UNIVERSITY of CALIFORNIA COOPERATIVE EXTENSION

Pistachio Short Course

Visalia, CA

Nov. 14-16, 2017

Site Selection: Soil Evaluation and Modification, Water Quality, Salinity Management and Reclamation

Blake Sanden
Irrigation/Soils, Kern

Mae Culumbar
Pomology, Fresno

Acknowledgements & thanks:

- **Louise Ferguson: support/encouragement & 'wild-hair' ideas**
- **Wonderful Orchards (former Paramount): original salinity trial 1994-2002. Continuuing quality tests**
- **Starrh & Starrh Farms: long-term salinity impacts planting to maturity. 2004-2014**
- **Houchin Farming: deep tillage trial 2005-2015**
- **Beau Antongiovanni**
- **Bone, Cauzza, Houchin, Maricopa, Starrh, Tracy, Warren Farms: expanded salinity survey 2014-16**

(Apologies to those who have heard most of this talk before, but there are some new goodies this time.)

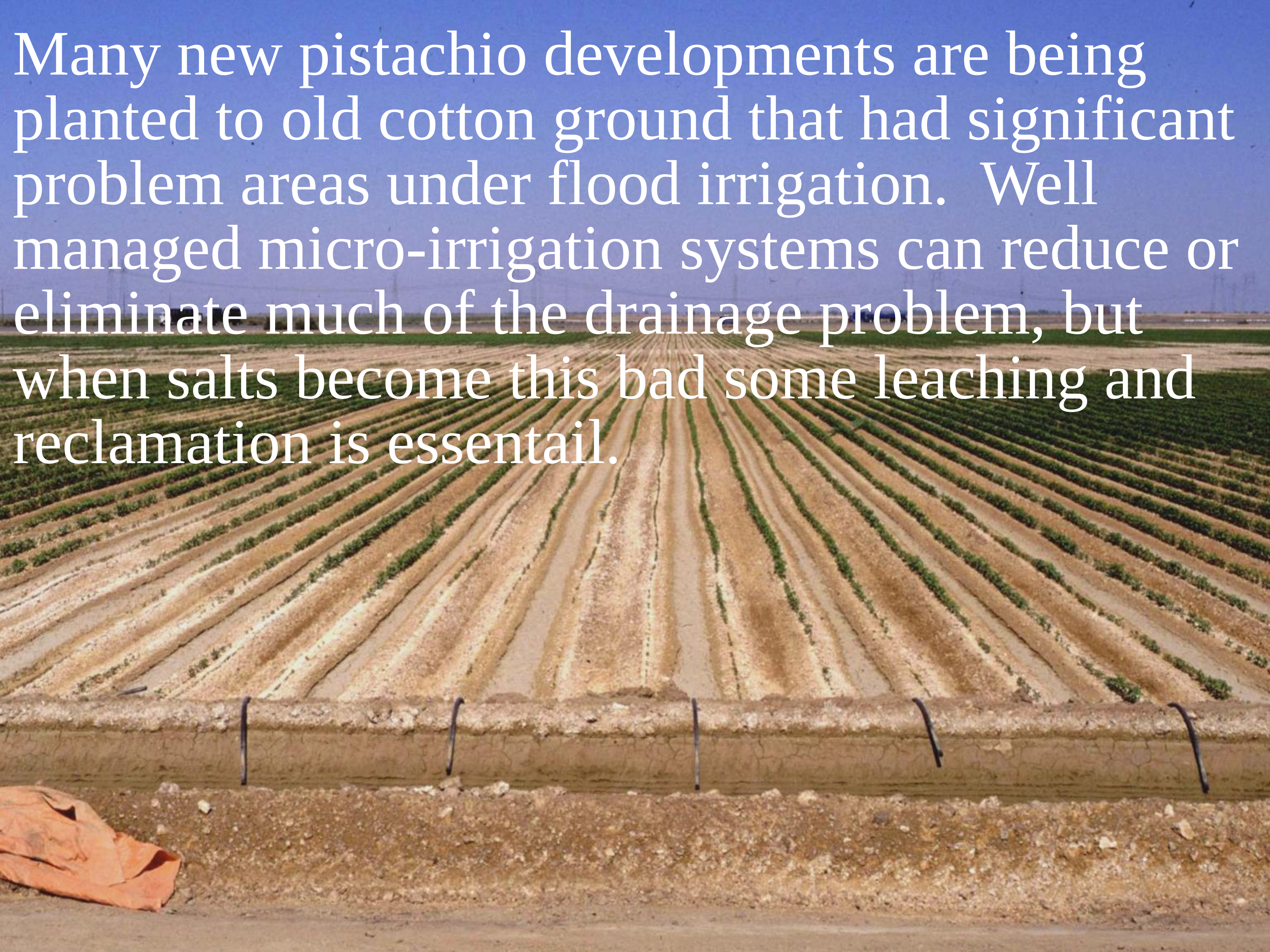
“Edjyikashun is the process of repitishun.”

Hodge Black – Arkansa born ag extension entomologist and Kern County UC Cooperative Extension director, 1960-1996

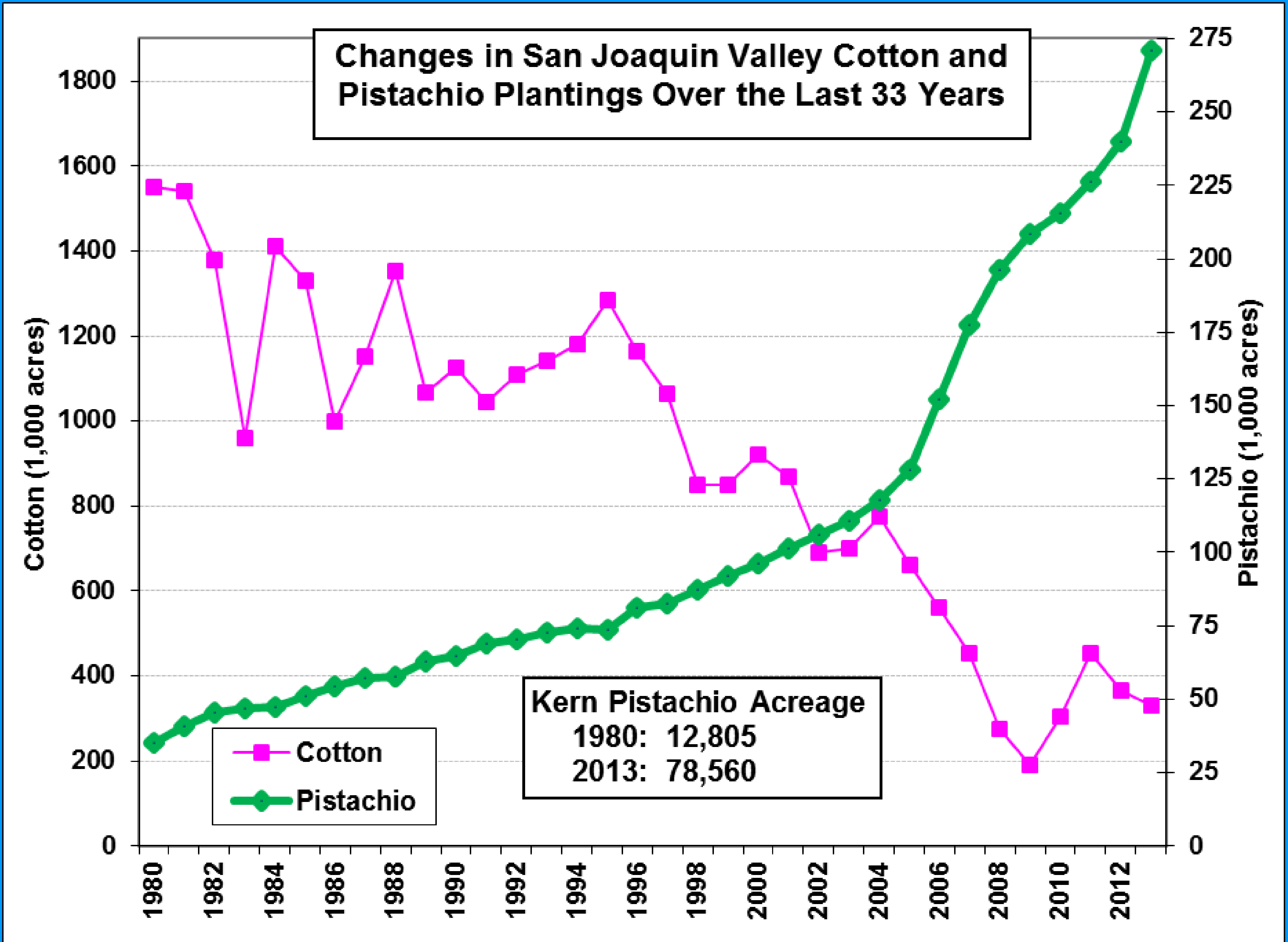
More than ¼ million acres along the Westside of the San Joaquin Valley are affected by poor drainage, perched water and salinity.

More than ½ million more acres are free of "perched water" but have poor surface soils with excessive silt and sodicity, resulting in "sealing" and poor structure not conducive to optimal root development.

Many new pistachio developments are being planted to old cotton ground that had significant problem areas under flood irrigation. Well managed micro-irrigation systems can reduce or eliminate much of the drainage problem, but when salts become this bad some leaching and reclamation is essentail.



Pistachio acreage has more than doubled in last 10 years




Good ground for $10,000/ac can't be found.
This isn't morning frost!


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

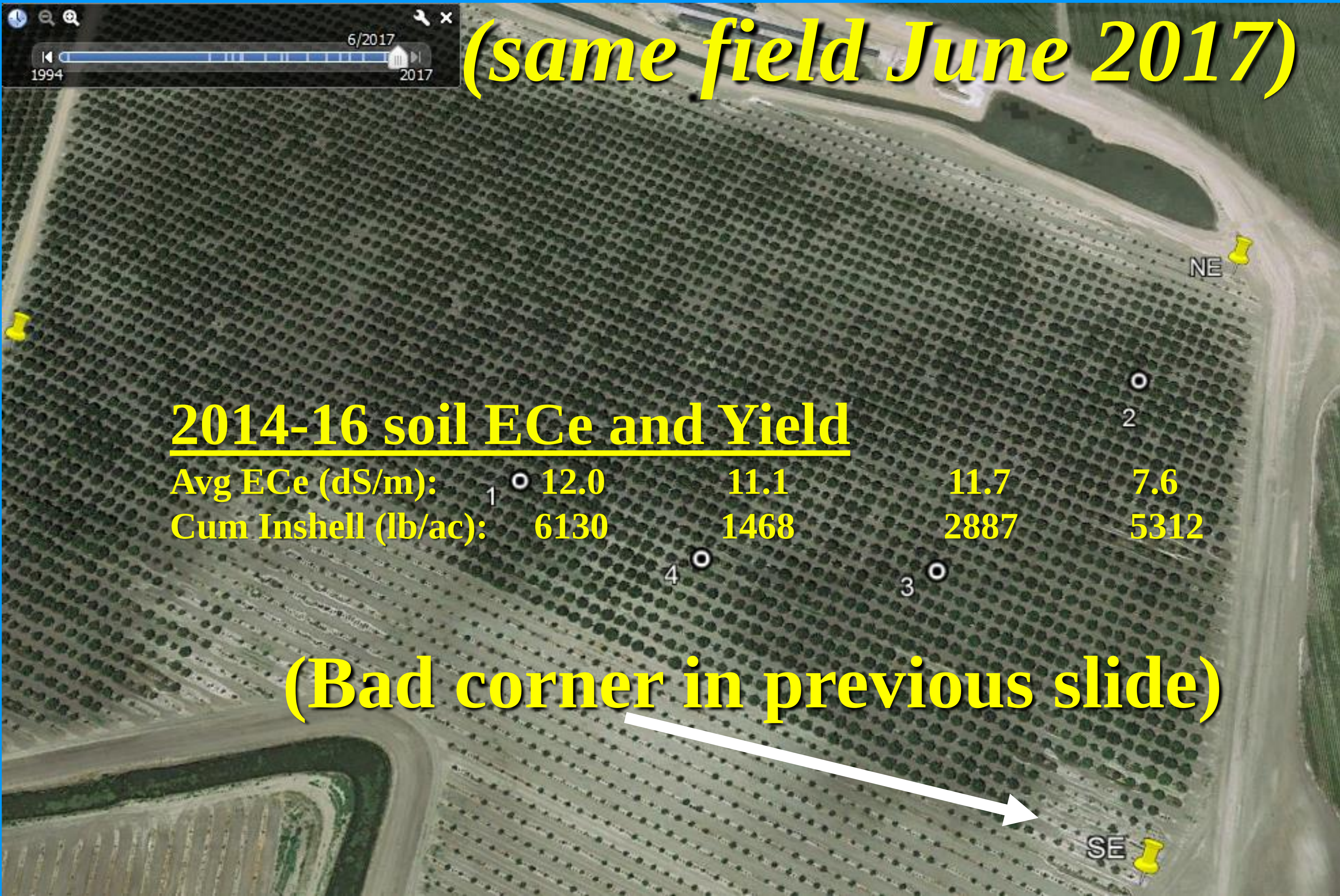

Just a little "black alkali"…
No problem, right?

Really?

Are some spots just too hot?


Yes, really – 5th leaf pistachios
(June 2011)
"Well, I can't grow good cotton on this ground so I might as well plant pistachios."

Well, maybe – 11th leaf pistachios (same field June 2017)



UC Extension recommendation for pistachio growers who want a uniform orchard without the risk of juvenile dieback:

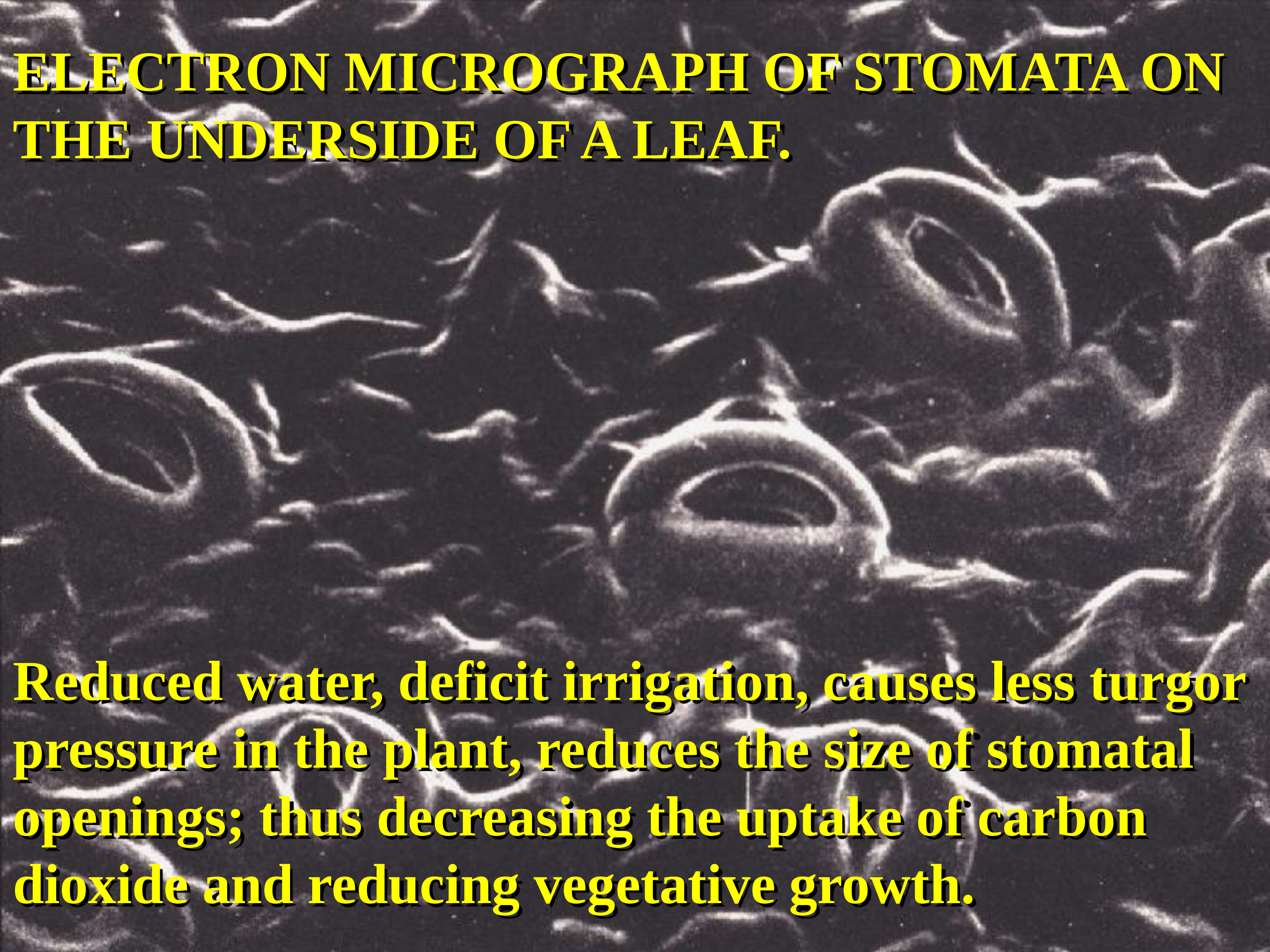
Planting pistachios in saline soils?

DON'T DO IT!!

Thank you.

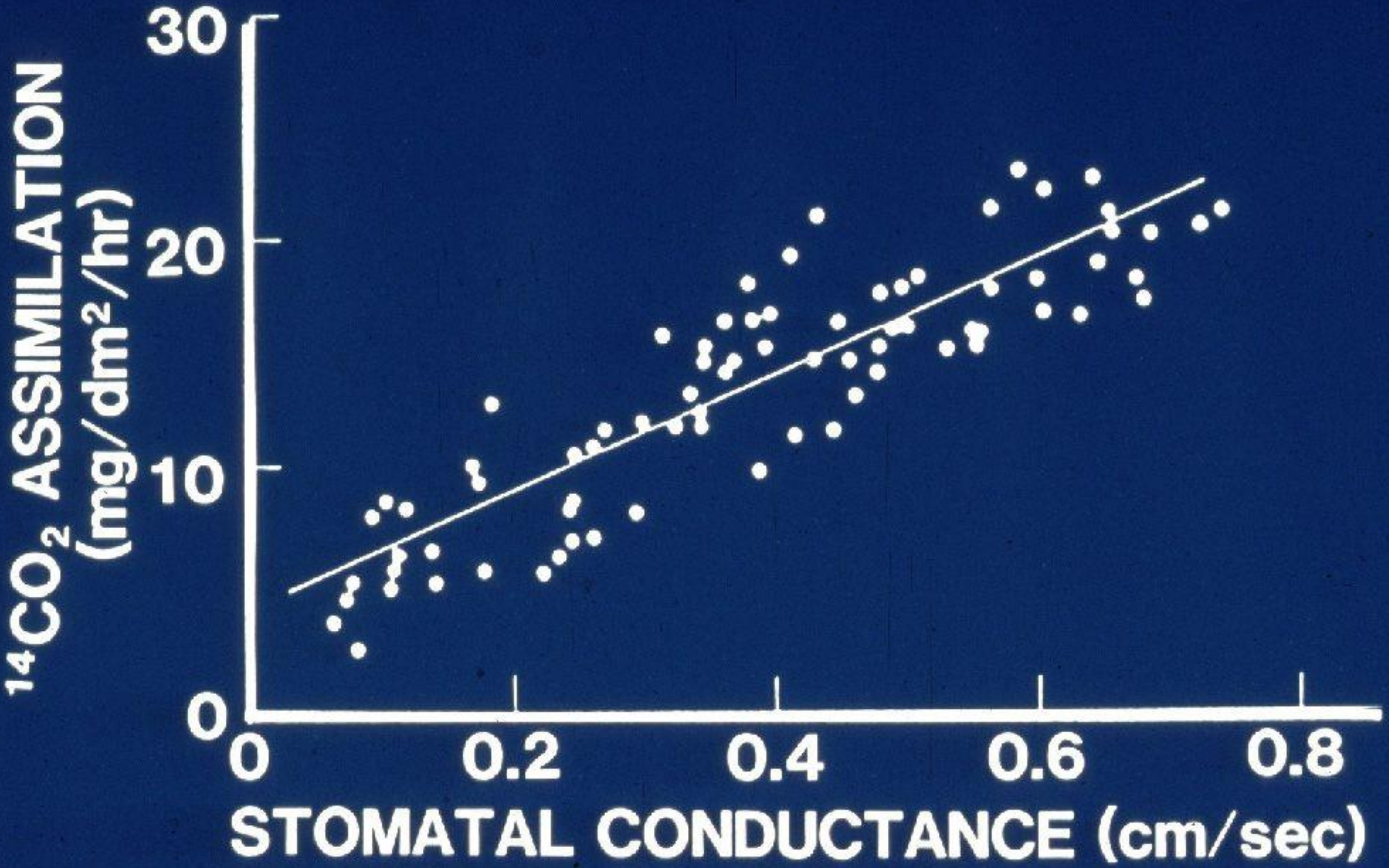
ROAD MAP:
Where's this talk going?

- Why evaluate?
- What to evaluate.
- How to do it.
- How to fix it.
- What we know so far.



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/dm^2/hr)
0
0.2
0.4
0.6
0.8
STOMATAL CONDUCTANCE (cm/sec)


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)
Pistachios can "tolerate" this much salt, but the resulting yield is bankruptcy for California.

Why evaluate?

- Uniformity
- Rapid maturity
- Quality/nut size
- High yield

Why evaluate?

- **CAPITAL INVESTMENT CONCERNS**

"Expensive" ground

- **$14,000/acre ground,** no amendments needed + 6% simple interest over 11 years = $9,240
- **FINAL COST**

  $23,240 or ...

"Cheap" ground

$7,000/acre ground

- Year 1: 1.5 t/ac Sulfur $800
- Year 2 - 11: $300/yr
  - Extra acid and gypsum through the system $3,000

(Simple interest, 11 yrs @ 6% $5,148)

- Year 7 - 11:
  - 1000 lb/ac cumulative yield loss compared to other ground $2,400

FINAL COST $17,548/acre

Why evaluate?

- **BEST INSURANCE AVAILABLE**

Cost Comparison for 150 Acres @ 121 trees/ac (18 x 20 foot spacing)

EVALUATION COST: Four zones–1, 2, 3 & 5 foot		ORCHARD COST	
Soil analyses	1,000	18,150 trees, stake, bud, train @ $12	217,800
Water analysis	50	Irrig System @ $1,500	225,000
Backhoe	500	Land @ $10,000	1,500,000
Consultant	600		
TOTAL	**$2,150**	**TOTAL**	**$1,942,800**

0.11% of initial capital.

Why evaluate?

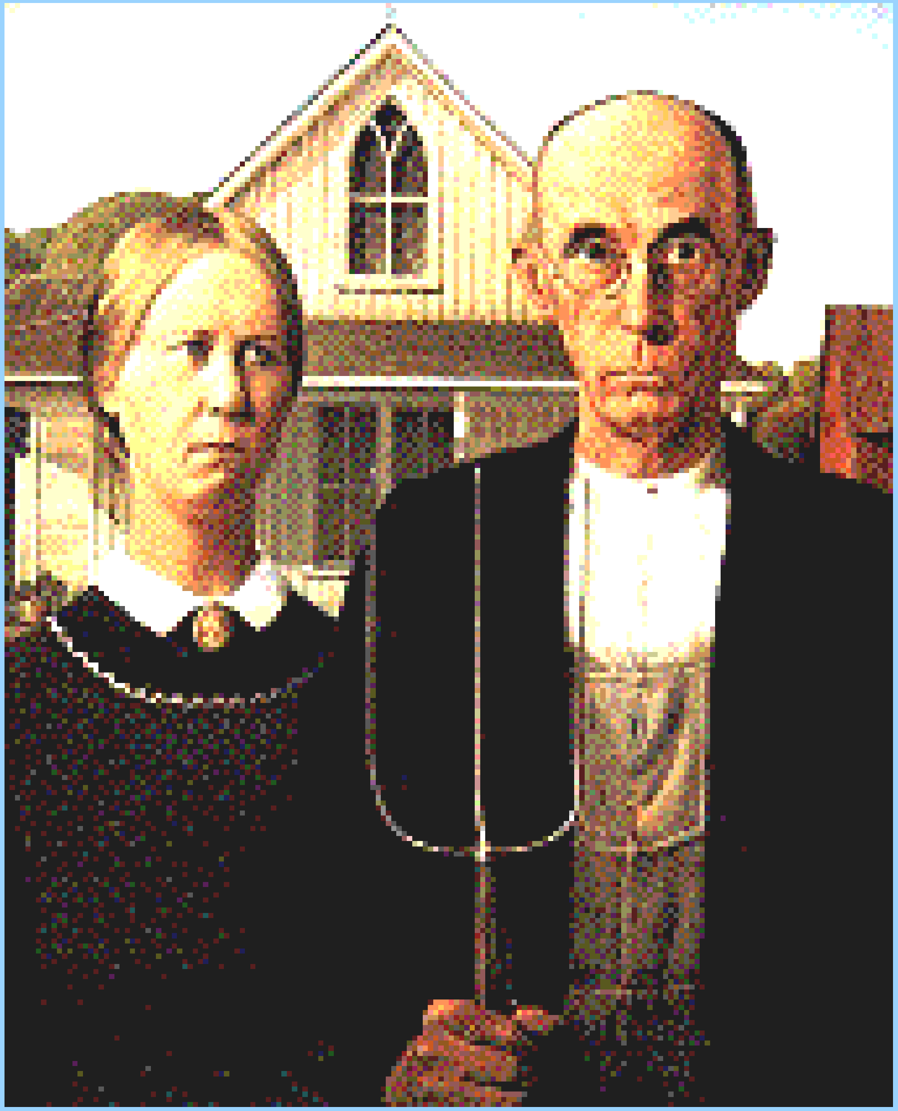
- **THE PERFECT GROUND ISN'T ALWAYS WHAT YOU GET**

- **4' of cheap water**
  - **EC 0.6 to 1.2 dS/m**
- **0.1 to 1.5% even slope**
- **Loam to sandy clay loam texture**
- **No perched water, good infiltration**
- **Grows 3.5 bale/ac cotton**

Why evaluate?

- **REALITY**

Most of us make due with what we get!



What to evaluate?

THE BIG PICTURE

- SOIL QUALITY
- SALINITY
- WATER PENETRATION

PROPOSED CROP

LIFE CYCLE & WATER USE
ROOTING CHARACTERISTICS
DESIRED STRUCTURE & SPACING
HARVEST REQUIREMENTS
FIELD TRAFFIC

NATURAL FACTORS

SITE SOIL CONSIDERATIONS

TOPOGRAPHY
TEXTURE
DRAINAGE
CHEMISTRY/AMENDMENTS

WATER CONSIDERATIONS

RELIABILITY OF SUPPLY
CHEMISTRY/AMENDMENTS
COST

ENGINEERING

IRRIGATION / LAND LEVELING

IRRIGATION METHOD
DISTRIBUTION PATTERN
IRRIGATION FREQUENCY
PRESSURE REGULATION
FILTRATION
DURABILITY
MONITORING
AMENDMENT APPLICATION
MAINTAINENCE / REPAIR
SYSTEM CAPITAL COST
ENERGY COST

How to do it

- **AERIAL/SATELITE PHOTOS**

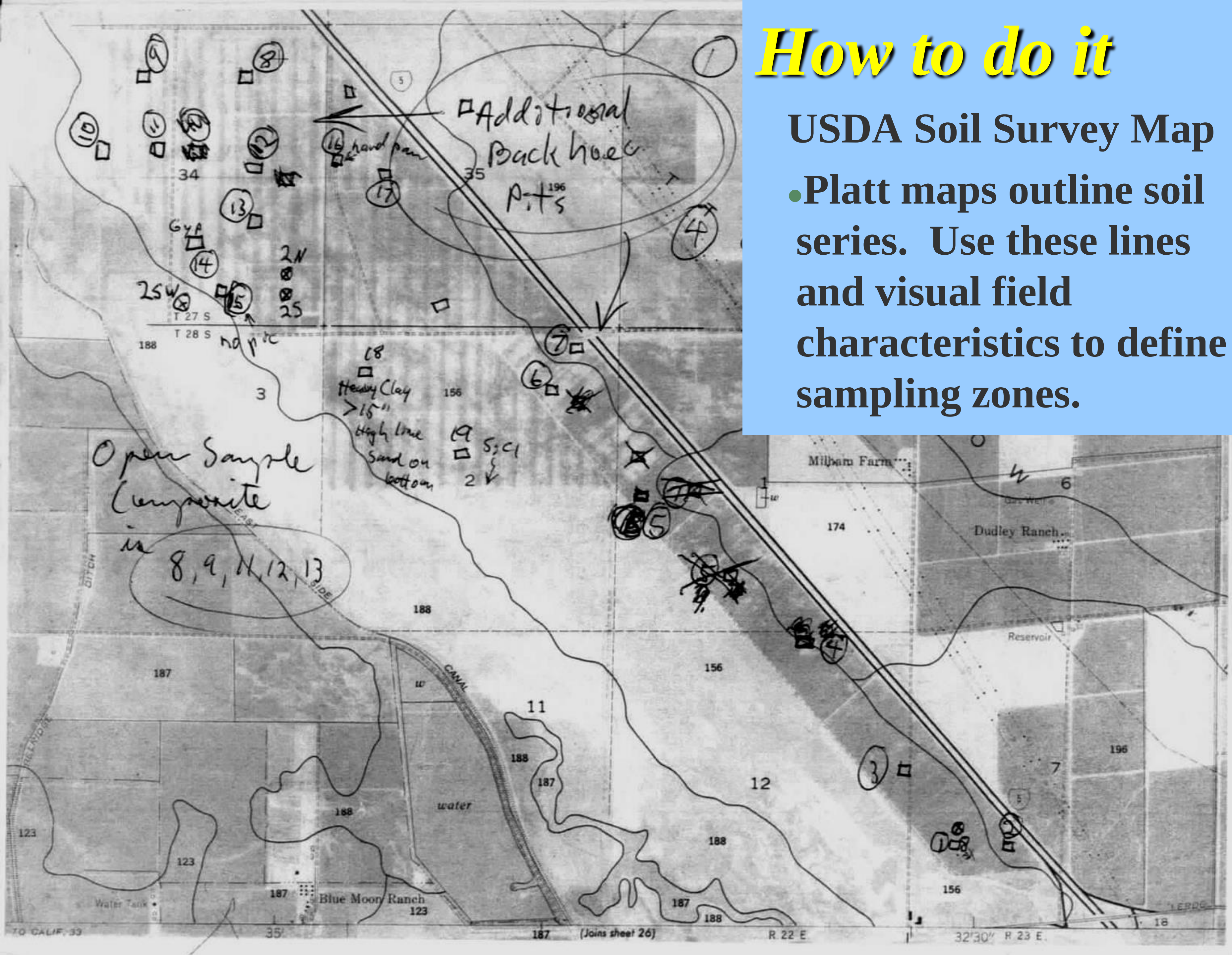
Old sloughs, streambeds and canals can have a long-term impact.

Especially for flood irrigated orchards.

How to do it

USDA Soil Survey Map

- Platt maps outline soil series. Use these lines and visual field characteristics to define sampling zones.



How to do it

- SOIL PROFILE
- SOIL TEXTURE

Analysis:

SP 48 -- saturation %

pH 8.2

EC_e 6.0 dS/m

SOIL SURVEY

BACKHOE PITS

AUGER, PUSH PROBE

mottles, dark yellowish brown (10YR 4/6) moist; weak fine subangular blocky structure; slightly hard, very friable, nonsticky and nonplastic; many very fine and few fine roots; common very fine and few fine tubular pores and many very fine interstitial pores; neutral; clear wavy boundary.

VIIIC8—48 to 56 inches; white (10YR 8/1) silt loam, gray (10YR 5/1) moist; common medium prominent brownish yellow (10YR 6/8) mottles, dark yellowish brown (10YR 4/6) moist; moderate medium subangular blocky structure; slightly hard, friable, slightly sticky and nonplastic; many very fine and common fine roots; many very fine and common fine tubular pores and common very fine interstitial pores; neutral; clear wavy boundary.

IXC9—56 to 65 inches; very pale brown (10YR 8/3) sand, grayish brown (10YR 5/2) moist; few fine prominent brownish yellow (10YR 6/8) mottles, dark yellowish brown (10YR 4/6) moist; single grain; loose, nonsticky and nonplastic; many very fine interstitial pores; neutral.

The soil is noneffervescent below a depth of 11 to 20 inches.

The A horizon has dry color of 10YR 5/2, 5/3, 6/2, or 6/3 and moist color of 10YR 4/2, 4/3, or 5/3. Clay content is 10 to 18 percent.

The C horizon has dry color of 10YR 6/2, 6/3, 6/6, 7/2, 7/3, 8/1, or 8/3 or 2.5Y 6/2 and moist color of 10YR 3/2, 3/3, 4/2, 4/6, 5/1, 5/2, or 5/3 or 2.5Y 4/2 or 6/2. Mottles have dry color of 10YR 5/6, 6/6, 6/8, or 8/3 or 7.5YR 5/4 and moist color of 10YR 3/6, 4/6, or 5/3 or 7.5YR 5/4. Texture is stratified sand, loamy sand, loamy fine sand, sandy loam, fine sandy loam, loam, or silt loam. Clay content is 10 to 18 percent. Reaction is slightly acid to moderately alkaline.

Exeter Series

The Exeter series consists of moderately deep, well drained soils on broad alluvial terraces. These soils formed in alluvium derived dominantly from granitic rock. Slope is 0 to 9 percent.

Soils of the Exeter series are fine-loamy, mixed, thermic Typic Durixeralfs.

Typical pedon of Exeter sandy loam, 0 to 2 percent slopes (fig. 4); on an alluvial terrace where slopes are 1 percent; about 3 miles west of Highway 65 on Highway 155, 150 feet north and 200 feet west of the southeast corner of sec. 7, T. 25 S., R. 27 E.; Richgrove Quadrangle.

Ap—0 to 4 inches; pale brown (10YR 6/3) sandy loam, dark brown (10YR 3/3) moist; weak very coarse platy structure; very hard, friable, nonsticky and nonplastic; common very fine roots; many very fine interstitial pores and few very fine tubular pores; neutral; clear smooth boundary.

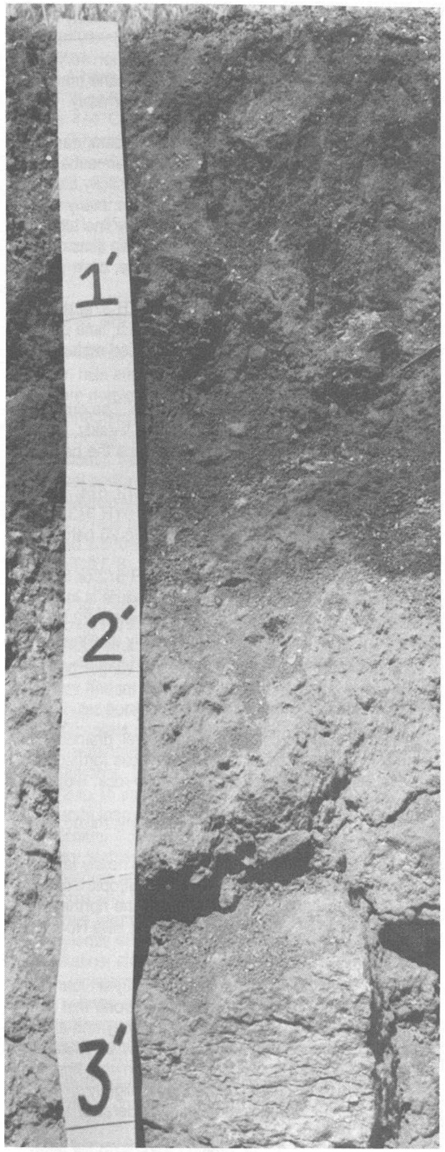


Figure 4.—Profile of Exeter sandy loam, 0 to 2 percent slopes. A duripan is at a depth of about 24 inches.

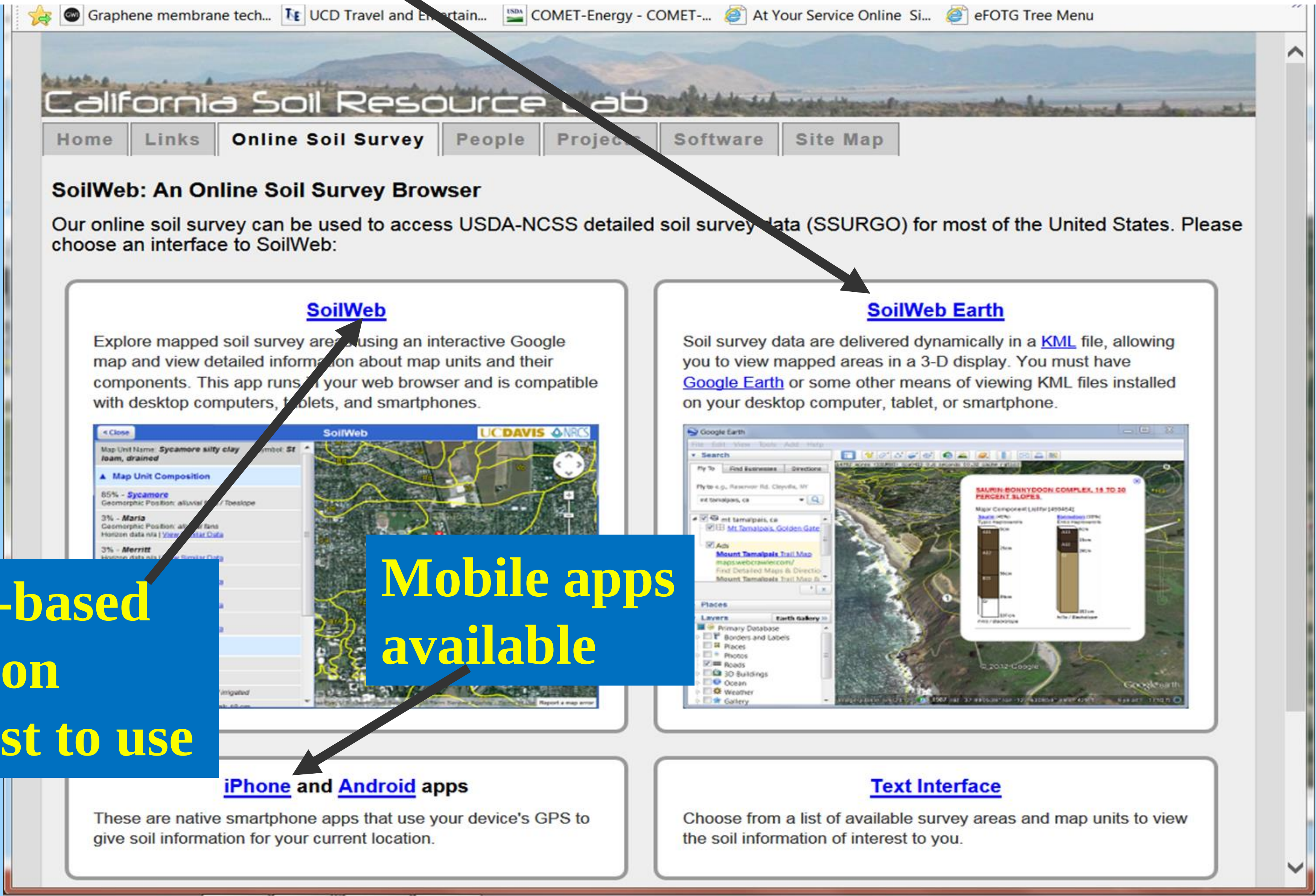
How to do it

- **USDA SOIL SURVEYS**

ONLINE SURVEYS

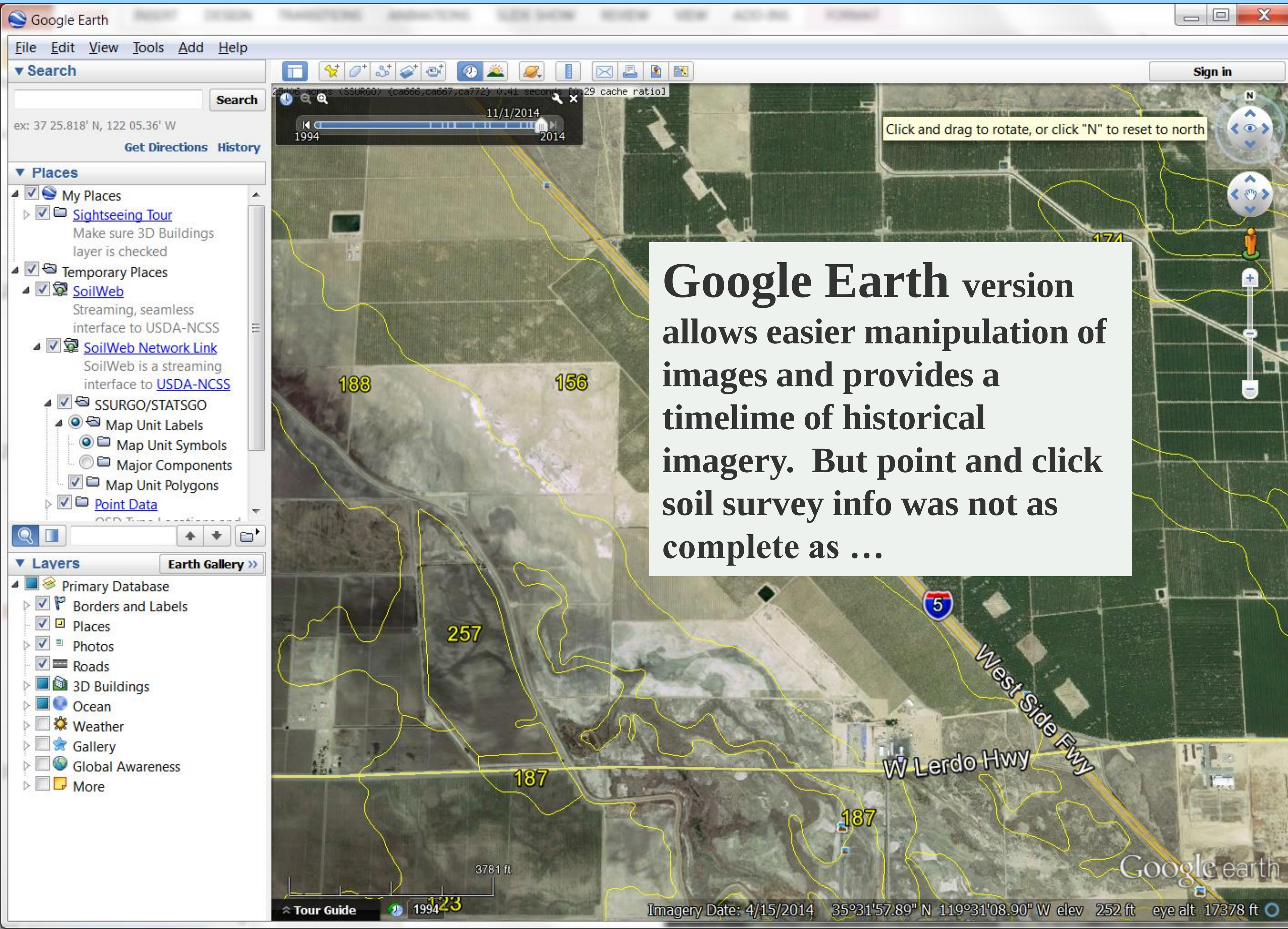
http://www.soils.usda.gov/survey/printed_surveys/california.html

Google Earth & UC/NRCS Soil Web Network (http://casoilresource.lawr.ucdavis.edu/drupal/)

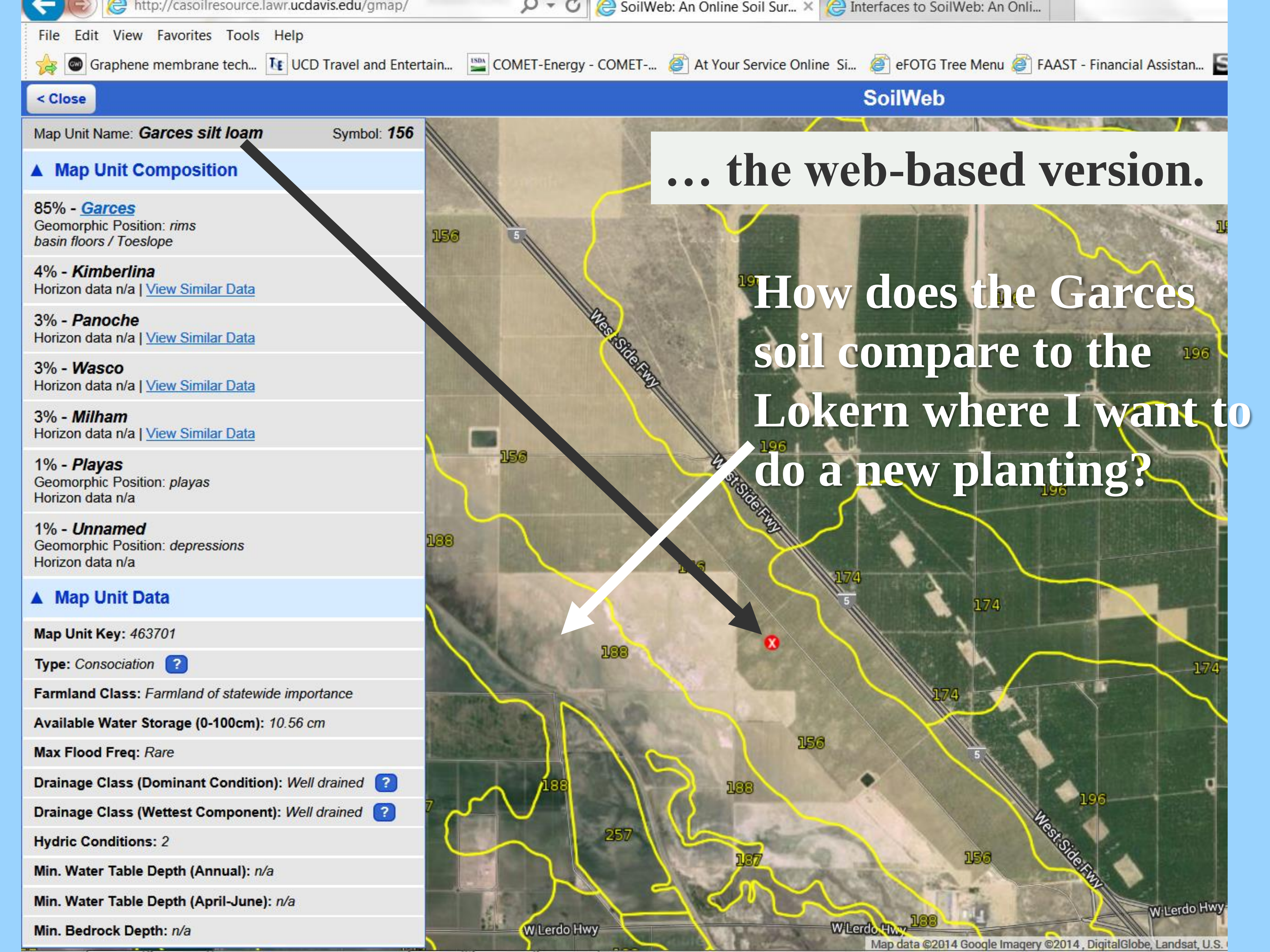


Web-based version easiest to use

Mobile apps available



Google Earth version allows easier manipulation of images and provides a timelime of historical imagery. But point and click soil survey info was not as complete as …



http://casoilresource.lawr.ucdavis.edu/gmap/
SoilWeb: An Online Soil Sur...
Interfaces to SoilWeb: An Onli...
File Edit View Favorites Tools Help
Graphene membrane tech...
UCD Travel and Entertain...
COMET-Energy - COMET-...
At Your Service Online Si...
eFOTG Tree Menu
FAAST - Financial Assistan...
< Close
SoilWeb
Map Unit Name: Garces silt loam
Symbol: 156
▲ Map Unit Composition
85% - Garces
Geomorphic Position: rims
basin floors / Toeslope
4% - Kimberlina
Horizon data n/a | View Similar Data
3% - Panoche
Horizon data n/a | View Similar Data
3% - Wasco
Horizon data n/a | View Similar Data
3% - Milham
Horizon data n/a | View Similar Data
1% - Playas
Geomorphic Position: playas
Horizon data n/a
1% - Unnamed
Geomorphic Position: depressions
Horizon data n/a
▲ Map Unit Data
Map Unit Key: 463701
Type: Consociation
Farmland Class: Farmland of statewide importance
Available Water Storage (0-100cm): 10.56 cm
Max Flood Freq: Rare
Drainage Class (Dominant Condition): Well drained
Drainage Class (Wettest Component): Well drained
Hydric Conditions: 2
Min. Water Table Depth (Annual): n/a
Min. Water Table Depth (April-June): n/a
Min. Bedrock Depth: n/a
… the web-based version.
How does the Garces soil compare to the Lokern where I want to do a new planting?
West Side Fwy
W Lerdo Hwy
156
188
196
174
257
187
Map data ©2014 Google Imagery ©2014 , DigitalGlobe, Landsat, U.S.

Soil survey data doesn't match ground observations of weed growth and salt precipitation

Garces silt loam #156

Depth Range (cm)	Horizon Designation	Percent Clay	Percent Sand	Percent Organic Matter	pH by water Extraction	Sat. Hydraulic Conductivity (mm/hr)	EC (dS/m)	SAR (%)	Carbonates (% of < 2 mm)
0 - 5	A	14	30.4	0.25	8.5	9.72	5	14	3
5 - 23	Bt	31	35.4	0	9	0.774	12	14	3
23 - 58	Btk	27.5	55.1	0	9	0.774	12	107	3
58 - 94	Ck	23.5	39.2	0	9	0	12	107	3
94 - 152	C	18.5	39	0	9	9.72	10	107	8

Lokern clay, saline-alkali, drained #188

Depth Range (cm)	Horizon Designation	Percent Clay	Percent Sand	Percent Organic Matter	pH by water Extraction	Sat. Hydraulic Conductivity (mm/hr)	EC (dS/m)	SAR (%)	Carbonates (% of < 2 mm)
0 - 18	Ap	47.5	23.3	2	8.2	3.276	1	0	0
18 - 53	A	50	22.1	0	8.2	3.276	2	0	3
53 - 121	C	50	22.1	0	8.2	32.4	2	0	3
121 - 168	2C	18	66.8	0	8.2	32.4	2	0	3

How to do it

- Ground truth assumptions about perched water, drainage ditches, saturated soil conditions that will reduce tree performance.

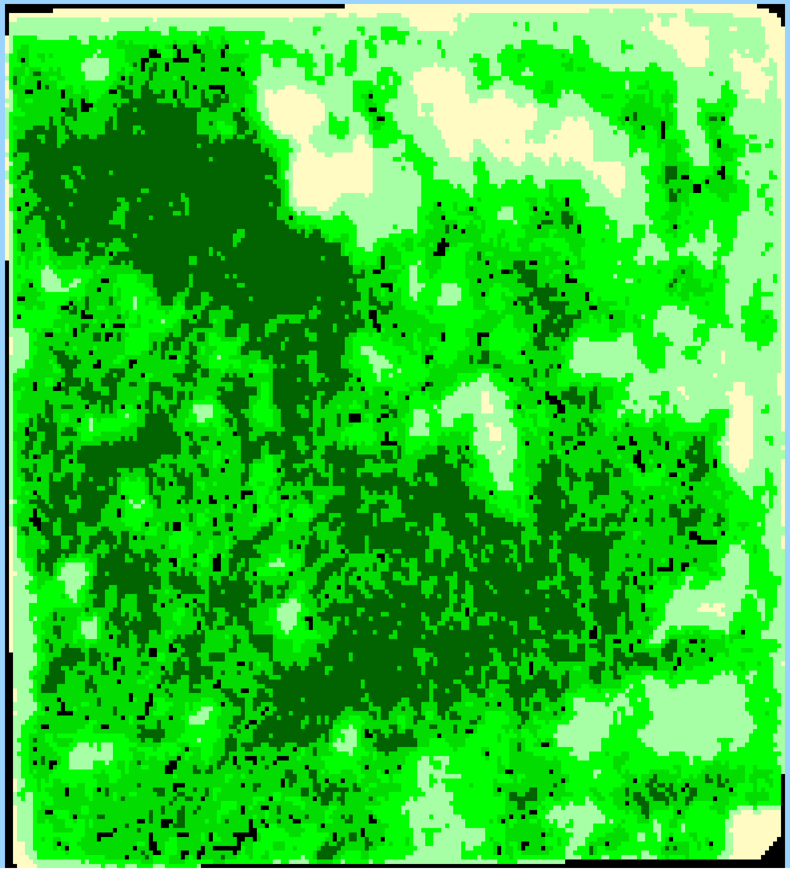
How to do it

- Is the "problem" soil related or management related?
- Visual band aerial reconnaissance in areas already developed into permanent crops can provide an idea of the benefits of micro-irrigation over flood.

How to do it: Processed spectral imaging of forage crops identifies problem areas.

Safflower, Western Kern County 8/2/99

Near Infrared | **NDVI Enhanced Image**

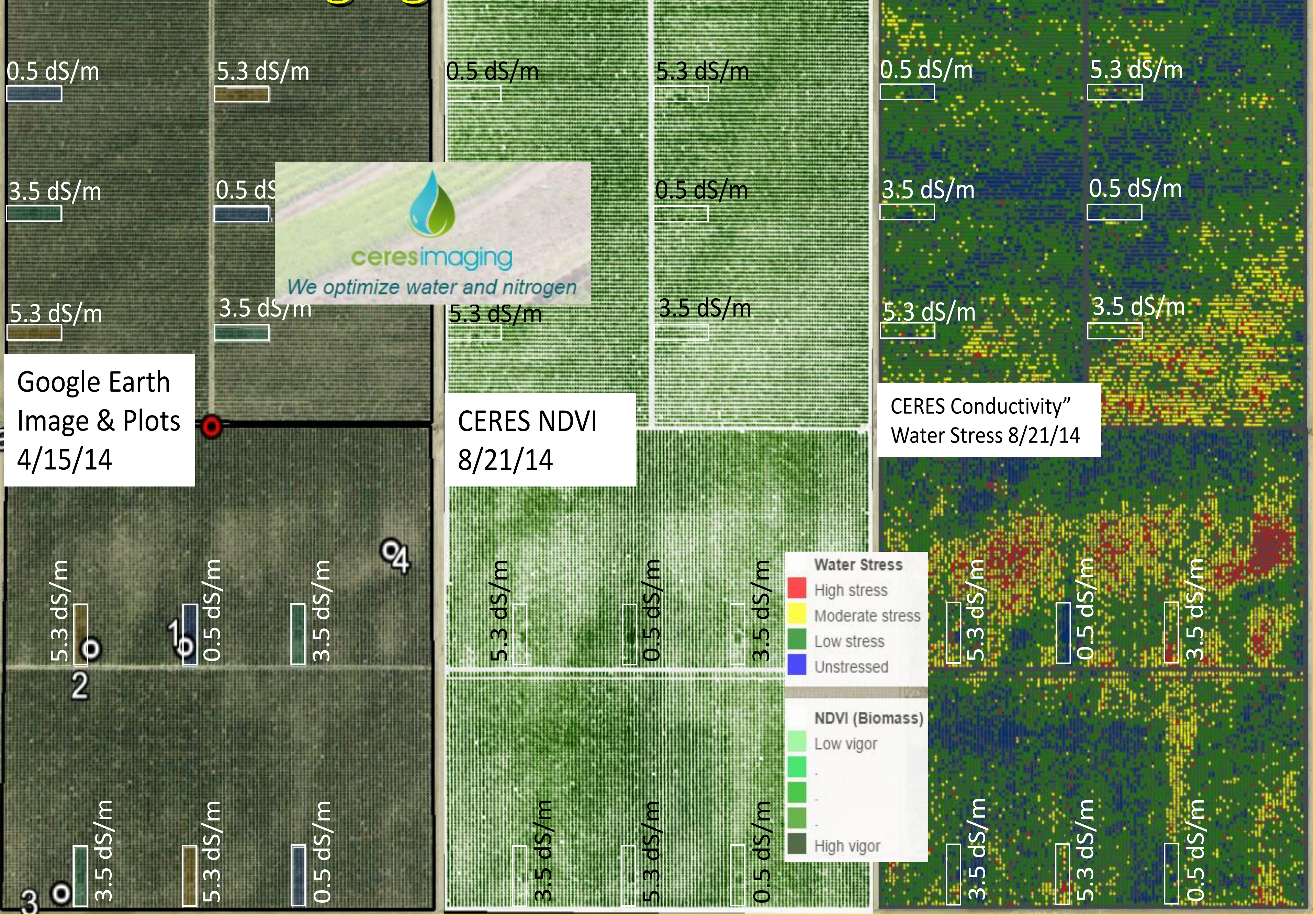


Near Infrared Reflectance is greatest where chlorophyll content is highest

Normalized Difference Vegetation Index =

$$\frac{\text{Near infrared reflectance} - \text{Infrared reflectance}}{\text{NIR} + \text{IR}}$$

CERES Imaging aerial NDVI and water Conductance



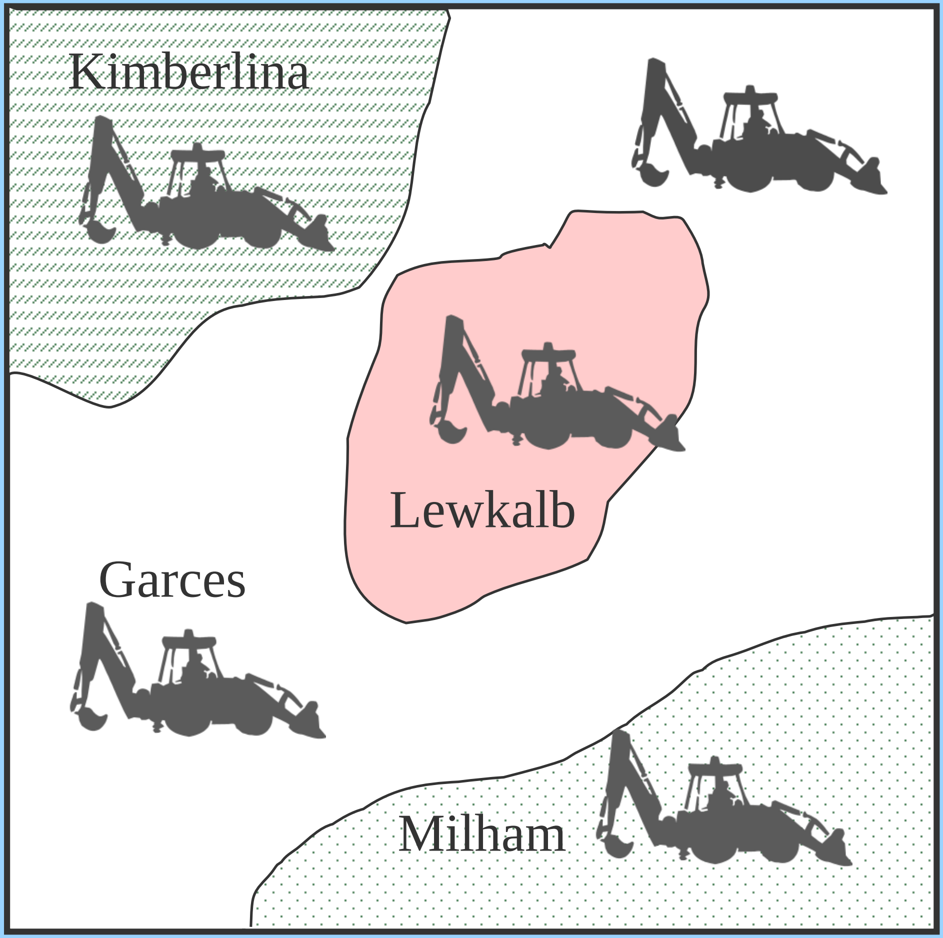
How to do it

SOIL PROFILE

- SOIL TEXTURE -- Sampling scheme for variable 160 acres

- Use soil probe or auger to composite sample 0-1 & 1-2 foot depths from at least 8 holes 50 feet apart for each soil type.

- Put at least one backhoe pit to 6 feet in each 40 acres of one soil type. Take deeper samples from pits.



How to do it

USDA Soil Survey Map

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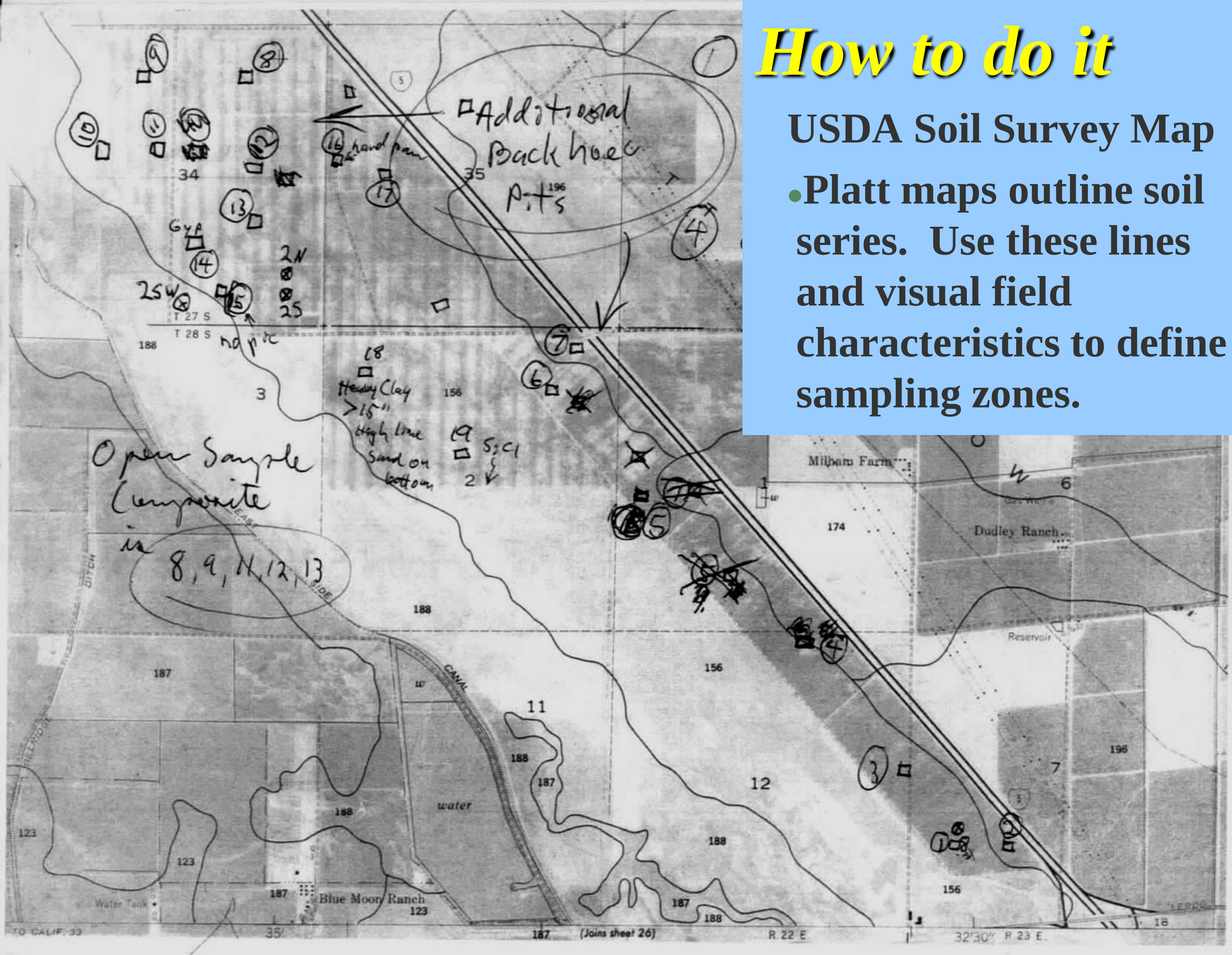
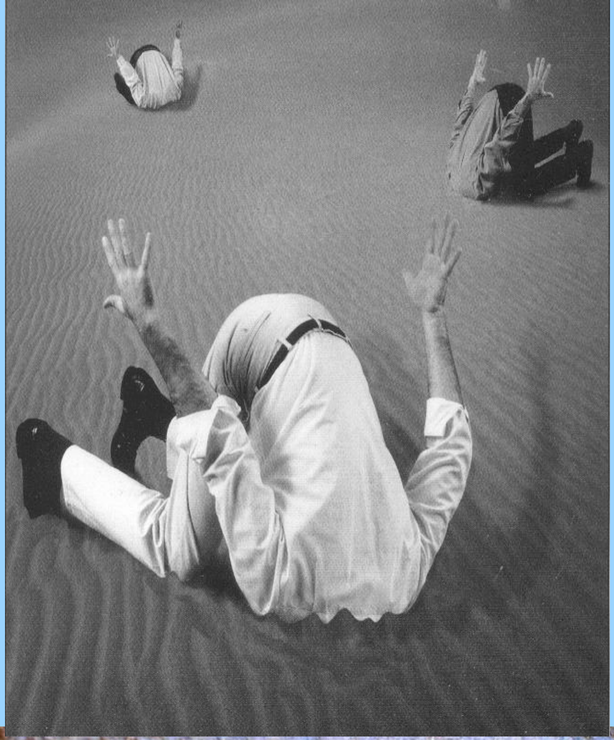


New pistachio developments in the ancient Buena Vista Lake bottom

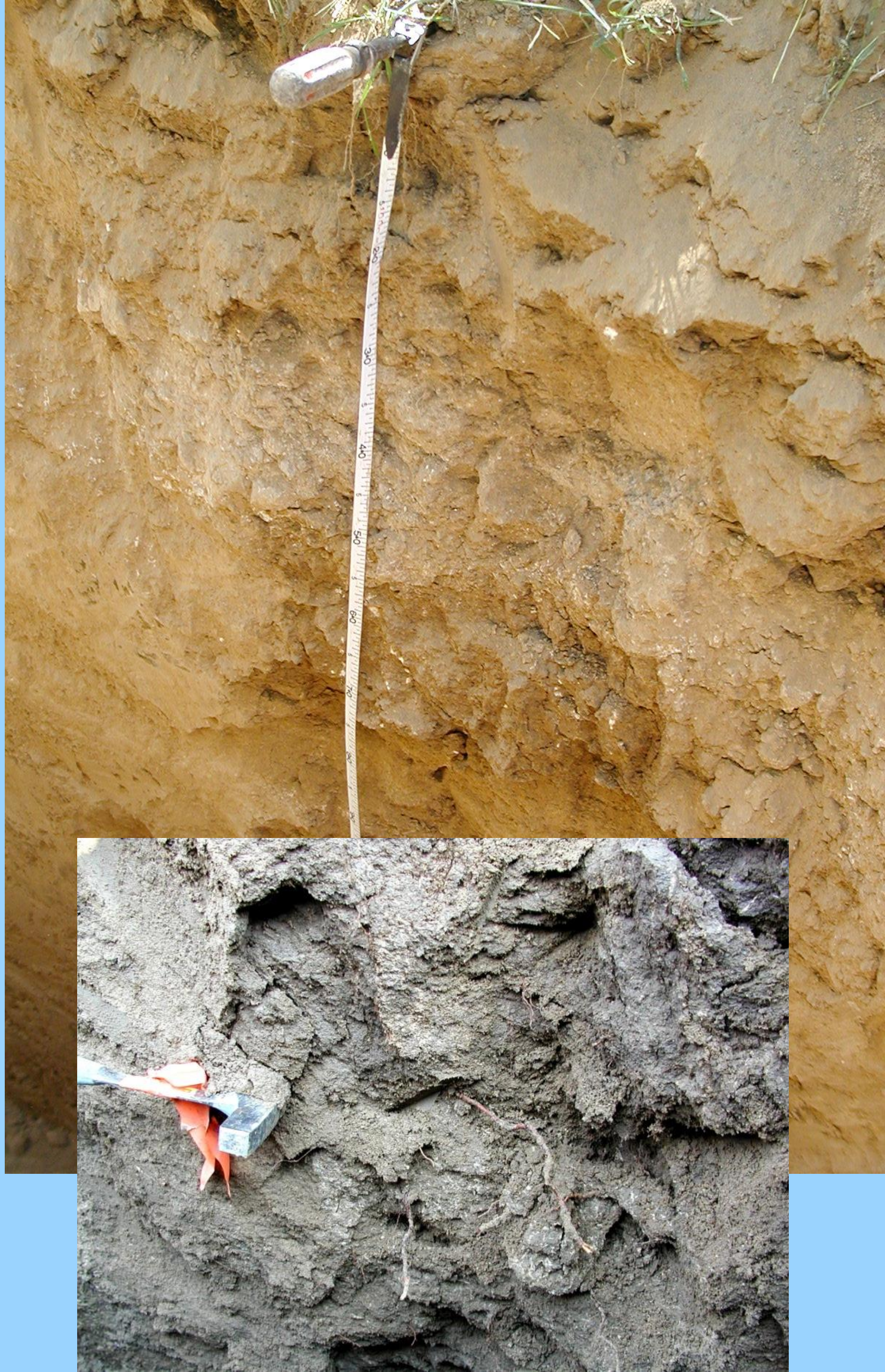
Check your dirt! It has more secrets than the CIA.



How to do it

- SOIL PROFILE
- BACKHOE PITS
  - SHOVEL
  - GEOLOGIST HAMMER/PICK
  - MEASURING TAPE
  - CLIPBOARD
  - BUCKETS/BAGS
  - AMPLE REFRESHMENTS


HSC



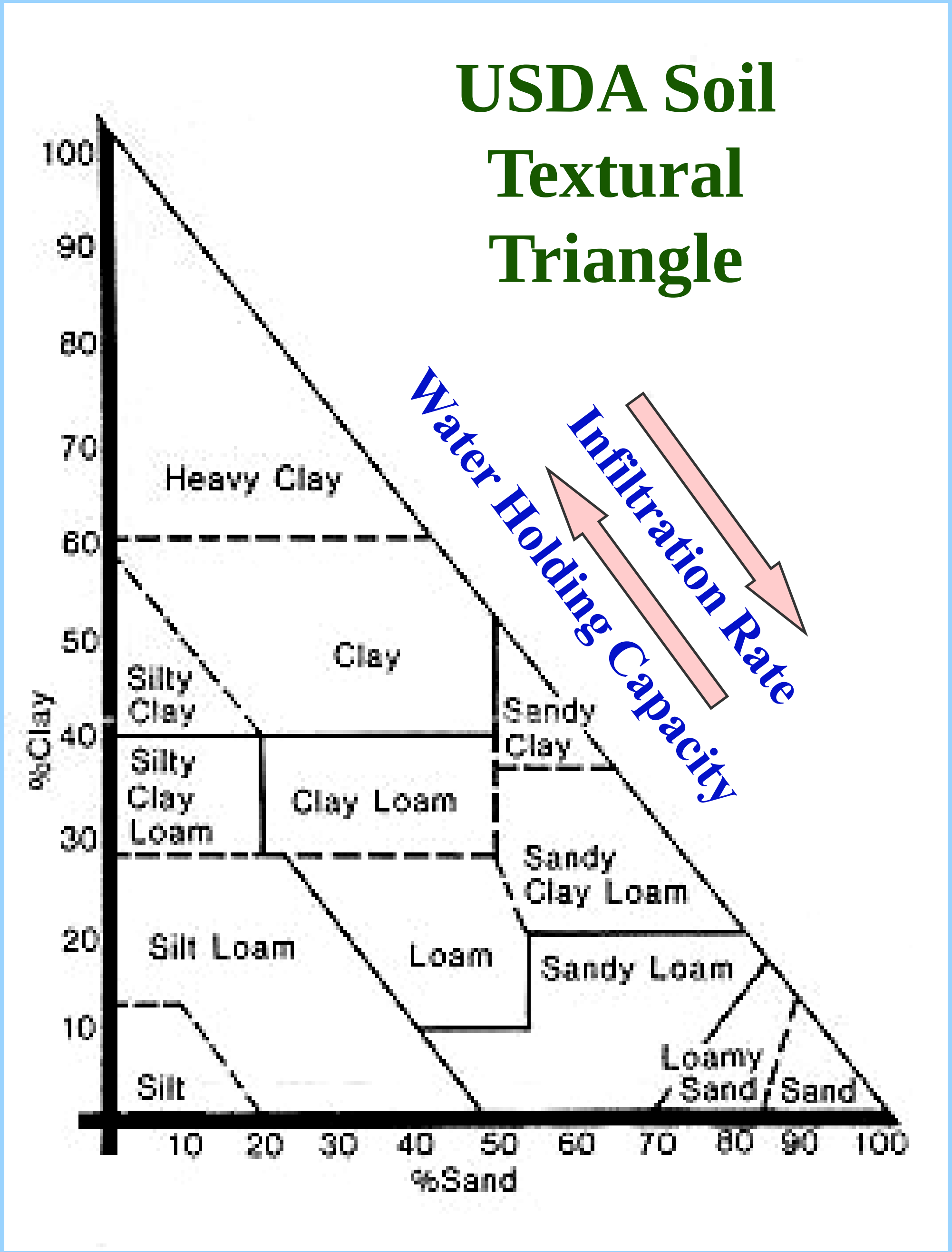
How to do it

- COLLECTING SAMPLES @ DEPTH IN SOIL PITS

What to evaluate?

- SOIL QUALITY

- TEXTURE
- STRUCTURE
- PERMEABILITY
- STRATIFICATION
- DRAINAGE
- SALINITY/Fertility

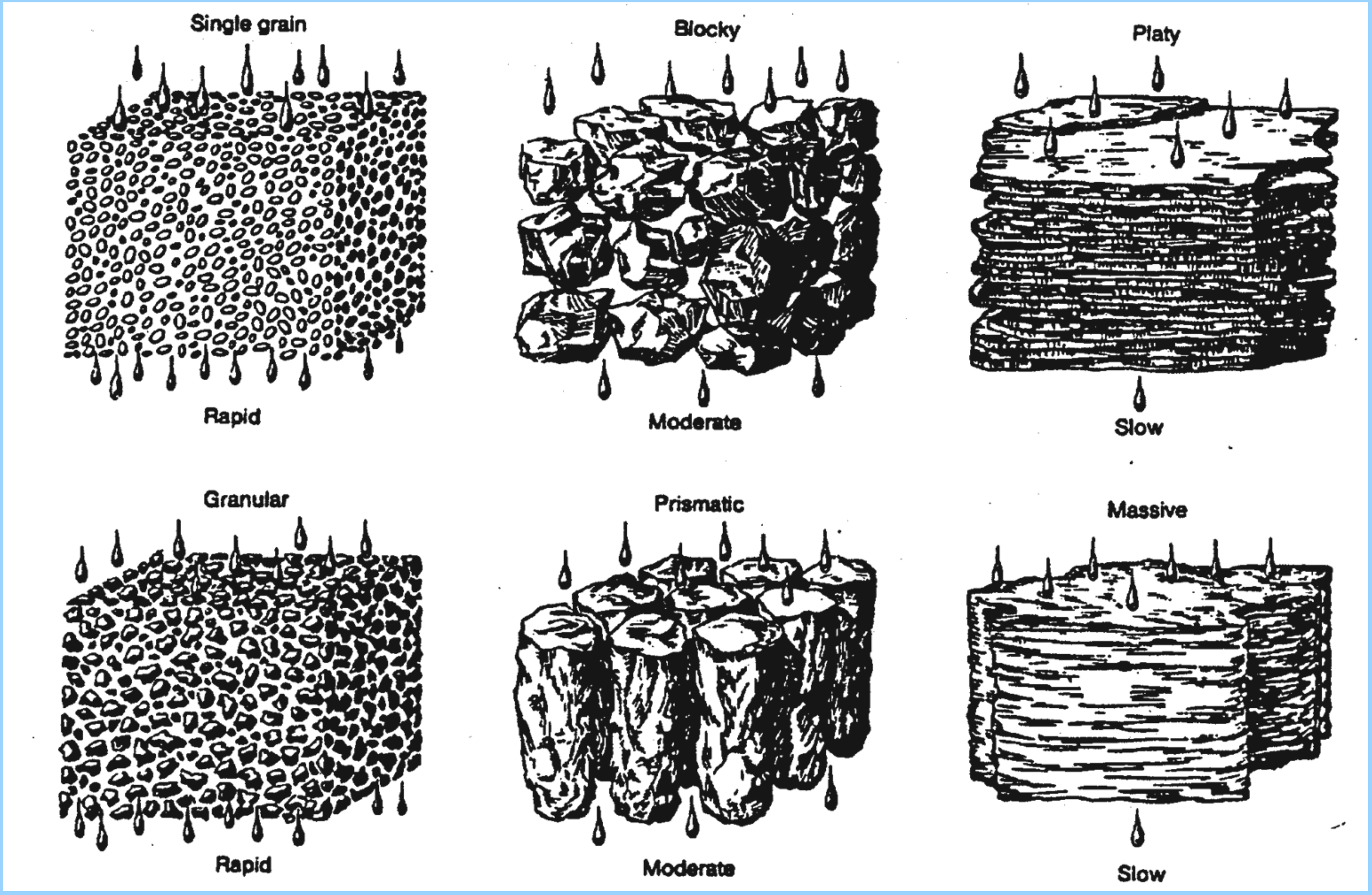


How to do it

- **SOIL TEXTURE**

Making a soil “ribbon” test from a moistened ball. Sandy Clay Loam – Westside Kern County

- # SOIL PROFILE -- STRUCTURE



How to do it

Record depths of layers, texture, lime, hardpans, rooting, drainage

Soil Eval Pits 2/25/04

7-W 1) 0-10" fsl
10-25" fscl
25-29" sicl
29-37 fsl
37-48 fsl - small gravel, silt
48-64 fragipan, thick platy, some gypsum
64-82 cemented hardpan, lime
82-90 - fsl - gravel

7-E 2) 0-15" fsl - Kimberlina
15-22 fssil w/ lime
22-31 fscl - dark, lime + gyps
31-54 fssicl/sicl - roots
54-70 fsl - kimberlina
70-85 fssil - weak nodulation / flaky

12-mid 3) 0-23" fsl - Kimberlina
23-33 fssil
33-46 fscl - nodules / small gravel < ¼"
46-57 fsl
57-74 fssicl - weak nodules, some pure silt
74-85 fsl

12-Nmid (4) 0-31 fsl - Kimberlina
31-34 fs sil
34-37 fscl - small gravel
37-61 Duripan, massive, hard
61-80 fssil, gyps, lime, nodules, loose hardpan

(9) 0-10" loam
10-32" siltl much lime
32-51 sil some lime
51-75 fs sil oxidized iron

(10) 0-3' sil - lime
3-4' caliche, cemented lime
4-5' weak hard pan
5-6' weak duripan, clay loam, iron mottles

(11) 0-10" Ap - scl
10-26" clay high lime
26-43" sicl - very high lime
43-55 sl - high lime
55-72 ls

(12) 0-10" - scl
10-38" - fsl - much lime
38-73" - fssil, lime, Fe + black mottles
73-85 - sl

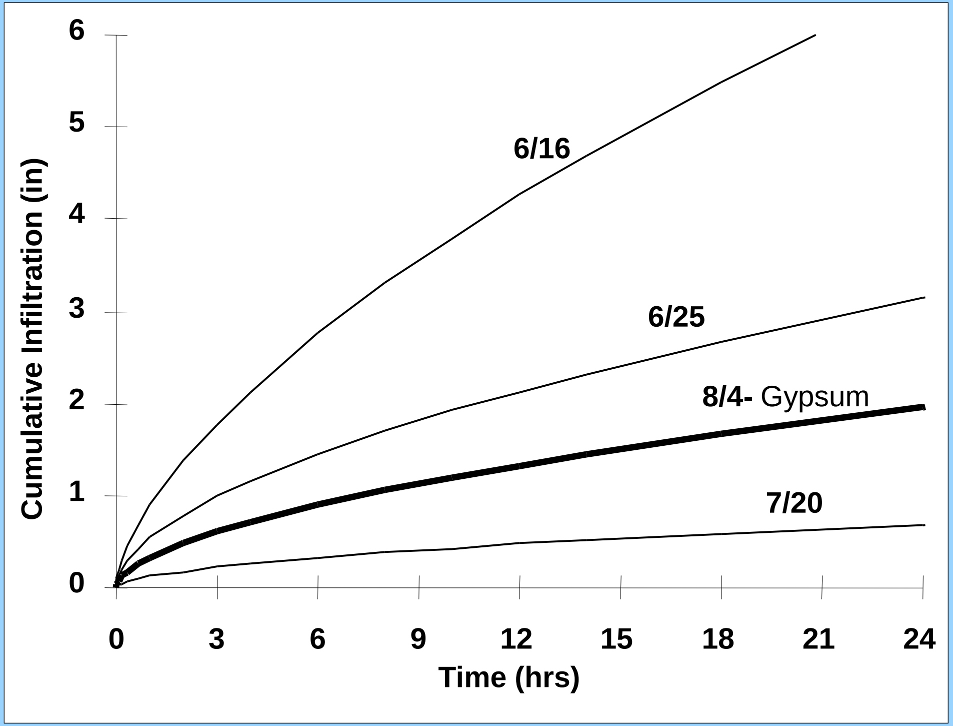
(13) a little more clay than above

(14) 12-40" much gypsum
(15) 0-10" l, 10-20" cl >20" clay

} Edge of dropoff grade E of low area

How to do it

- **PERMEABILITY**
  - Soil Survey Estimate
  - Infiltration tests
    - Block furrow
    - Two point
    - Ring infiltrometer



How to fix it

- ***Pick irrigation system that matches soil infiltration!!!***

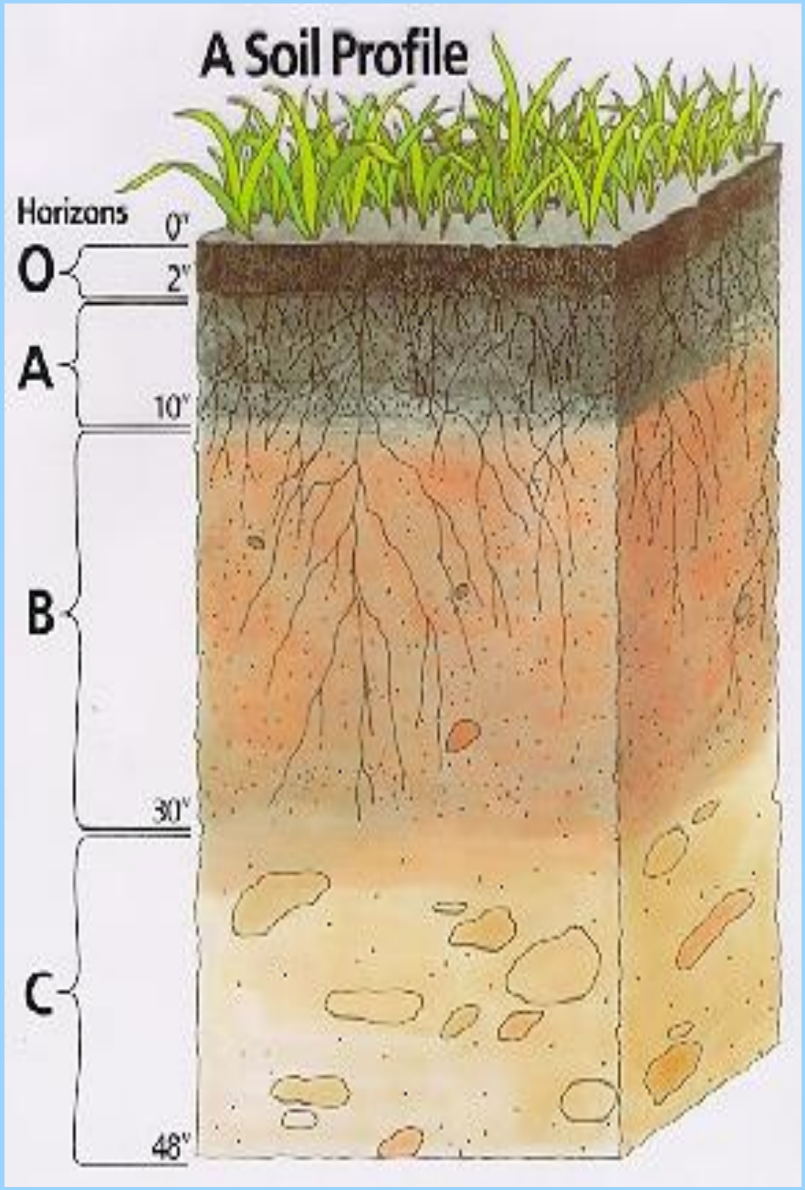
2.5”/week peak season

- **Deep rip before planting**
- **Calcium suppying amendments**
- **Organic matter**
- **Cover crops**

What to evaluate?

- **SOIL PROFILE**

- **TEXTURE**
- **STRUCTURE**
- **PERMEABILITY**
- **STRATIFICATION**
- **DRAINAGE**
- **SALINITY/Fertility**



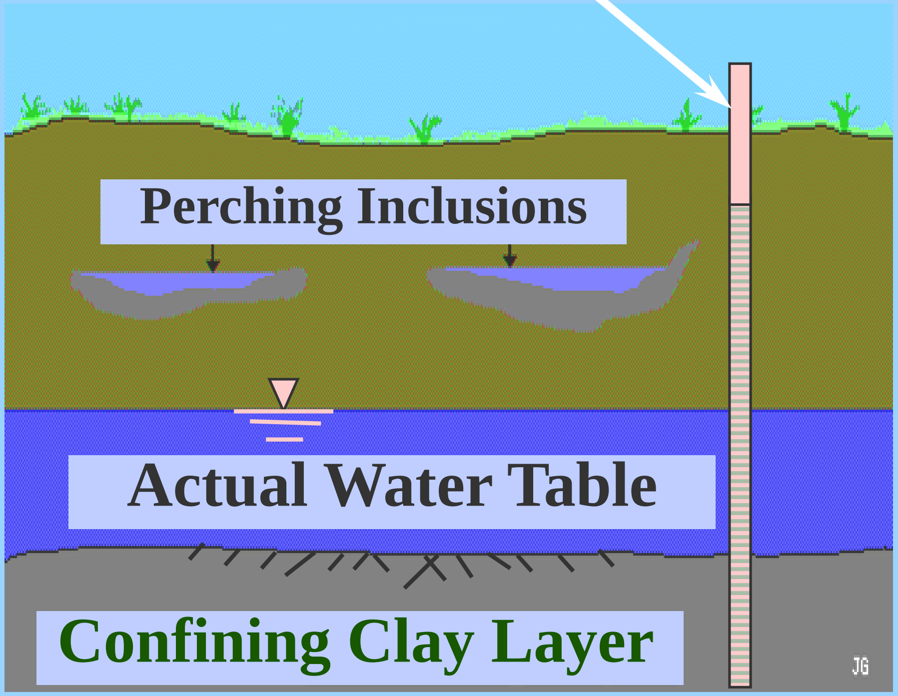
Fine sandy silt layer with high alkalinity and poor structure at the 34 to 44 inch depth may impede root development between 2 layers of Buttonwillow/Garces clay loam. Slip plowing below this depth is advisable.

What to evaluate?

- **SOIL PROFILE**

- **TEXTURE**
- **STRUCTURE**
- **PERMEABILITY**
- **STRATIFICATION**
- **DRAINAGE**
- **SALINITY/Fertility**

Monitoring well to determine shallow water table depth



What to evaluate?

Depth to perched water and localized salinity

How to do it

Submit soil and water samples to a CERTIFIED ag lab.

FRUIT GROWERS LABORATORY, INC.

ANALYTICAL CHEMISTS

October 7, 2003

Lab ID : VI 342083-06
Customer ID: 4-18085

Sampled On : September 19, 2003
Sampled By : Neil Jessup
Received On: September 24, 2003
Depth : 0-36"

Description : Site 6 Pistachio
Project : Goose Lake Farms

PISTACHIO SOIL ANALYSIS

Test Description	Result		Optimum Range	Graphical Results Presentation: Very Low	Moderately Low	Optimum	Moderately High	Very High
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					
				Strongly Acidic	Moderately Acidic	Near Neutral	Moderately Alkaline	Strongly Alkaline
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.

BPa:

Table continued next page...

Corporate Offices & Laboratory
PO Box 272 / 853 Corporation Street
Santa Paula, CA 93061-0272
TEL: 805/659-0910
FAX: 805/525-4172

Office & Laboratory
2500 Stagecoach Road
Stockton, CA 95215
TEL: 209/942-0181
FAX: 209/942-0423

Field Office
Visalia, CA
TEL: 559/734-9473
FAX: 559/734-8435
Mobile: 559/737-2399

October 7, 2003

Lab ID : VI 342083-06
Customer ID: 4-18085
Description : Site 6 Pistachio

PISTACHIO SOIL ANALYSIS

Test Description	Result		Optimum Range	Graphical Results Presentation
Others				Satisfactory / Possible Problem / Moderate Problem / Increasing Problem
Soil Salinity	6.89	mmhos/cm	0.5 - 2.0	
SAR	16.3		0.1 - 6	
Limestone	1.5	%	See Note 2	
				0 / 1 / 2 / 3 / 4 / 5 / 6
Lime Requirement	0.0	Tons/AF	---	
				Very Low / Moderately Low / Optimum / Moderately High / Very High
Moisture	2.9	%	1/2 Satn. %	
				Loamy Sand / Sandy Loam / Loam / Silt Loam / Clay Loam / Clay / Organic
Saturation	25.5	%	20 - 60	

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.

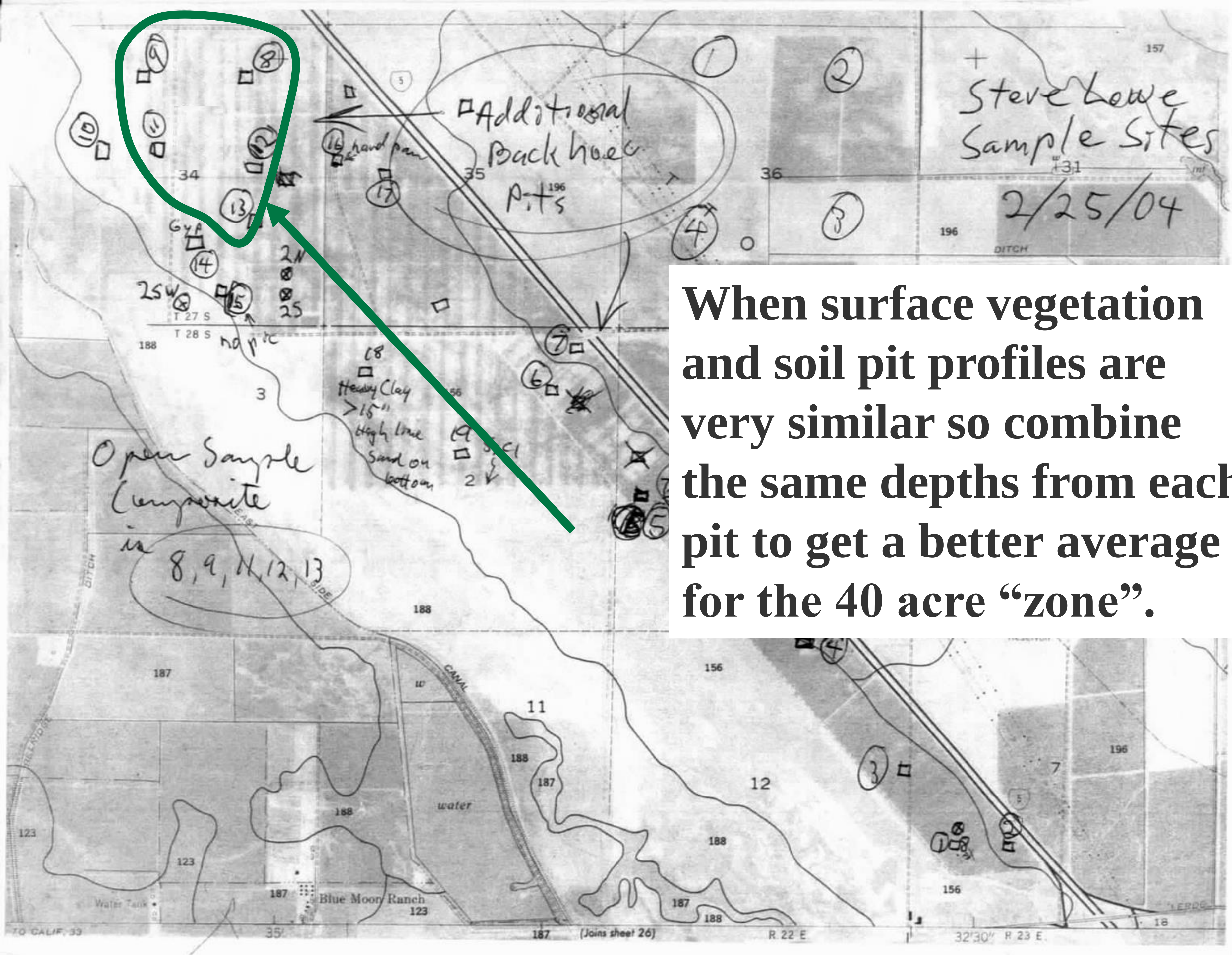
BPa:

1) The need for soil Nitrate is dependant upon crop phenology (Growth Stage) and crop requirement. A soil Nitrate level of 10 - 40 ppm is preferred for a short time during critical periods of uptake into the tree. It is highly desirable to have low soil Nitrate (< 5ppm) prior to winter rainfall and cold soil conditions. Use the leaf Nitrogen level to determine primary Nitrogen requirement.
2) The presence of limestone may result in some chlorosis (yellowing) of the leaves, depending upon the tolerance of the rootstock used.

FRUIT GROWERS LABORATORY, INC.

DHN:meh

Darrell H. Nelson, President



When surface vegetation and soil pit profiles are very similar so combine the same depths from each pit to get a better average for the 40 acre "zone".

How to do it

- **Soil and Water Analyses**

GROWERS TESTING SERVICES
1525-A EAST ACEQUIA AVE.
VISALIA CA 93292
(559)732-8378 fax(559)627-5460

SOIL ANALYSIS for: [ ]

Date
Date

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-[illegible] dr[illegible]
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)
*** CEC = (Cation Exchange Capacity)

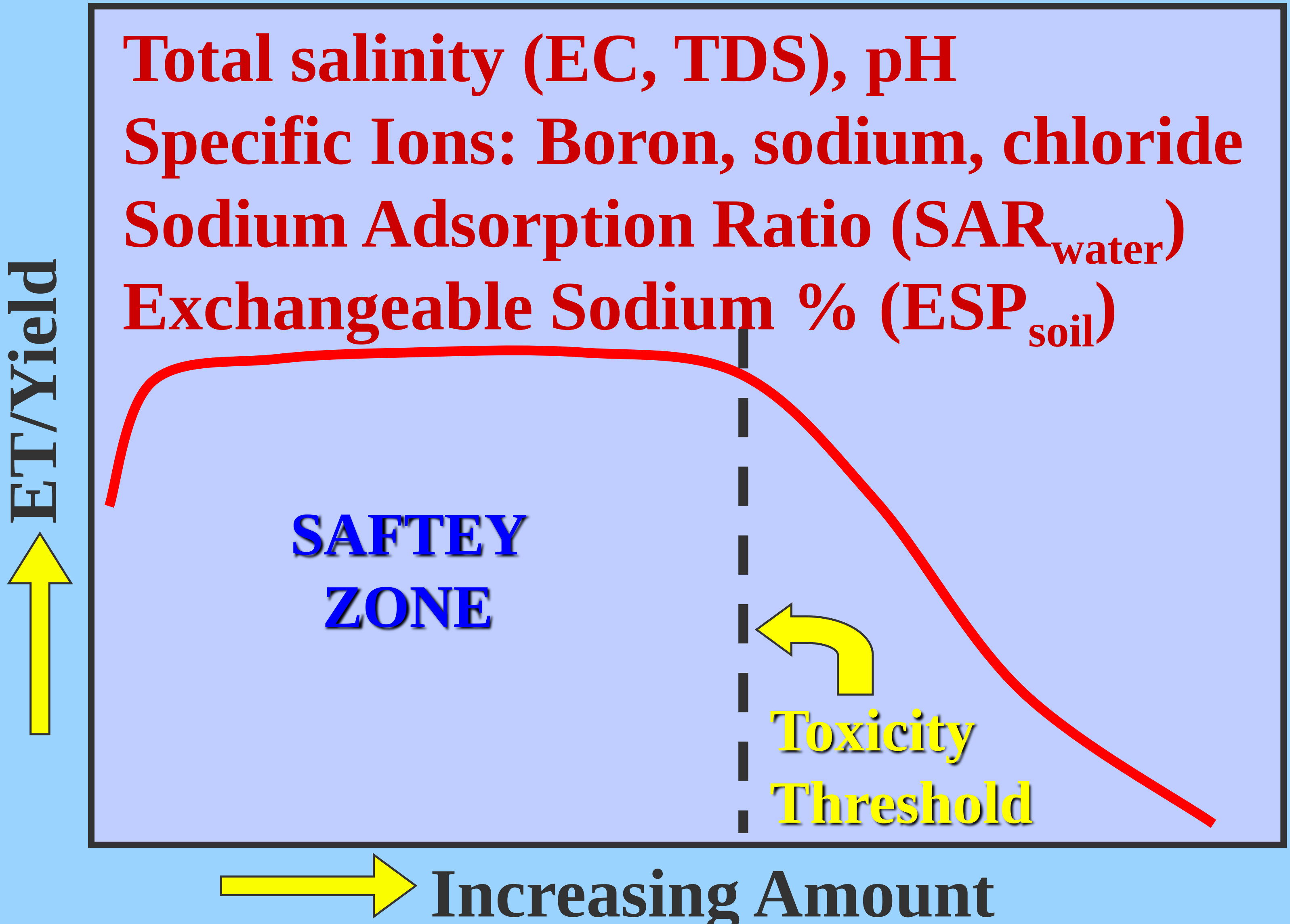
GTS #	Description	Trace Metals ppm Zn	Mn	Fe	Cu	Free Lime	% CaCO3	ppm SO4-S	% SAR	*** % CBC
4875	(8-13) 0-1'	1.6	8.8	9.6	1.1	HIGH	7.5	121.	29.0	88.8
4876	(8-13) 1-2'	1.1	1.0	8.2	0.8	HIGH	7.4	564.	73.0	88.8
4877	(8-13) 2-3'	1.3	0.8	6.0	0.4	HIGH	6.0	610.	75.0	88.8
4878	(8-13) 3-4'	1.4	0.7	8.2	0.4	HIGH	3.0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

Different labs have different formats. Stick to one lab with consistent, quality results and a format you understand.

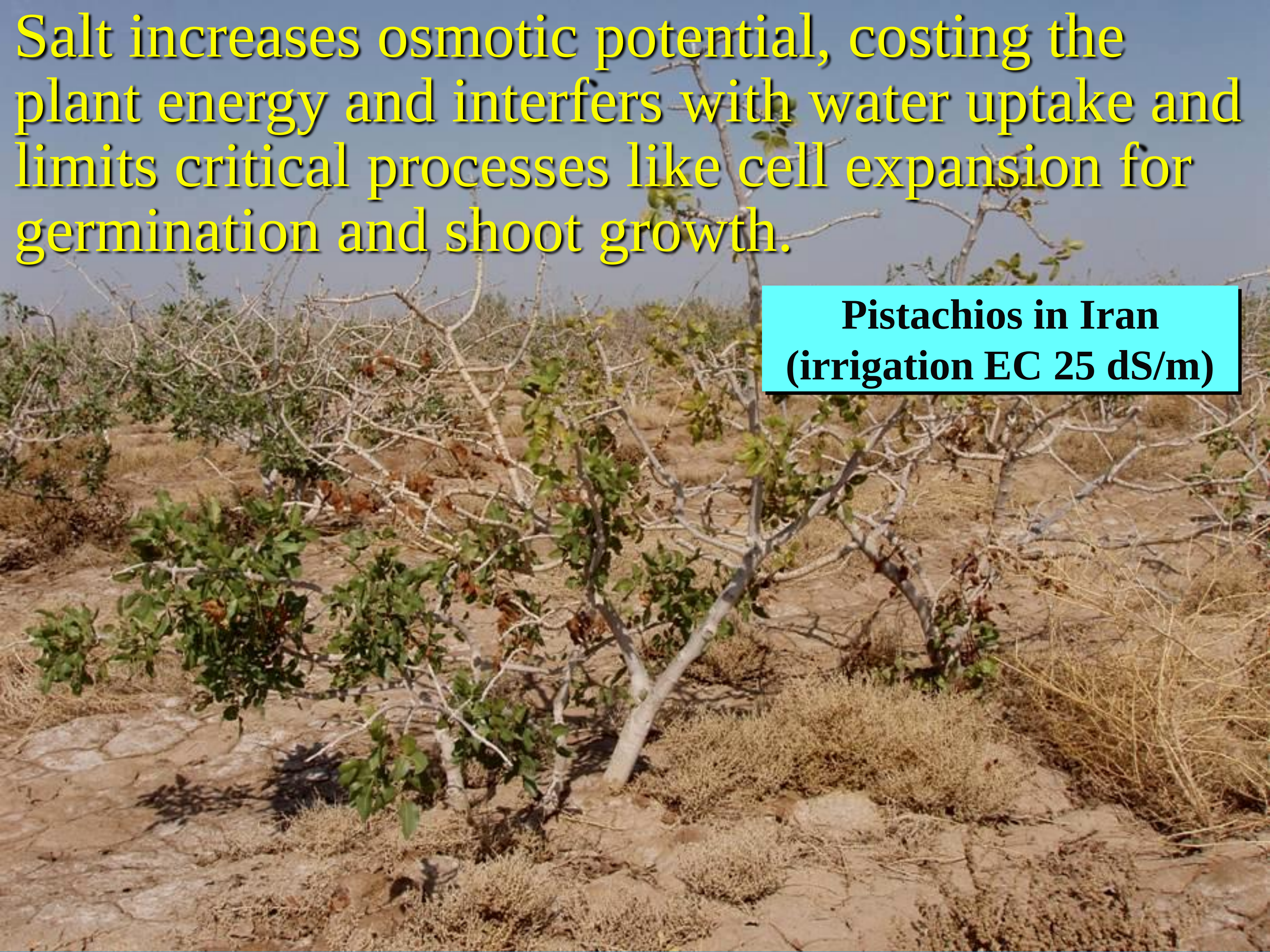
GENERAL SALINITY CONCERNS FOR SOIL & WATER QUALITY

What to evaluate?

- **SALINITY CONCERNS**



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)

CLASSIC GUIDELINES

Water Quality for Agriculture. **R.S. Ayers, D.W. Westcot. FAO Drainage Paper 29 Rev. 1,** Reprinted 1989, 1994
http://www.fao.org/DOCREP/003/T0234E/T0234E00.htm

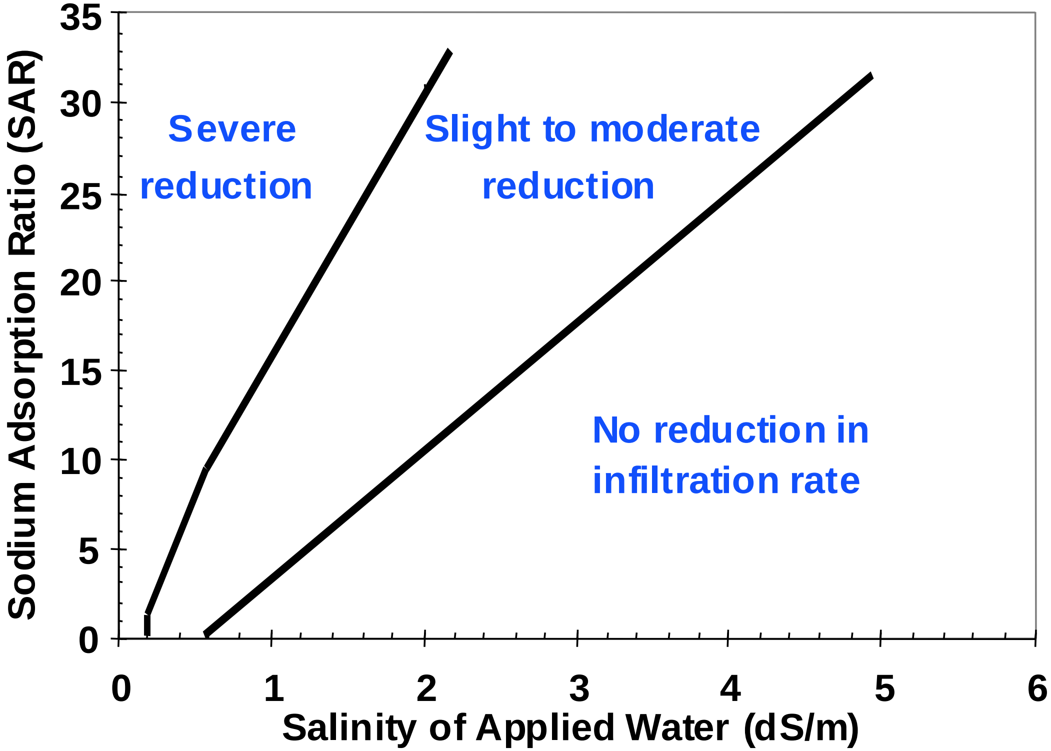
Excess sodium & bicarbonate destroying soil aggregation

Table 1 GUIDELINES FOR INTERPRETATIONS OF WATER Q
IRRIGATION[1]

Osmotic stress interfering with water uptake

Potential Irriga Problem		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 in 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

Toxicity, burn, nutrient problems



Infiltration Response to SAR and EC_{irr}

(Ayers, R.S. and D.W. Westcott. 1985. Water quality for agriculture. United Nations FAO Irrig & Drainage Paper No. 29, Rev.1.)

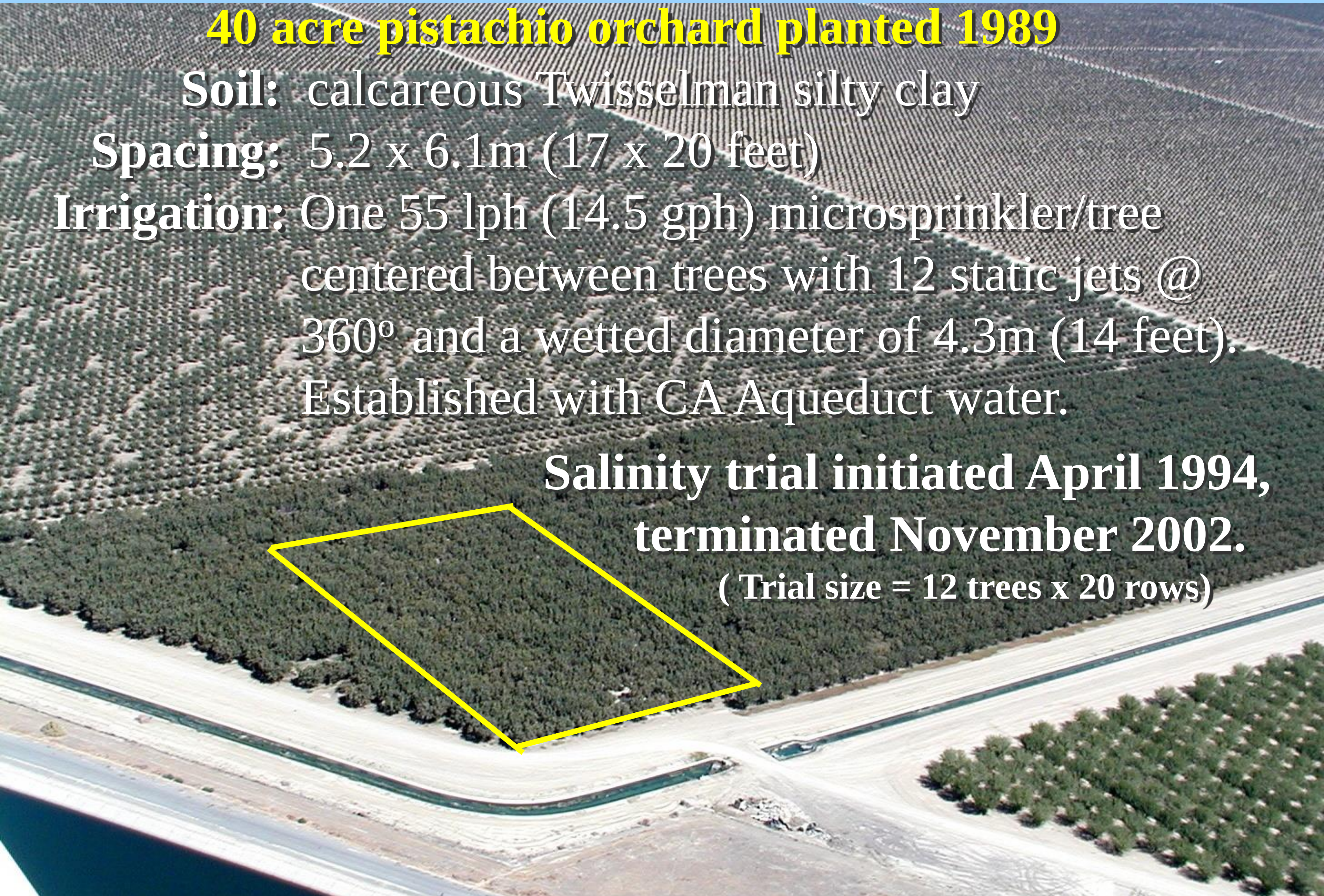
Impact of pH on micronutrient availability and emitter clogging.

- Mo deficiency
- Low Ca
- High Fe, Mn & emitter clogging

- Lime precip
- Chlorosis
- Fe, Zn, Cu, Mn deficiency

CURRENT SALINITY THRESHOLDS & RECOMMENDATIONS FOR PISTACHIO

First CA Trial – NW KERN COUNTY (Aerial 9/19/02)



40 acre pistachio orchard planted 1989

Soil: calcareous Twisselman silty clay

Spacing: 5.2 x 6.1m (17 x 20 feet)

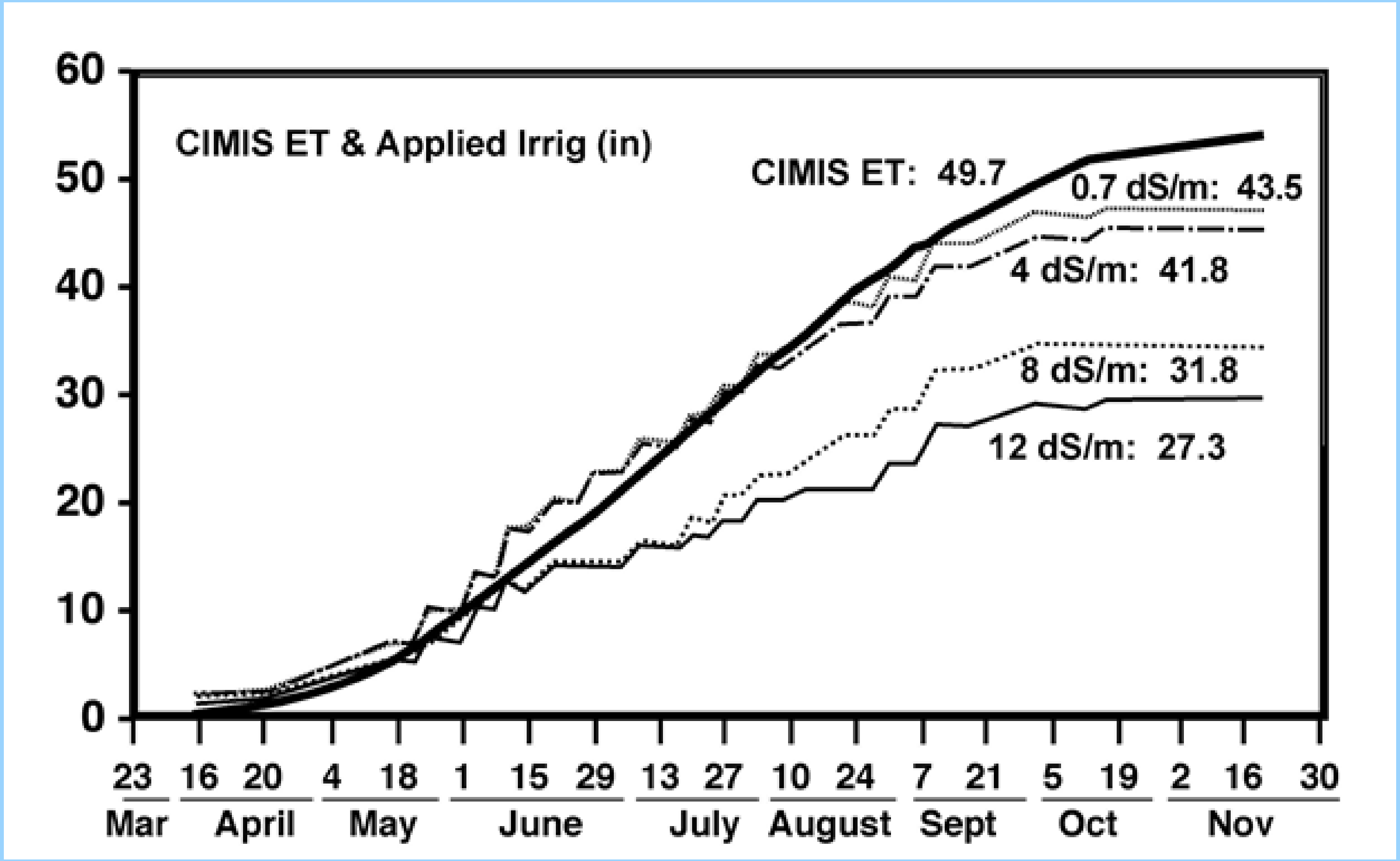
Irrigation: One 55 lph (14.5 gph) microsprinkler/tree centered between trees with 12 static jets @ 360º and a wetted diameter of 4.3m (14 feet). Established with CA Aqueduct water.

Salinity trial initiated April 1994, terminated November 2002.

(Trial size = 12 trees x 20 rows)

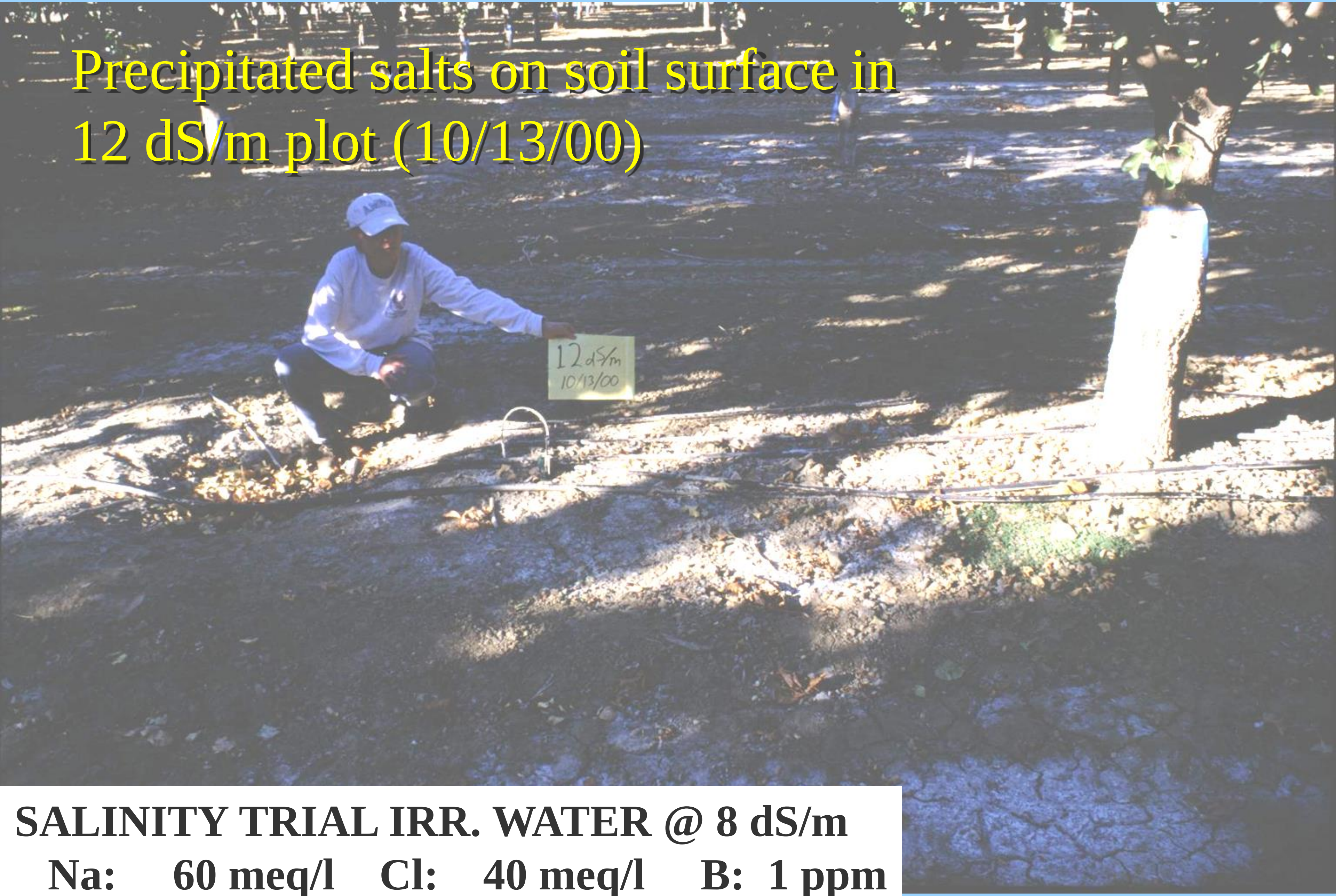

Plots only 4 trees
long for original
salinity trial

•SOIL SALINITY & ET for 2002 SEASON



Pistachio's showed significant decreases in relative cumulative transpiration for westside salt tolerance trial but average yields did not decline until irrigation salinity was > 8 dS/m.

Precipitated salts on soil surface in 12 dS/m plot (10/13/00)



SALINITY TRIAL IRR. WATER @ 8 dS/m

Na:	**60 meq/l**	**Cl:**	**40 meq/l**	**B:**	**1 ppm**
	1,380 ppm		**1,400 ppm**		

Cumulative Yields by Salinity

Yield (kg/tree) Rootstock	Cumulative and (Average Annual) Yield per tree; 1997 - 2002				
	Irrigation Water / Root Zone Salinity*				12 dS/m yield as a % of control yield
	0.75 / 4.7*	4.0 / 8.7*	8.0 / 11.3*	12.0+ / 13.2*	
Atlantica	46.3 (7.7)	47.3 (7.8)	42.4 (7.1)	38.0 (6.3)	82%
PGI	57.3 (9.6)	52.1 (8.7)	51.6 (8.6)	51.8 (8.6)	90%
PGII	50.3 (8.4)	51.8 (8.6)	54.6 (9.1)	42.9 (7.2)	85%
UCB1	56.0 (9.3)	62.0 (10.3)	53.6 (9.4)	36.2 (6.0)	65%

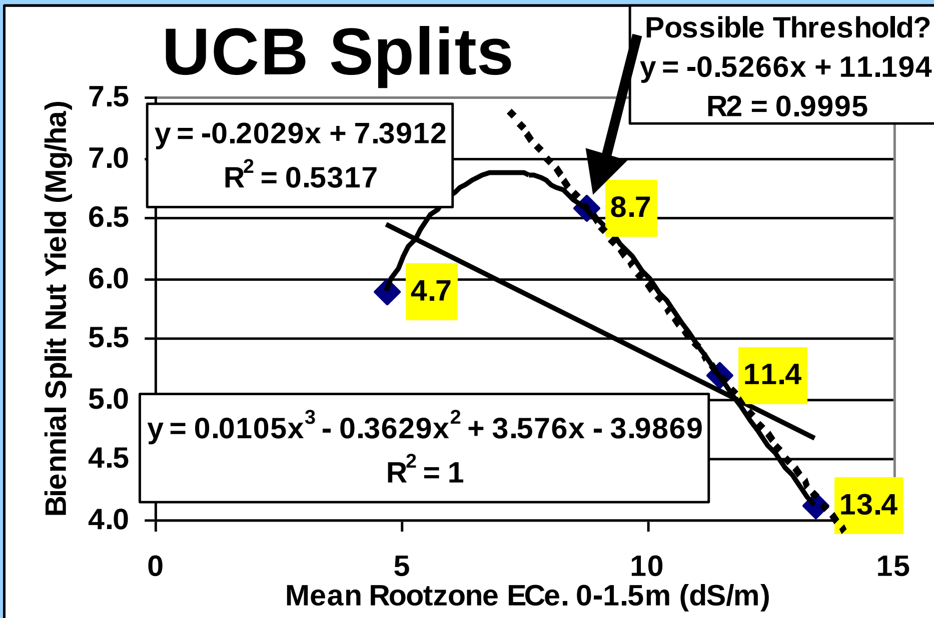
*Soil salinities are end of season 2002 values.

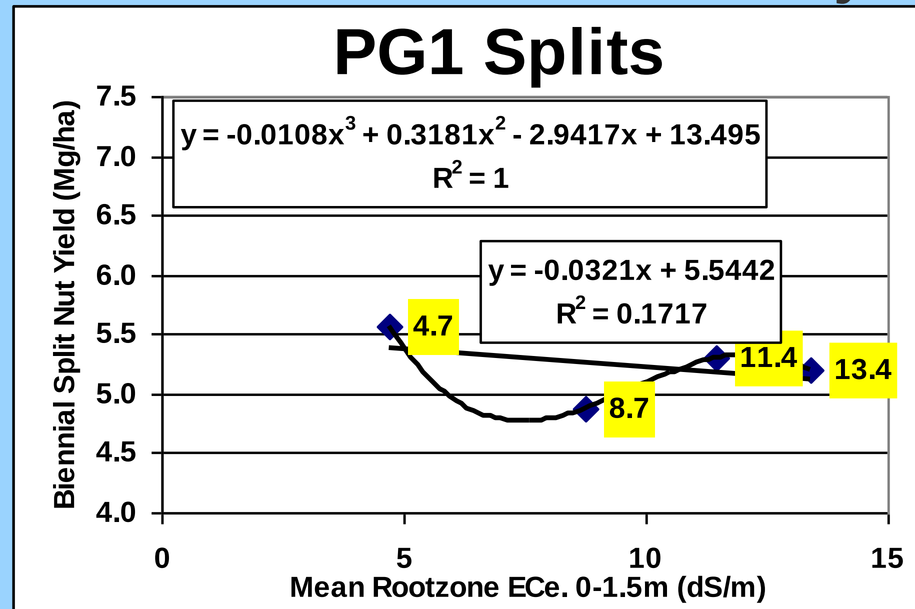
+12 dS/m irrigation was only applied for 1997 through 2002 seasons.

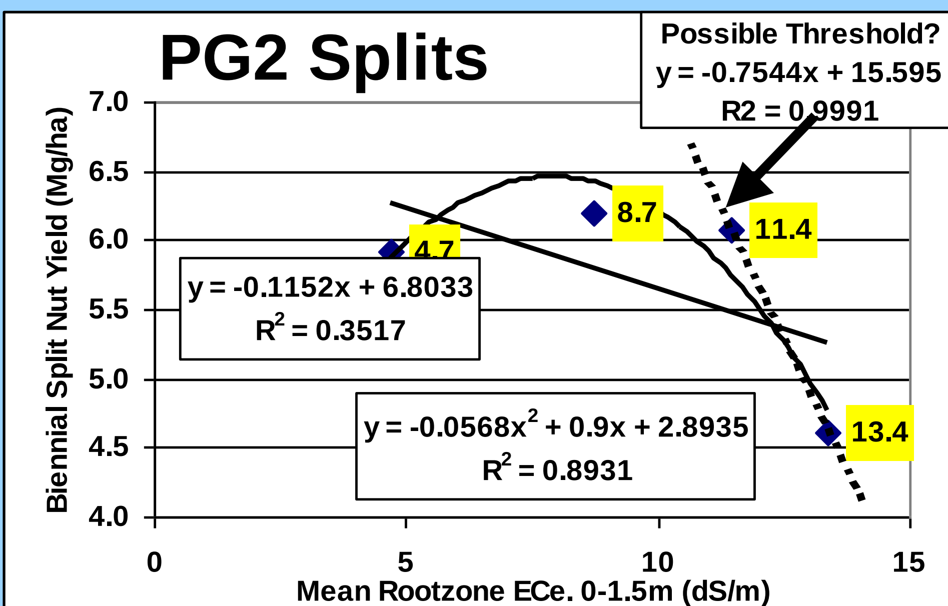
8th-13th Leaf Average Annual Yield for 0.75 to 8 dS/m water (lb/ac):

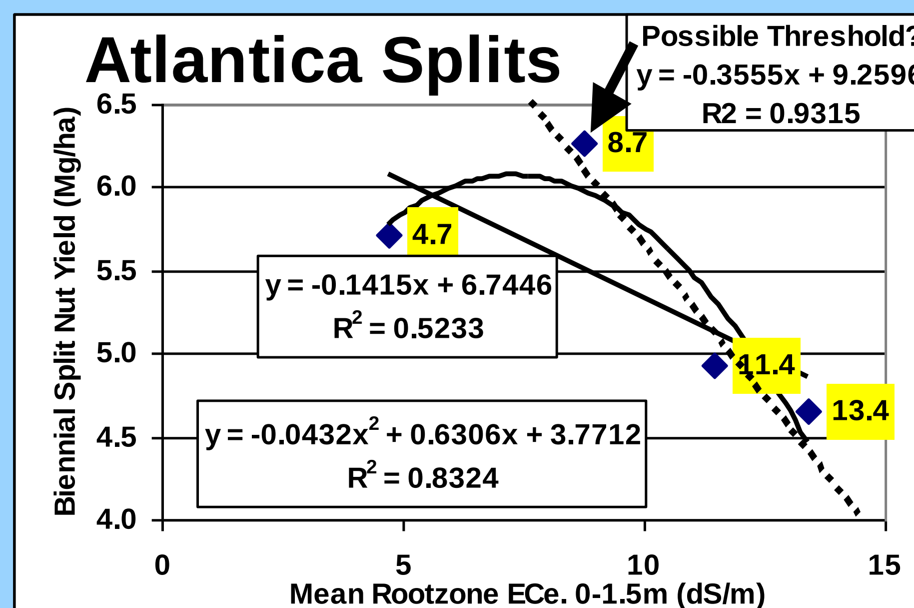
PG1	UCB1
2,531	2,727

Westside Salinity Trial 2001/2002 Biennial Split Nut Yields for all Varieties as a Function of Rootzone Salinity

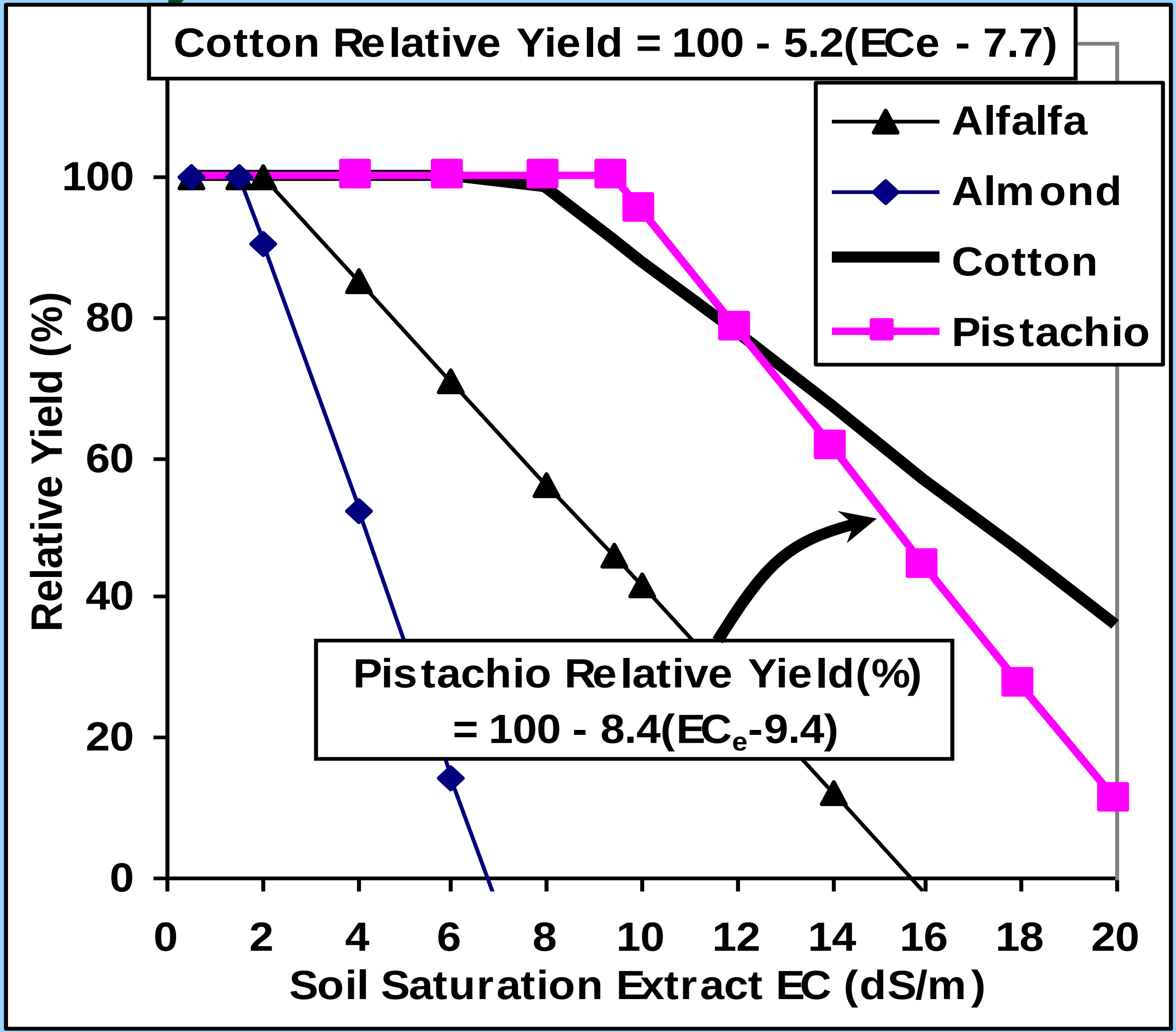






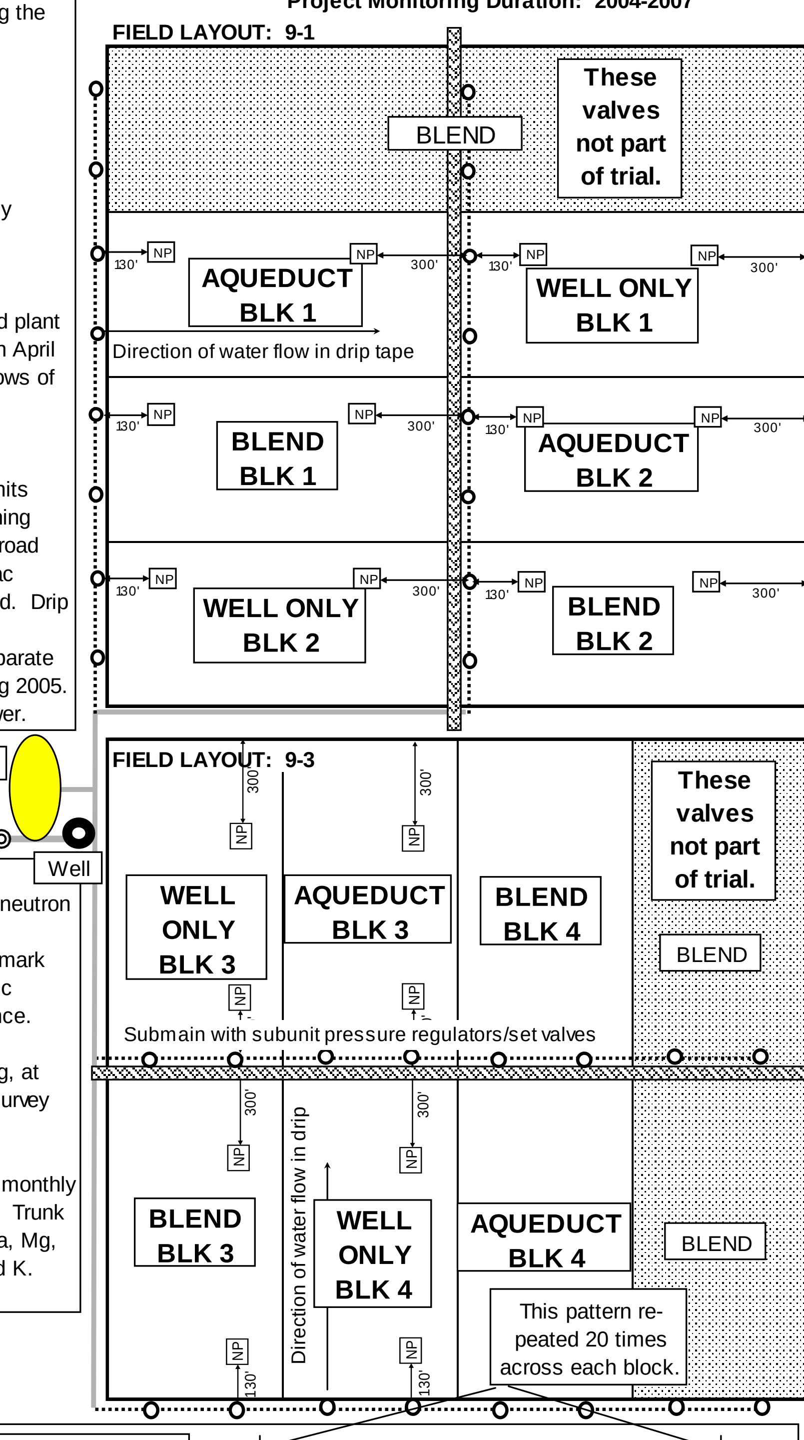


Relative yield of as a function of soil ECe



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.

WHAT ABOUT DEVELOPING NEW PISTACHIO PLANTINGS USING SALINE WATER?



Belridge Salinity Trial (with cotton interplant)

-- 2, 155 acre fields

-- 12, 19.5 acre testplots

Objectives

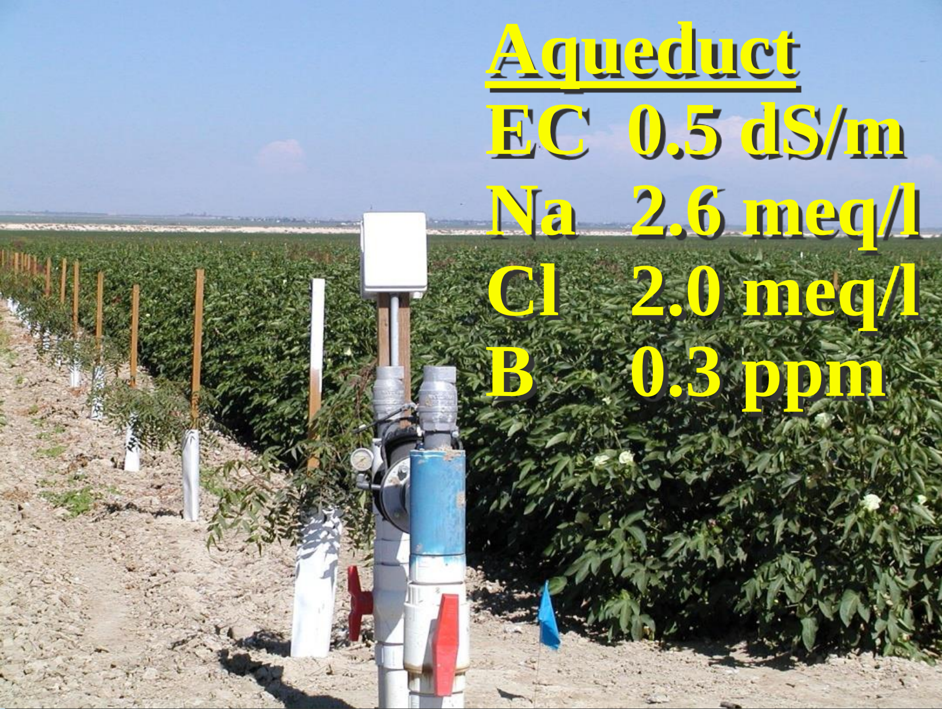
1. **Assess the viability of large-scale cotton production and pistachio interplanting using saline groundwater (EC 5 dS/m and B @ 10 ppm) and optimal irrigation scheduling with SDI.**

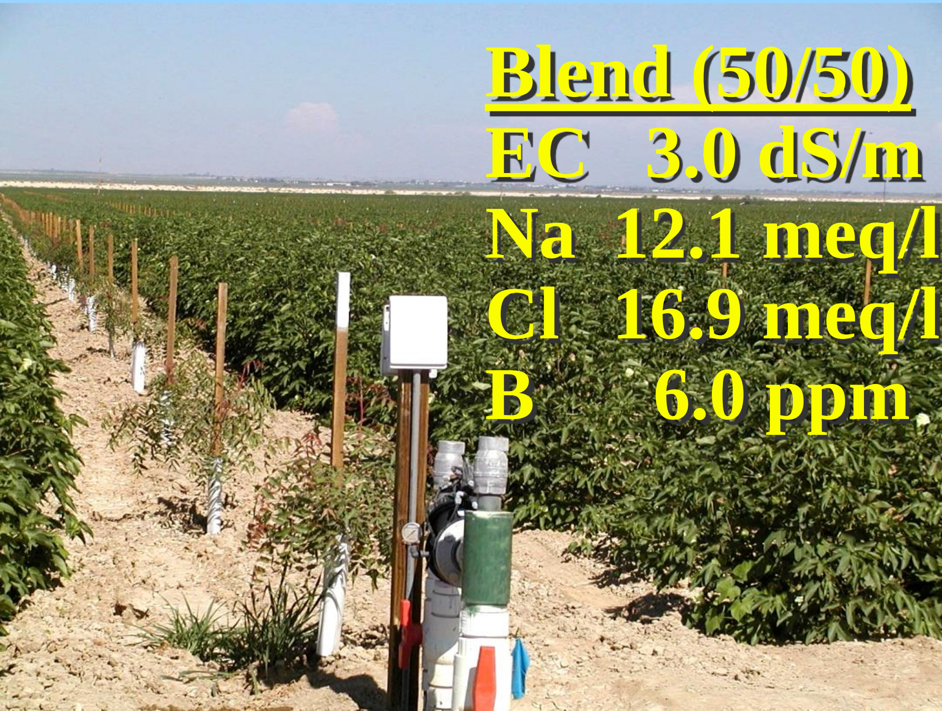
2. **Reexamine the pistachio salt tolerance threshold when starting with new trees.**

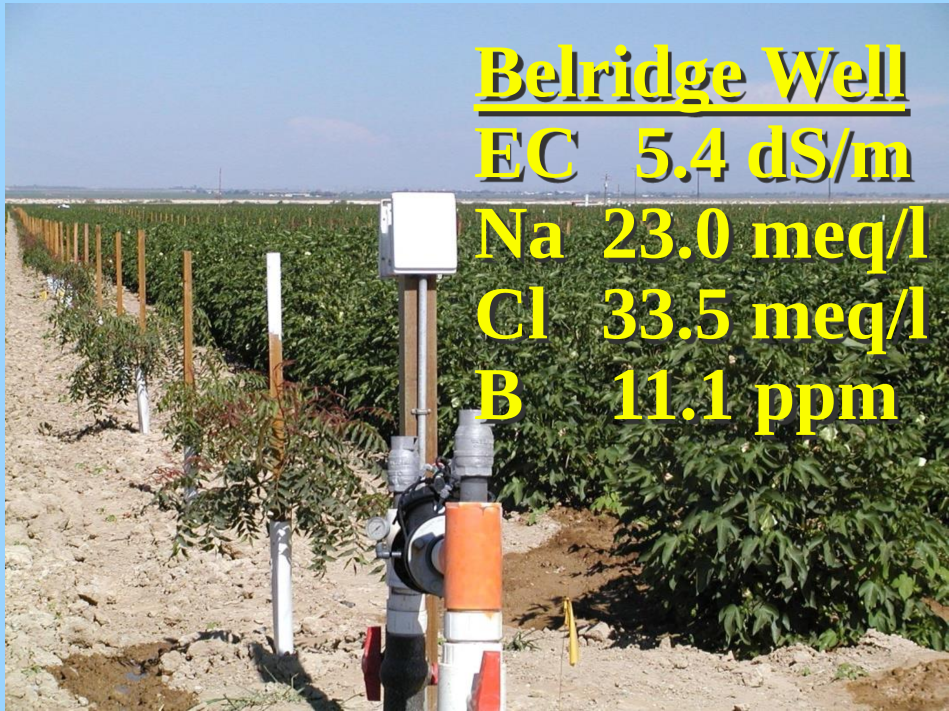
3. **Compare total project profitability under SDI using 3 different levels of salinity: saline water, non-saline CA Aqueduct water and a 50/50 blend.**

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

(1st leaf, 8/2/05)



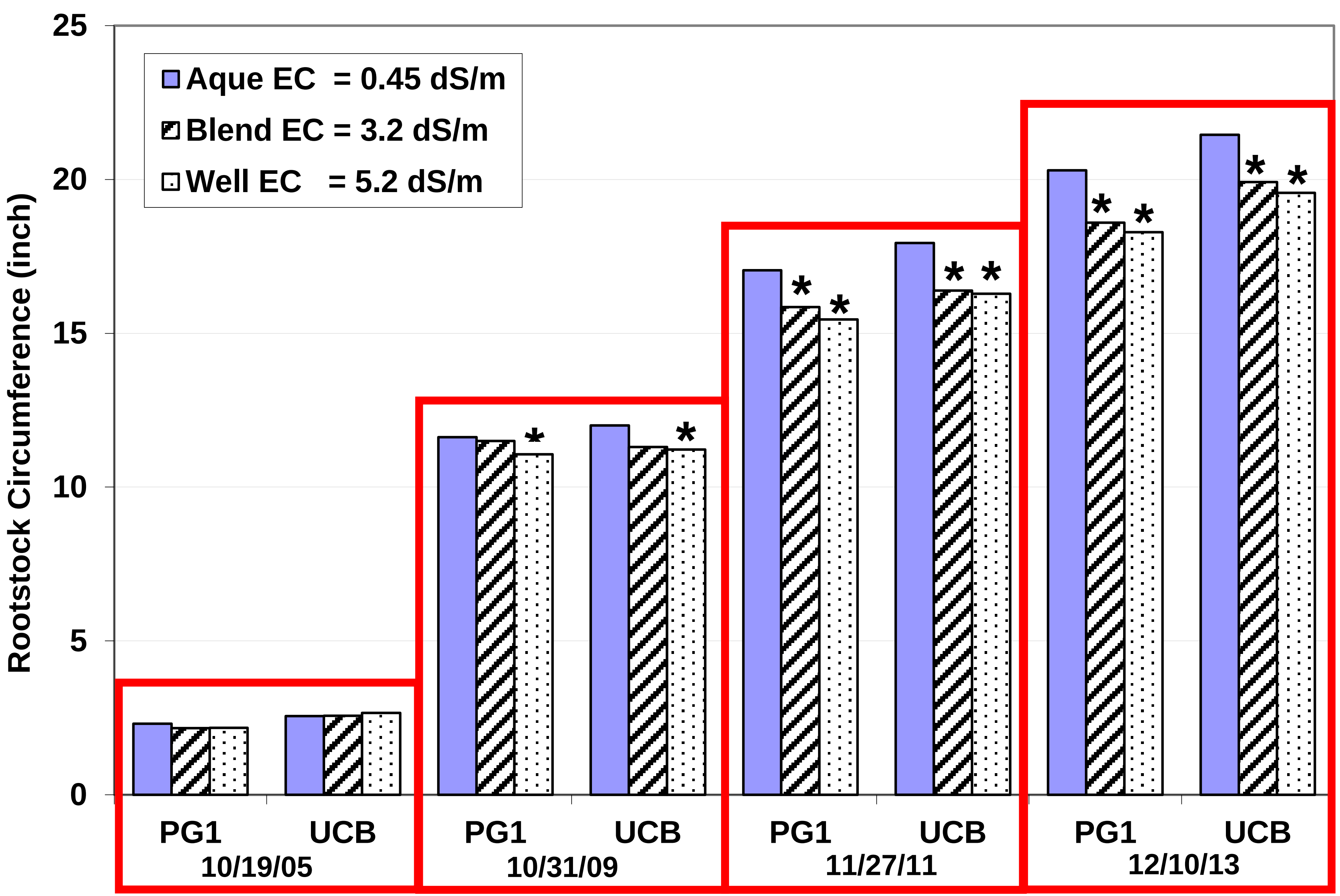




Marginal burn was seen on most leaves

9-1 West Compare

2009-13 rootstock growth decreased 7 to 10% from well water



Trees planted March 5-11, 2005. *Irrigation salinity impact statistically significant

Change in tissues and soil salinity

	NO3-N (ppm)	NH4-N (ppm)	PO4-P (ppm)	K (%)	Na (ppm)	Cl (%)	B (ppm)
Rootstock Leaves 9/15/05					**Pistachio 2005**		
Aque	63	160	580	1.02	222	**0.27**	**194**
50/50	55	128	545	1.06	220	**0.27**	****492**
Well	65	148	500	1.08	314	****0.38**	****673**

Critical levels of specific ions in leaf tissue (For August tissue samples prior to harvest.)

	Degree of toxicity		
	None	Increasing	Severe
Specific ion	Levels in Leaf Tissue		
Chloride (%)	< 0.2	0.2 – 0.3	> 0.3
Boron (mg/l)	< 300	300 - 700	> 800

	K (%)	Na(ppm)	Cl (%)	B(ppm)
(PG1)			**Pistachio 2009**	
	2.69	100	0.20	378
	2.83	94	0.22	**831
	2.79	90	0.22	**780
(UCB1)			**Pistachio 2009**	
	2.08	80	0.16	318
	2.17	81	0.17	**616
	2.28	91	0.19	**716

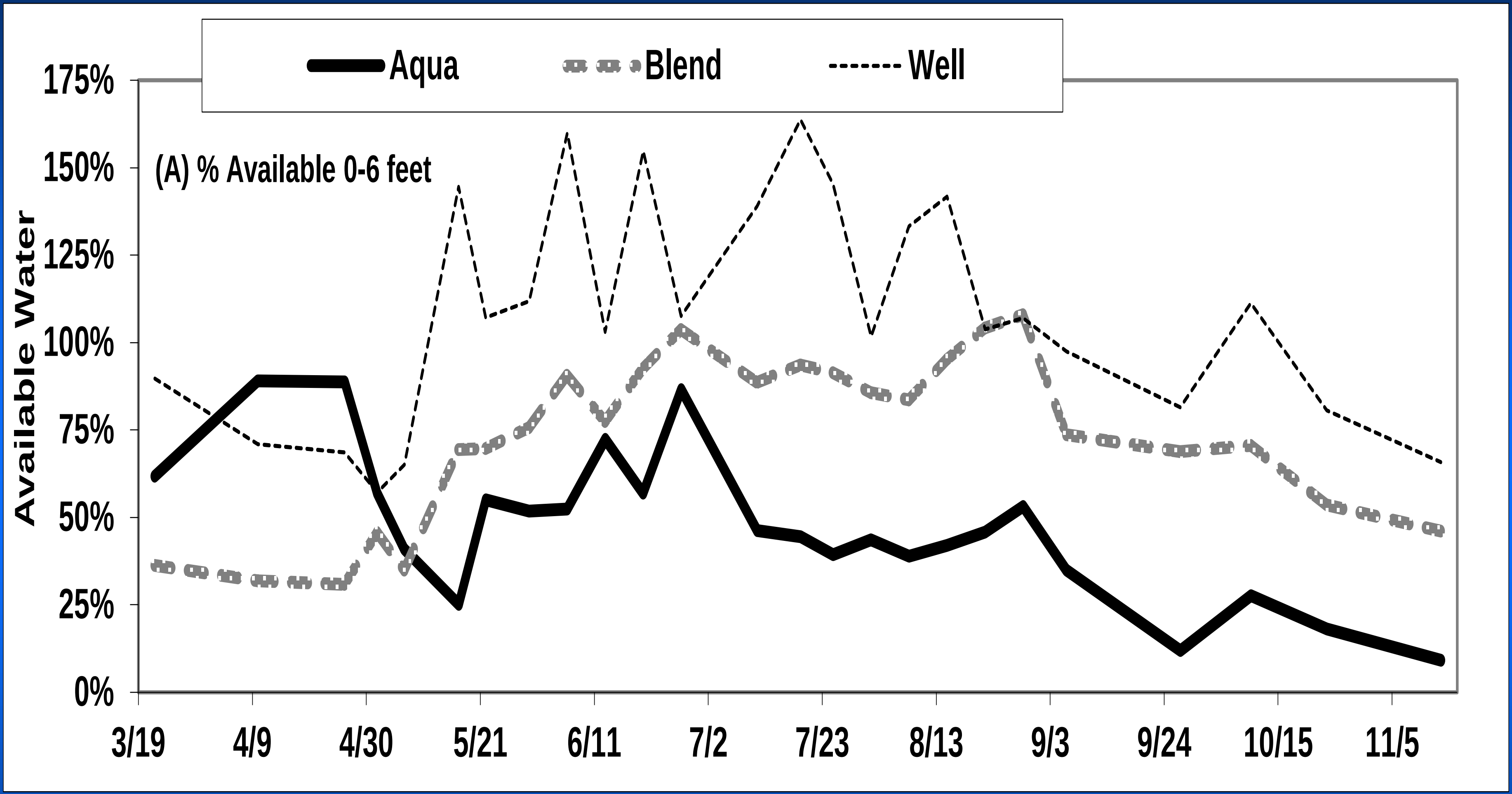
	NH4-N	PO4-P	K	Na	Cl	B
Kerman Leaves 8/28/13 (PG1)					**Pistachio 2013**	
Aque	1.96	0.09	1.97	400	0.20	637
Blend	2.23	0.12	2.49	425	0.33	**1345
Well	1.88	0.10	2.45	400	0.38	**1790
Kerman Leaves 8/28/13 (UCB1)					**Pistachio 2013**	
Aque	1.95	0.10	1.87	450	0.20	537
Blend	2.22	0.12	2.14	475	0.23	**959
Well	2.09	0.11	2.11	450	0.25	**1122

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**

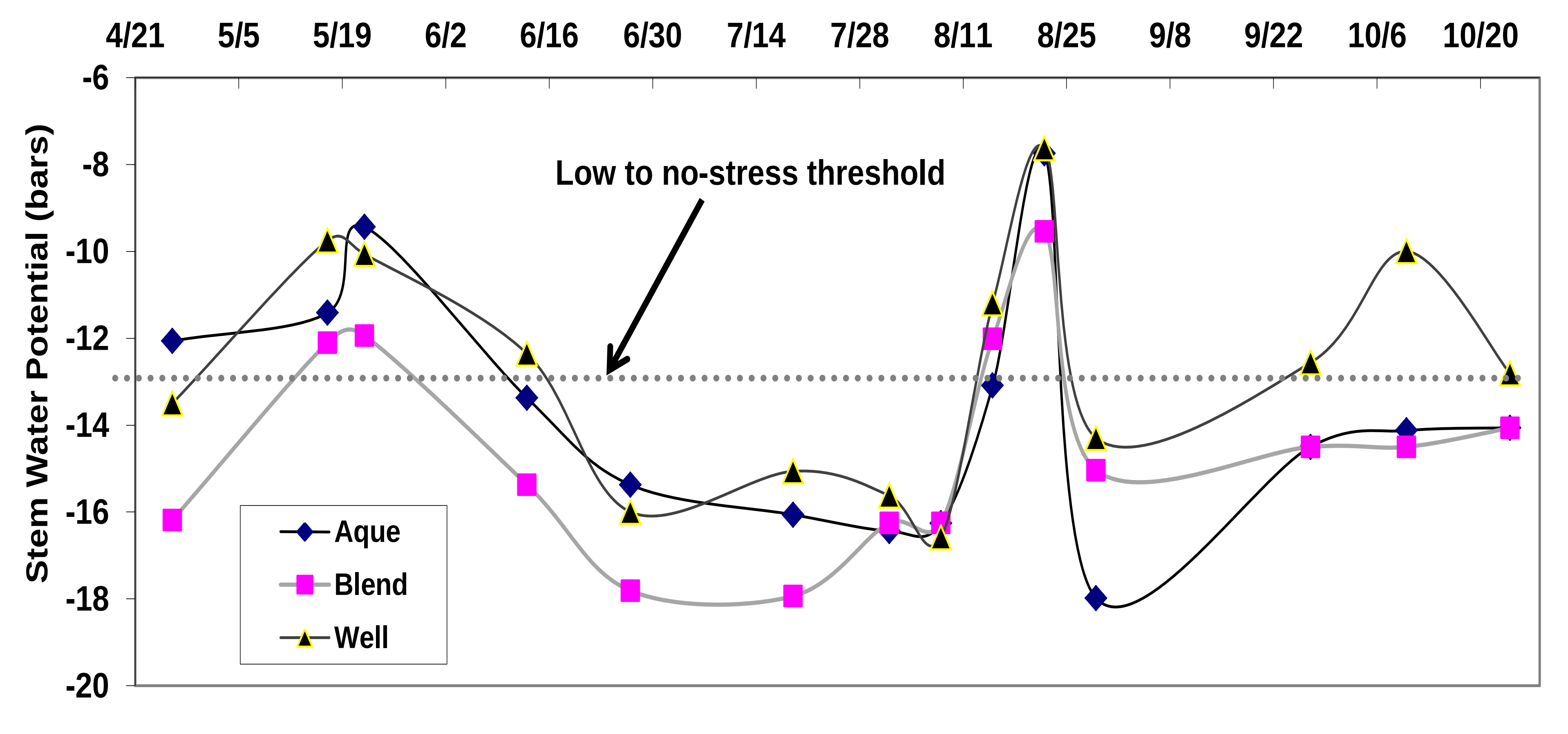
[1]Irrigation inches for total tree spacing, salt totals (lb/ac) calculated for a 9.5 foot wide subbing area centered on the tree row. Assumes 640 ppm soluble salt = 1 dS/m and a 5 ac-ft depth of soil = 20 million lbs.

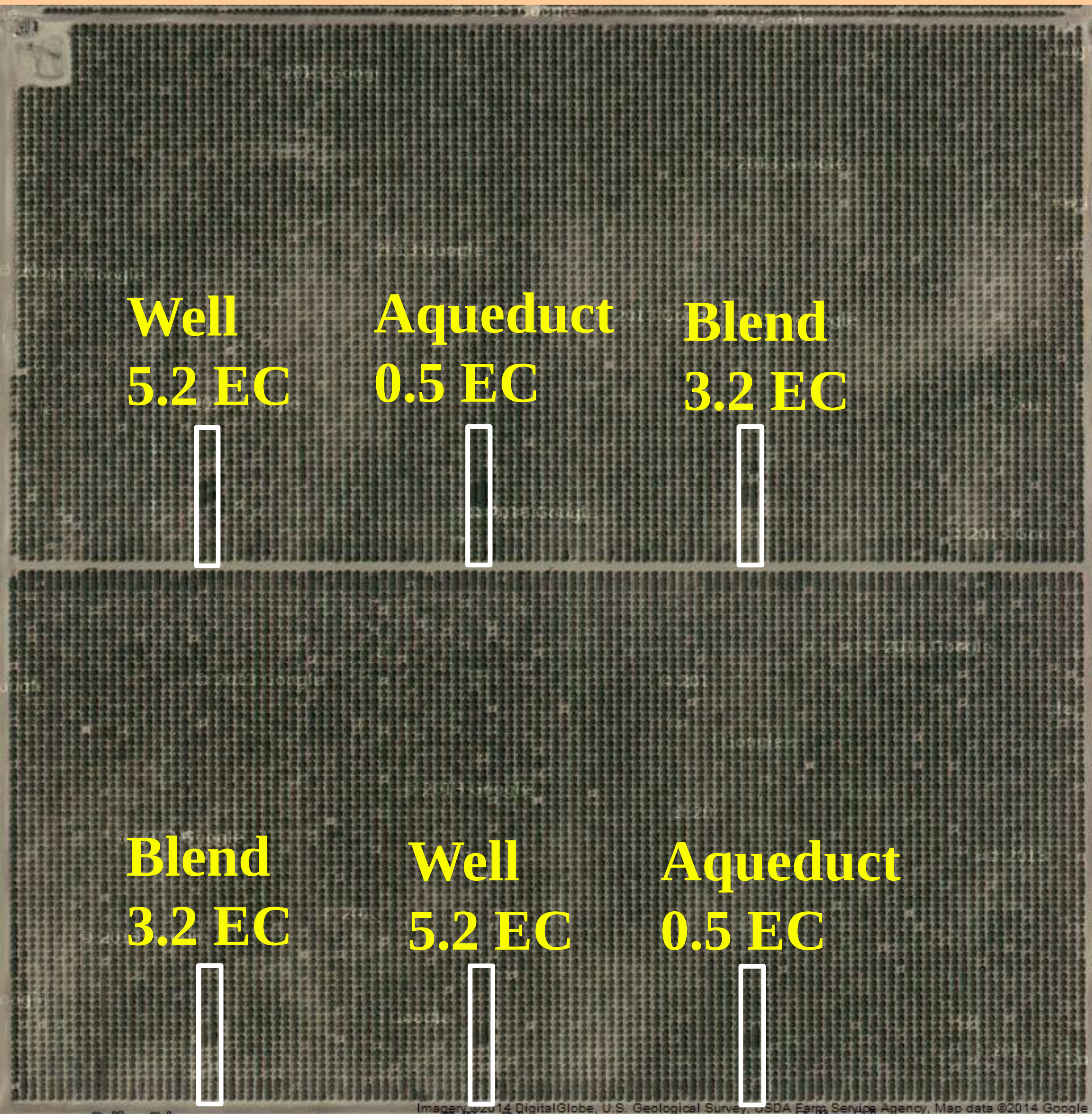
[2]Maximum increase in soil saturated paste EC for a 5 foot rootzone with no precipitation of salts and no leaching past the 5 foot depth.



2013 neutron probe soil moisture showed even more leaching for the 5.2 dS/m treatment

2013 Stem Water Potential (3.2 dS/m treatment had significantly greater stress from April to August)



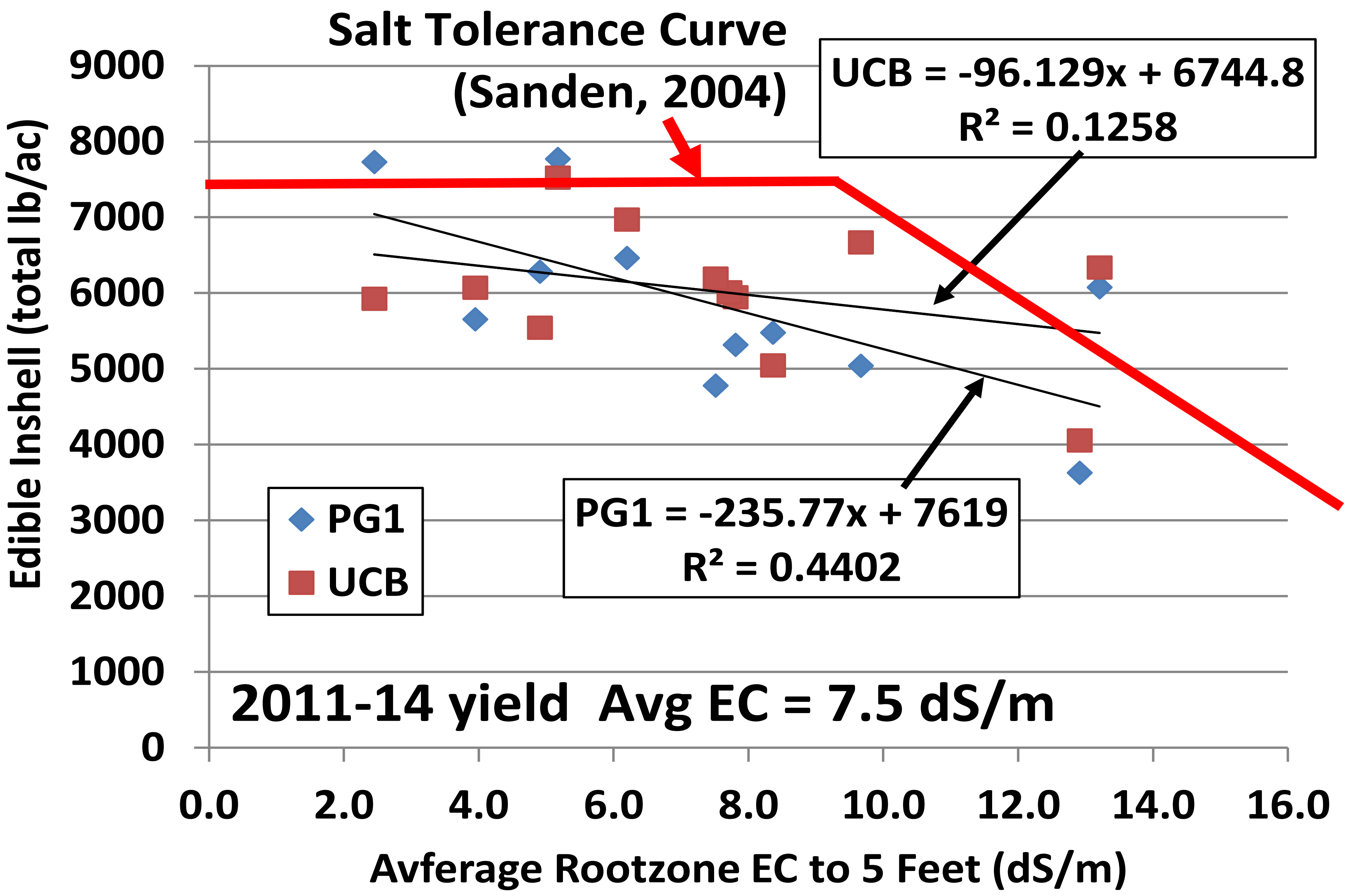


July 2014 aerial of southern half of trial. White boxes are the 40 tree harvested plots.

But it's the nuts that count!

1st Harvest
9/23/11
2nd Harvest
9/13/12
3rd Harvest
9/5/13

2011-14 Yield Decline byRootstock & Rootzone Salinity

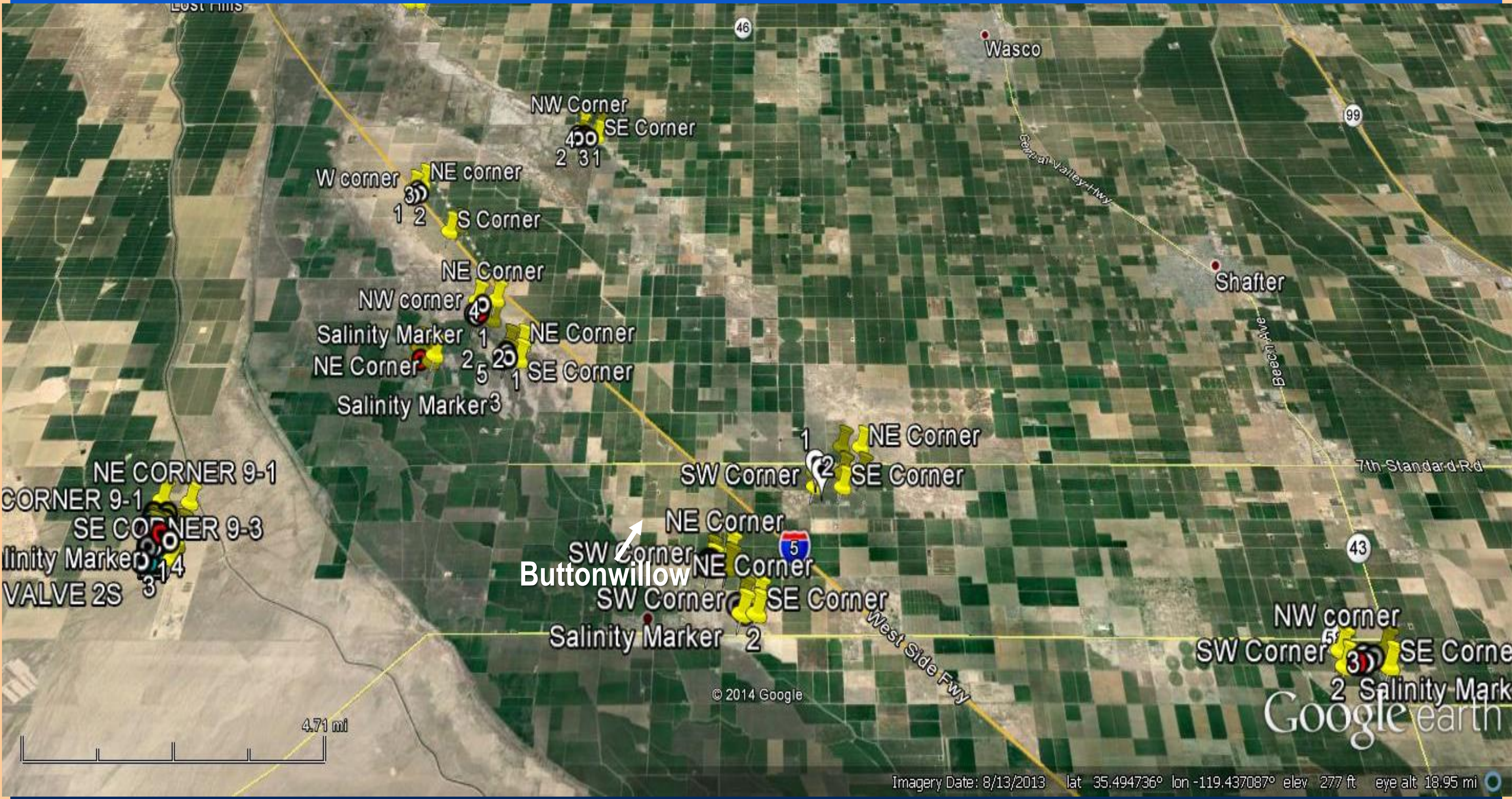


Practically speaking a salinity threshold of 5 to 6 dS/m average rootzone ECe is evident after 10 years with a yield decline of 3.0% for PG1 and 1.4% for UCB for every additional unit increase in ECe.

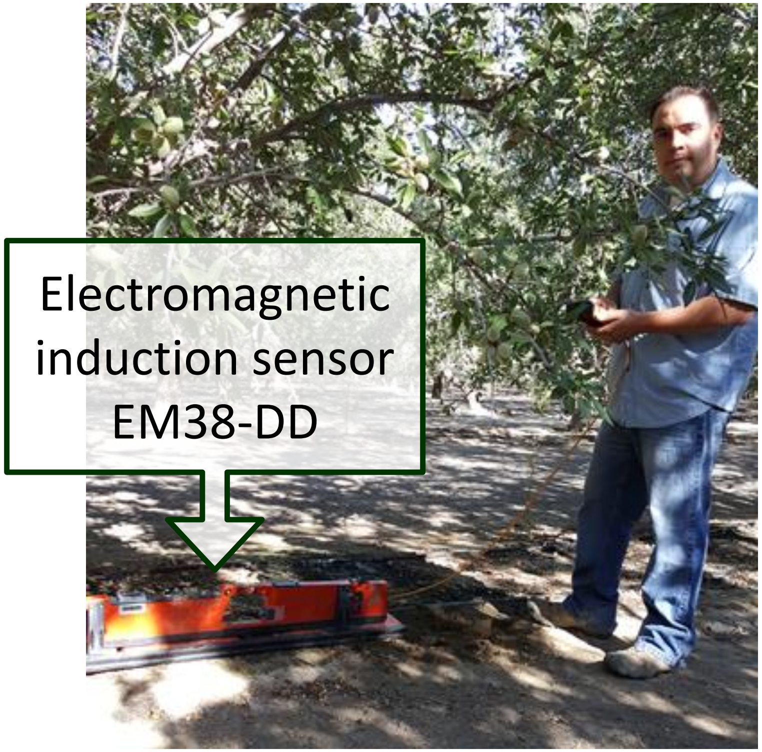
Latest project: A "real world" pistachio salt tolerance survey

Building on a one field 10 year trial that indicated pistachio yield loss occurs at a lower soil salinity than previously published, complete a 2 to 4 year cycle of tree, soil and yield data collection from an additional 9 other salt-affected orchards with variable rootzone salinity of 2 to 25 dS/m EC. The final product will be a "real world" production relevant salt tolerance curve for pistachios in the SJV.

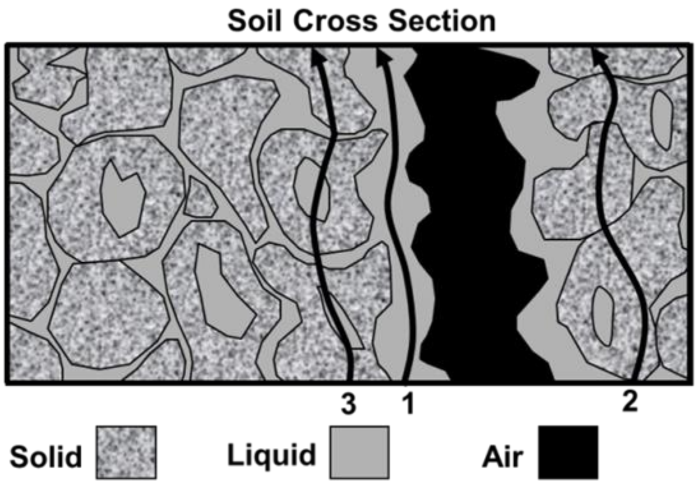
2014-16 Defining a 'Real World' Salt Tolerance Curve for San Joaquin Valley Pistachios (Areal extent of survey over 10 pistachio fields (1300 ac, over 203 miles^2 in NW Kern County)



Soil apparent electrical conductivity (EC_a)



Several depths of penetration
0-75 cm, 0-150 cm



Rhoades et al., 1989

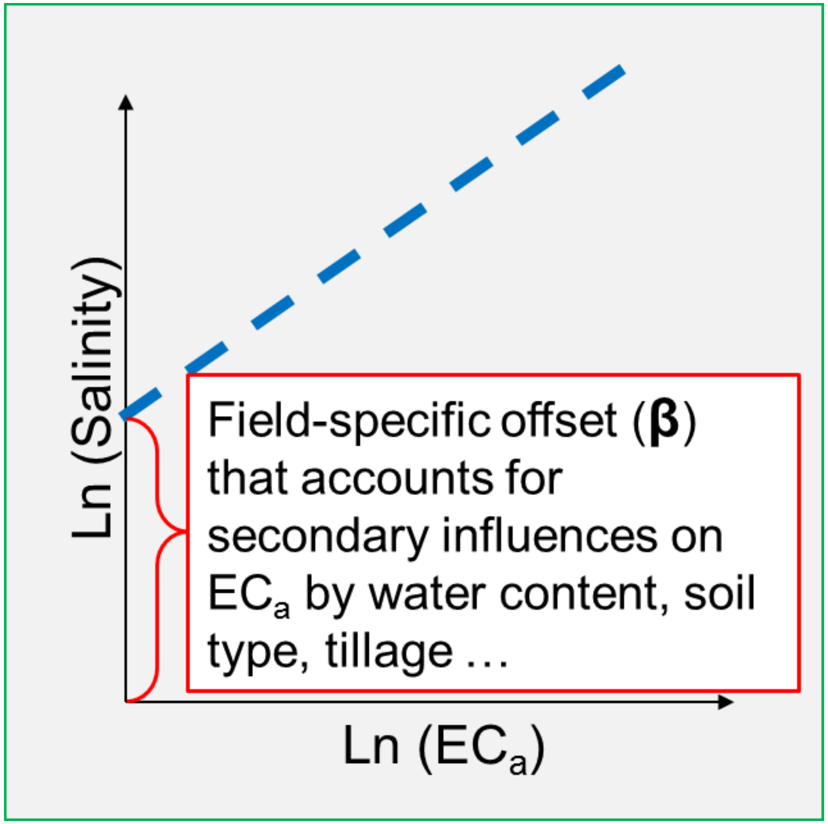
EC_a complex measurement:

- Salinity (**EC_e**) ↑
- Texture (Sand ↓; Clay ↑)
- Water Content ↑
- Gravel (↓)
- ....

Farm-scale ANOCOVA EC_a-salinity calibration

How to reduce soil sampling expenses when
- mapping multiple fields?
- monitoring with high temporal resolution?

$$\ln(\mathrm{EC_e}) = \ln(\beta) + \alpha \times \ln(\mathrm{EC_a}) + \varepsilon$$



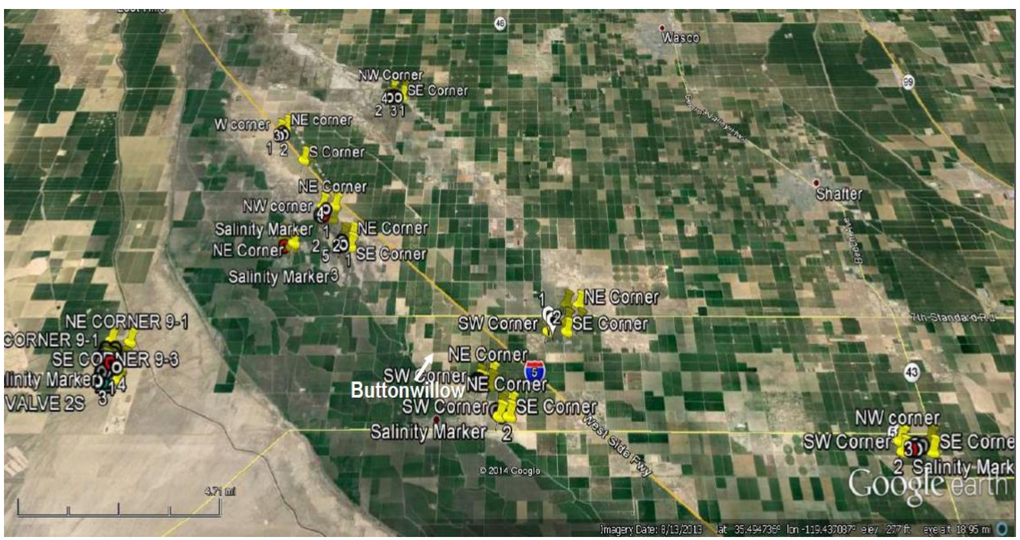
ANOCOVA modeling

Corwin and Lesch, 2014. *A simplified regional-scale electromagnetic induction—salinity calibration model using ANOCOVA modeling*. Geoderma 230, 288-295

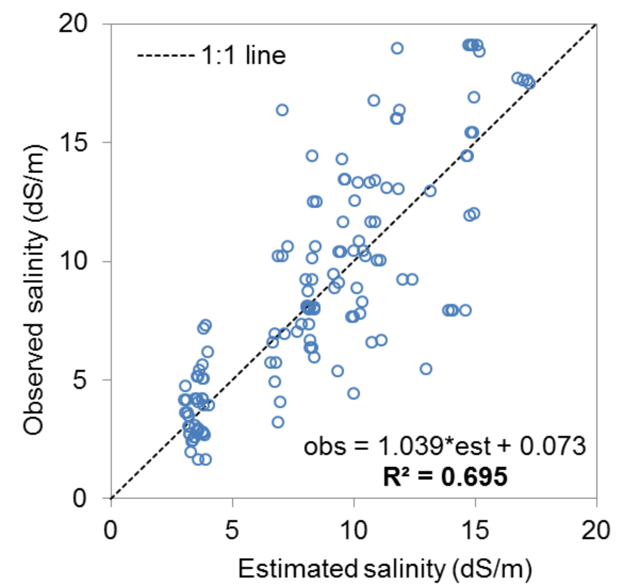
CS2: Multi-field ANOCOVA EC_a-salinity calibration over pistachio fields

- 14 pistachio fields sampled by Blake Sanden
- 140 soil samples (**0–1.2 m**): Salinity (**EC_e**), and other soil properties

  → Apparent Electrical Conductivity (**EC_a**) measurements at 0-0.75 (EC_aH) & **0-1.5 m (EC_aV)** with EM38 Dual Dipole

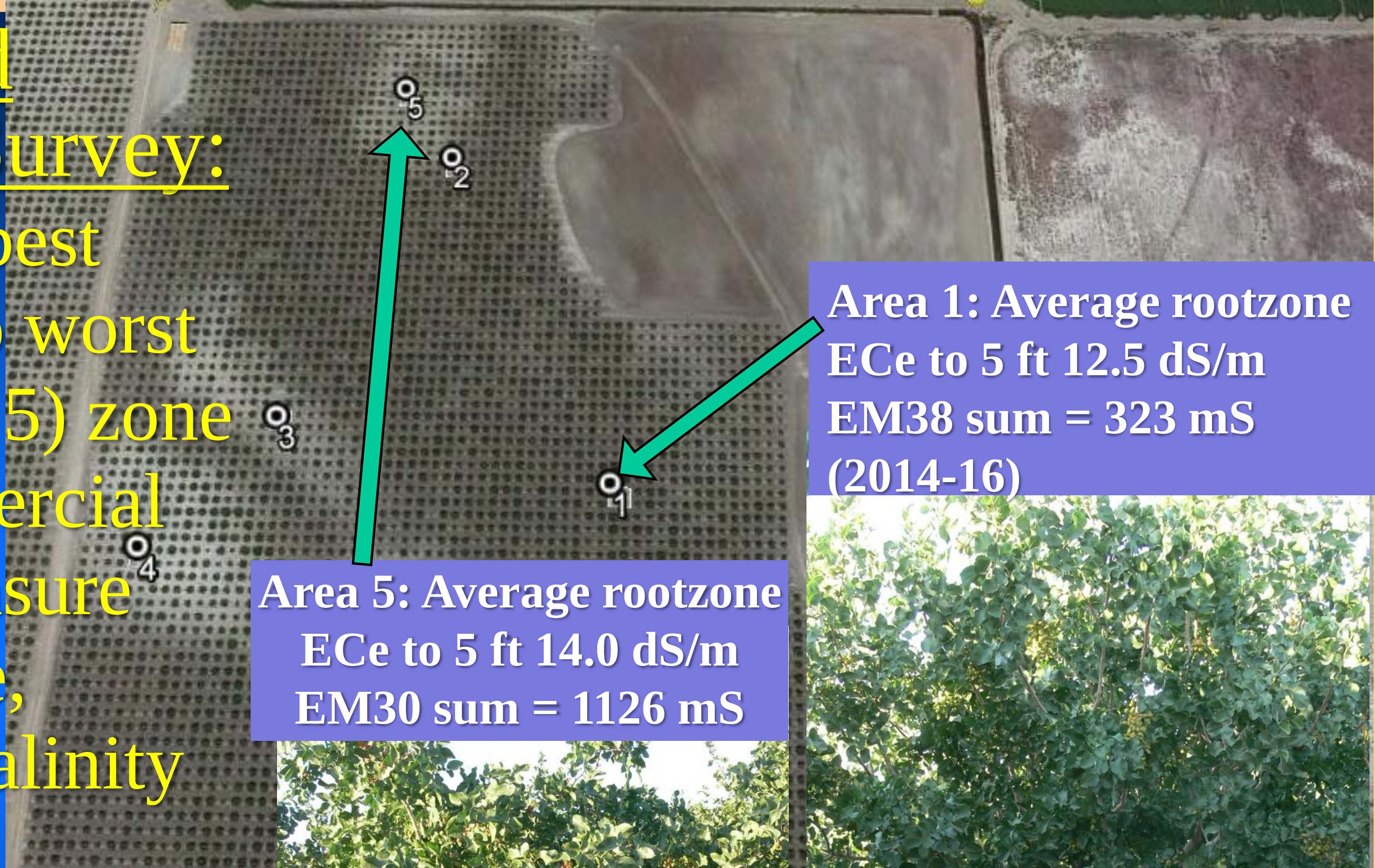


Preliminary analyses ↓



Expanded Salinity Survey:

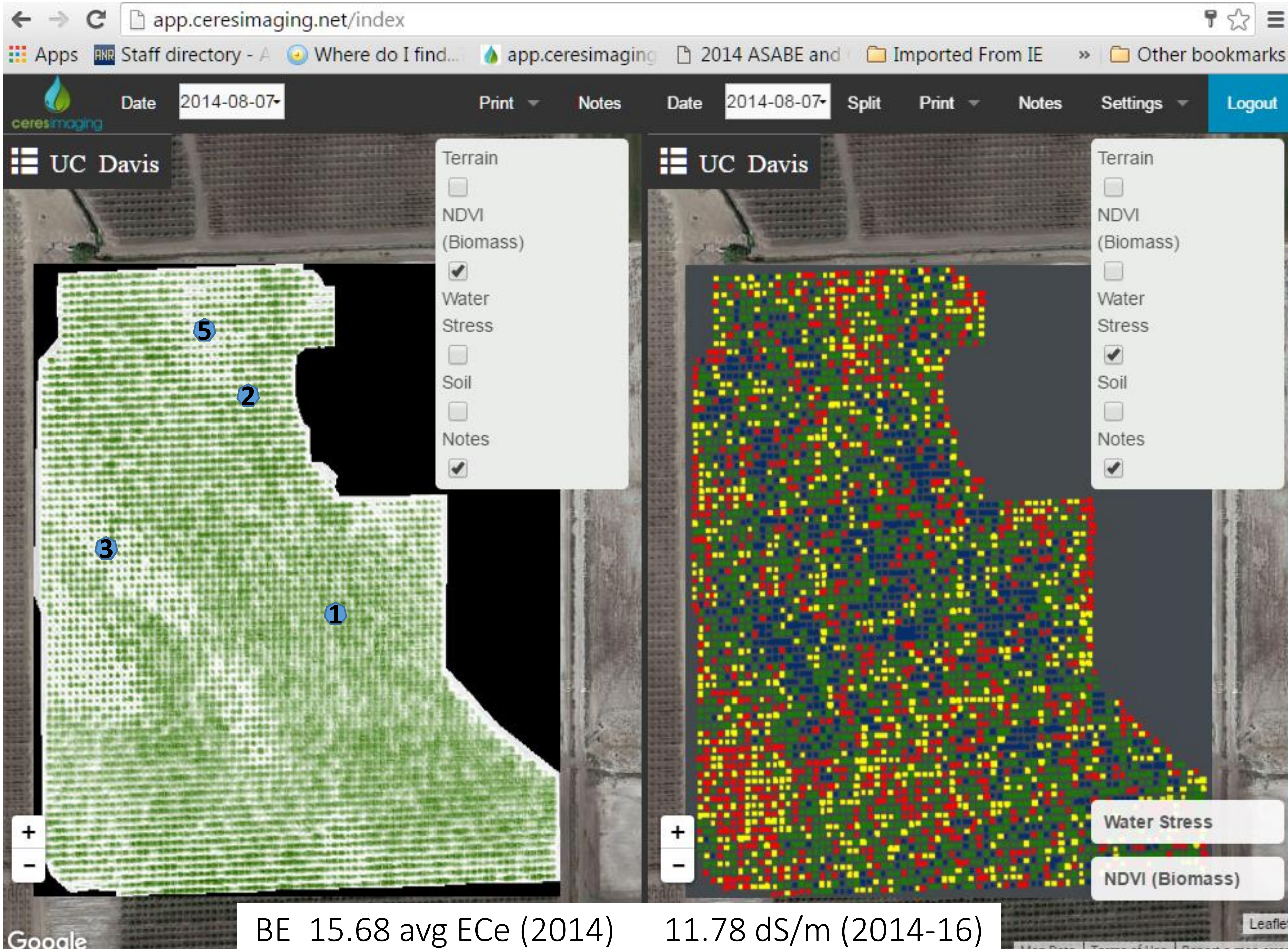
select the best (Area 1) to worst (Area 4 or 5) zone in a commercial field. Measure tree stature, rootzone salinity and yield



Area 1: Average rootzone ECe to 5 ft 12.5 dS/m EM38 sum = 323 mS (2014-16)

Area 5: Average rootzone ECe to 5 ft 14.0 dS/m EM30 sum = 1126 mS

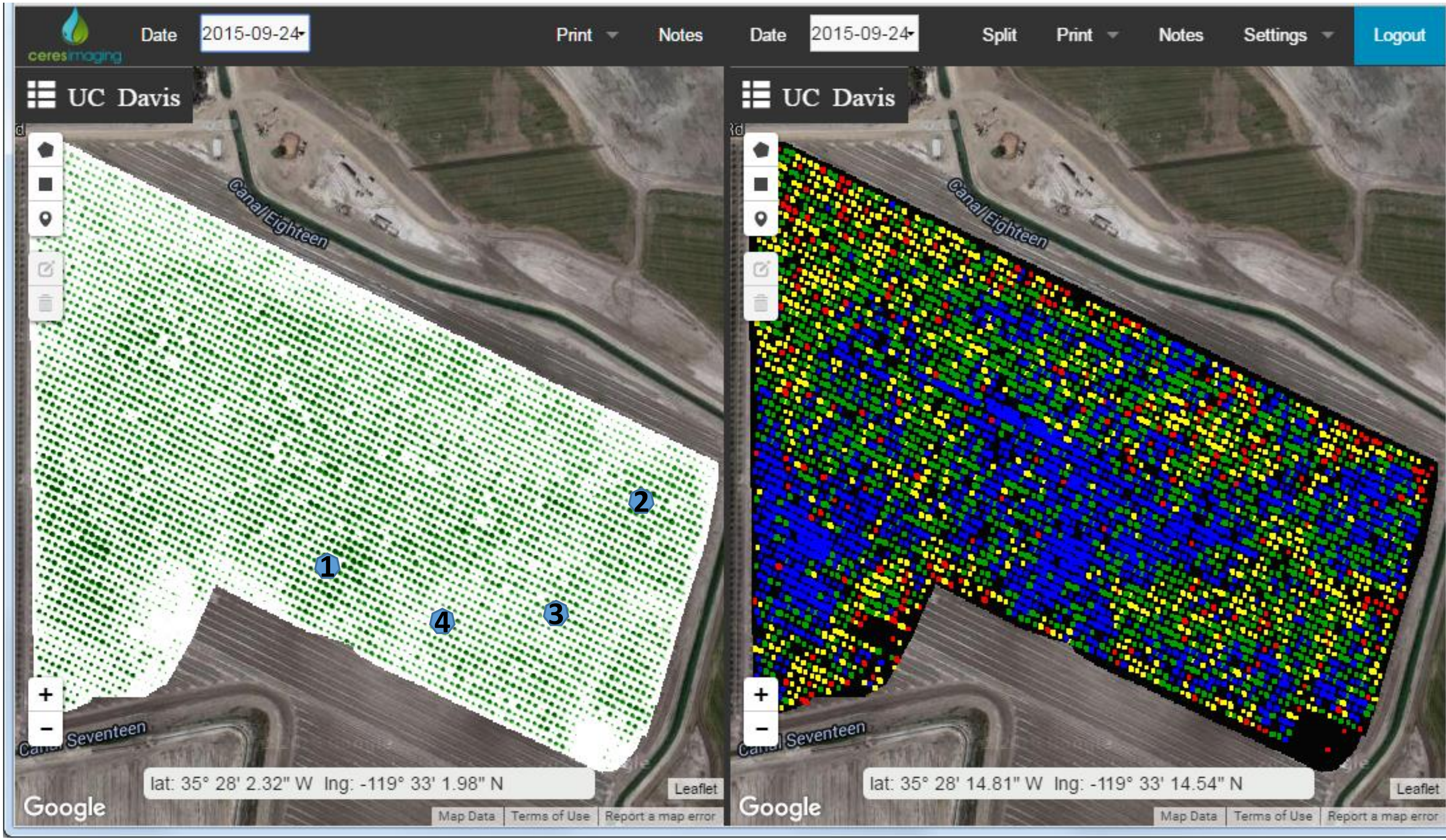
Geonics EM38-DD magnetic conduc-tance probe for non-invasive estimate of ECa.

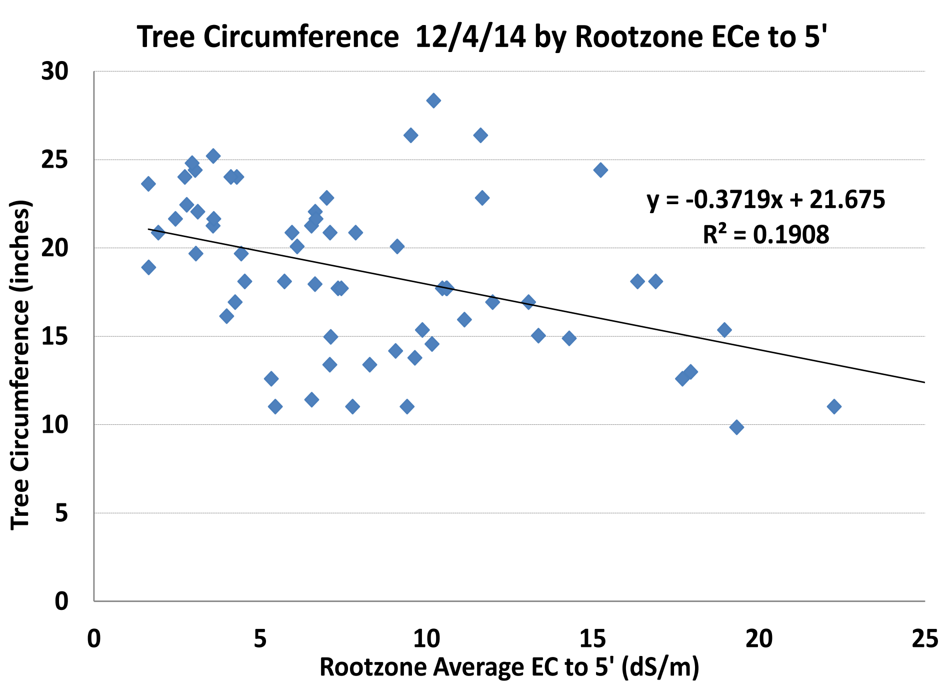


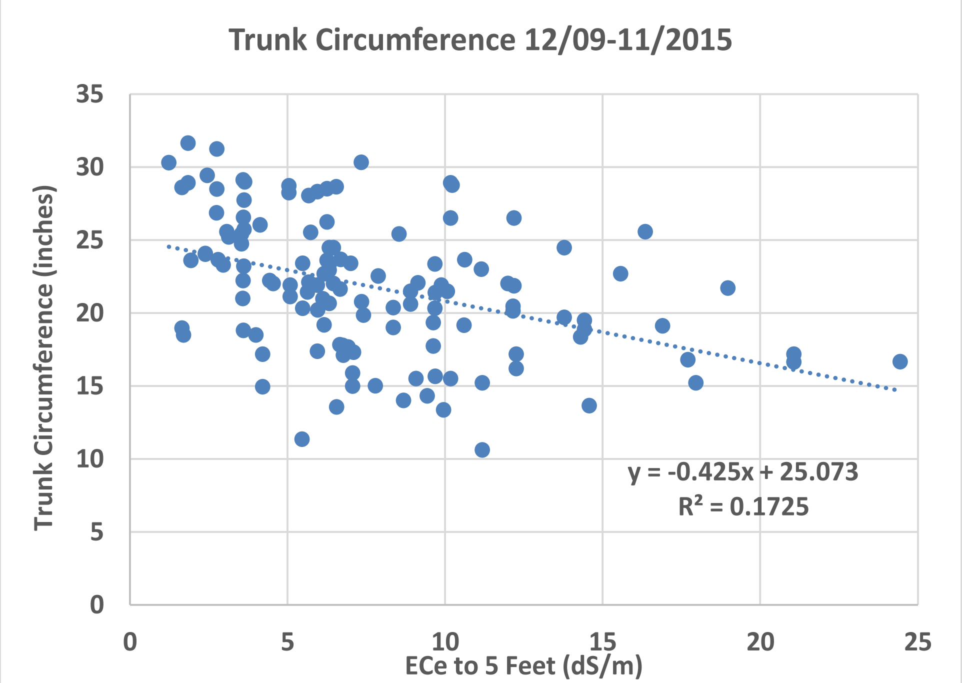
BE 15.68 avg ECe (2014) 11.78 dS/m (2014-16)

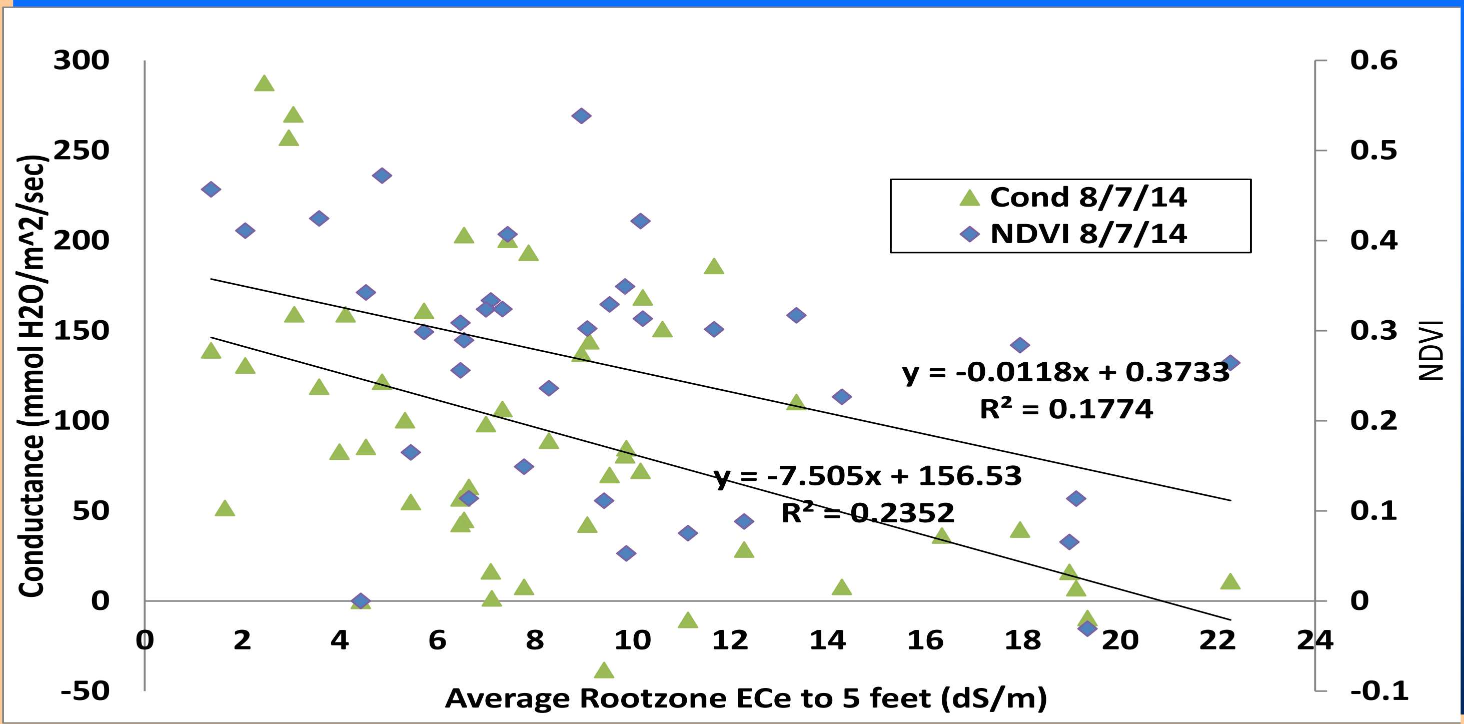

BW 10.59 avg ECe
2014-16
Really?
Some spots
are just too
hot!
1
2
3
4
373 ft
Google E

BW 14.11 avg ECe, 2014
10.59 dS/m 2014-16





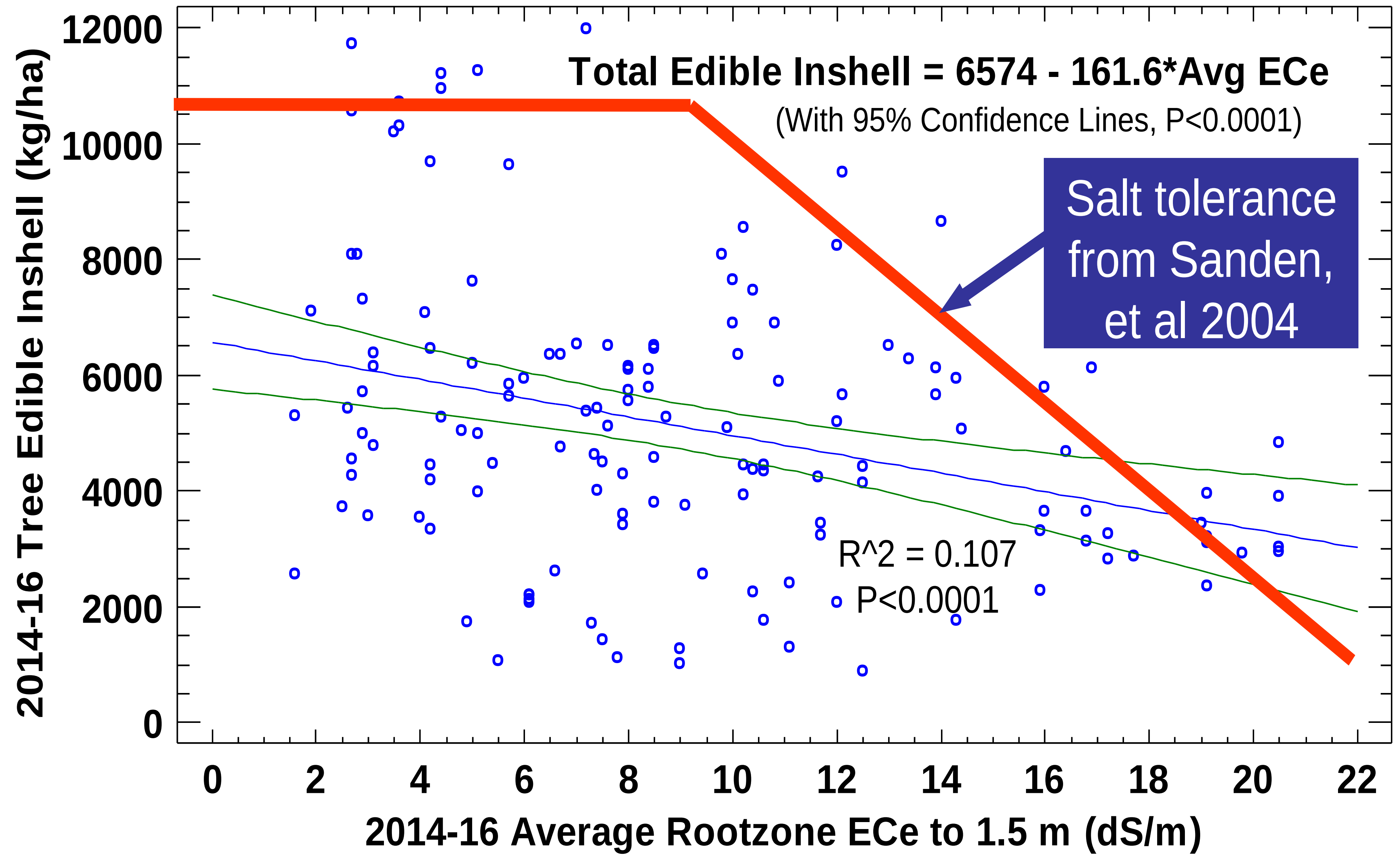




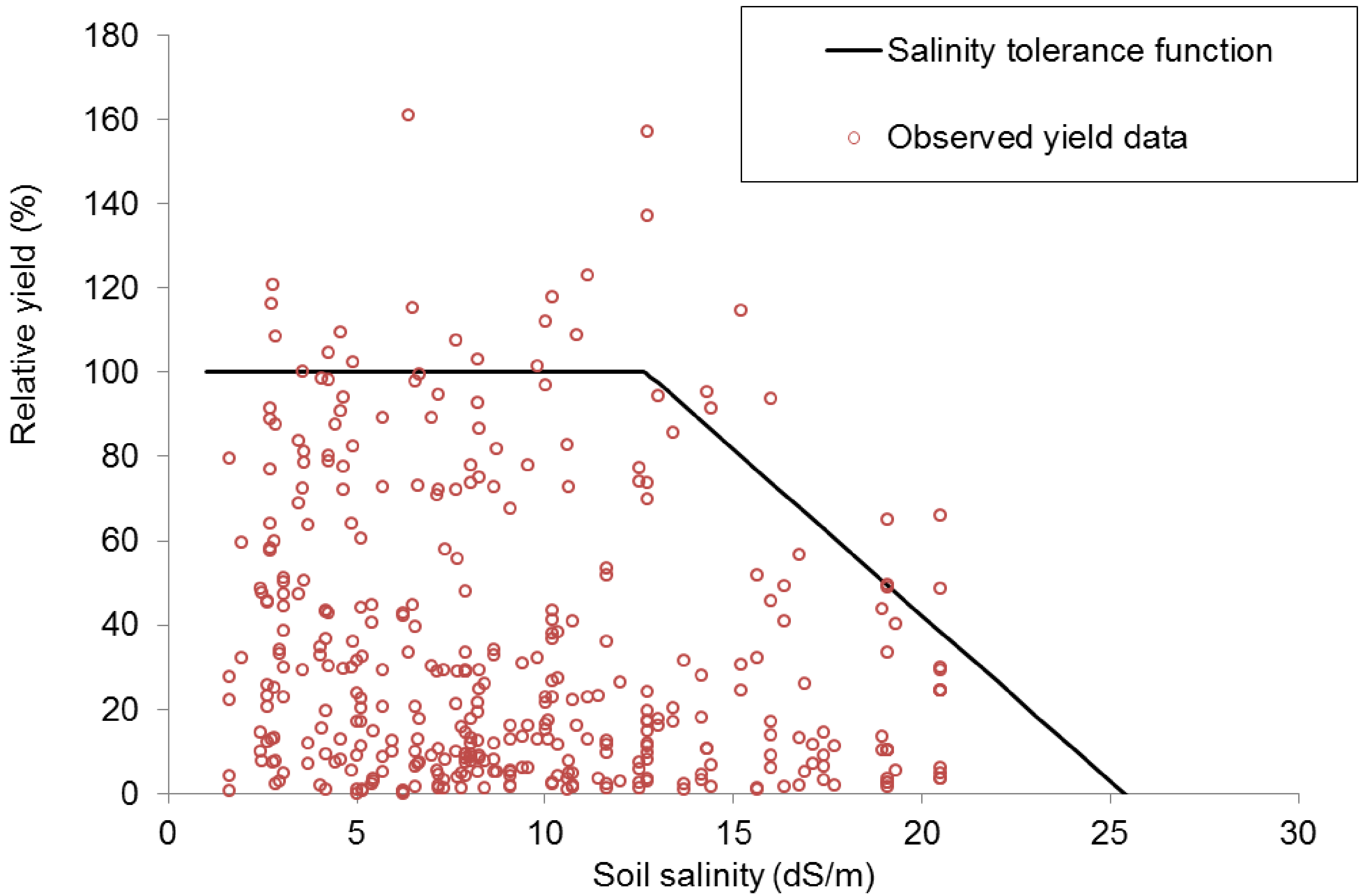
Tree trunk circumfer-ence, canopy Conductance (water stress) & NDVI by rootzone salinity


Hand-harvest a group of 4
adjacent trees in each area

Cumulative 2014-16 Yield Decline by Average 3 Year Rootzone Salinity to 1.5 m

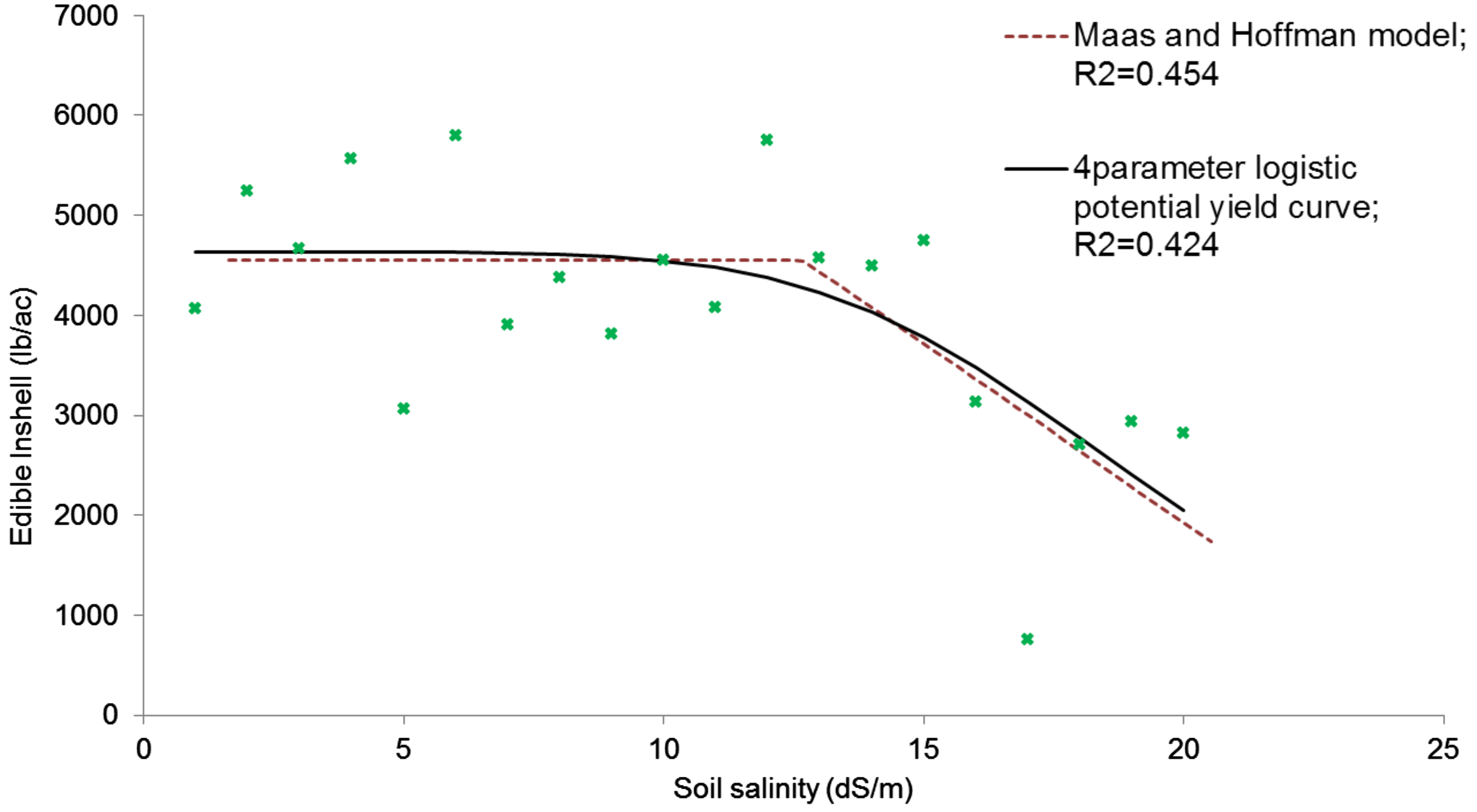


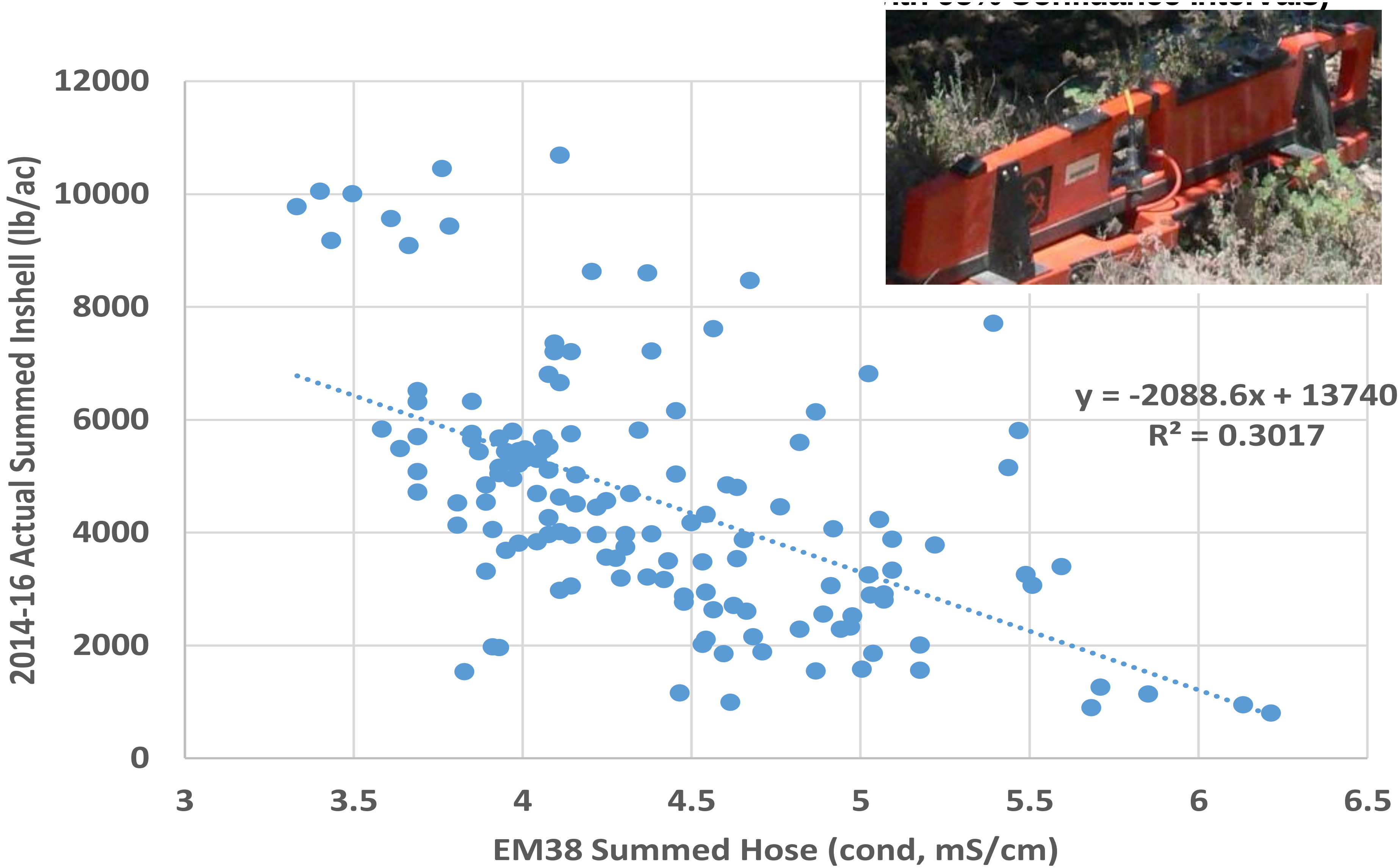
Interpretation of the model:
only 5% of probability that yield will exceed the predicted potential at any given salinity level



Estimated 95th percentiles for all EC_e intervals

Fitting tolerance functions

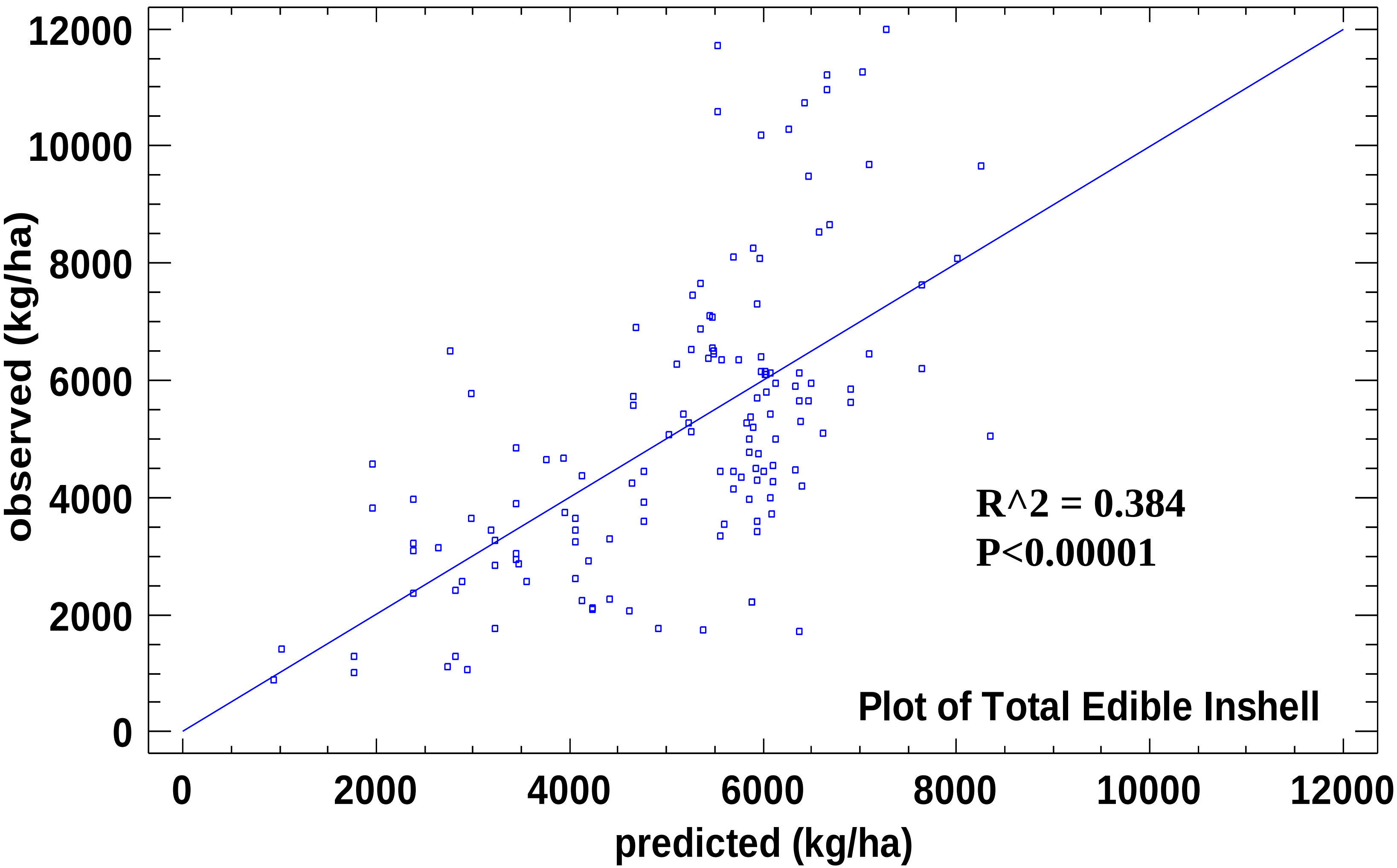




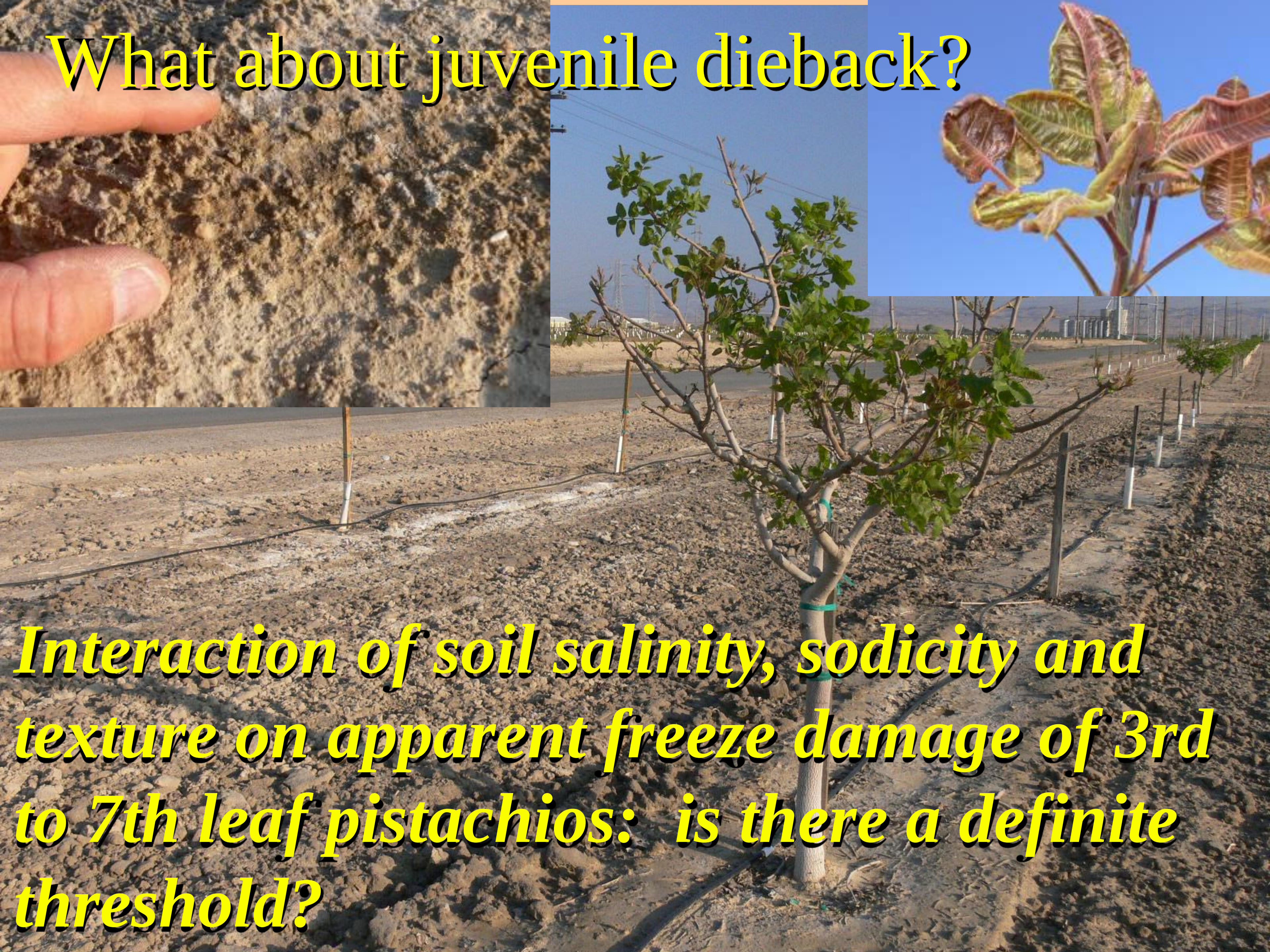
2014-16 cumulative edible inshell yield as a function as a function of summed EM38 vertical and horizontal readings centered on the berm and 0.3m out.

Parameter	Estimate	Standard Error	T Statistic	P-Value
CONSTANT	32820	5471	5.999	0.0000
pH	-3469	706.7	-4.909	0.0000
Na	-17.17	14.96	-1.148	0.2530
Cl	-31.11	13.47	-2.309	0.0225
B	-119.1	63.87	-1.864	0.0645
Avg ECe	173	130.5	1.325	0.1873

Multiple regression model using pH, sodium, chloride, boron and average ECe as predictors of yield. Na and EC are NOT statistically significant!

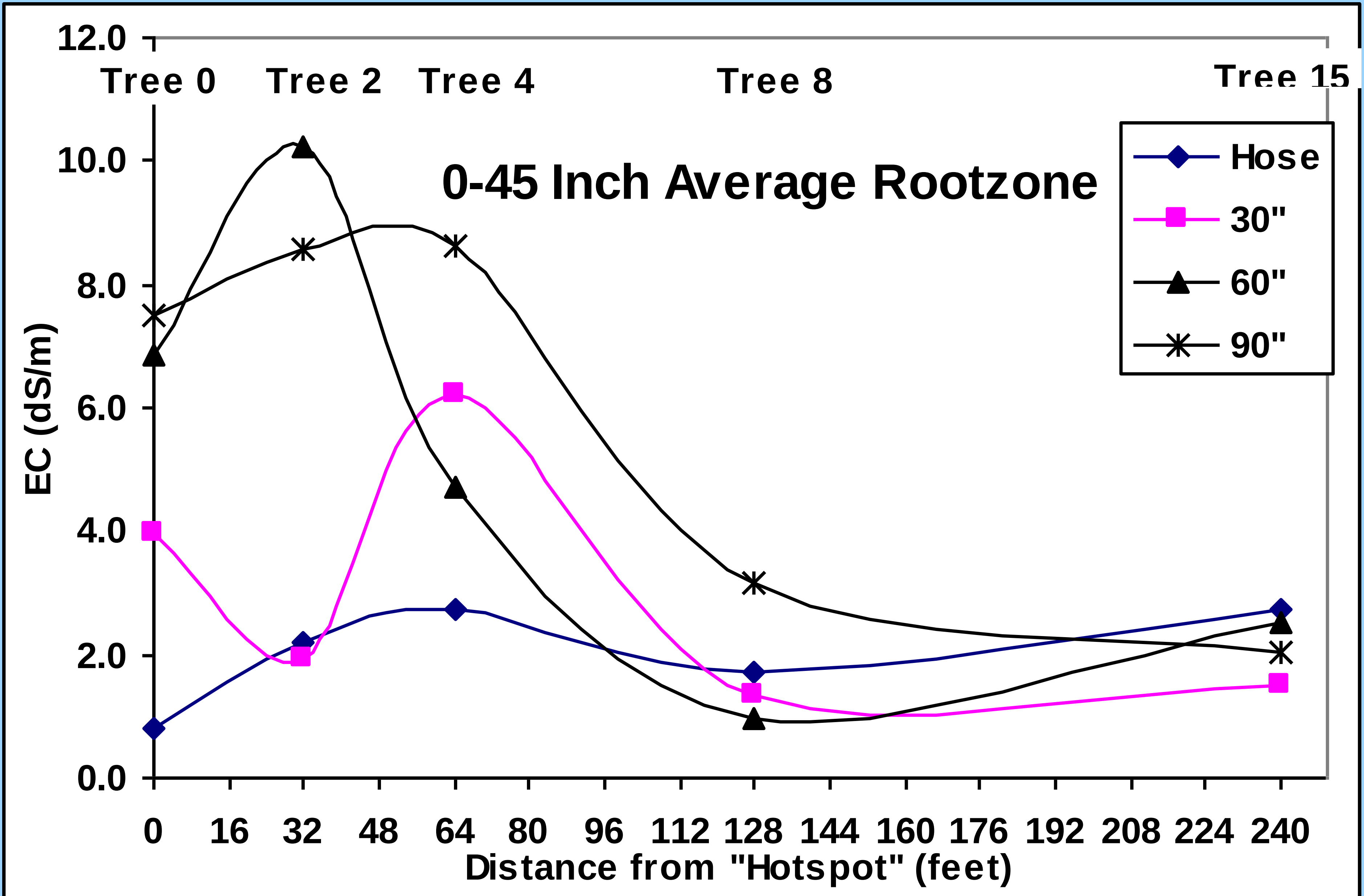


What about juvenile dieback?



Interaction of soil salinity, sodicity and texture on apparent freeze damage of 3rd to 7th leaf pistachios: is there a definite threshold?

Average ECe by tree and distance from hose



TENTATIVE THRESHOLDS to MINIMIZE FROST SENSITIVITY DAMAGE:

- **SOIL ROOTZONE SALINITY < 5 dS/m**
- **SOLUBLE SODIUM < 40 meq/l (920 ppm)**
- **Na/Ca RATIO < 15**

Observation: Juvenile frost dieback is NOT due to sodium toxicity. High salt load prevents sufficient 'dry-down' and tree hardening off before winter.

How to do it   How to fix it

- Leaching calculations for composite pit samples

FIX: Monitor soil EC, calculate reclamation leaching

Gooselake soils data – composite pits 8, 9, 11, 12, 13

Depth	SP	pH	EC	Ca	Mg	Na	SAR	ESP
0-1'	40	7.9	5.5	34.2	4.6	21.7	4.9	5.7
1-2'	45	8.0	6.7	29.9	4.3	39.6	9.6	11.4
2-3'	45	8.0	7.3	25.1	4	51.8	13.6	15.8

Average salinity = 6.5 dS/m

Guidelines to evaluate orchard soils and water supplies for excess salinity for mature pistachio trees

	Degree of restriction for pistachios		
EC (dS/m) of:	None	Increasing	Severe
Avg. root zone[1]	< 6	6 - 8	> 8-12
Irrigation water[1]	< 4	4 - 8	> 8-12

[1] Guidelines based on field data where the annual leaching fractions were about 15% for the "No restriction level" and 30% for the "Severe Level".

How to do it   How to fix it

- **WATER QUALITY – Soil structure may suffer with Well 1 quality.**

Analysis:

	Well 1	Aque	Well 2	
pH	**8.4**	**7.4**	**7.4**	
EC_w	1.0	0.5	5.8	dS/m
Ca	0.5	1.2	26.5	meq/l
Mg	0.1	1.0	15.3	meq/l
Na	9.6	2.5	23.9	meq/l
HCO_3	**4.2**	**1.6**	**1.5**	**meq/l**
CO_3	1.0	<0.1	<0.1	meq/l
Cl	4.6	2.0	36.9	meq/l
SO_4	0.1	0.9	24.0	meq/l
B	0.7	0.3	11.0	mg/l
NO_3	5.2	0.6	8.0	mg/l
SAR	17.5	2.4	5.4	
SAR_{adj}	16.6			

- Mo deficiency
- Low Ca
- High Fe, Mn & emitter clogging

- Lime precip
- Chlorosis
- Fe, Zn, Cu, Mn deficiency

<u>FIX</u>: Inject acid. 200 - 500 lb/ac-ft H_2SO_4

(Use Excel Program for weights of sulfuric and NpHuric reqd to neutralize HCO3 and release Ca from lime.)

Fine, ball-milled reclaimed sulfur applied @ 1.5 t/ac

2 foot banded appliation:
= 15 t/ac to reduce pH in tree row

Incorporated with bent 15” furrowing shovel welded to 30” chisel shank and sunk into slip trench

Incorporation to 28” depth

Soil analyses from composite sample of Auger & Backhoe treatments prior to planting and end of first season.

2005 **Date Sampled: 11/15/05; Grower/Location/Project: Houchin Ripping**

Depth (inches)	**SP** %	**pH**	EC dS/m	SAR	Ca meq/l	Mg meq/l	Na meq/l	Cl meq/l	B	HCO3 meq/l	CO3 meq/l	Lime %
0-20"	63	7.6	2.33	7	7.64	1.38	14.6	7.5	0.5	1.9	<0.1	0.4
20-40"	58	7.8	3.36	11	7.73	2.28	25.1	12.5	0.7	1.6	<0.1	13.8
40-60"	48	8.0	3.71	10	9.78	3.28	25.5	17.7	0.7	1.4	<0.1	12.6

2006 **Date Sampled: 11/9/06; Grower/Location/Project: Houchin Ripping**

Depth (inches)	**SP** %	**pH**	EC dS/m	SAR	Ca meq/l	Mg meq/l	Na meq/l	Cl meq/l	B	HCO3 meq/l	CO3 meq/l
0-15"	61	7.2	3.15	3	24.5	4.31	10.9	2.4	0.44	3.6	<0.1
15-30	60	7.6	2.32	5	11.8	2.48	12.5	1.3	0.43	2.4	<0.1
30-45	56	7.8	1.87	7	4.9	1.32	12.8	2.2	0.53	2.5	<0.1
45-60	42	7.9	1.88	9	3.7	1.30	13.9	2.6	0.49	2.4	<0.1

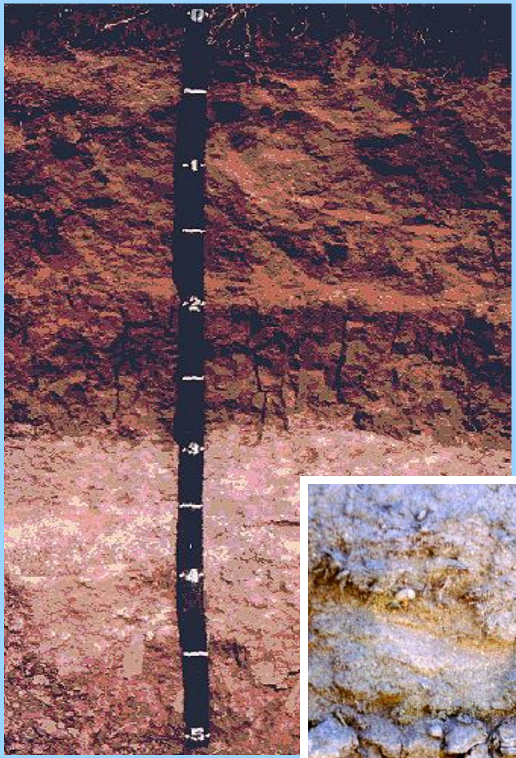
Soil Fertility 11/9/06

Depth (inches)	NO3-N (ppm)	Olsen-P (ppm)	AA-K (ppm)	Zn (DTPA)	Mn (DTPA)	Cu (DTPA)	Fe (DTPA)
0-15"	18.9	18.6	375	0.7	4.6	1.5	21.9
15-30	7.2	6.2	230	0.2	0.8	1.5	9.5
30-45	4.8	9.6	185	0.3	0.6	1.1	6.7
45-60	3.1	6.0	126	0.1	0.8	0.6	5.5

Finally, what about ground prep and deep tillage?

How to do it

- **STRATIFICATION**



How to fix it

<u>FIX</u>: IRON!!


D9H

How to fix it

WALNUT RESPONSE TO DEEP TILLAGE UNDER FLOOD IRRIGATION

Tillage Method	*Yield (lb/acre)	*Trunk circumference (in)	+Root count (per 3 cu ft)
None	**1,009**	**14.8**	**78**
Ripper	**1,120**	**16.6**	**94**
Slip plow	**1,185**	**16.7**	**118**
Moldboard plow	**1,433**	**17.0**	**175**

*Measured during fourth year of production.

+Measured during eighth year of production.

How to fix it? ***Slip plow made no difference with in almonds with fanjets in Arbuckle.***

		Nut Yield (lb/ac)	
Year	Tree Age (years)	Slip Plowed	Non Slip Plowed
2000	4	894	830
2001	5	1070	1243
2002	6	2725	2761
2003	7	2165	2323
2004	8	1869	1865
2005	9	1548	1841
2006	10	2910	2862
2007	11	2770	2571
*Cumulative Yield		15951	16296

*Edstrom, J., S.Cutter. 2004. Nickels soil lab projects – Deep tillage slip plow affects on almonds. 2004 Conference Proceedings, CA Almond Board. Pp.75-76. (J. Edstrom, personal communication, 10/7/08)

Effect of Pre-plant Tillage on Pistachio Development Under Drip Irrigation (planted 2006)

Treatments:

1. **Auger only:** no deep tillage. Row marked with furrowing shovel, sulfur applied as above and incorporated with second pass of same shovel. Standard 3 point hitch auger to be used at planting same as all other treatments

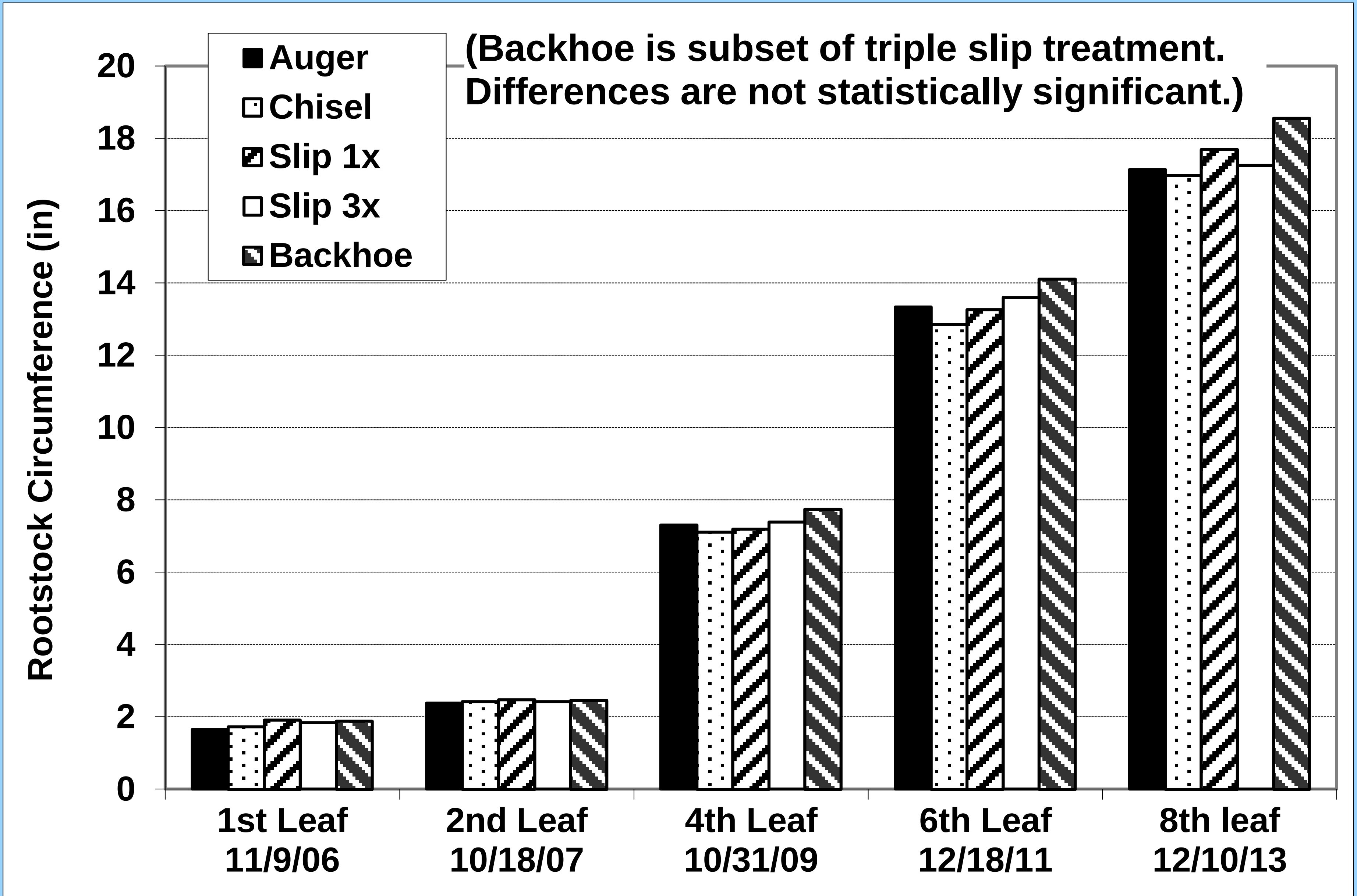
2. **Cotton chisels:** standard gang of 7, 36 inch chisels, one pass down the tree row to a depth of 30 inches.

3. **Slip plow** (standard tillage for whole project): one slip plow pass down the tree row with a 15 inch shoe penetrating 42 to 50 inches.

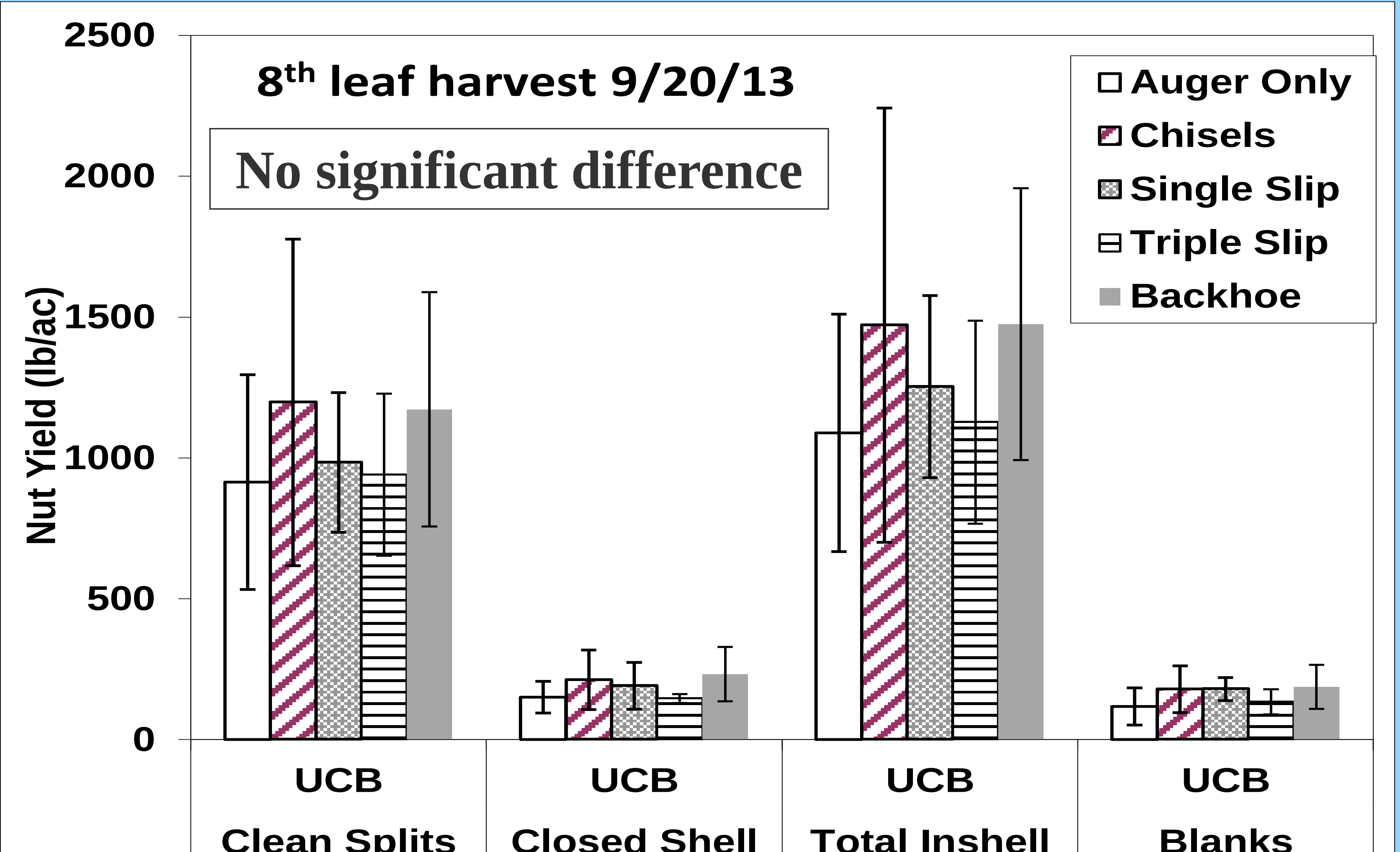
4. **Triple slip:** slip plow treatment down tree row (as above) with an additional pass 6 foot on either side. A final fourth pass was repeated down the center (tree row) pass to achieve a 52 inch penetration and further fracture the profile. This treatment is meant to be similar from the benefit that might be gained by "straddle ripping" after slip plowing.

   - **Backhoe to 7 feet:** installed as a subplot in the Triple Slip treatment, a 3 x 51 foot trench to 7 feet was excavated along the space that will be occupied by trees 4,5 and 6 (counting from the West). **This subplot provides for replicated observations on trees receiving the maximum amount of deep tillage possible.**


Rootstock circumference: No significant differences after 8 seasons



2nd Harvest 9/20/13, 8th Leaf
Average 1283 lb/ac inshell and 71.2% splits



Happy planting … and praying!

California Soils Resource Lab (UC and NRCS):
http://casoilresource.lawr.ucdavis.edu/drupal/ "On-line Soil Survey"
UC Soils-to-Go:
http://soilstogo.uckac.edu/
Use the following links for more information:
Full California soil surveys (as PDF) published online:
http://soils.usda.gov/survey/online_surveys/california/
For georeferenced spatial and tabular data available for California (more difficult to access and requires use of GIS software):
https://soildatamart.nrcs.usda.gov/County.aspx?State=CA
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