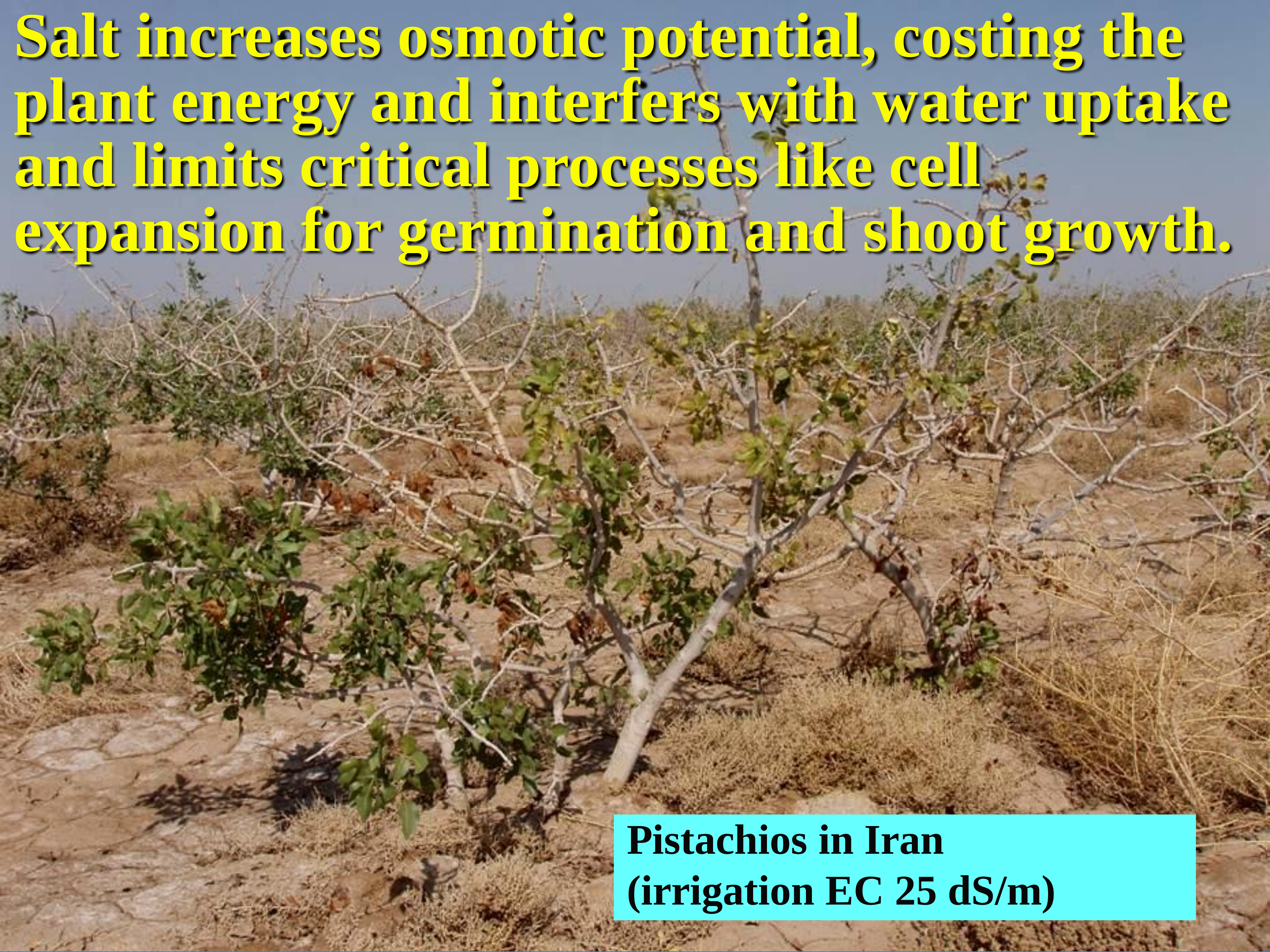
Marginal burn was seen on most leaves

9-1 West Compare

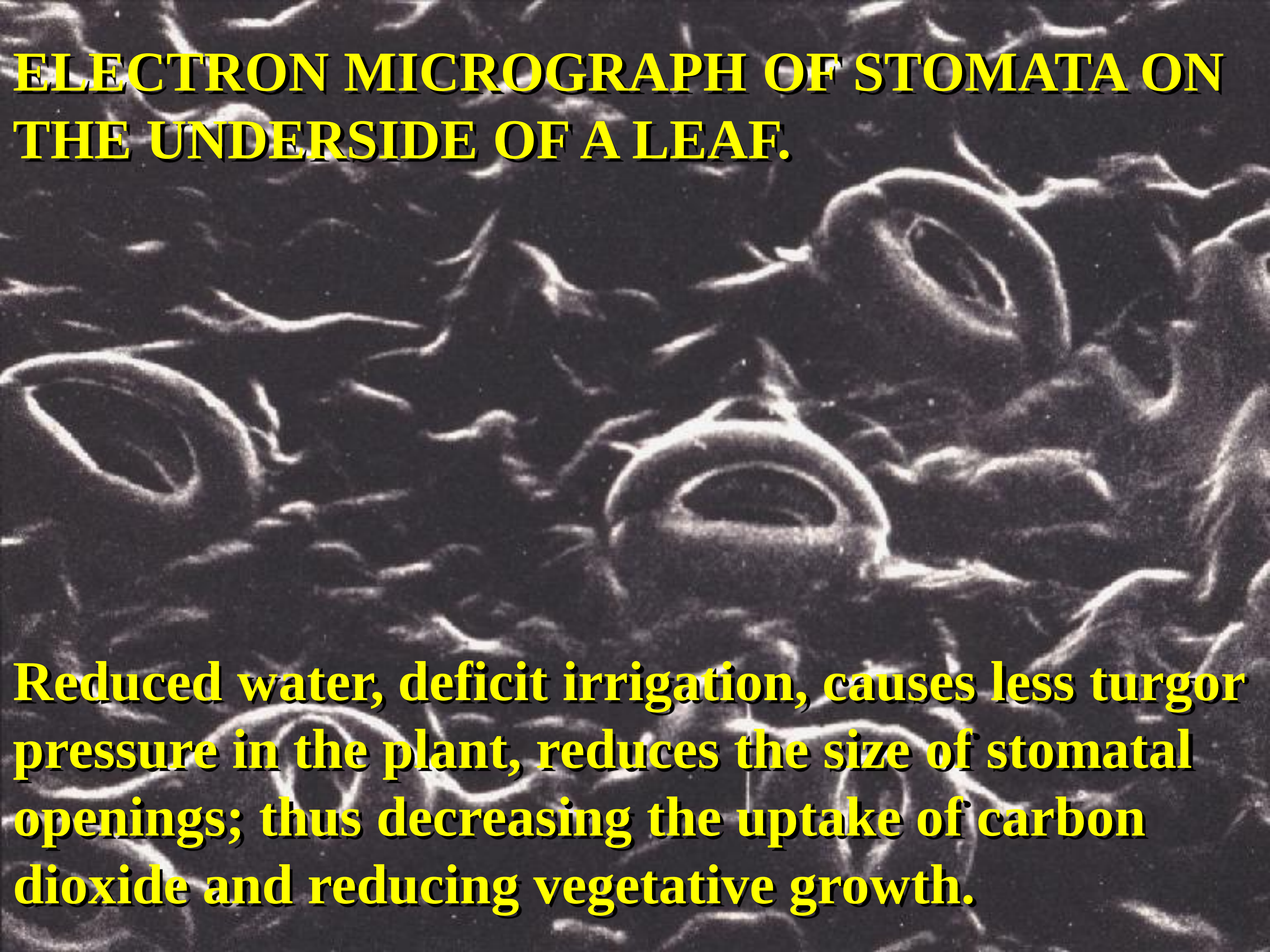


Contours of soluble boron in pistachio rows, 2005-2013

Salt increases osmotic potential, costing the plant energy and interfers with water uptake and limits critical processes like cell expansion for germination and shoot growth.

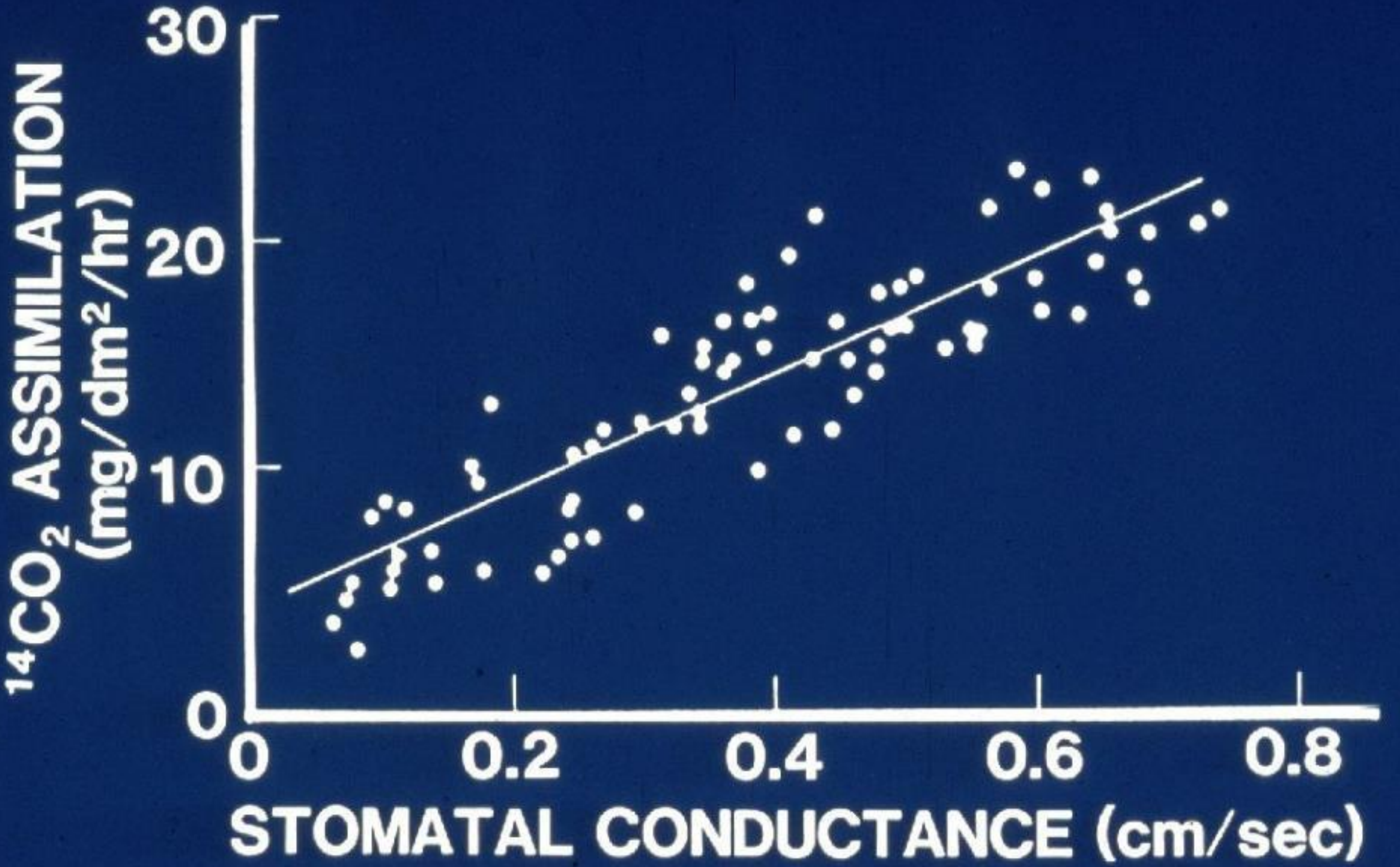


Pistachios in Iran
(irrigation EC 25 dS/m)



ELECTRON MICROGRAPH OF STOMATA ON THE UNDERSIDE OF A LEAF.

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



30
20
10
0
$^{14}CO_2$ ASSIMILATION (mg/dm²/hr)
0
0.2
0.4
0.6
0.8
STOMATAL CONDUCTANCE (cm/sec)

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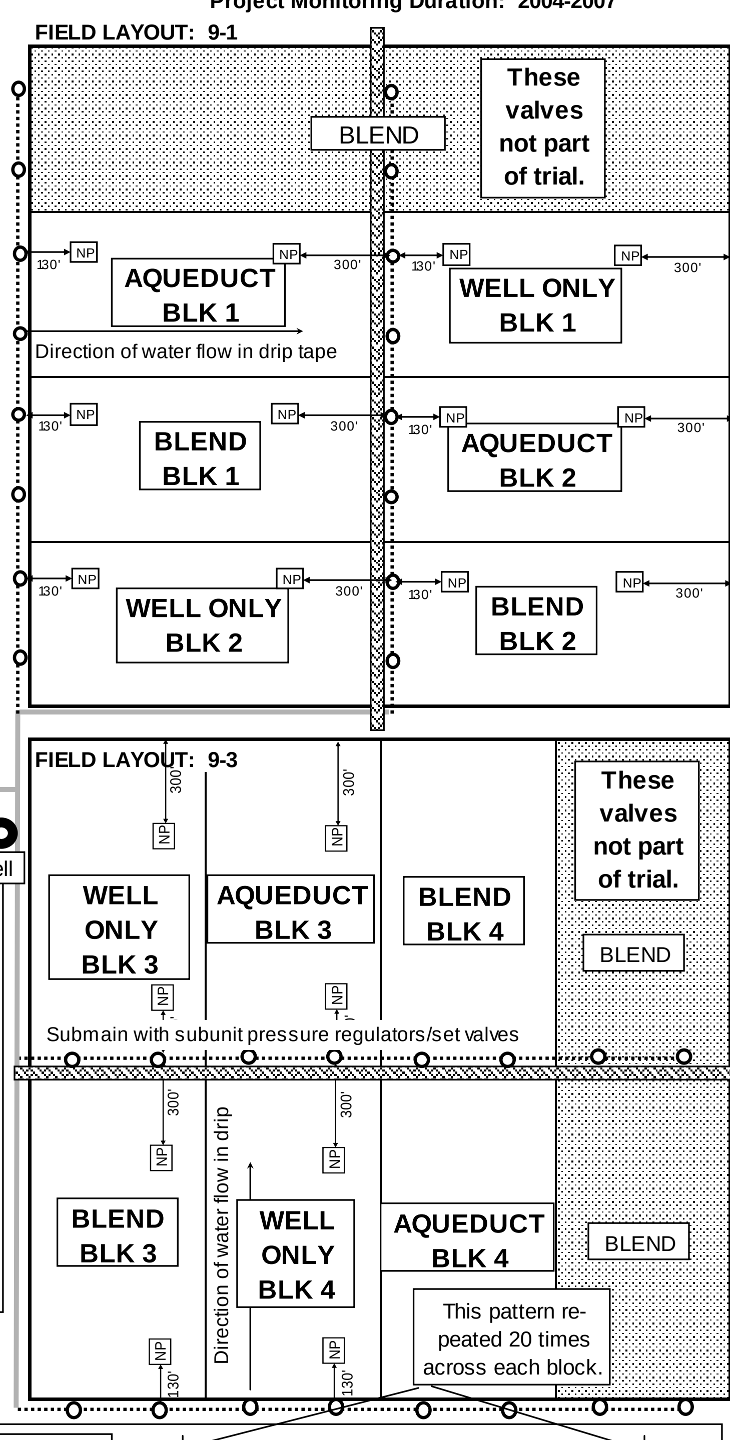


Belridge Salinity Trial
-- 2, 155 acre fields
-- 12, 19.5 acre testplots

Salt added to crop rootzone from start of project

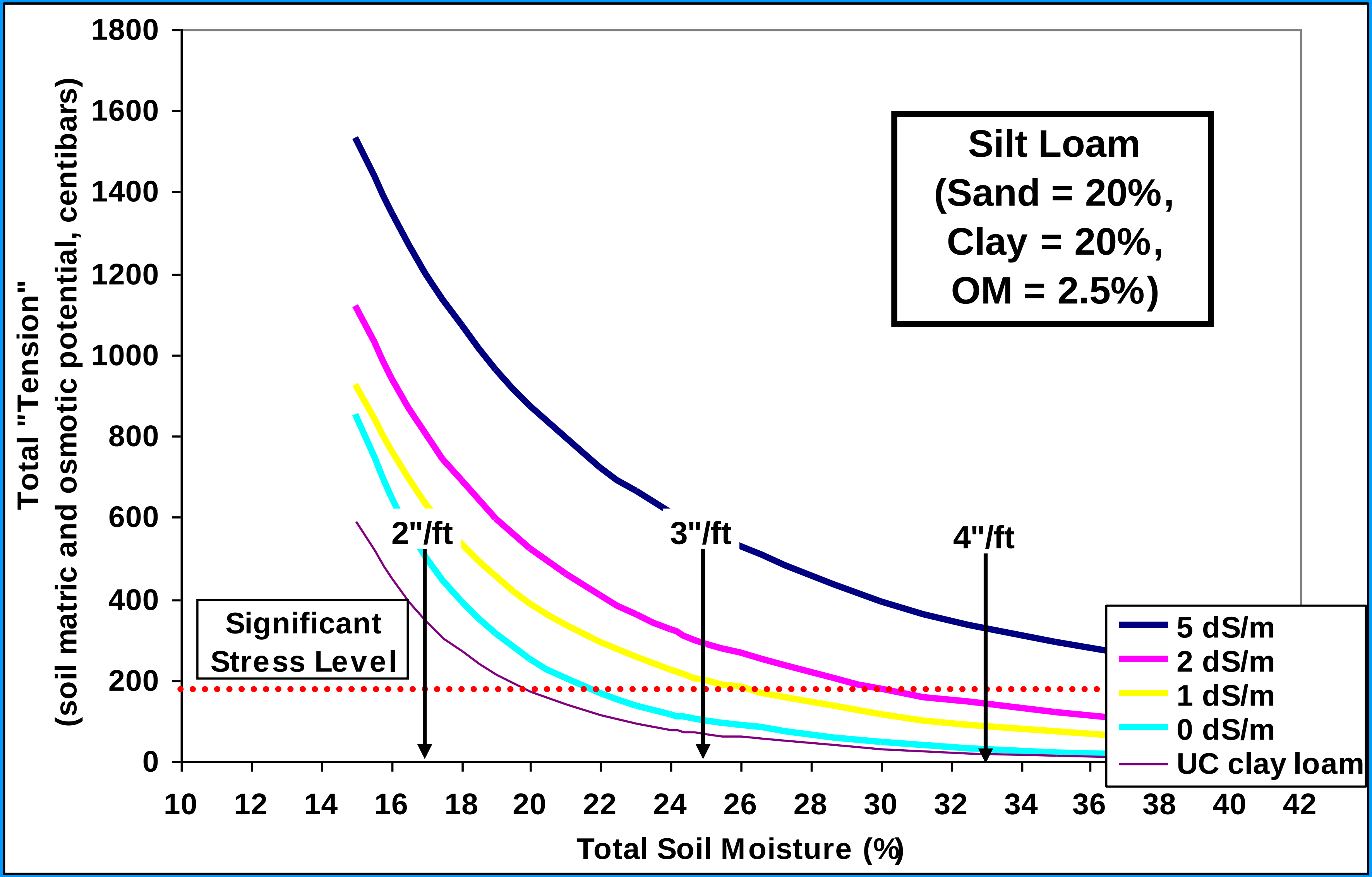
Irrigation Treatment (avg dS/m)	2005 Irrig (in)	2005 Salt [1](lb/ac)	2008 Irrig (in)	2008 Salt (lb/ac)	2011 Irrig (in)	2011 Salt (lb/ac)	2013 Irrig (in)	2013 Salt (lb/ac)	**Total Irrig (in)**	**Total Salt (lb/ac)**	**[2]EC+ Max (dS/m)**
Aque (0.5)	10	1,742	8.8	1,553	33	3,387	33.3	5,686	**215.8**	**32,848**	**2.6**
Blend (3.2)	10	8,570	8.7	8,185	41	40,838	50.5	33,730	**247.9**	**193,172**	**15.1**
Well (5.2)	12	14,782	9.6	13,296	35	48,596	39.0	72,794	**225.0**	**300,395**	**23.5**

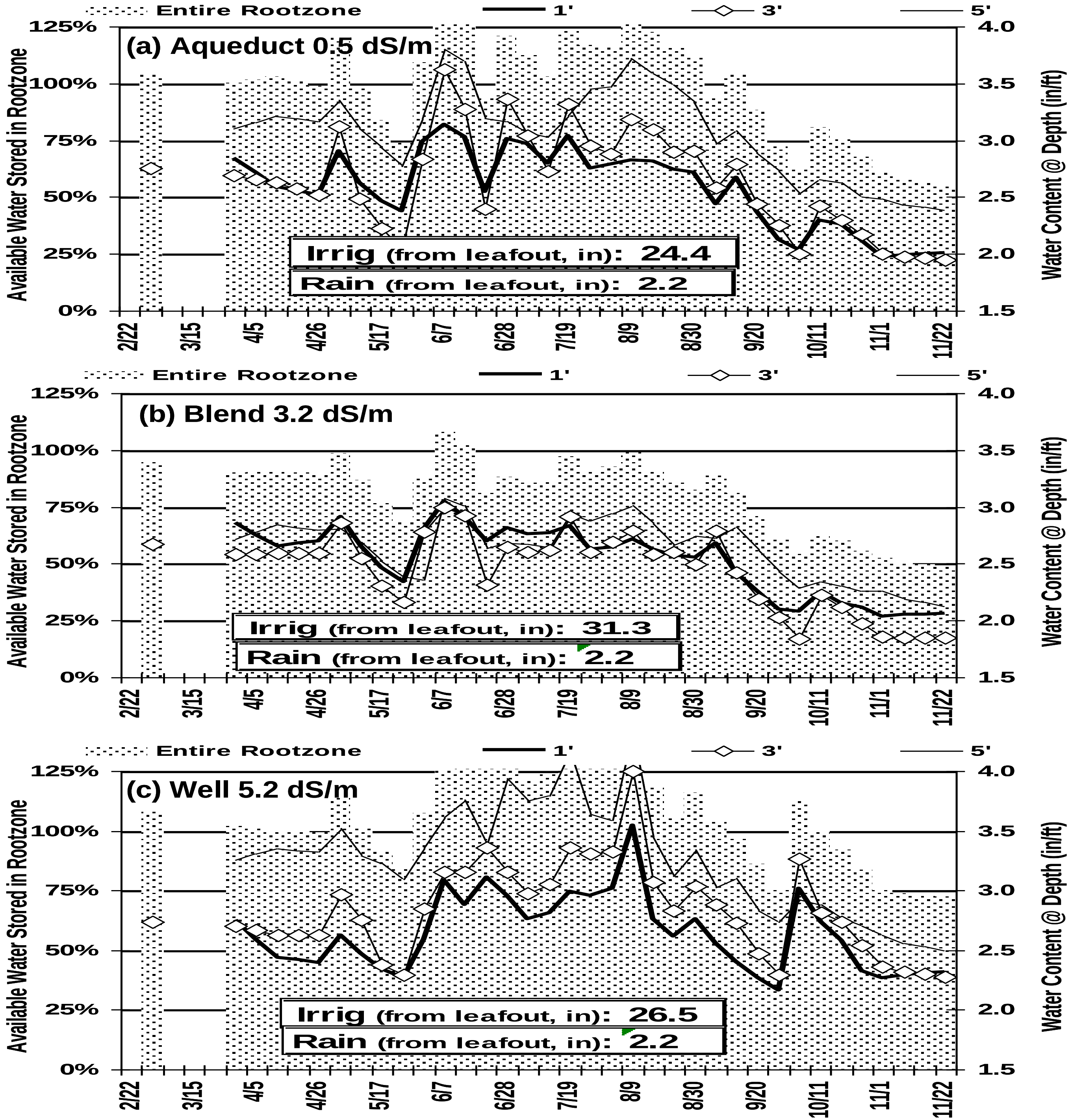
[1]Irrigation inches for total tree spacing, salt totals (lb/ac) calculated for a 9.5 foot wide subbing area centered on the tree row. Assumes 640 ppm soluble salt = 1 dS/m and a 5 ac-ft depth of soil = 20 million lbs.

[2]Maximum increase in soil saturated paste EC for a 5 foot rootzone with no precipitation of salts and no leaching past the 5 foot depth.

Plant stress can be high even with wet soil

(Effective soil moisture tension for a silt loam soil)





2011 neutron probe soil moisture readings showed significant leaching for the WELL treatment

So where do I start on assessing salinity problems and management solutions?

GOOSE LAKE RANCH

Received Time Mar. 19. 10:17AM

Pits 8, 9, 11, 12 +13

GTS #	Description	% SP	pH	mmhos/cm ECe	Saturation Extract meq/l Ca	Mg	Na	K	Cl	HCO3	ppm B	Exchangeable Cations meq/100 grams K	Ca	Mg	Na	Soluble Salts % ESP*	% ESP++	Nutr... NO3-N	NO3-... dr...
48[illegible]	(8-13) 0-1'	40.	7.9	5.5	34.23	4.61	21.75	0.17	9.4	3.0	0.57	0.43	24.80	1.60	2.13	7.4	5.70	17.	7
48[illegible]	(8-13) 1-2'	45.	8.0	6.7	29.89	4.28	39.58	0.10	14.2	1.3	1.28	0.25	67.07	2.10	3.61	4.9	11.40	48.	22
48[illegible]	(8-13) 2-3'	45.	8.0	7.3	25.05	3.95	51.76	0.10	10.8	1.1	2.05	0.19	68.21	1.93	4.65	6.2	15.80	31.	14
4878	(8-13) 3-4'	48.	8.2	13.9	24.40	3.86	126.14	0.08	15.4	1.2	3.27	0.17	43.46	1.77	10.40	18.6	32.50	32.	15
4879	(8-13) 4-5'	48.	8.0	15.2	23.75	3.78	152.24	0.10	25.2	1.6	3.65	0.23	27.74	1.52	11.70	28.4	37.20	27.	13

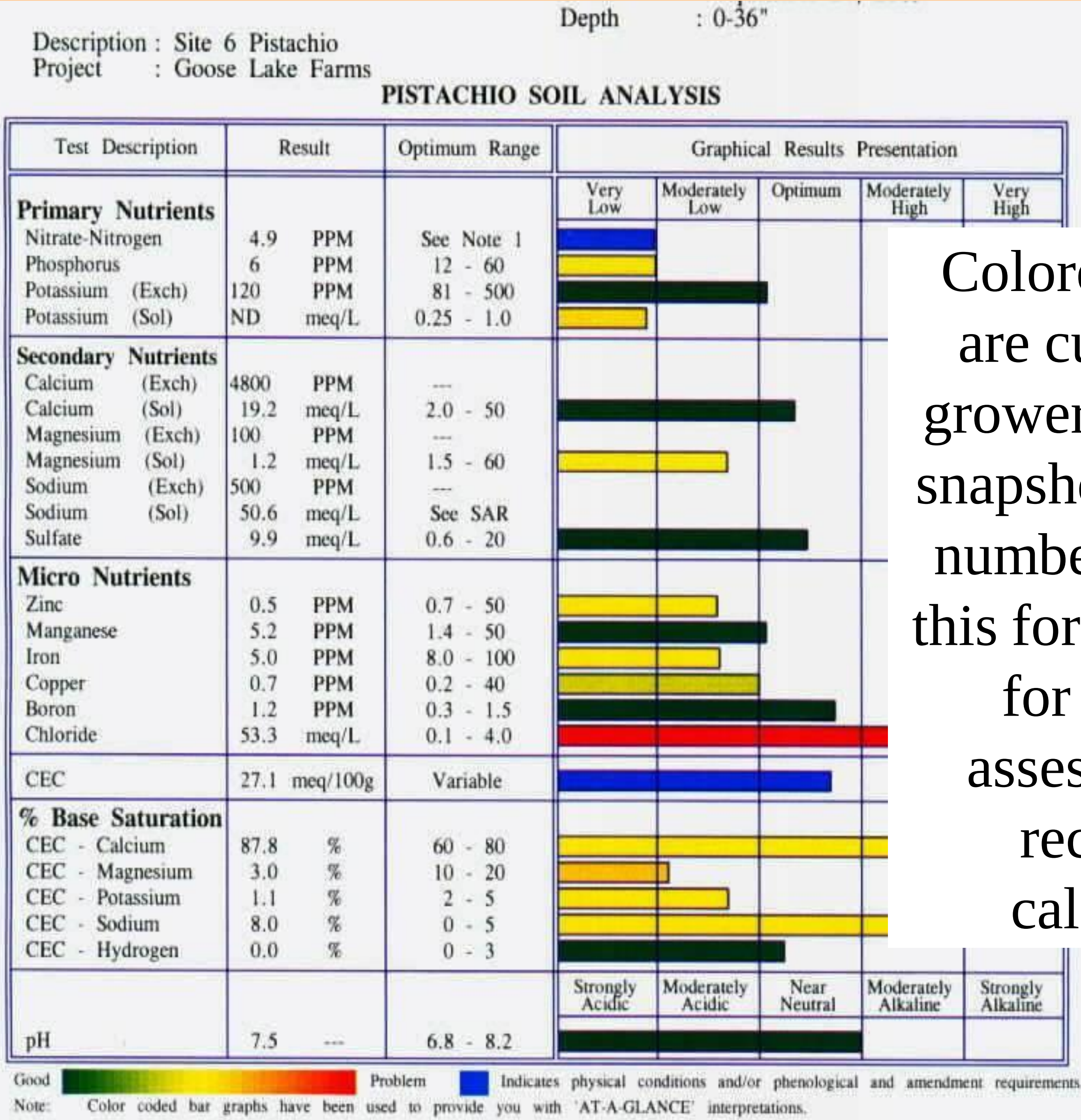
* ESP = (Calculated from Exchangeable Cations)

++ ESP = (Calculated from Soluble Salts and SAR)

*** CBC = (Cation Exchage Capacity)

GTS #	Description	Trace Metals ppm Zn	Mn	Fe	Cu	Free Lime	% CaCO3	ppm SO4-S	% SAR	*** % CBC
4875	(8-13) 0-1'	1.6	8.8	9.6	1.1	HIGH	7.5	121.	29.0	88.8
4876	(8-13) 1-2'	1.1	1.0	8.2	0.8	HIGH	7.4	564.	73.0	88.8
4877	(8-13) 2-3'	1.3	0.8	6.0	0.4	HIGH	6.0	610.	75.0	88.8
4878	(8-13) 3-4'	1.4	0.7	8.2	0.4	HIGH	3.0	640.	55.8	88.8
4879	(8-13) 4-5'	1.3	0.7	10.0	0.4	HIGH	4.5	236.	41.2	88.8

Start with the data. CURRENT soil and water analyses are essential. Organize by depth in Excel format.



Description : Site 6 Pistachio
Project : Goose Lake Farms
Depth : 0-36"

PISTACHIO SOIL ANALYSIS

Test Description	Result		Optimum Range
Primary Nutrients			
Nitrate-Nitrogen	4.9	PPM	See Note 1
Phosphorus	6	PPM	12 - 60
Potassium (Exch)	120	PPM	81 - 500
Potassium (Sol)	ND	meq/L	0.25 - 1.0
Secondary Nutrients			
Calcium (Exch)	4800	PPM	---
Calcium (Sol)	19.2	meq/L	2.0 - 50
Magnesium (Exch)	100	PPM	---
Magnesium (Sol)	1.2	meq/L	1.5 - 60
Sodium (Exch)	500	PPM	---
Sodium (Sol)	50.6	meq/L	See SAR
Sulfate	9.9	meq/L	0.6 - 20
Micro Nutrients			
Zinc	0.5	PPM	0.7 - 50
Manganese	5.2	PPM	1.4 - 50
Iron	5.0	PPM	8.0 - 100
Copper	0.7	PPM	0.2 - 40
Boron	1.2	PPM	0.3 - 1.5
Chloride	53.3	meq/L	0.1 - 4.0
CEC	27.1	meq/100g	Variable
% Base Saturation			
CEC - Calcium	87.8	%	60 - 80
CEC - Magnesium	3.0	%	10 - 20
CEC - Potassium	1.1	%	2 - 5
CEC - Sodium	8.0	%	0 - 5
CEC - Hydrogen	0.0	%	0 - 3
pH	7.5	---	6.8 - 8.2

Good — Problem ■ Indicates physical conditions and/or phenological and amendment requirements.
Note: Color coded bar graphs have been used to provide you with 'AT-A-GLANCE' interpretations.

Colored bar charts are cute and give growers an intuitive snapshot of what the numbers mean, but this format is useless for doing salt assessments and reclamation calculations.

Table 1. **Guidelines for water quality for irrigation**[1]
(Adapted from FAO Irrigation and Drainage Paper 29)

Potential Irrigation Problem		Units	Degree of Restriction on Use		
			None	Slight to Moderate	Severe
Salinity *(affects crop water availability)*					
	EC_w	dS/m	< 0.7	0.7 – 3.0	> 3.0
	TDS	mg/l	< 450	450 – 2000	> 2000
Infiltration *(affects infiltration rate of water into the soil. Evaluate using EC_w and SAR together)*					
Ratio of SAR/EC_w			< 5	5 – 10	> 10
Specific Ion Toxicity *(sensitive trees/vines, surface irrigation limits)*					
	Sodium (Na)[2]	meq/l	< 3	3 – 9	> 9
	Chloride (Cl)[2]	meq/l	< 4	4 – 10	> 10
	Boron (B)	mg/l	< 0.7	0.7 – 3.0	> 3.0

[1] Adapted from University of California Committee of Consultants 1974.

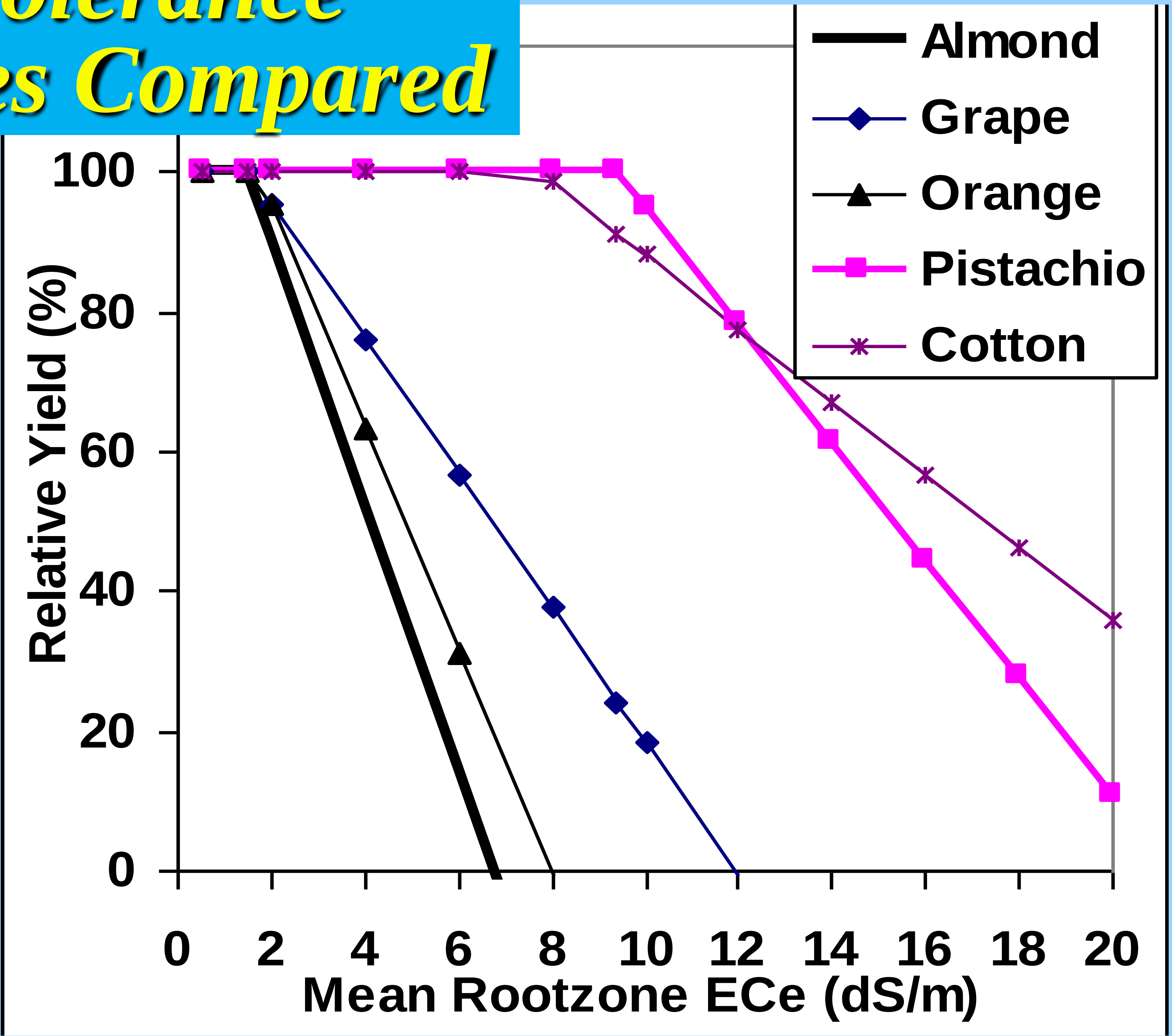
[2] For surface irrigation, most tree crops and woody plants are sensitive to sodium and chloride; use the values shown. Most annual crops are not sensitive; use the salinity tolerance only. With overhead sprinkler irrigation and low humidity (< 30 percent), sodium and chloride may be absorbed through the leaves of sensitive crops.

SOIL SALINITY & SPECIFIC ION TOXICITY THRESHOLDS

S = sensitive, <5-10 meq/l. MT=moderately tolerant, <20-30 meq/l

Crop	EC_{thresh} (dS/m)	Slope (%)	Sodium (meq/l)	Chloride (meq/l)	Boron (ppm)
Almond	1.5	19	S	S	0.5-1.0
Apricot	1.6	24	S	S	0.5-0.75
Avocado			S	5.0	0.5-0.75
Date palm	4.0	3.6	MT	MT	
Grape	1.5	9.6		10-30	0.5-1.0
Orange	1.7	16	S	10-15	0.5-0.75
Peach	1.7	21	S	10-25	0.5-0.75
Pistachio	**9.4**	**8.4**	**20-50**	**20-40**	**3-6**
Plum	1.5	18	S	10-25	0.5-0.75
Walnut			S		0.5-1.0

Salt Tolerance Curves Compared



Salt Affected Relative Yield(%) =

$$100 - \text{Slope}*(\text{Soil } EC_e - EC_{threshold})$$

Almond Relative Yield(%) =

$$100 - 19*(\text{Soil } EC_e - 1.5)$$

Analysis:

pH 8.4

EC_w 1.0 dS/m

Ca 0.5 meq/l

Mg 0.1 meq/l

Na 9.6 meq/l

HCO_3 4.2 meq/l

CO_3 1.0meq/l

Cl 4.6meq/l

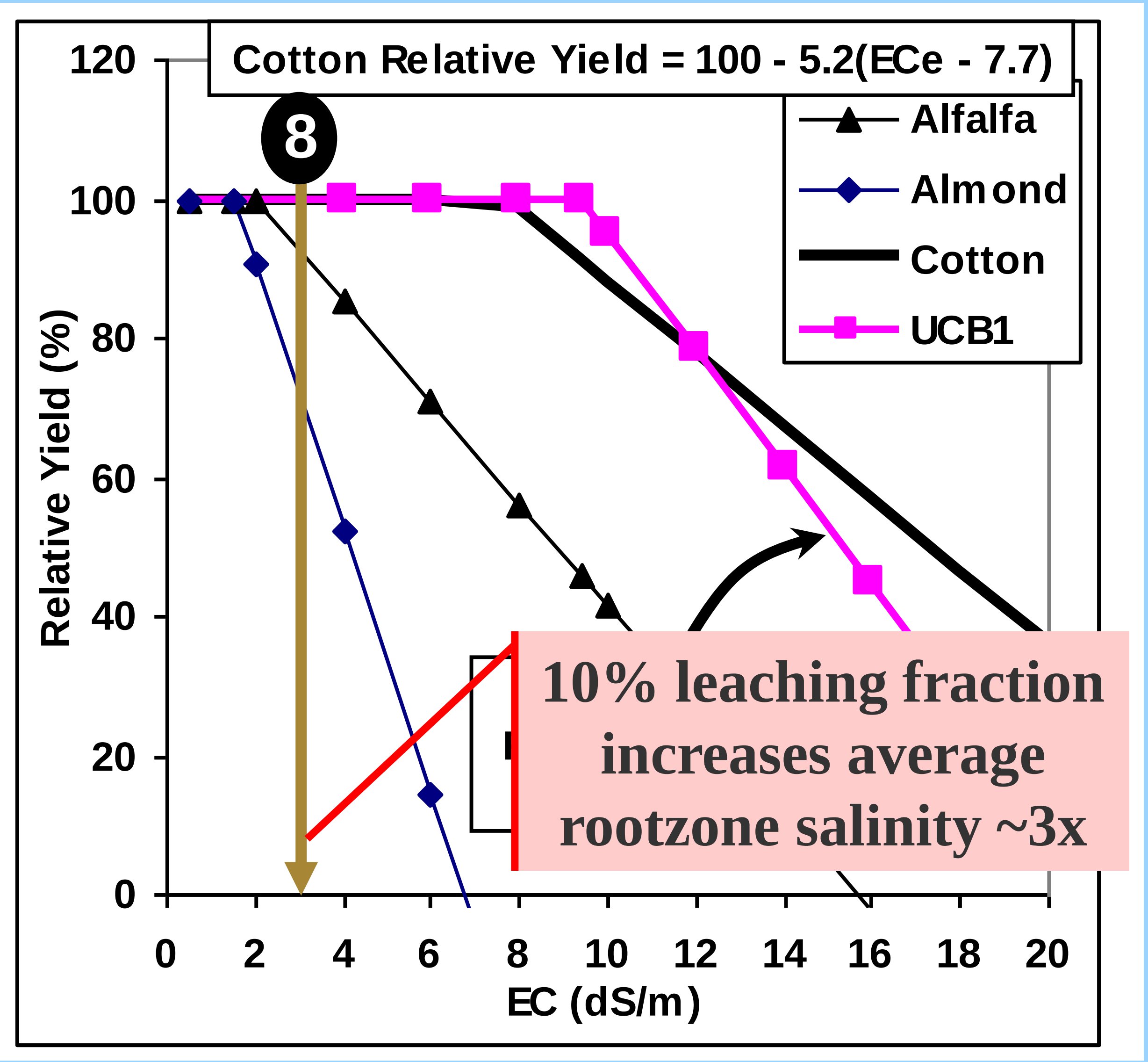
SO_4 0.1meq/l

B 0.7mg/l

NO_3 5.2mg/l

SAR 17.5

SAR_{adj} 16.6



FIX: Pistachio: – normal irrigation.

Almond: increase leaching fraction to 15%.

Almond Relative Yield =

$$100 - \text{slope}(EC_{thresh} - EC_e)$$

<u>Rule of Thumb:</u>

Long-term $EC_{rootzone}$ ~ 3 to 4*$EC_{irr\ water}$ @ 10% LF
Long-term $EC_{rootzone}$ ~ 2 to 3*$EC_{irr\ water}$ @ 15% LF

10%LF = 100-19(3-1.5) = 71.5%
15%LF = 100-19(2-1.5) = 90.5%

Table 3. NW Kern: Milham fine sandy loam, flood (soil sampled 11/6/05)

Site/Depth	SP	pH	EC (dS/m)	Ca (meq/l)	Mg (meq/l)	Na (meq/l)	K (meq/l)	ESP/ SAR	Cl (meq/l)	B (ppm)	HCO3 (meq/l)	SO4 (meq/l)	*Sum Cations*	*Sum Anions*
Field B-N/S, Zone1 (Well 1 high salt + Aqueduct/Semitropic Canal)														
0-20"	42	7.9	2.07	10.1	2.0	8.4	0.2	3.6	9.0	0.2	5	5.4	*20.7*	*19.4*
20-40"	41	7.9	4.26	20.7	4.3	19.1	0.2	6.3	19.0	0.3	13	10.7	*44.3*	*42.7*
40-60"	39	7.7	0.86	3.6	0.9	4.2	0.1	2.8	3.8	0.2	3	1.3	*8.8*	*8.1*
Well 1		7.4	**1.50**	2.0	0.0	12.0		11.9	10.1	0.4	1.1	2.4	*14.0*	*13.5*
Field S-1, Zone1 (Well 4 low salt + Aqueduct/Semitropic Canal)														
0-20"	40	7.8	0.63	3.0	0.7	2.9	0.1	1.8	1.3	0.2	5	0.2	*6.7*	*6.5*
20-40"	42	8.1	0.43	0.8	0.3	3.0	0.1	4.5	1.0	0.2	3	0.2	*4.2*	*4.2*
40-60"	36	8.0	0.64	1.0	0.5	4.1	0.1	5.6	2.1	0.3	4	0.2	*5.7*	*6.3*
Well 4		9.0	**0.61**	0.4	0.0	4.7		10.5	2.5	0.1	0.9	1.7	*5.2*	*5.1*

Relative yield (%) for a 5 foot rootzone (Well 1):

= 100 – 19*((2.07+4.26+0.86)/3 – 1.5) = 82.9%

Relative yield (%) for a 40 inch rootzone:

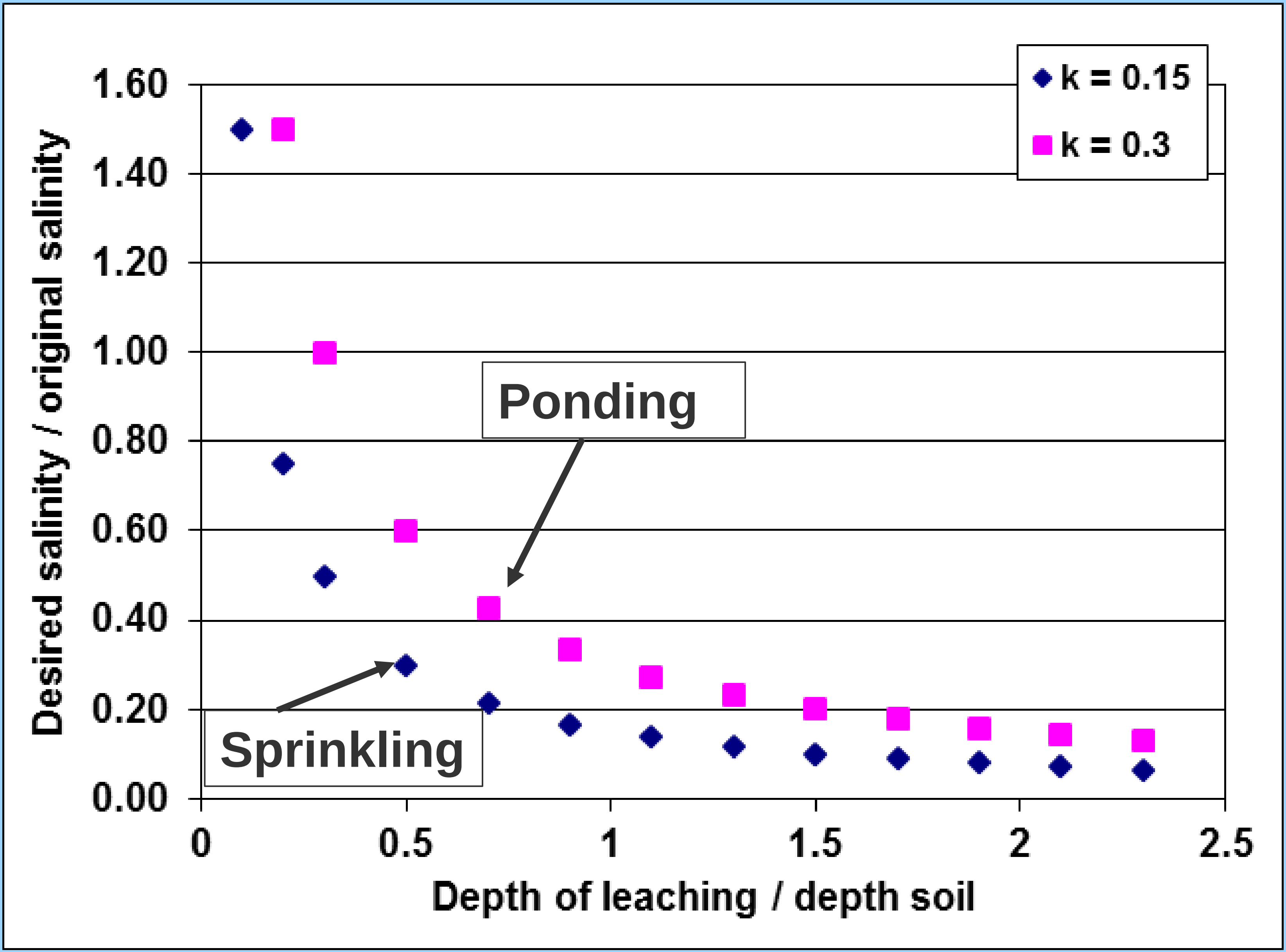
= 100 – 19*((2.07+4.26)/2 – 1.5) = 68.4%

Table 4. SW Kern: Bakersfield sandy loam, flood

Depth	SP	pH	EC	Ca (meq/l)	Mg (meq/l)	Na (meq/l)	K (meq/l)	SAR	Cl (meq/l)	B (ppm)	HCO3 (meq/l)	SO4 (meq/l)	Sum Cations	Sum Anions
0-1'	43	7.0	3.9	27.8	3.0	7.4	0.3	1.9	0.8	0.6	1.3	33.3	38.5	37.5
1-2'	45	7.5	4.2	24.3	4.0	13.9	0.2	3.7	2.4	0.5	1.1	32.1	42.4	35.6
2-3'	43	7.6	3.9	18.1	3.3	17.0	0.2	5.2	4.3	0.5	1.6	18.1	38.6	24.0
3-4'	43	7.5	4.2	23.6	4.4	14.1	0.1	3.8	5.7	0.4	1.2	30.0	42.2	36.9
Well		7.9	0.59	2.6	0.2	3.1	0.0	2.6	0.8	0.2	3.7	1.2	5.8	5.7

Relative yield (%) = 100 – 19*((3.9+4.2+3.9+4.2)/4 – 1.5) = 51.5%

Mass Balance Leaching for Ponding vs Sprinkling or Intermittent Ponding



<u>Reclamation:</u> Using an average rootzone EC of 4.05 dS/m over 4 feet, the depth of leaching required to reclaim this rootzone to an EC of 1.5 can be calculated with the following equation (Hoffman, 1996):

Required Leaching Ratio (depth water/depth soil) = K / (Desired EC/Original EC)	
	(Use K factor of 0.1 to 0.15 for sprinkling, drip or repeated flooding. Use 0.3 for continuous ponding.)

Required Leaching Ratio (depth water/depth soil) = 0.15/(**1.5/4.05**) = 0.405

Actual depth of leaching water = 0.405 * 4 feet = **1.62 feet = 19.4 inches** http://cekern.ucanr.edu/Irrigation_Management/ANALYTICAL_CONVERSIONS_AND_LEACHING_CALCULATIONS/

CALCULATING LEACHING DEPTH TO ACHIEVE DESIRED SALINITY FOR SOIL RECLAMATION

(Using fresh water with EC <= 1 mmho/cm)

Google: cekern leaching

CALCULATING SAR, ESP AND DESIRED LEACHING DEPTH

EXAMPLE	Sample	Data Required from Soil Extract Analysis											Sprinkling / Drip to Leach Rootzone	
	Thickness	(%)		(dS/m)	(meq/l)						Desired	Dsrd/Orig	(ft water /	(inch water
Depth	(inches)	SP	pH	EC	Ca	Mg	Na	SAR	ESP	EC/ESP	Salinity	EC	ft soil)	for sample)
0-1'	12	40	7.9	5.5	34.2	4.6	21.7	4.9	5.7	1.0	3	0.55	**0.28**	**3.30**
1-2'	12	45	8.0	6.7	29.9	4.3	39.6	9.6	11.4	1.7	3	0.45	**0.34**	**4.02**
2-3'	12	45	8.0	7.3	25.1	4	51.8	13.6	15.8	2.2	3	0.41	**0.37**	**4.38**
													TOTAL DEPTH OF LEACHING REQUIRED (inches):	**11.70**

ENTER YOUR DATA BELOW

YOUR SOIL	Sample	Data Required from Soil Extract Analysis											Sprinkling / Drip to Leach Rootzone	
	Thickness	(%)		(dS/m)	(meq/l)						Desired	Dsrd/Orig	(ft water /	(inch water
Depth	(inches)	SP	pH	EC	Ca	Mg	Na	SAR	ESP	EC/ESP	Salinity	EC	ft soil)	for sample)
								#####	#DIV/0!	#DIV/0!		#DIV/0!	**#DIV/0!**	**#DIV/0!**
								#####	#DIV/0!	#DIV/0!		#DIV/0!	**#DIV/0!**	**#DIV/0!**
								#####	#DIV/0!	#DIV/0!		#DIV/0!	**#DIV/0!**	**#DIV/0!**
													TOTAL DEPTH OF LEACHING REQUIRED (inches):	**#DIV/0!**

Always want EC/ESP < 5 to avoid serious infiltration problems.

Calculating required leaching = 19.4 inches

ENTER YOUR DATA BELOW

YOUR SOIL Depth	Sample Thickness (inches)	Data Required from Soil Extract Analysis: SP (%)	pH	EC (dS/m)	Ca (meq/l)	Mg (meq/l)	Na (meq/l)	SAR
0-1'	12	43	7.0	3.9	27.8	3.0	7.4	1.9
1-2'	12	45	7.2	4.2	24.3	4.0	13.9	3.7
2-3'	12	43	7.6	3.9	18.1	3.3	17	5.2
3-4'	12	43	7.5	4.2	23.6	4.4	14.1	3.8

SAR	ESP	EC/ESP	Desired Salinity	Dsrd/Orig EC	Sprinkling / Drip to Leach Rootzone (ft water / ft soil)	Sprinkling / Drip to Leach Rootzone (inch water for sample)
1.9	1.5	0.4	1.5	0.38	**0.39**	**4.68**
3.7	4.0	1.0	1.5	0.36	**0.42**	**5.04**
5.2	6.0	1.5	1.5	0.38	**0.39**	**4.68**
3.8	4.1	1.0	1.5	0.36	**0.42**	**5.04**
TOTAL DEPTH OF LEACHING REQUIRED (inches):						**19.44**

B-N/S, Well 1 EC @ 1.50, LF = 0.33 **33% over ET**

S-1, Well 4 EC @ 0.61, LF = 0.07 **7% over ET**

SW Kern, Well EC @ 0.59, LF = 0.07 **7% over ET**

Table 5. Average rootzone saturation extract EC (dS/m) after long-term irrigation with a given salinity of water (ignoring precipitation/dissolution reactions in the soil) and Leaching Fraction.

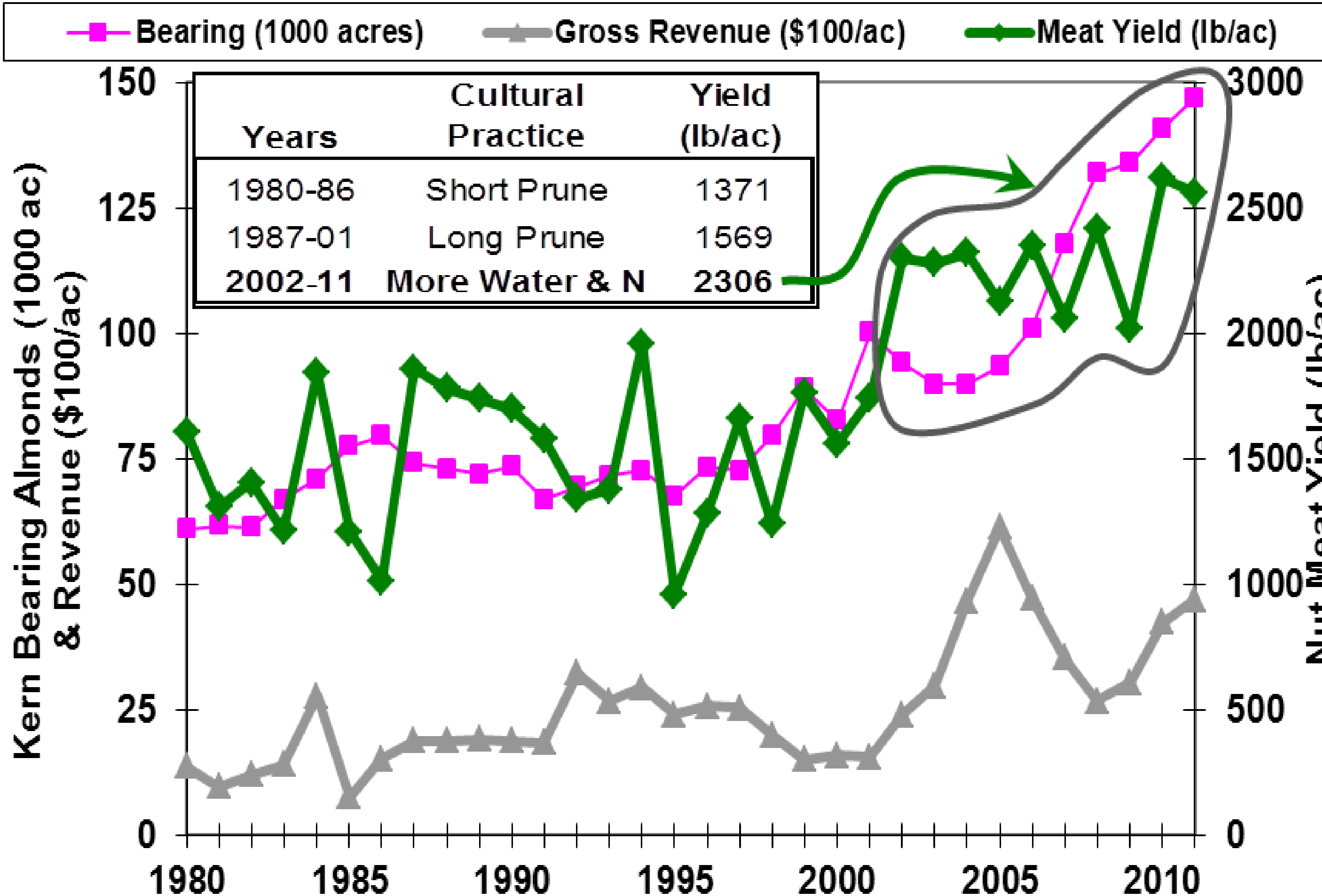
Irrigation Water EC (dS/m)	Leaching Fraction (LF) above crop ET requireme				
	0.05	**0.1**	**0.15**	**0.2**	**0.3**
0.2	0.63	0.41			
0.6	1.89	1.24	0.97		
1	3.15	2.06	1.61	1.35	
1.4	4.42	2.89	2.26	1.89	1.48
1.8	5.68	3.72	2.90	2.43	1.90
2.2	6.94	4.54	3.55	2.97	2.32
2.6	8.20	5.37	4.19	3.52	2.74
3	9.46	6.19	4.84	4.06	3.17
3.4	10.72	7.02	5.48	4.60	3.59
3.8	11.98	7.85	6.12	5.14	4.01
4.2	13.25	8.67	6.77	5.68	4.43

SOLVING FOR DESIRED LEACHING FRACTION DIRECTLY:

$$LF = 0.326\,(\text{Desired } EC_e/EC_{irr})^{-1.64}$$

What about salinity buildup under super efficient irrigation?

Trends in Kern County Almonds



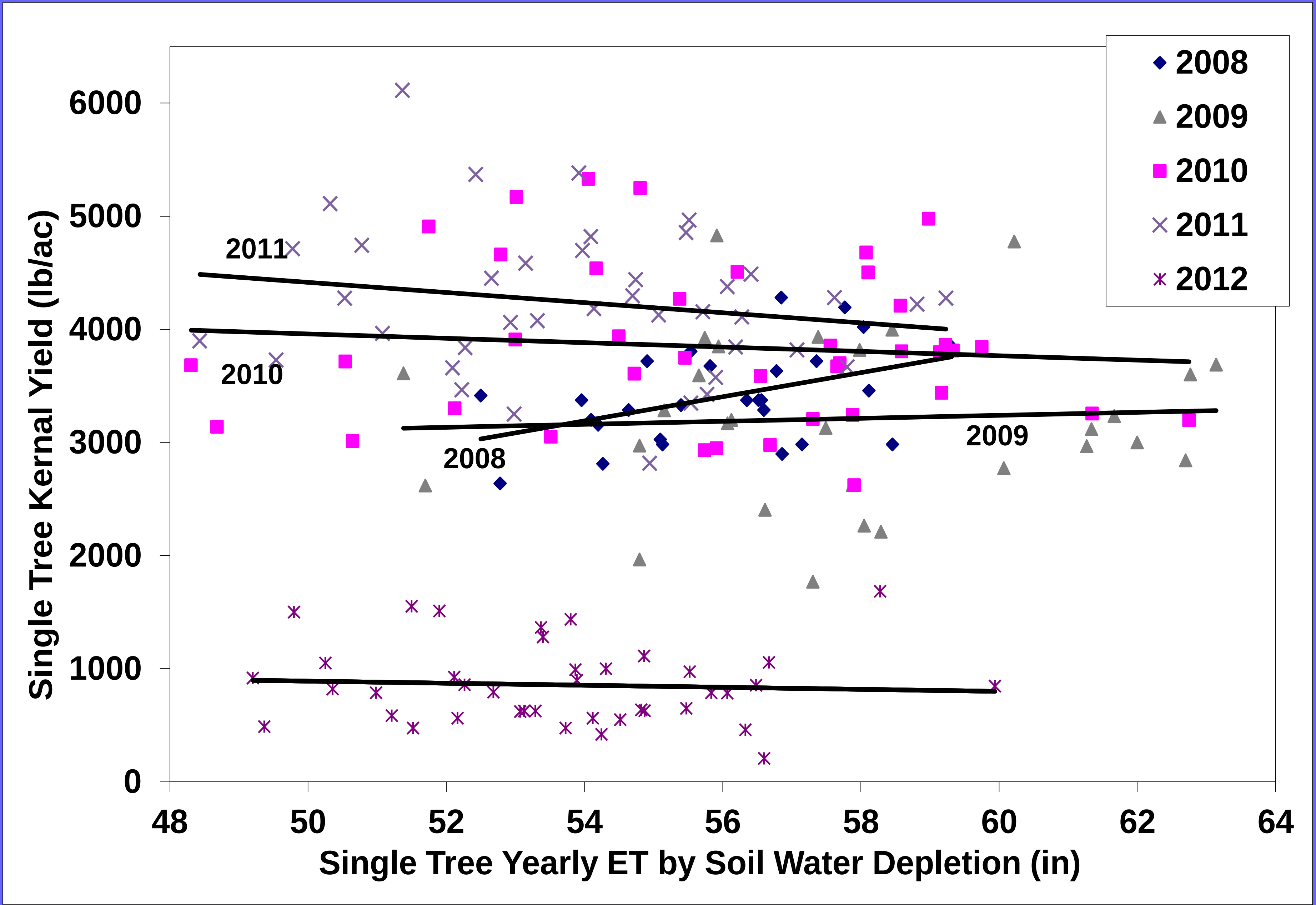
Where did we end up on the Brown fertility trial in NW Kern County using CA Aqueduct water?

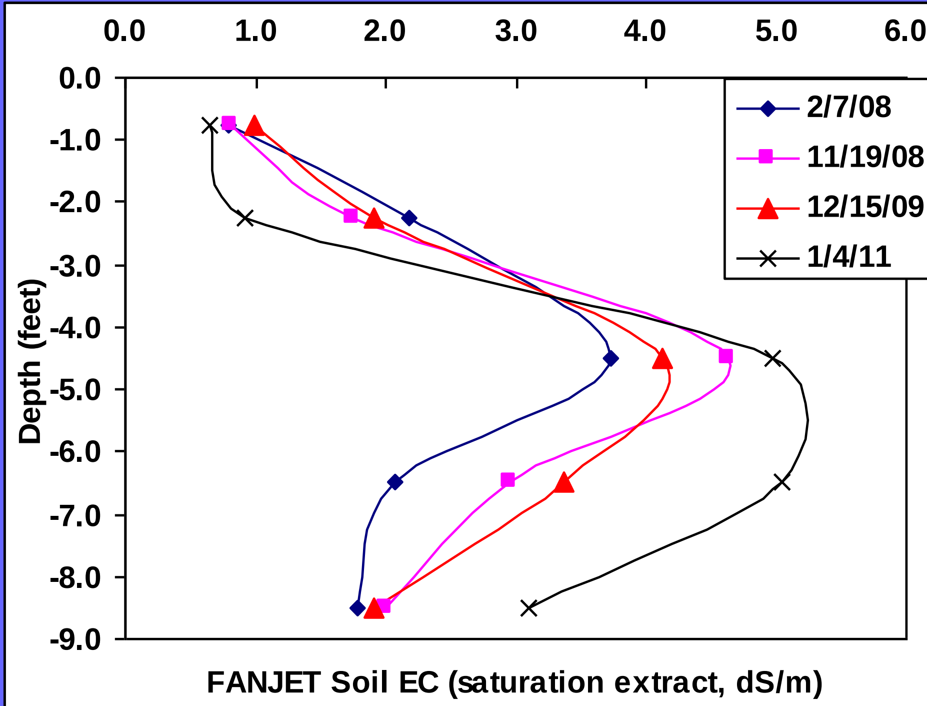
Patrick Brown fertility trial 2008-2012

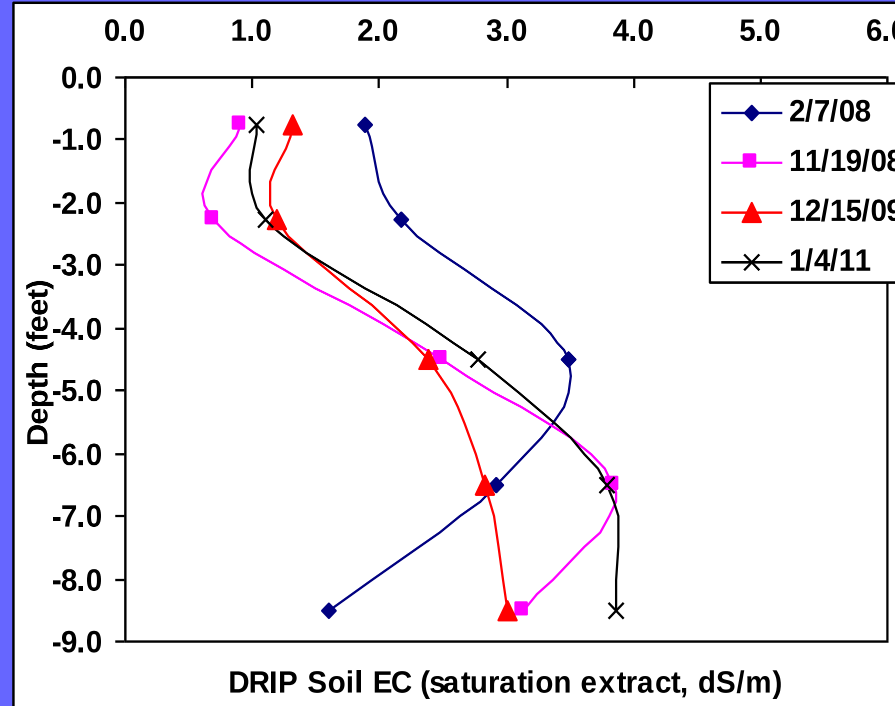
12 treatments total

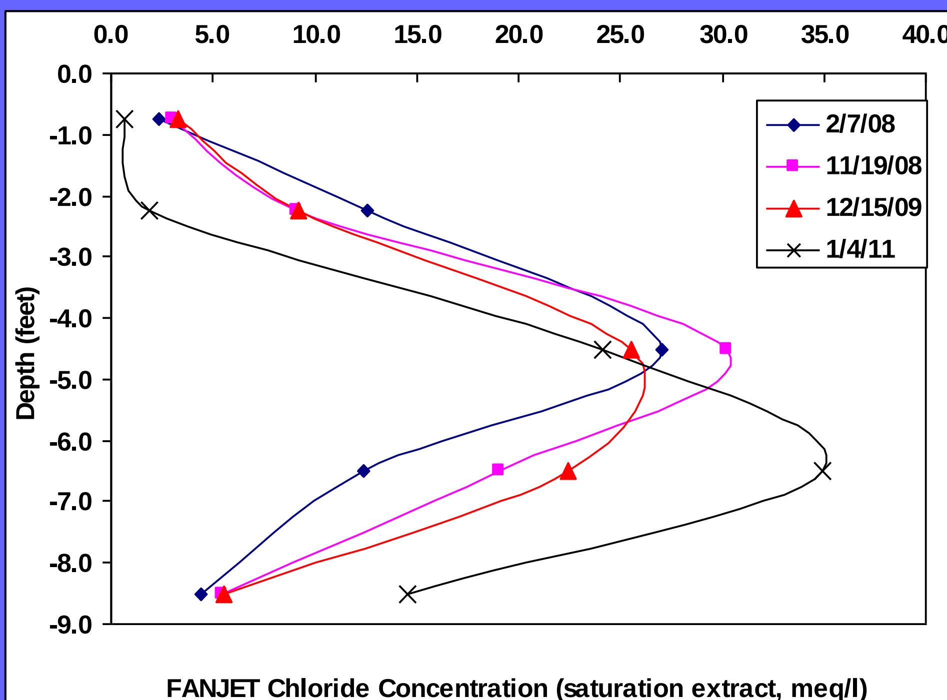
- **4 N levels, 2 sources**
  125, 200, 275, 350 lb/ac
- **3 K levels, 3 sources**
  100, 200, 300 lb/ac

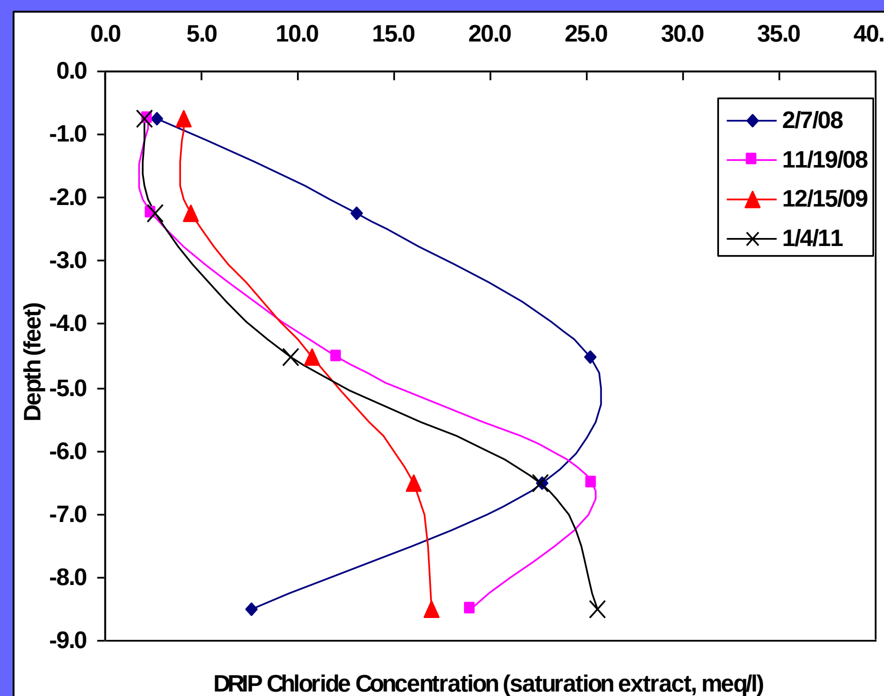
Do you get 6,000 lb/ac with 60” ET?

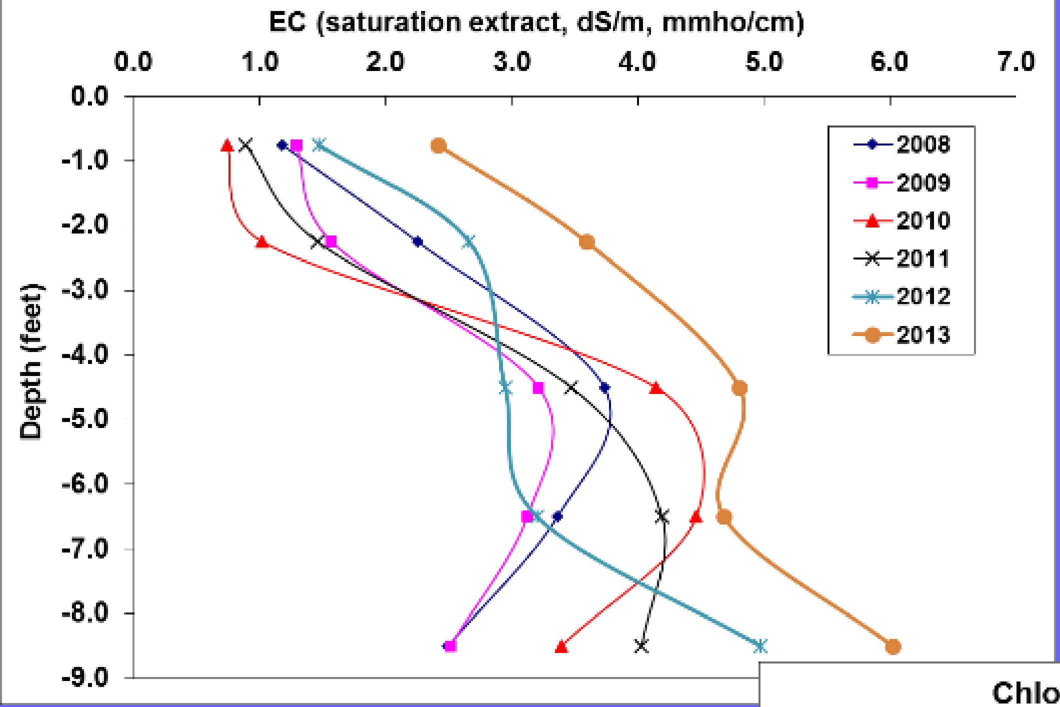


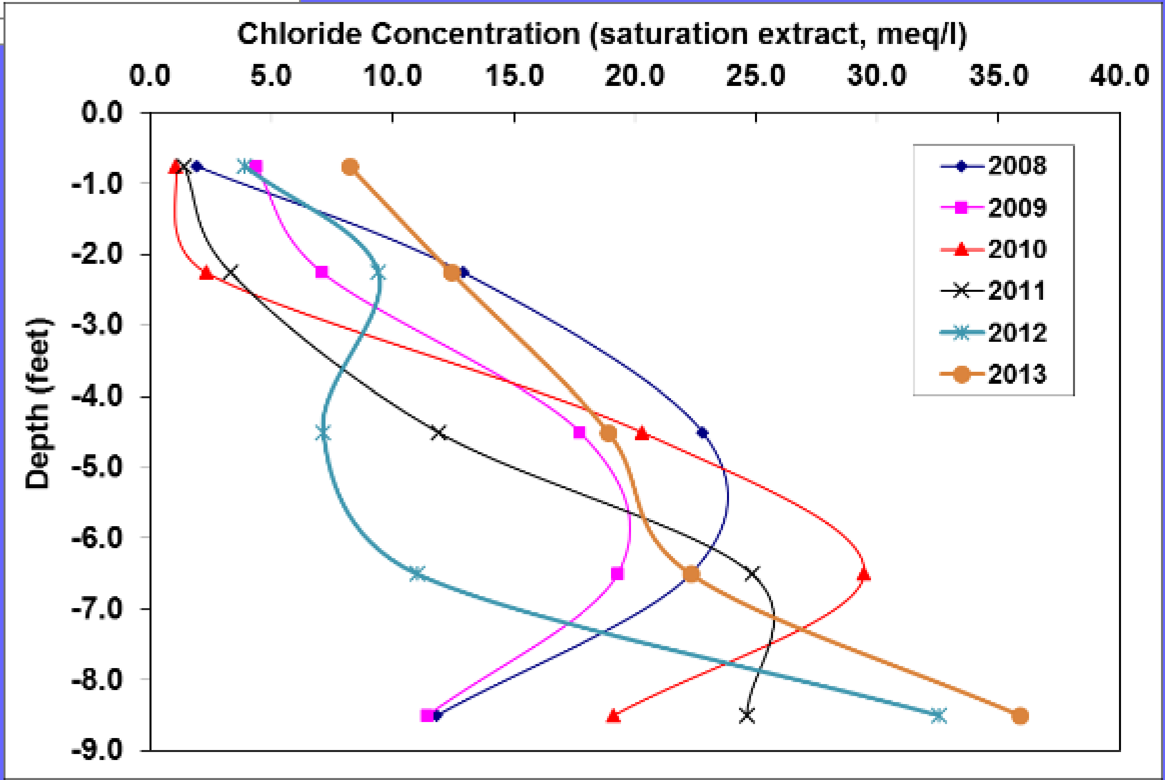

0.0 1.0 2.0 3.0 4.0 5.0 6.0
0.0 -1.0 -2.0 -3.0 -4.0 -5.0 -6.0 -7.0 -8.0 -9.0
Depth (feet)
2/7/08
11/19/08
12/15/09
1/4/11
FANJET Soil EC (saturation extract, dS/m)


0.0 1.0 2.0 3.0 4.0 5.0 6.0
0.0 -1.0 -2.0 -3.0 -4.0 -5.0 -6.0 -7.0 -8.0 -9.0
Depth (feet)
2/7/08
11/19/08
12/15/09
1/4/11
DRIP Soil EC (saturation extract, dS/m)


0.0 5.0 10.0 15.0 20.0 25.0 30.0 35.0 40.0
0.0 -1.0 -2.0 -3.0 -4.0 -5.0 -6.0 -7.0 -8.0 -9.0
Depth (feet)
2/7/08
11/19/08
12/15/09
1/4/11
FANJET Chloride Concentration (saturation extract, meq/l)


0.0 5.0 10.0 15.0 20.0 25.0 30.0 35.0 40.0
0.0 -1.0 -2.0 -3.0 -4.0 -5.0 -6.0 -7.0 -8.0 -9.0
Depth (feet)
2/7/08
11/19/08
12/15/09
1/4/11
DRIP Chloride Concentration (saturation extract, meq/l)


EC (saturation extract, dS/m, mmho/cm)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
-6.0
-7.0
-8.0
-9.0
Depth (feet)
2008
2009
2010
2011
2012
2013


Chloride Concentration (saturation extract, meq/l)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
-6.0
-7.0
-8.0
-9.0
Depth (feet)
2008
2009
2010
2011
2012
2013

In its simplest form, the leaching fraction (LF) or water percolating below the rootzone can be reduced to a simple mass balance of salt in, salt out:

$$\frac{D_{dw}}{D_{iw}} = \frac{EC_{iw}}{EC_{dw}}$$

Where:

$\mathbf{D_{dw}}$ = depth of drain water below rootzone

$\mathbf{D_{iw}}$ = depth of irrigation water

$\mathbf{EC_{iw}}$ = electroconductivity (or chloride concentration) of irrigation water

$\mathbf{EC_{dw}}$ = electroconductivity (or chloride concentration) of drain water

Problem: **Salts concentrate in the lower rootzone and eventually have to be leached. A Cl mass balance can also be used to estimate WUE.**

MICROSPRINKLER -- Cl (soil saturation extract, meq/l)

Sample Depth (ft)	2008	2009	2010	2011	2012	2013
-0.75	1.9	4.3	1.02	1.4	3.9	8.2
-2.25	12.9	7.1	2.29	3.3	9.4	12.4
-4.50	22.8	17.7	20.29	11.9	7.1	18.9
-6.50	22.3	19.3	29.46	24.8	11.0	22.3
-8.50	11.8	11.4	19.13	24.6	32.6	35.9
Avg 0-6.5 feet	**15.0**	**12.1**	**13.3**	**10.3**	**12.8**	**19.5**

LEACHING FRACTION ESTIMATE

2008	2009	2010	2011	2012	2013
0.54	0.34	0.68	0.61	0.36	0.21
0.15	0.24	0.49	0.40	0.19	0.15
0.09	**0.11**	**0.10**	0.16	0.24	0.10
0.09	0.10	0.07	**0.08**	0.17	0.09
0.16	0.16	0.10	0.08	**0.06**	**0.06**

(Average Cl_{irrig} concentration = 2.2 meq/l)

WATER USE EFFICIENCY

2008	2009	2010	2011	2012	2013
0.65	0.75	0.59	0.62	0.73	0.83
0.87	0.81	0.67	0.71	0.84	0.87
0.92	**0.90**	**0.91**	0.86	0.81	0.91
0.92	0.91	0.94	**0.92**	0.86	0.92
0.86	0.86	0.91	0.92	**0.94**	**0.95**

$$FieldWUE = 1 - LF$$

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)

Trends in individual tree salinity and almond kernel yield

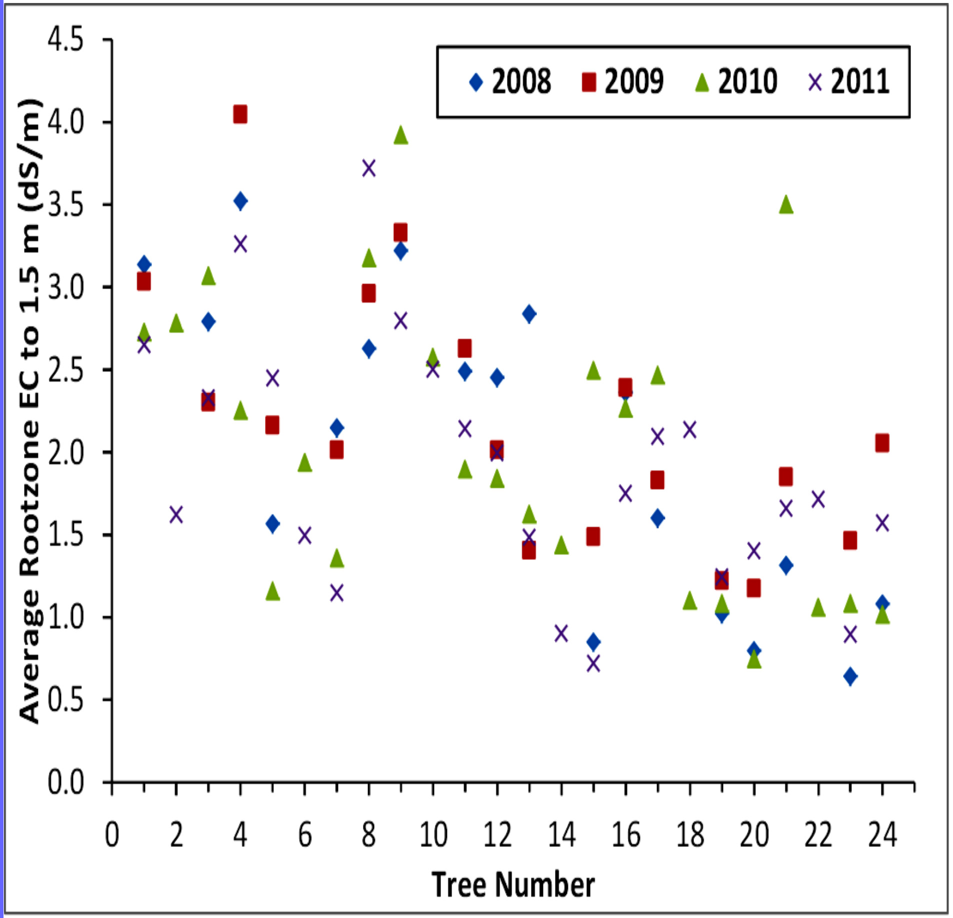


Fig. 2.a. All years average rootzone ECe to 1.5 m by tree number approximately west to east.

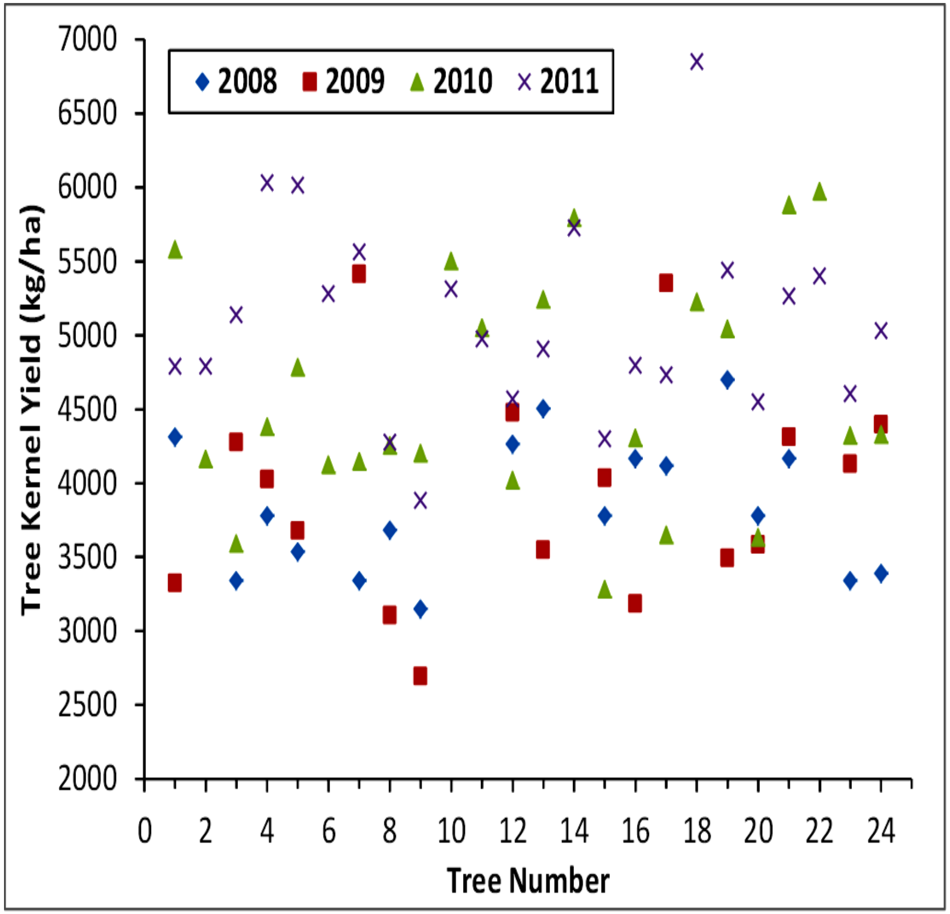


Fig. 2.b. All years tree kernel yield by tree number approximately west to east.

Comparison of “relative yield” as a function of salinity for a 3 foot and 5 foot rootzone

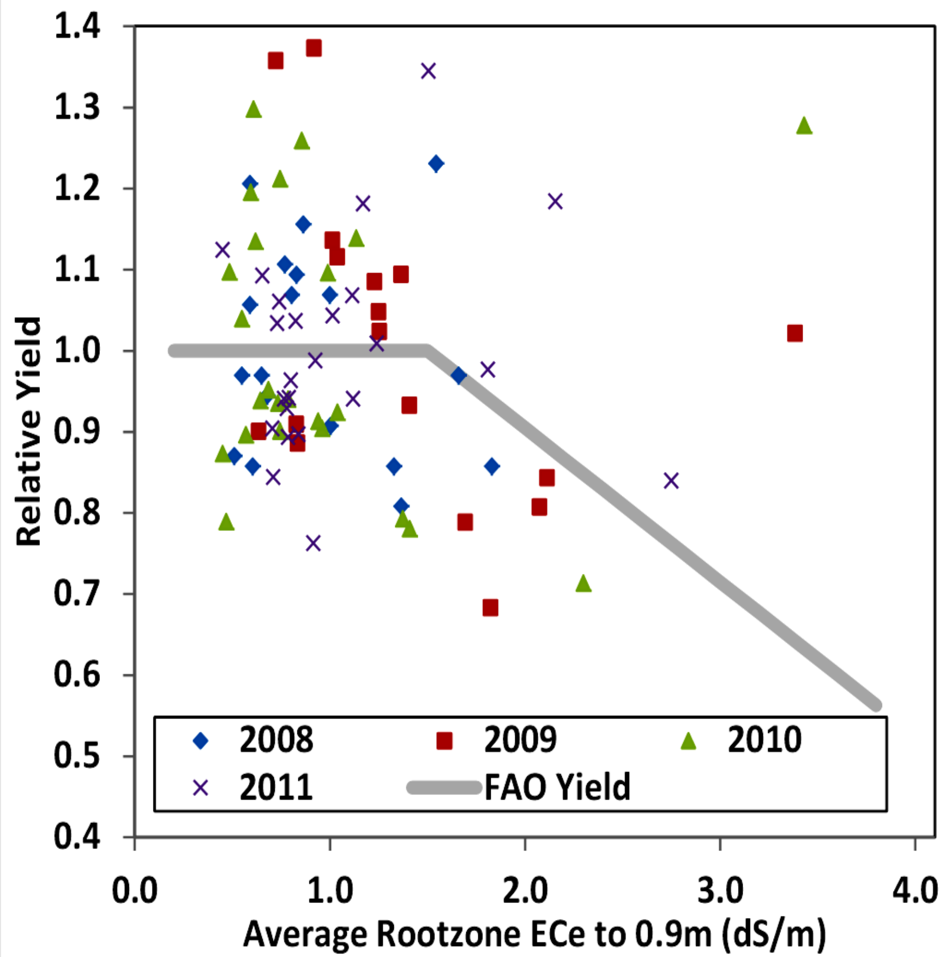


Fig. 3.a. Relative kernel yield as a function of average rootzone salinity (0-0.9 m) for all years and the “classic” almond salt tolerance curve (Ayers and Westcott, 1985).

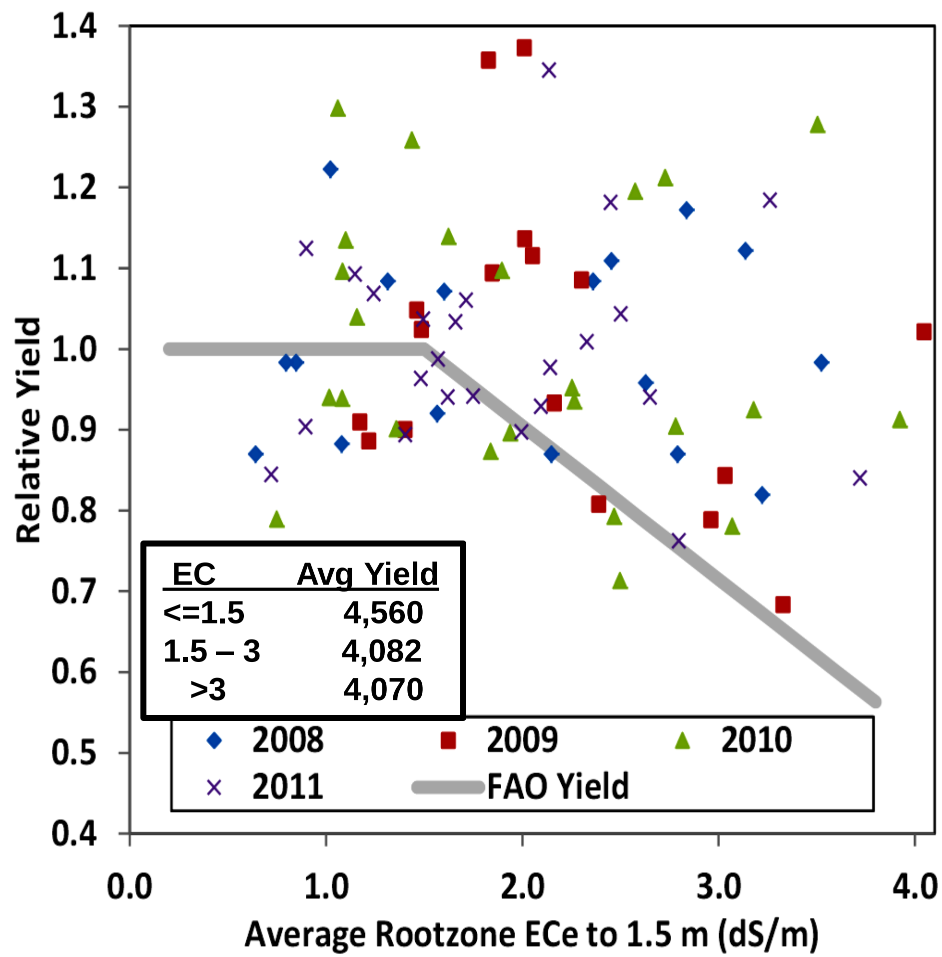


Fig. 3.b. Relative kernel yield as a function of average rootzone salinity to 1.5 m for all years and the “classic” almond salt tolerance curve (Ayers and Westcott, 1985).

UNIVERSITY of CALIFORNIA COOPERATIVE EXTENSION

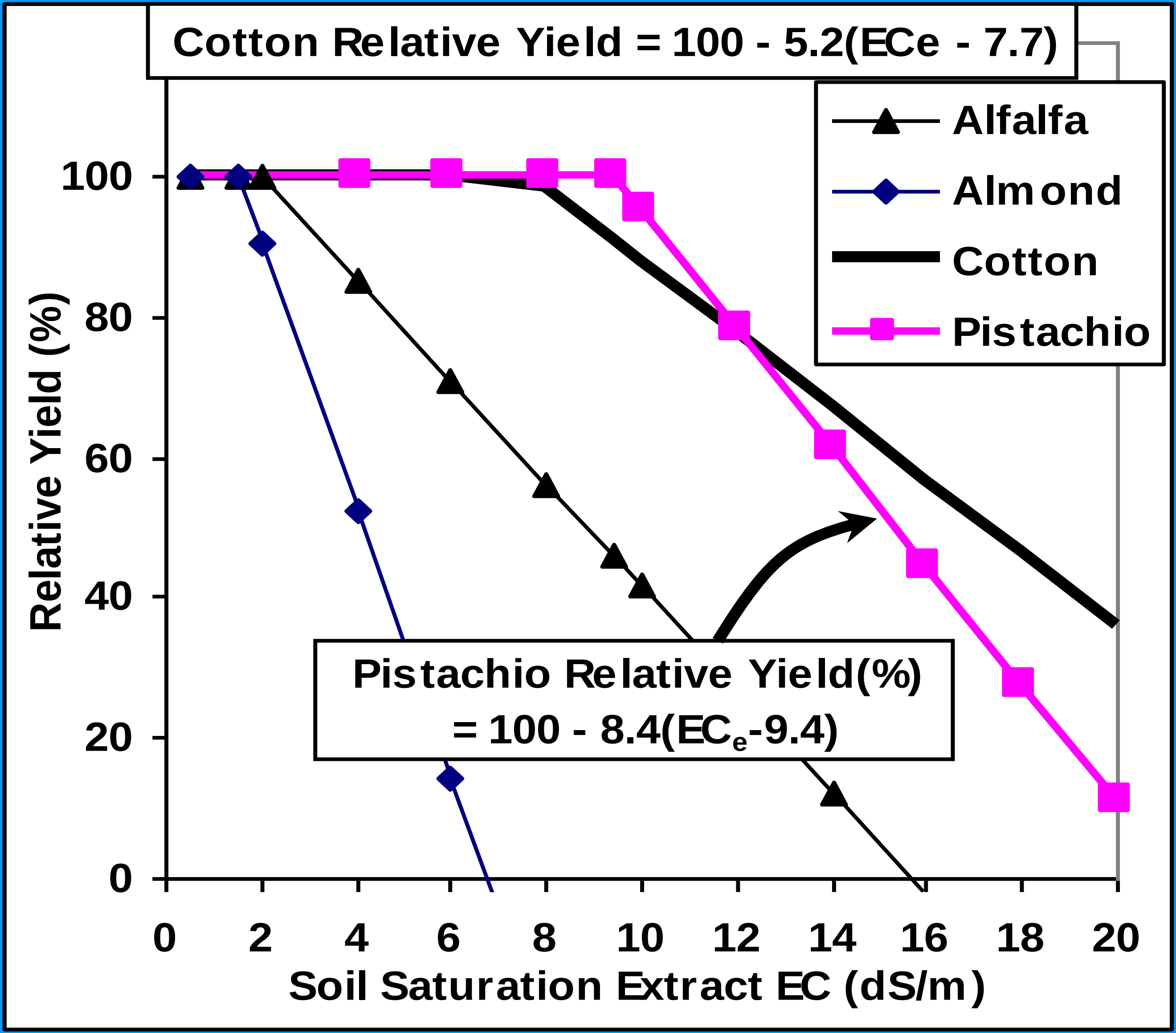
Cal ASA Annual Conference: Building Resiliency in California Agriculture Fresno, CA February 4-5, 2014

Salinity Tolerance of Pistachio: Long-term Management Issues and Research Gaps

Blake Sanden - Irrigation/Agronomy, Kern
Craig Kallsen – Subtropicals/Pistachios, Kern
Louise Ferguson – Pomology Specialist UCD

Relative yield of as a function of soil ECe

Current salinity thresholds for pistachios



Sanden, B.L., L. Ferguson, H.C. Reyes, and S.C. Grattan. 2004. Effect of salinity on evapotranspiration and yield of San Joaquin Valley pistachios. Proceedings of the IVth International Symposium on Irrigation of Horticultural Crops, Acta Horticulturae 664:583-589.


This isn't morning frost!

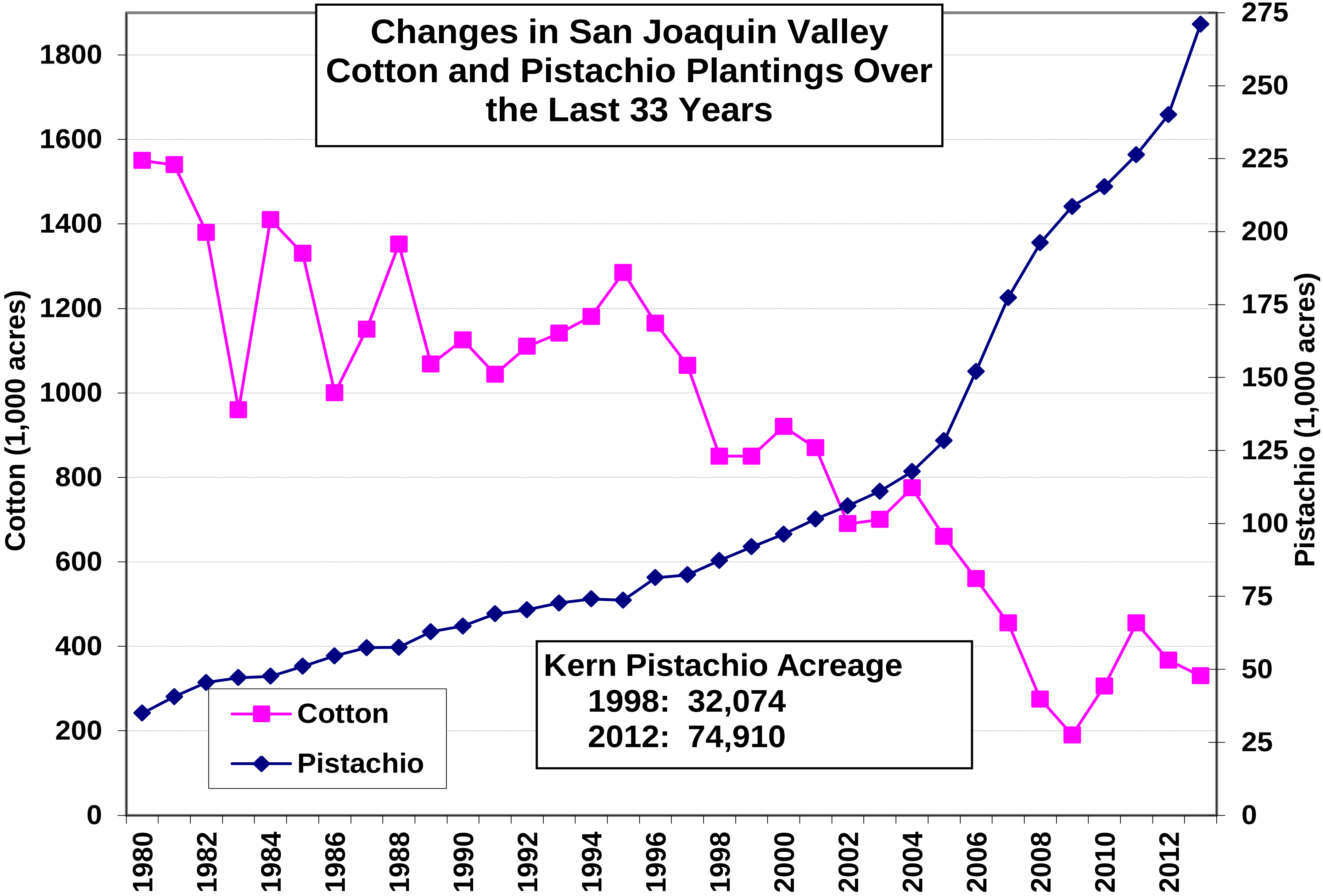

This doesn't look too salty…
or is it?


Just a little “black alkali”…

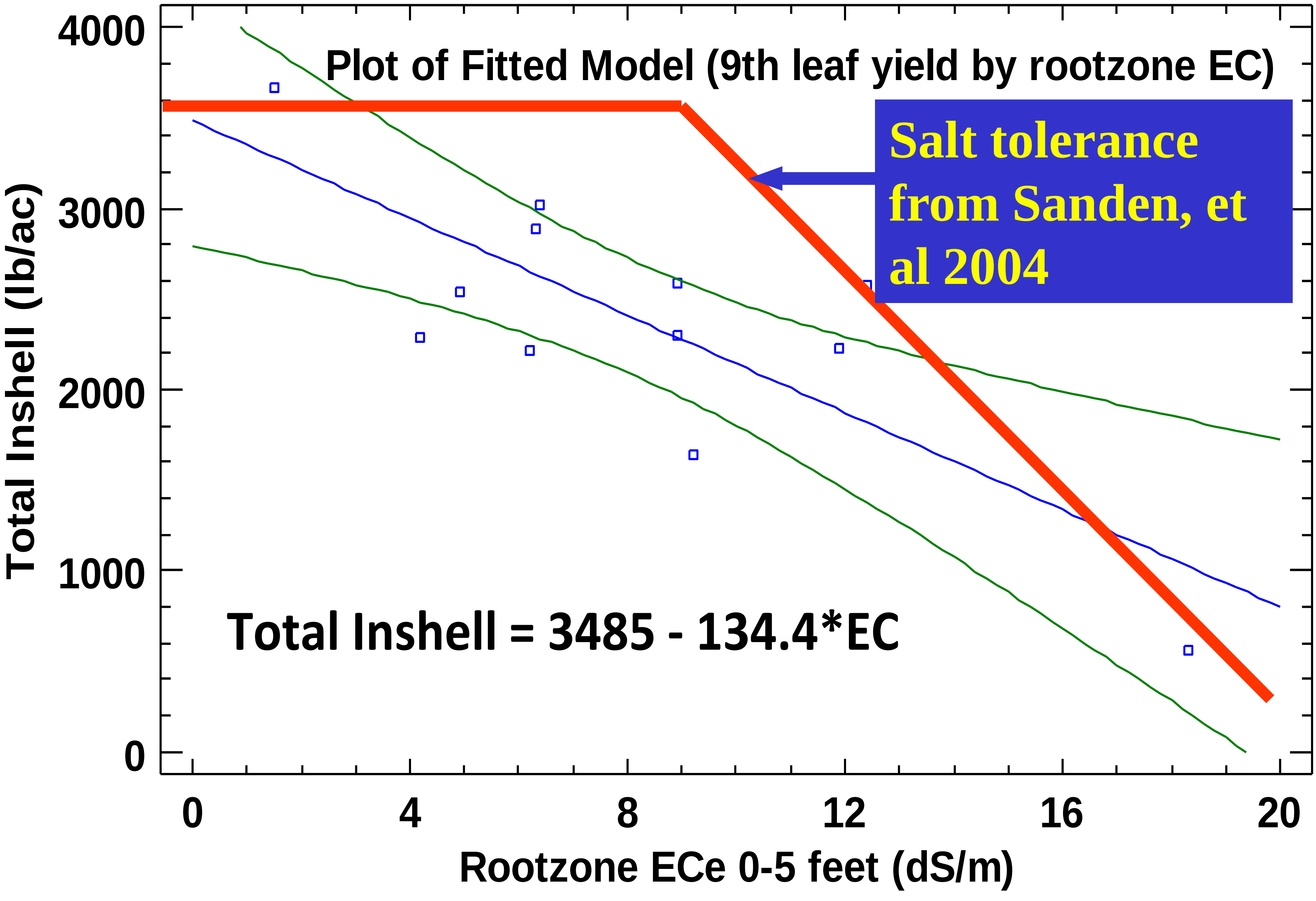
Really?

Some spots are just too hot!

Pistachio acreage has more than doubled in last 10 years



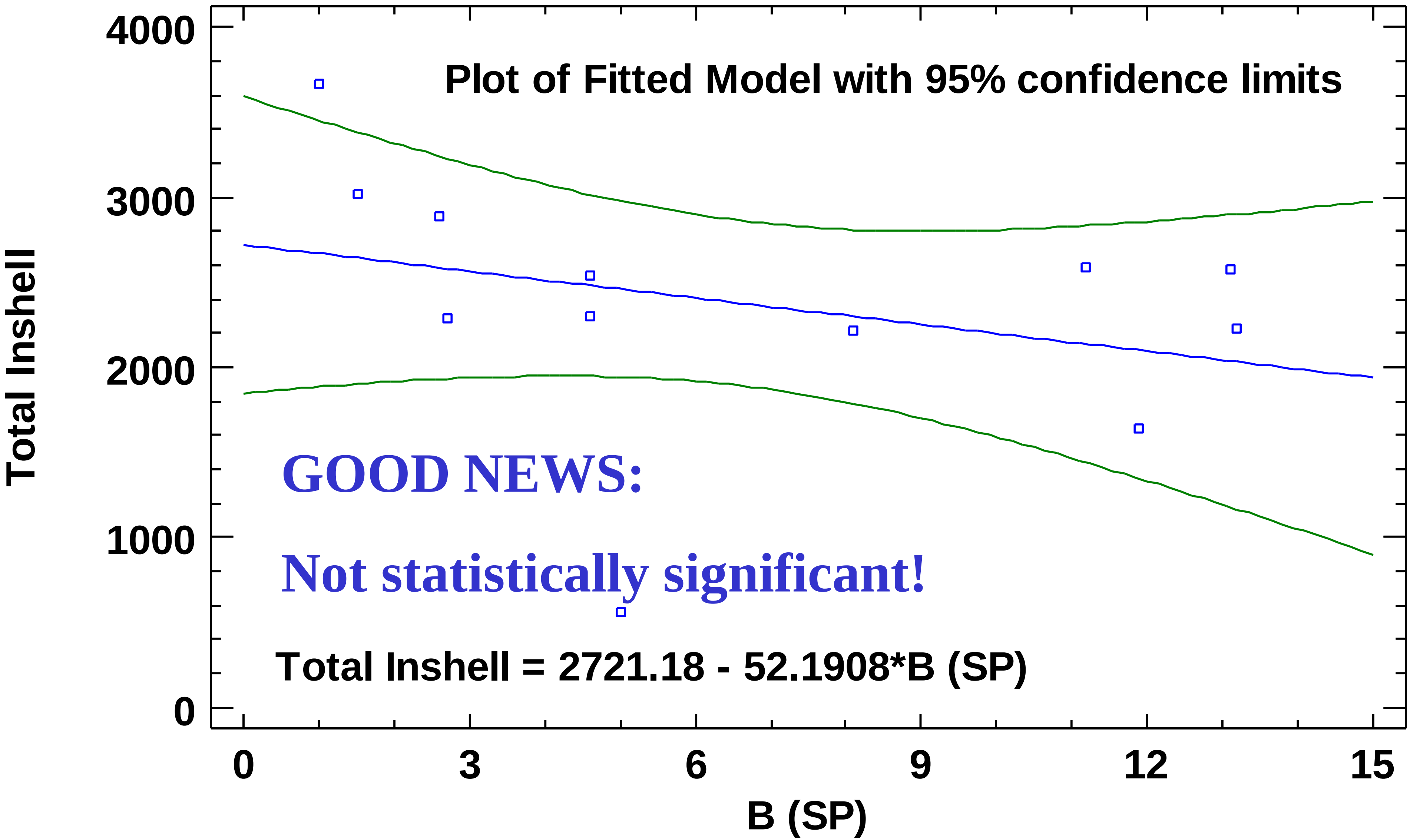
2013 PistachioYield Decline by Rootzone Salinity



Marginal burn was seen on most leaves

9-1 West Compare

2013 Yield Decline by Rootzone Soluble Boron Concentration



Conclusions

SOME ECONOMIC SENSE …

- Pumped saline water cost ~$65/ac-ft. Expensive canal water ~$1000/ac-ft in a drought.
- At 42 inches (3.5 ac-ft) to irrigate SJV pistachios the difference in water cost = $3,272 /ac
- @ $2.50/lb = 1,309 lb/ac pistachios

Conclusions

- Without effective winter rainfall/fresh-water irrigation > 6 inches every couple years, excessive salt buildup will reduce young pistachio growth and eventually yield.
- High Na/Ca ratios can make this problem worse and even lead to frost susceptibility (not a problem for this trial)
- Presently adsorbed boron could have a time bomb affect
- Use of saline well water could save $4,000 - 20,000/ac (depending on the cost of fresh water) over 20 years if appropriate leaching can be maintained