Salinity Management – Soil and Cropping Systems Strategies

Michelle Leinfelder-Miles
Delta Crops Resource Management Advisor
UC Cooperative Extension, San Joaquin County

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Introduction to Salinity

Salt problems occur on approximately one-third of all irrigated land in the world.

Why do salts exist in soil?

- Parent material weathers to form salts
- Salts are carried in irrigation water
- Soil amendments may contain salts
- Presence of shallow, saline groundwater

Introduction to Salinity

- Examples of soluble salts are NaCl, $CaCl_2$, $MgCl_2$, $CaSO_4$, $CaCO_3$, and KCl
- Electrical conductivity (EC) - Positive and negative ions disassociate in solution and will move toward an electrode of opposite charge, creating a current.
  - ECe – soil saturated paste; ECw - water
- Salinity may also be characterized by the Sodium Adsorption Ratio (SAR) or Exchangeable Sodium Percentage (ESP), which express the sodium status of an alkaline soil

Introduction to Salinity

Saline soil: has sufficient soluble salts to impair productivity.

- ECe > 4 dS/m (Non-alkaline soil with pH < 8.5)

Sodic soil: has sufficient Na^+ to impair productivity

- SAR > 13 (An alkaline soil with pH > 8.5)

Effects of Salinity on Plant Growth

- Osmotic stress

  (*most common means by which salt impairs plant growth*)

- Specific ion toxicities

  (Na^+, Cl^-, B)

- Degraded soil conditions that limit plant water availability

Strategies for Salinity Management

- Recognize the difference between applied water salinity and soil salinity.
  - Crop salinity tolerances are expressed as both seasonal average applied water salinity and average root zone soil salinity.
- Irrigation water carries salts, and when irrigation water is applied to fields, salts are added to the soil.
- Salts accumulate in the soil at higher concentrations than they existed in the applied water, and salts may accumulate unevenly in the soil.
- It is important to test water and soil salinity regularly to understand baseline conditions and changes over time.

Site Selection/Pre-planting

Test soil and water.

- Typical soil sampling for nutrient status is 1-2 ft, so over time, growers may not be aware of the soil salinity profile.

Consider seasonal patterns and patterns across the field.

- Leach salts before planting and consider irrigation modifications.

Consider crop tolerances and when the crop is most sensitive to salinity (often the seedling stage).

- Establish stand with best quality water or blend sources (if different sources are available).

Variety Selection

Relative salt tolerance ratings exist for many crops grown in California, as do threshold tolerances where we would expect to see yield decline.*

- Absolute tolerance will vary based on climate, soil, cultural practices, crop development, and variety.

Nevertheless, plant breeding should not be considered a substitute for soil salinity management.

**See Water Quality for Agriculture, FAO 29.*
http://www.fao.org/docrep/003/T0234E/T0234E00.HTM

Soil Amendments

Most effective in sodic soils:

- Calcium amendments can replace sodium on the soil and improve soil structure so that sodium can be leached.
- Gypsum (CaSO$_4$) is the most common amendment and may be used in acidic or alkaline soils.
- If soil contains “free lime”, (calcium carbonate, CaCO$_3$), then adding an acid, like sulfuric acid (H$_2$SO$_4$) will liberate the Ca in the soil.
  - Free lime may be present in alkaline soils.

Soil Amendments

- The amount of amendment depends on the amount of exchangeable Na^+ in the soil and could be costly.
- The process can be slow – amendments must solubilize and react in the soil.
- ***Soil amendments do NOT eliminate the need for leaching.***

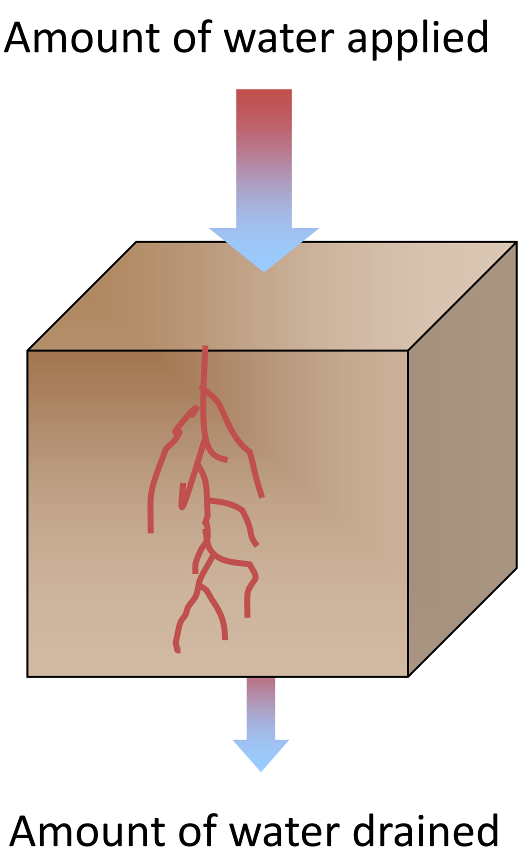
See https://extension.arizona.edu/sites/extension.arizona.edu/files/pubs/az1413.pdf
"Using Gypsum and Other Calcium Amendments in Southwestern Soils"

Leaching

- Leaching must be practiced when soil salinity has the potential to impact yield.
- It occurs when water is applied in excess of soil moisture depletion due to evapotranspiration (ET).
- Leaching may occur during the rainy season or whenever an irrigation event occurs.
  - During the season, leaching may not be advised because of the potential for nutrients to be lost.

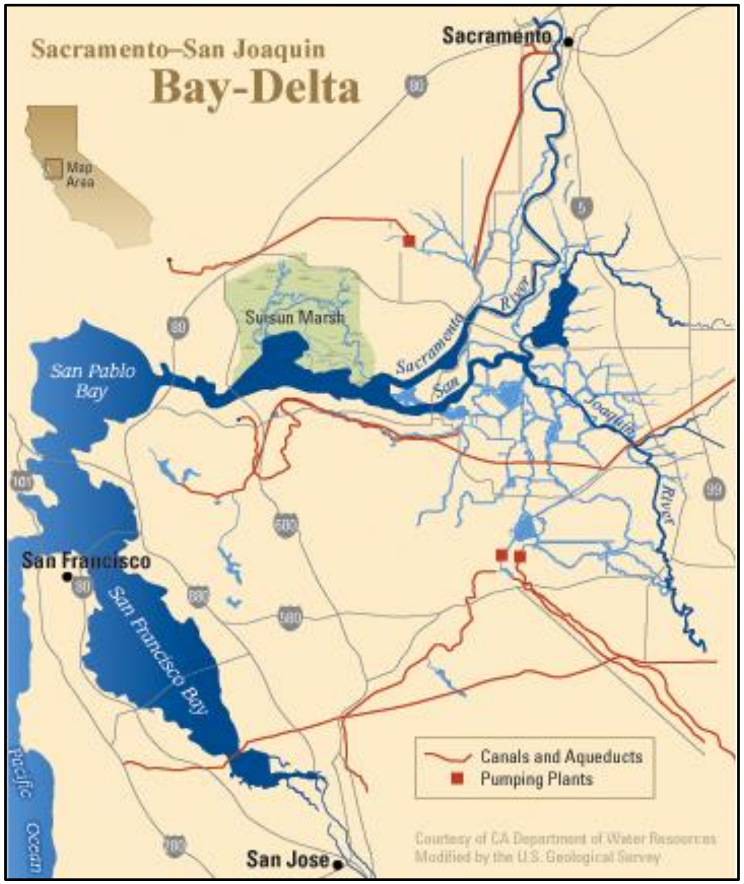
Leaching

- Leaching fraction (Lf) is the fraction of the total applied water that passes below the root zone.
- Leaching requirement (Lr) is the minimum amount of the total applied water that must pass through the root zone to prevent a reduction in crop yield from excess salts.



(Image courtesy S. Grattan, UC Davis)

Delta Research Project



Delta Research Projects

Drip-irrigated tomato field

Electrical Conductivity, ECe (dS/m)

Spring 2013

Depth (cm)	Bed Center			Furrow
0 - 10	0.84	0.74	1.24	
10 - 20	0.93	0.84	0.75	0.72
20 - 30	0.81	0.84	0.92	0.74
30 - 40	0.94	0.84	0.73	0.76
40 - 50	0.67	0.92	0.74	0.79
50 - 60	0.64	0.76	0.74	0.79
60 - 70	0.68	0.79	0.75	0.71
70 - 80	0.82	0.77	0.79	0.71
80 - 90	0.83	0.77	0.74	0.73
90 - 100	0.81	0.80	0.78	0.66

Fall 2015

Depth (cm)	Bed Center							Furrow
0 - 10	2.50	2.51	2.97	2.34	2.67	2.27	2.76	2.69
10 - 20	1.37	1.17	1.12	1.02	1.05	0.96	2.51	4.49
20 - 30	0.85	0.85	0.85	0.86	0.90	1.08	0.81	1.04
30 - 40	0.87	0.94	0.99	0.92	0.95	0.87	0.74	0.76
40 - 50	1.12	0.89	1.26	1.15	0.99	0.86	0.85	0.71
50 - 60	1.06	1.05	1.37	1.08	0.89	0.84	0.61	0.71
60 - 70	0.94	0.96	1.52	1.16	1.09	0.88	0.71	0.87
70 - 80	0.83	0.94	1.32	1.49	1.21	1.11	1.01	0.87
80 - 90	1.15	1.17	1.46	1.51	1.58	1.56	1.43	1.21
90 - 100	1.47	1.75	1.66	1.68	1.67	1.68	1.68	1.51

Legend*				
2.5	3.5	5.0	7.6	13.0

*Ayers and Westcot, 1985

(Project Leaders: B. Aegerter and M Leinfelder-Miles)

Delta Research Projects

Furrow-irrigated tomato field

Electrical Conductivity (dS/m)
Fall 2015

Field top (BED CENTER → FURROW)

depth								
0 - 4"	5.2	2.1	1.8	1.4	2.2	2.0		
4 - 8"	1.1	0.8	0.9	0.9	0.8	0.6	1.3	4.1
8 - 12"	0.9	0.8	0.8	0.7	0.7	1.0	0.9	0.9
12 - 16"	1.2	0.9	0.7	0.8	0.7	0.8	0.9	0.8
16 - 20"	1.0	0.9	0.8	0.8	0.7	1.0	0.9	0.9
20 - 24"	1.2	1.4	1.0	0.8	0.8	0.8	1.0	1.0
24 - 28"	1.7	1.2	1.4	1.0	1.0	1.0	1.1	1.1
28 - 32"	1.4	1.1	1.2	1.0	2.0	1.0	1.0	1.0
32 - 36"	1.6	1.2	1.0	1.0	0.9	1.0	1.1	1.1
36 - 40"	1.7	1.5	1.5	1.2	1.0	1.0	1.2	1.4

Field bottom (BED CENTER → FURROW)

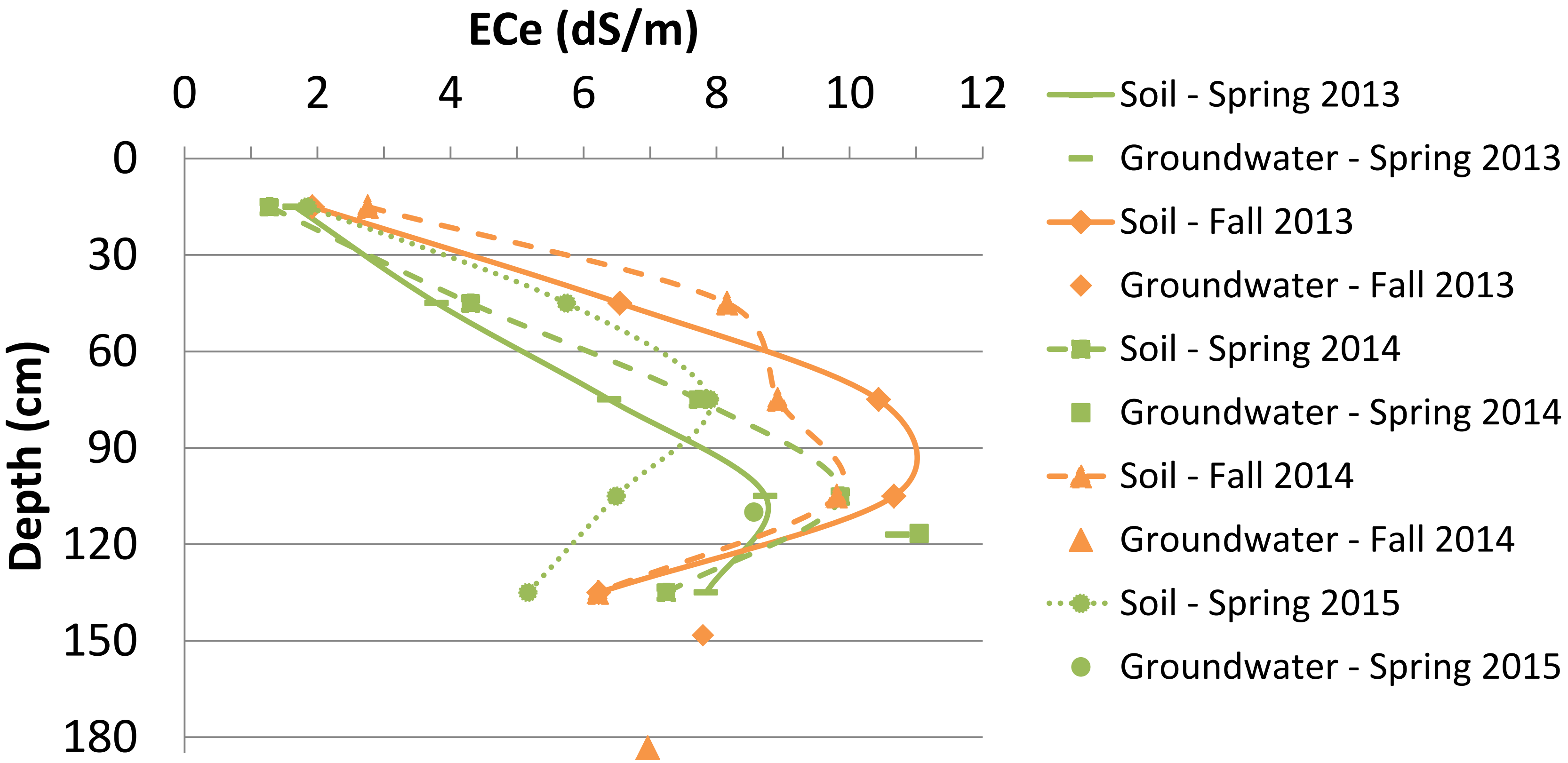
depth								
0 - 4"	8.0	2.8	2.7	2.6	2.0	2.3		
4 - 8"	2.1	2.0	2.2	1.5	1.0	0.8	1.8	3.6
8 - 12"	1.9	1.9	1.8	1.1	0.8	1.2	1.5	1.7
12 - 16"	2.4	2.3	2.1	1.5	1.3	1.8	2.3	1.8
16 - 20"	3.1	3.2	3.2	2.4	2.2	2.4	2.8	2.2
20 - 24"	3.6	3.9	3.2	3.1	2.6	2.6	2.7	2.5
24 - 28"	3.8	3.8	3.5	3.7	3.1	3.3	3.5	3.5
28 - 32"	5.6	6.0	5.5	5.3	4.7	4.6	4.4	4.5
32 - 36"	4.6	4.6	4.8	5.6	4.5	5.3	5.8	4.8
36 - 40"	3.9	3.6	3.8	3.8	3.2	3.1	2.9	3.6

Legend*					
	2.5	3.5	5	7.6	13

*Ayers and Westcot, 1985
(Project Leaders: B. Aegerter and M Leinfelder-Miles)

Delta Research Projects

Flood irrigated alfalfa field, silty clay loam



*Shallow groundwater appeared to be impairing leaching .

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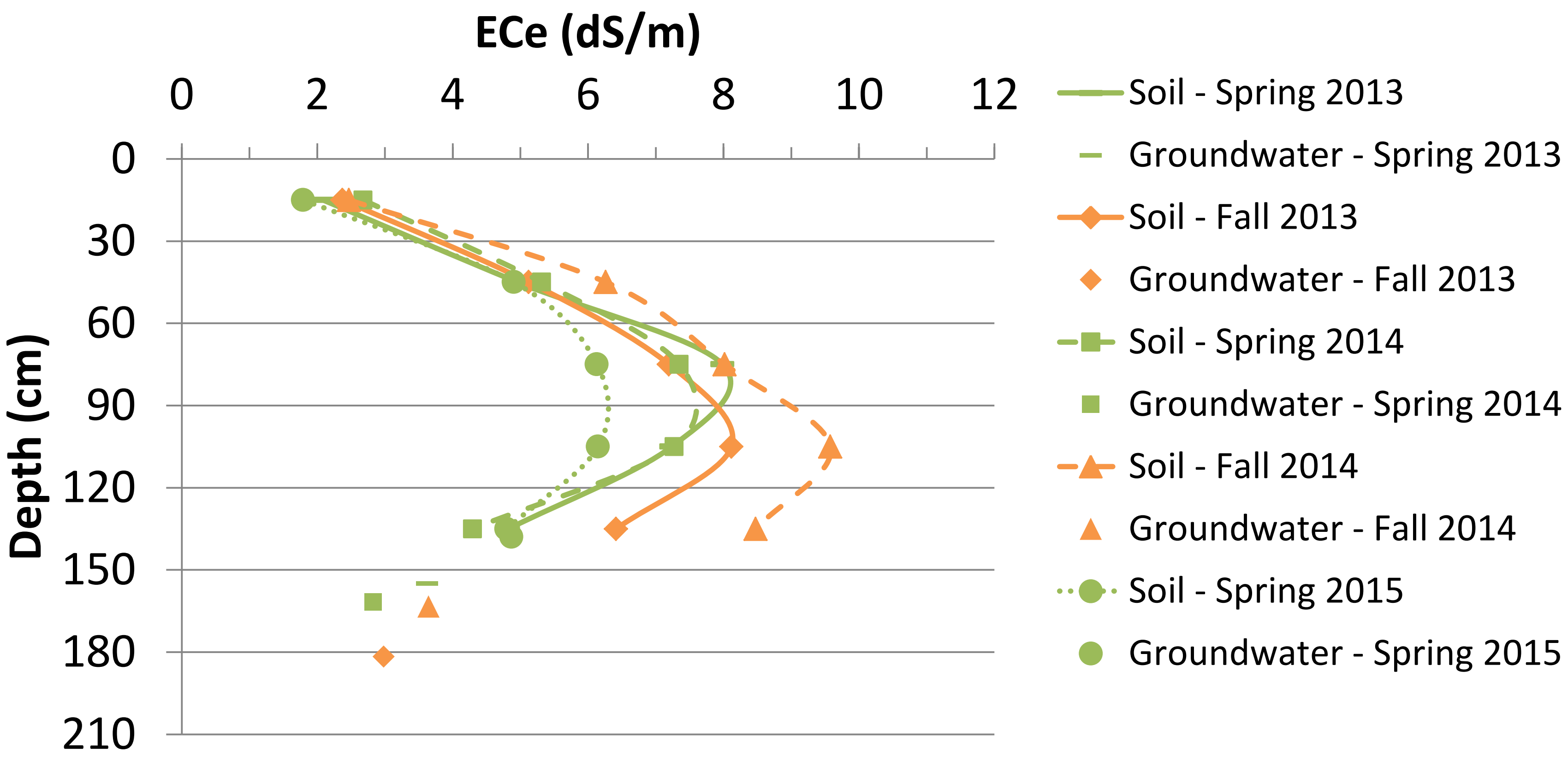
Flood irrigated alfalfa field, fine sandy loam



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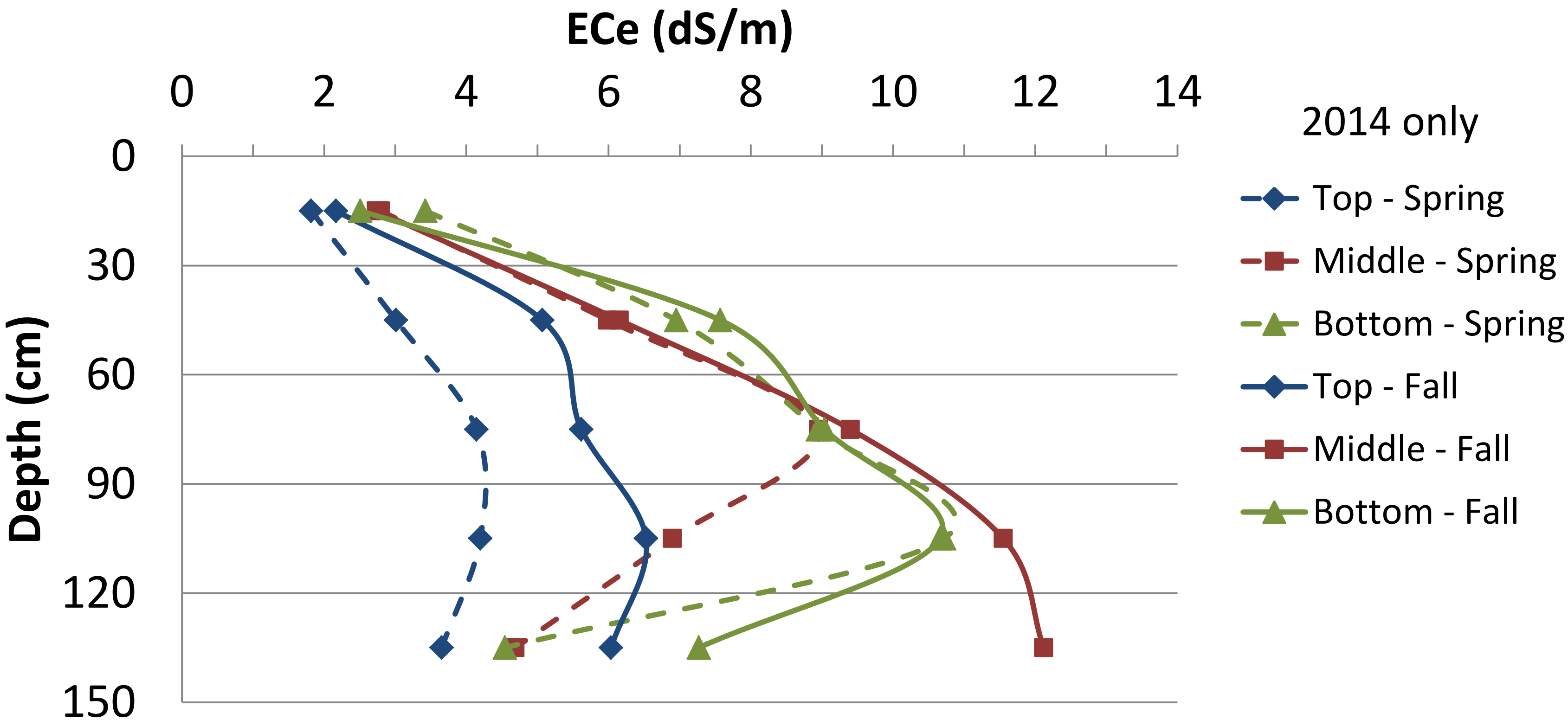
Flood irrigated alfalfa field, fine sandy loam

(same field as previous slide, now shown by field section)



*Management may improve leaching at this site because the coarser-textured soil has better water infiltration.

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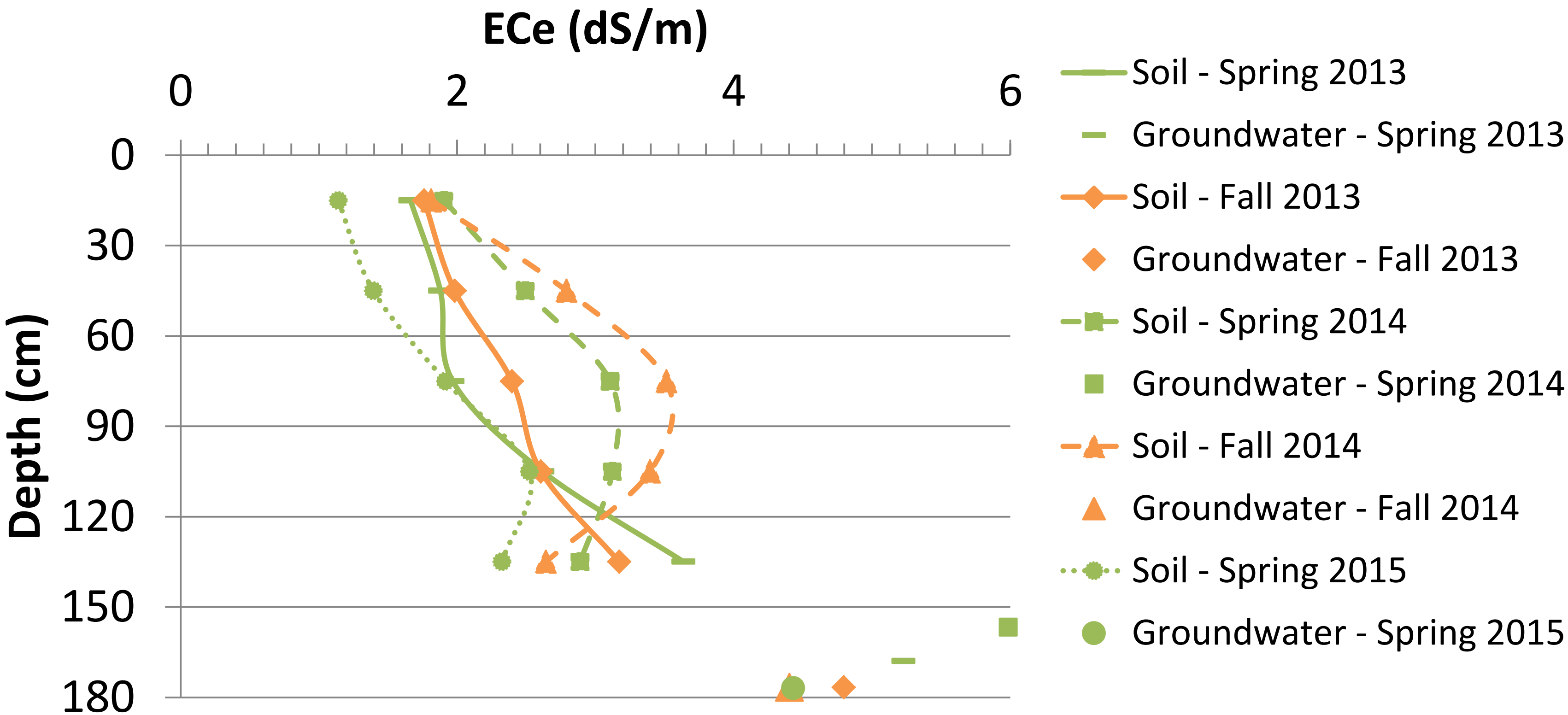
Flood irrigated alfalfa field, fine sandy loam



*Highest seasonal average applied water salinity, but lower root zone salinity compared to other sites. This soil was more easily leached than the clay loam soils. LF around 25%.

Delta Research Projects

3. Drip-irrigated vineyard

Grapes, South - Electrical Conductivity (ECe, dS/m)

Depth	Vine Row 0 cm	30 cm	60 cm	90 cm	Alley Center 120 cm
0 - 30		1.20	2.19	3.57	2.18
30 - 60		1.06	2.15	3.57	2.61
60 - 90		3.03	2.94	4.44	5.18
90 - 120		3.82	4.15	4.90	5.35
120 - 150		2.30	1.88	2.79	2.49

Legend*				
1.50	2.50	4.10	6.70	12.00

Grapes, South - Saturation Percentage

Depth (cm)	Vine Row 0	30 cm	60 cm	90 cm	Alley Center 120 cm
0 - 30		0.66	0.69	0.66	0.67
30 - 60		0.84	0.82	0.83	0.79
60 - 90		0.91	0.98	0.96	0.94
90 - 120		0.89	1.00	0.95	0.90
120 - 150		1.02	1.08	0.98	1.00

*Ayers and Westcot, 1985

Research Summary

- Project results illustrate the inherent low permeability of certain Delta soils, the shallow depth of groundwater, the build-up of salts in the soil to levels that have the potential to affect crop yields, and a low achieved Lf.
- The Delta's unique growing conditions put constraints on growers' ability to leach salts.
- ***Enhance leaching during the off-season by leveraging rainfall with irrigation water to wet profile before a rain event.***

Overall Conclusions on Salinity Management

- Understand the differences among saline and sodic soils because management may differ.
- Consider salinity condition at site selection by testing soil and water, leaching salts, and managing irrigation.
- Variety selection and soil amendments may help mitigate salinity condition, but these do not eliminate the need for leaching.
- Research results illustrate the challenges associated with leaching but suggest strategies for alleviating salty conditions.