The Effects of Water Quality on Soil Salinity and Leaching Fractions in the Delta

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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

- Consist of positively-charged cations and negatively-charged anions
- Ions disassociate in solution and will move toward an electrode of opposite charge, creating a current
- Current is measured with Electrical Conductivity (EC) meter
- Soil saturated paste (ECe), water (ECw)
- Units 1 dS/m = 1 mmhos/cm = 1,000 µS/cm

Effects of Salinity on Plant Growth

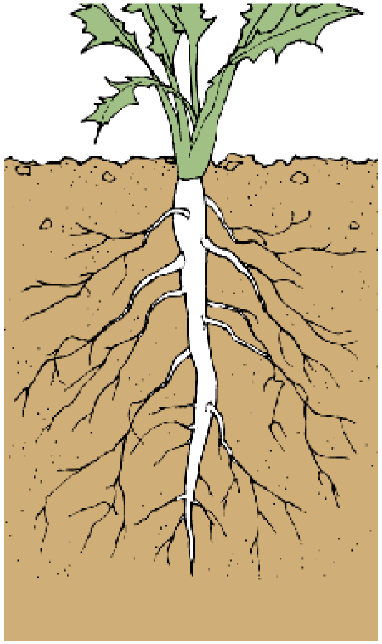
- Osmotic stress

  (*most common means by which salt impairs plant growth*)
- Specific ion toxicities
- Degraded soil conditions that limit plant water availability

Effects of Salinity on Plant Growth

Osmotic stress:

- Low soil salinity: concentration of solutes is higher in roots than in the soil-water solution, and water moves freely into roots
- Higher soil salinity: plants must transport solutes to the roots to keep root solutes higher than soil-water solution solutes and avoid water stress



Remobilizing solutes requires energy, which is then not used for plant growth.

Plants exhibit lower growth or generic stunting which farmers may not realize as being salt-induced.

Effects of Salinity on Plant Growth

Specific ion toxicity:

- Chloride and boron are micronutrients
- Sodium is not an essential nutrient and can limit plant uptake of other cations
- Burning on leaf tips and margins
- Symptoms limit photosynthetic capacity of the plant

Effects of Salinity on Plant Growth

Soil physical degradation:

- Impairs infiltration and drainage
- Visual indicators include white crusts on soil surface, black crusts, or slick spots
- Can result in standing water and poor soil aeration, neither of which promote plant health and growth

Applied water salinity vs. 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.
- Salts may accumulate disproportionately in the soil.
- Crop salinity tolerances are expressed as both seasonal average applied water salinity and average root zone soil salinity.

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1. 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

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2. Flood-irrigated alfalfa fields

Four out of seven sites had an ECe that met or exceeded 10 dS/m at 90 cm (3 ft) below the surface.

- Typical soil sampling for nutrient and salinity status is 60 cm or less
- Over time, growers may not be aware of the degree to which soil salinity has increased in their fields.

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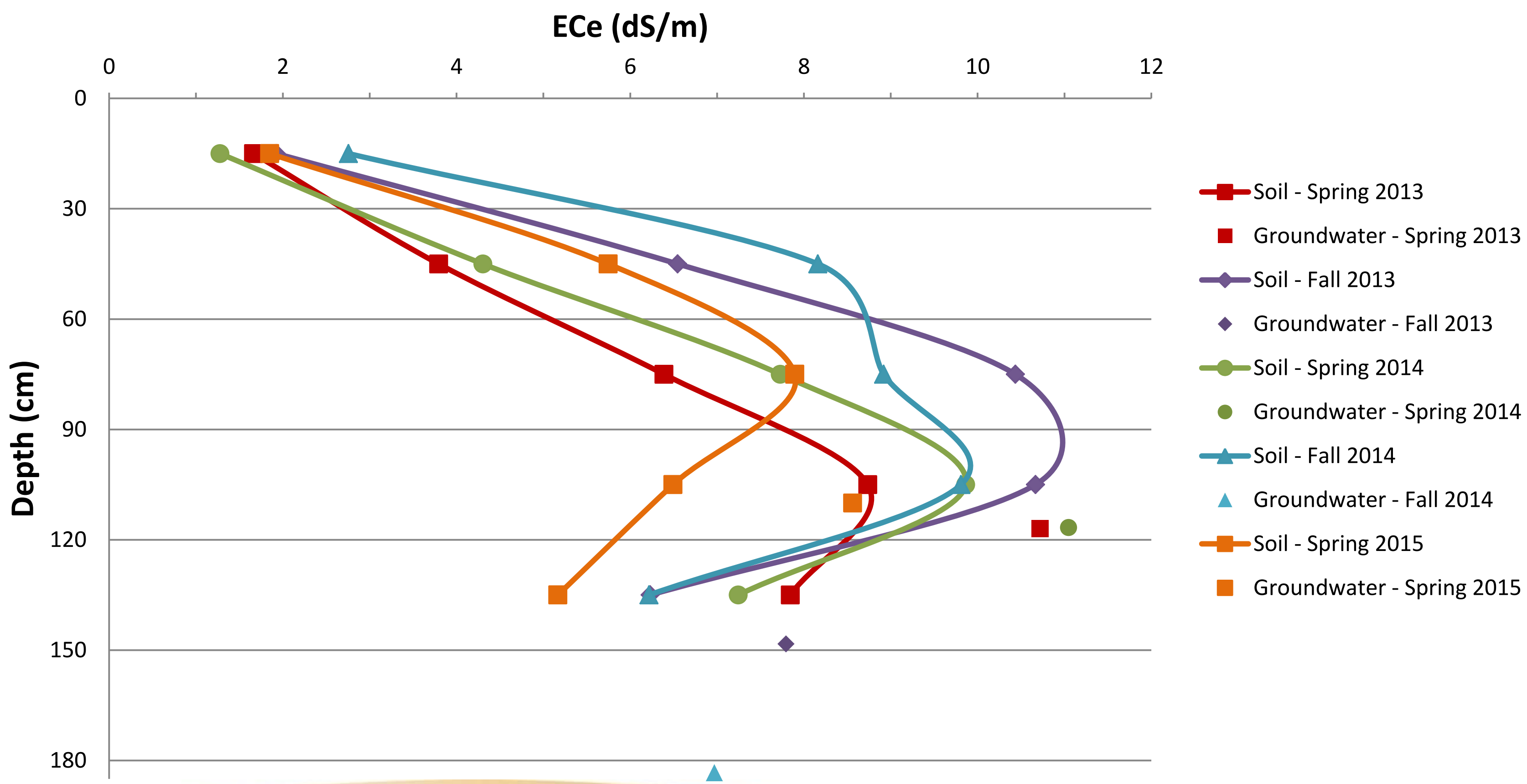
2. Flood-irrigated alfalfa fields



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3. Ryer Island

Sampling in August 2016

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Field Methods: Pear orchard

- 8 holes were augered in-line with tree rows across 20-row span
- 4 holes were augered between tree and sprinkler riser
- 4 holes were augered opposite the tree from the sprinkler in "shadow"
- Holes were augered in 30-cm increments to 150 cm
- Samples from same depth were composited, for 5 total samples
- Soil moisture, groundwater depth and salinity also sampled

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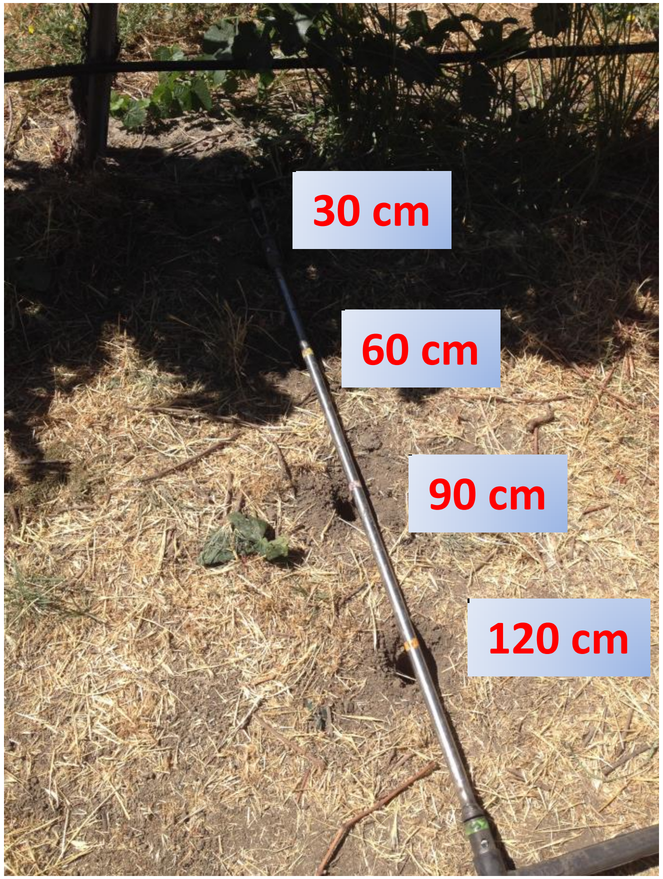
Field Methods: Vineyard

- Grid pattern 30, 60, 90, and 120 cm from the vine row
- 30-cm increment depths, down to 150 cm
- Vine spacing was 240 cm
- Soil moisture, groundwater depth and salinity also sampled



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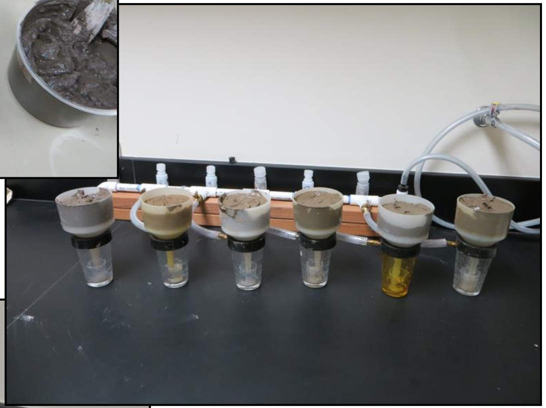
Laboratory Methods:

- Oven-dry and grind soils
- Make soil saturated pastes
- Extract liquid and dissolved salts under partial vacuum
- Measure EC with conductivity meter



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Pears - Electrical Conductivity

Depth (cm)	ECe (dS/m)
0 - 30	0.442
30 - 60	0.249
60 - 90	0.711
90 - 120	1.178
120 - 150	1.116

- Groundwater: 165 cm, 0.35 dS/m
- Average root zone salinity: 0.74 dS/m
- Yield declines expected when average root zone salinity is 2.5 dS/m
- We would not expect salinity at this site to be impacting yield.

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

Depth (cm)	Vine Row 0 ↓ 30 cm	60 cm	90 cm	Alley Center 120 cm ↓
0 - 30	1.705	1.62	2.18	1.24
30 - 60	1.068	1.36	2.45	2.05
60 - 90	2.179	2.63	5.41	4.00
90 - 120	1.045	1.78	1.80	2.30
120 - 150	0.693	0.75	0.84	0.96

Legend*				
1.50	2.50	4.10	6.70	12.00

- Groundwater: 221 cm, 0.21 dS/m
- Average root zone salinity: 1.9 dS/m
- Wetting zone extends to about 90 cm deep and wide
- There is potential for salinity to impact yield

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* Ayers and Westcot, 1985

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3. Ryer Island

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

- Groundwater: 284 cm, 0.97 dS/m
- Average root zone salinity: 3.1 dS/m
- Wetting zone extends to about 120 cm deep and wide
- There is potential for salinity to impact yield

* Ayers and Westcot, 1985

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3. Ryer Island

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

Depth (cm)	Vine Row 0 ↓	30 cm	60 cm	90 cm	Alley Center 120 cm ↓
0 - 30		1.705	1.62	2.18	1.24
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Grapes, North - Saturation Percentage

Depth (cm)	Vine Row 0 ↓	30 cm	60 cm	90 cm	Alley Center 120 cm ↓
0 - 30		0.70	0.69	0.68	0.67
30 - 60		0.76	0.80	0.75	0.84
60 - 90		0.93	0.95	0.94	0.92
90 - 120		0.96	0.93	0.92	0.93
120 - 150		1.02	1.06	1.12	1.13

Delta Research Projects

3. Ryer Island

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
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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

Salinity Management by Leaching

- The primary management strategy for combating salinity is leaching, and leaching must be practiced when soil salinity has the potential to impact yield.
- Leaching 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.

Salinity Management by Leaching

The leaching fraction (Lf) is the fraction of the total applied water that passes below the root zone:

$$Lf = ECw/Ecdw \quad \text{(Equation 1)}$$

where ECw is the electrical conductivity of the applied water, and ECdw is the electrical conductivity of the drainage water at the bottom of the root zone, which is equal to 2ECe.

Salinity Management by Leaching

The 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:

$$Lr = ECw/(5ECet - ECw) \quad \text{(Equation 2)}$$

where ECet is the average soil salinity, as measured by saturated paste extract, that a crop can tolerate.

Salinity Management by Leaching

Alfalfa example:

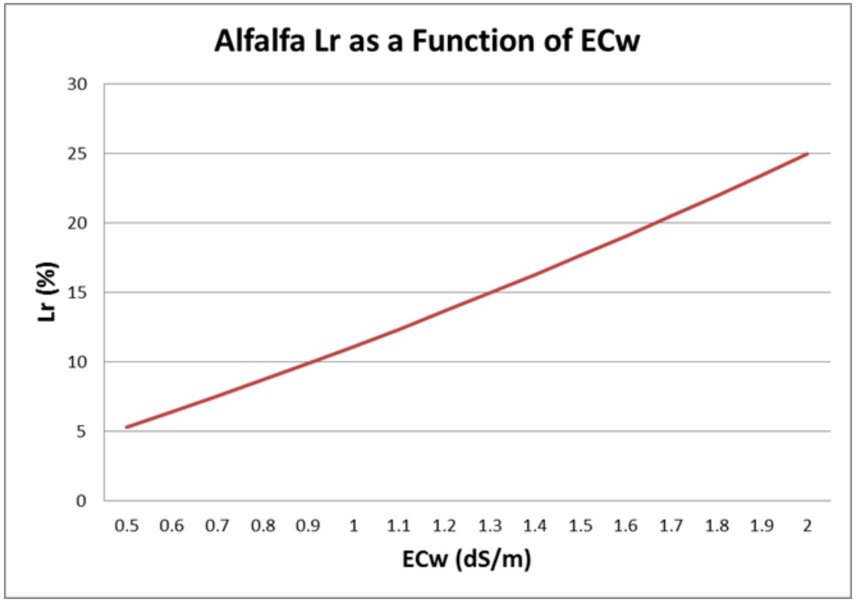
$$Lr = ECw/(5ECet - ECw) \quad \text{(Equation 2)}$$

- Thresholds Ecet = 2.0 dS/m, ECw = 1.3 dS/m)
- Lr = 15%

Salinity Management by Leaching

Alfalfa example (cont):

- When ECw ranges from 0.5-2.0 dS/m, the Lr is 5-25%
- A 15% Lr is a general "rule of thumb" in agriculture but may not always be possible due to low permeability soils, shallow/saline groundwater or other agronomic considerations



Salinity Management by Leaching

Ryer Island case study:

- Lf = ECw/ECdw (Equation 1)
- ECe at the base of the root zone is 3.55 dS/m
- ECdw = 2ECe = 7.1 dS/m
- Seasonal average ECw = 142 µS/cm (0.142 dS/m) (CDEC)
- Lf = 2%

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

Depth (cm)	Vine Row 0 ↓	30 cm	60 cm	90 cm	Alley Center 120 cm ↓
0 - 30		1.705	1.62	2.18	1.24
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Base of root zone

Salinity Management by Leaching

- Using the same ECw, a grape ECet value of 1.5 dS/m, and Equation 2, the Lr for maintaining 100 percent yield potential for grapes is 2 percent.
- Thus, in 2016, the achieved Lf at the vineyard was equal to the Lr for maintaining yields.

Salinity Management by Leaching

- We can calculate the Lr for 2015 using CDEC data (ECw = 504 µS/cm or 0.504 dS/m)
- Using Equation 2, the 2015 Lr was 7%.
- This illustrates that as ECw increases, a higher Lr will be required to maintain crop yields.
- If it is not possible to apply enough water to achieve a 7% Lf due to poor soil permeability, proximity of groundwater, or other agronomic considerations, then a higher ECw, as in 2015 compared to 2016, would suggest detrimental effects on crop yields, increases in the salt load of the soil, or both.

Conclusions

- Leaching is the primary means of managing salinity.
- Ryer Island data illustrate the inherent low permeability of certain Delta soils, 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 manage salts by leaching and achieve a Lf that meets the Lr to sustain crop yields.
- Salinity will continue to impact Delta agriculture, especially under conditions of higher surface water salinity.

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