Assessing and managing salinity

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Acknowledgements:

Sharon Benes, CSU Fresno
Steve Grattan, UC Davis

More information:

FAO Irrigation and Drainage Paper 29: Water Quality and Agriculture

http://www.fao.org/DOCReP/003/T0234e/T0234e00.htm

FAO Irrigation and Drainage Paper 48: Use of Saline Water for Crop Production

http://www.fao.org/docrep/t0667e/t0667e00.htm

UCANR Pub. 3375: Agricultural Salinity and Drainage

http://anrcatalog.ucdavis.edu/Details.aspx?itemNo=3375

Demystify salinity management:

- ✓ **What is salinity?**
- ✓ **How is salinity characterized and measured?**
- ✓ **How much leaching is needed to maintain crop production?**

Constituents of salinity

Cations:
Ca^{2+}
Mg^{2+}
Na^{+} (toxic ion)
K^{+}

Anions:
Cl^{-} (toxic ion)
SO_4^{2-}
CO_3^{2-}
HCO_3^{-}
NO_3^{-}

pH

Alkalinity:

$CO_3^{--} + HCO_3^{-}$

Specific Ion Toxicity:

Na, Cl, Boron

Osmotic Effect of Salts

Specific Ion Toxicity

Specific Ion Toxicity

Specific Ion Toxicity	Units	Degree of Restriction on Use[1] No restriction	Slight to Moderate	Severe
Sodium (Na^+)		***------ Trees, Vines, and other Sensitive Crops -------***		
surface irrigation	mg/L	< 70	70 - 200	> 200
sprinkler irrigation	mg/L	< 70	> 70	
		---------- Vegetables ----------		
sprinkler irrigation	mg/L	< 115	115-460	> 460
		---------- Strawberry ----------		
drip irrigation	mg/L	< 69	69 - 207	> 207
Chloride (Cl^-)				
		------ Trees, Vines, and other Sensitive Crops -------		
surface irrigation	mg/L	< 140	140-350	> 350
sprinkler irrigation	mg/L	< 100	> 100	
		---------- Vegetables ----------		
sprinkler irrigation	mg/L	< 175	175-700	> 700
		---------- Strawberry ----------		
drip irrigation	mg/L	< 140	140 - 350	> 350
		---------- All crops ----------		
Boron (B)	mg/L	< 0.7	0.7-3	> 3

[1.] Adapted from FAO irrigation and drainage paper 29, 1985

Quantifying Salinity

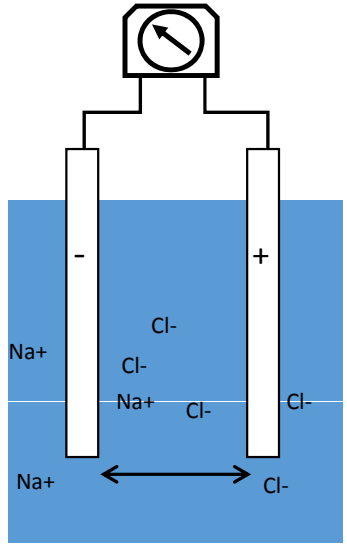
- Electrical Conductivity (dS/m)
- Total Dissolved Solids (mg/L or ppm)
- Sodium Adsorption Ratio
- Adjusted Sodium Adsorption Ratio
- Exchangeable Sodium Percentage (soil)

Electrical Conductivity (EC) can be related to salinity

DeciSiemens per meter = dS/m

1 dS/m = 1 mmho/cm = 1 mS/cm
1 dS/m = 1000 µS/cm

EC_w = TDS/640 for EC < 5 dS/m

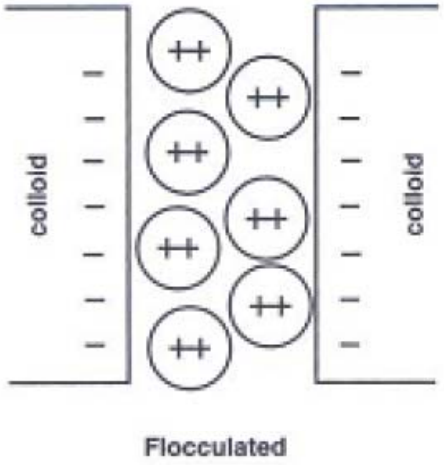


EC_w = TDS/800 for EC between 5 and 10 dS/m or salts dominated by Calcium

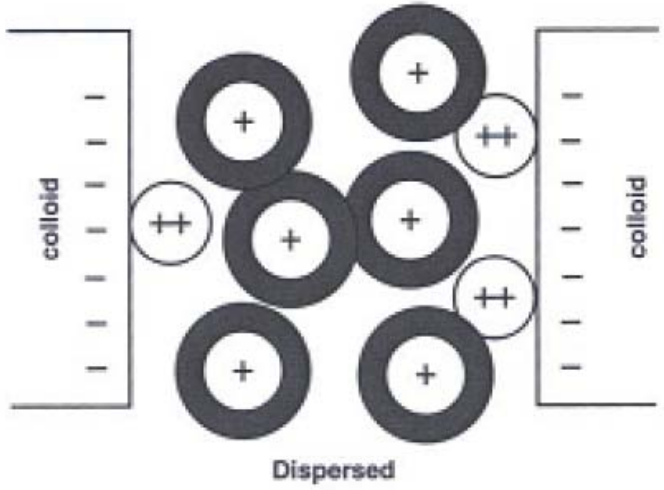
Assessing Soil Sodicity

$$Sodium\ Absorption\ Ratio = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

Concentrations in meq/L



Calcium and Magnesium dominated



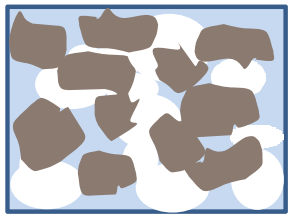
Sodium dominated

Types of Electrical Conductivity Measurements

EC_w = EC of **w**ater

EC_e = EC of saturated soil paste **e**xtract
(extracted with distilled water)

EC_{sw} = EC of **s**oil **w**ater (pore water, drainage water)



EC_a = EC_b = **a**pparent or **b**ulk soil EC

Converting among EC Measurements

$EC_e = EC_{sw} / 2$

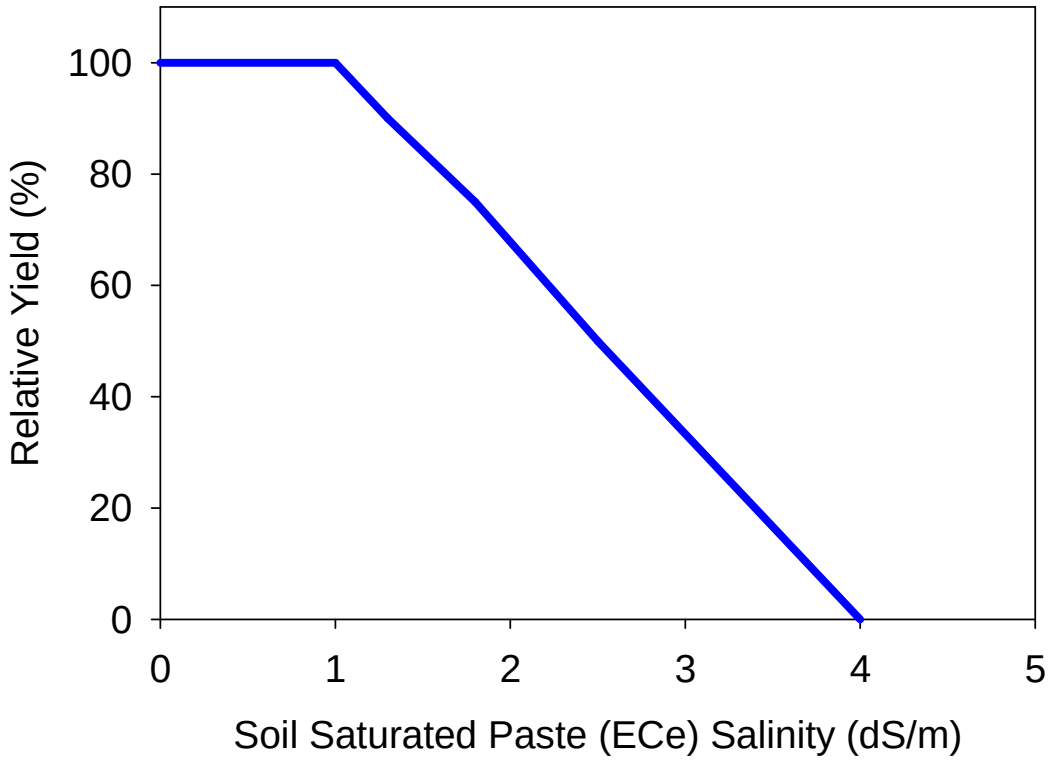
$EC_{sw} = 3 \times EC_w$

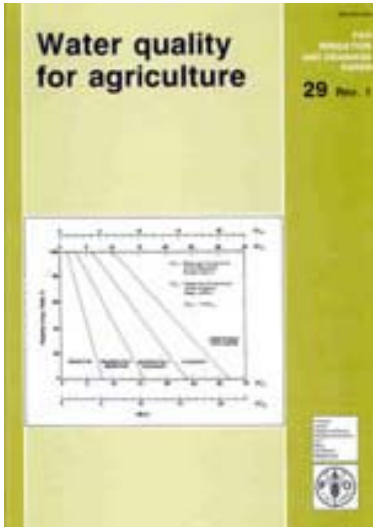
$EC_e = A \times EC_w$

A = concentration factor dependent on LF (1.6 for a LF = 0.15)

Crop sensitivity to soil salinity is related to ECe

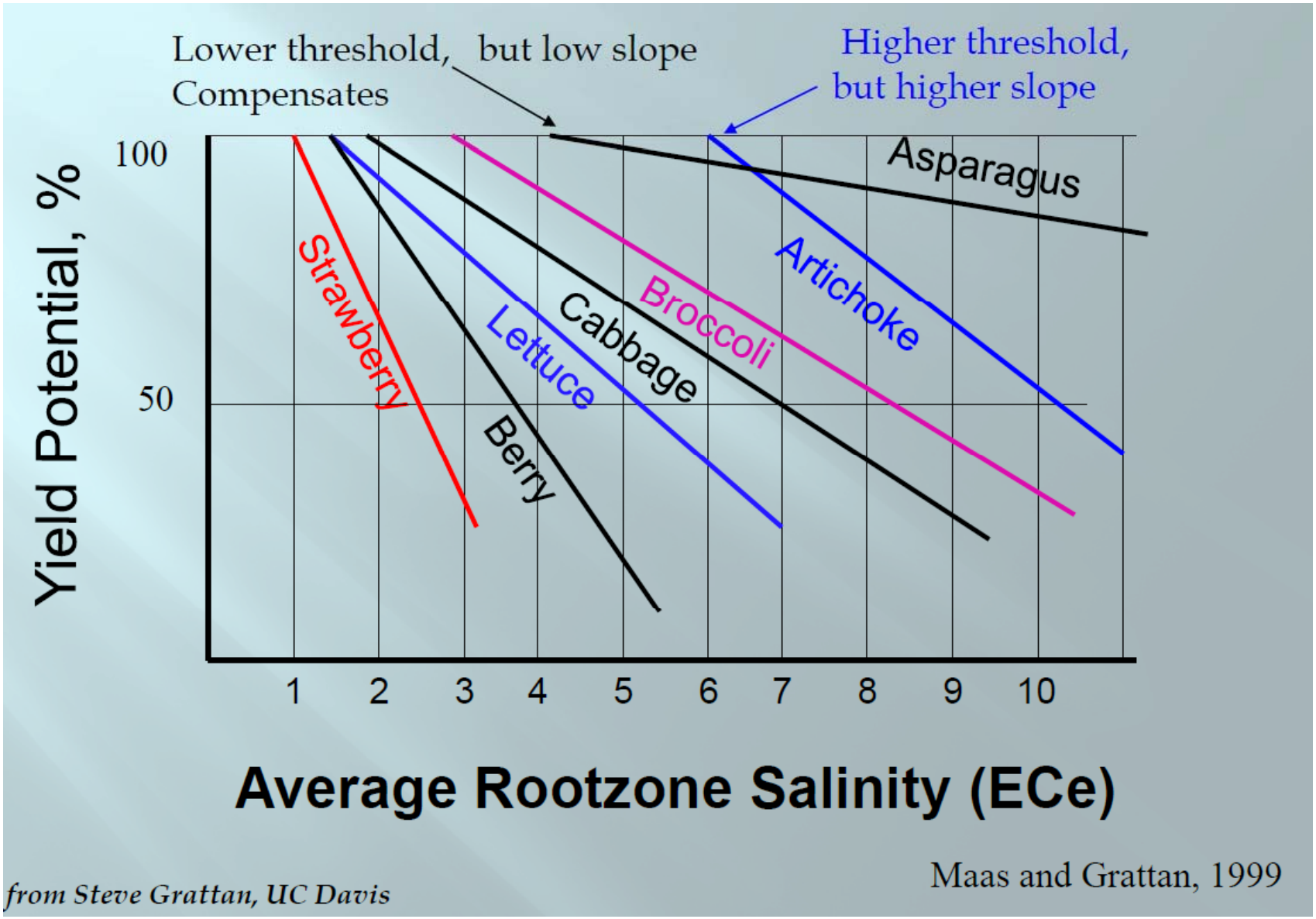
Relative Yield (%) = 100 - slope×(EC_e - EC_e threshold)





Ayers and Westcot, 1985

Maas and Hoffman, 1977



Maas and Grattan, 1999

from Steve Grattan, UC Davis

Salinity Effects on Cool Season Vegetables

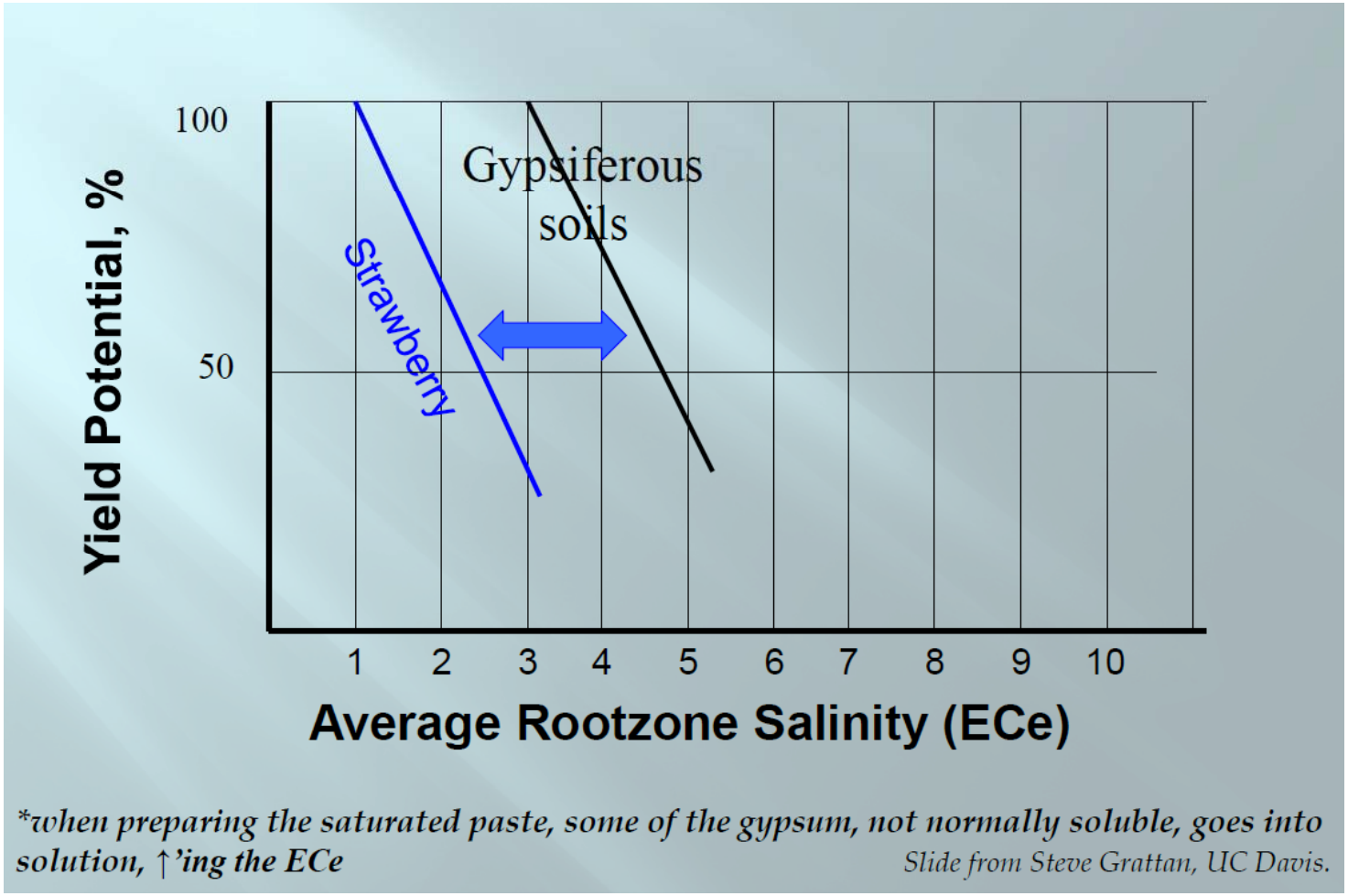
	Yield Potential [1]					
	100%		90%		75%	
Crop	EC_e	EC_w	EC_e	EC_w	EC_e	EC_w
	dS/m					
Broccoli	2.8	1.9	3.9	2.7	5.5	3.7
Cabbage	1.8	1.2	2.8	1.9	4.4	2.9
Celery	1.8	1.2	3.4	2.3	5.8	3.9
Lettuce	1.3	0.9	2.1	1.4	3.2	2.1
Spinach	2.0	1.3	3.3	2.2	5.3	3.5

EC_e = EC of saturated soil extract

EC_w = EC of irrigation water

1. Adapted from FAO irrigation and drainage paper 29, 1985

Salt tolerance is often higher in water or soil dominated by gypsum



**when preparing the saturated paste, some of the gypsum, not normally soluble, goes into solution, ↑'ing the ECe*

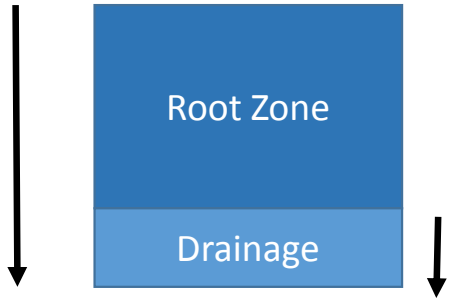
Slide from Steve Grattan, UC Davis.

What is a leaching fraction (LF)?

Water applied to prevent the build up of salts in the soil.

$$\mathrm{LF} = \frac{depth\ of\ water\ draining\ below\ root\ zone}{depth\ of\ applied\ water}$$

Applied Water
= rainfall + irrigation – runoff
= 10 inches



Water Draining below Root Zone
= 2 inches

Leaching Fraction = 2 in./10 in. = 0.2 or 20%

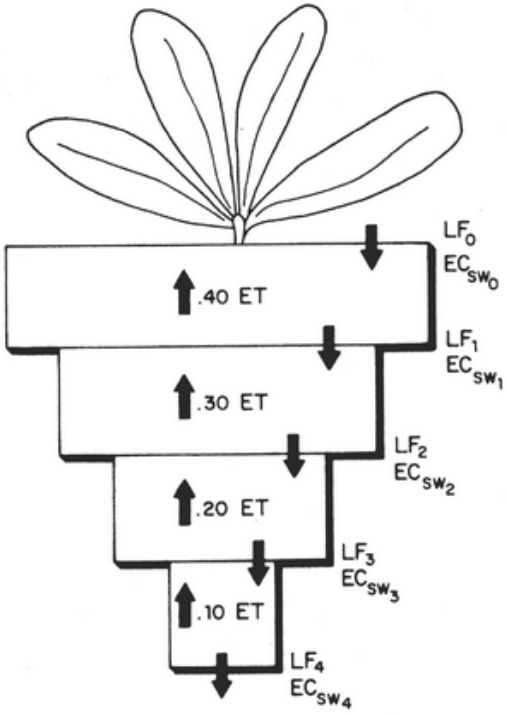
Other considerations to leaching

- **Need drainage (clay pan, perched water table)**
- **Leads to the leaching of nutrients**
- **Make most of winter rain and pre-irrigations**

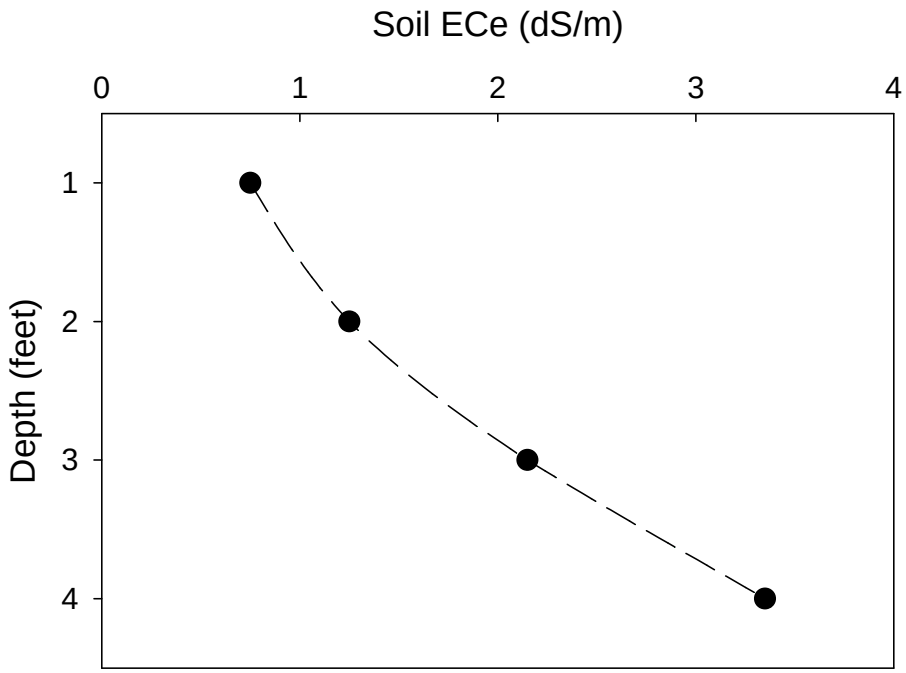
Enhance Infiltration and Drainage

- **Tile Drainage**
- **Soil amendments**
- **Cover crops**
- **Deep tillage**

Assumptions in estimating a leaching fraction:



LR = 15%, ECw = 1



Estimating the Leaching Requirement

$$LR = \frac{ECw * 100}{(5 * ECe) - ECw}$$

Example:
Water ECw = 1.5 dS/m
Yield Threshold (100%): ECe = 2.5 dS/m

$$\frac{1.5\ ds/m * 100}{(5 * 2.5 ds/m) - 1.5} = 14\%$$

Estimating the Leaching Requirement

Soil Salinity (EC_e) in dS/m	Salinity of Irrigation Water (EC_w) in dS/m												
	0.2	0.5	0.7	1	1.3	1.5	2	2.5	3	4	5	6	7
0.5	9	25	39	67	108	--	--	--	--	--	--	--	--
1	4	11	16	25	35	43	67	100	--	--	--	--	--
1.5	3	7	10	15	21	25	36	50	67	114	--	--	--
2	2	5	8	11	15	18	25	33	43	67	100	--	--
2.5	2	4	6	9	12	14	19	25	32	47	67	92	--
3	1	3	5	7	9	11	15	20	25	36	50	67	88
3.5	1	3	4	6	8	9	13	17	21	30	40	52	67
4	1	3	4	5	7	8	11	14	18	25	33	43	54
4.5	1	2	3	5	6	7	10	13	15	22	29	36	45
5	1	2	3	4	5	6	9	11	14	19	25	32	39
5.5	1	2	3	4	5	6	8	10	12	17	22	28	34
6	1	2	2	3	5	5	7	9	11	15	20	25	30
6.5	1	2	2	3	4	5	7	8	10	14	18	23	27
7	1	1	2	3	4	4	6	8	9	13	17	21	25

How do you determine how much water to apply to attain a desired leaching fraction?

$$Applied\ Water = \frac{ETc}{1 - LF}$$

Example:

If LF = 0.3 (30%) and ET = 15 inches

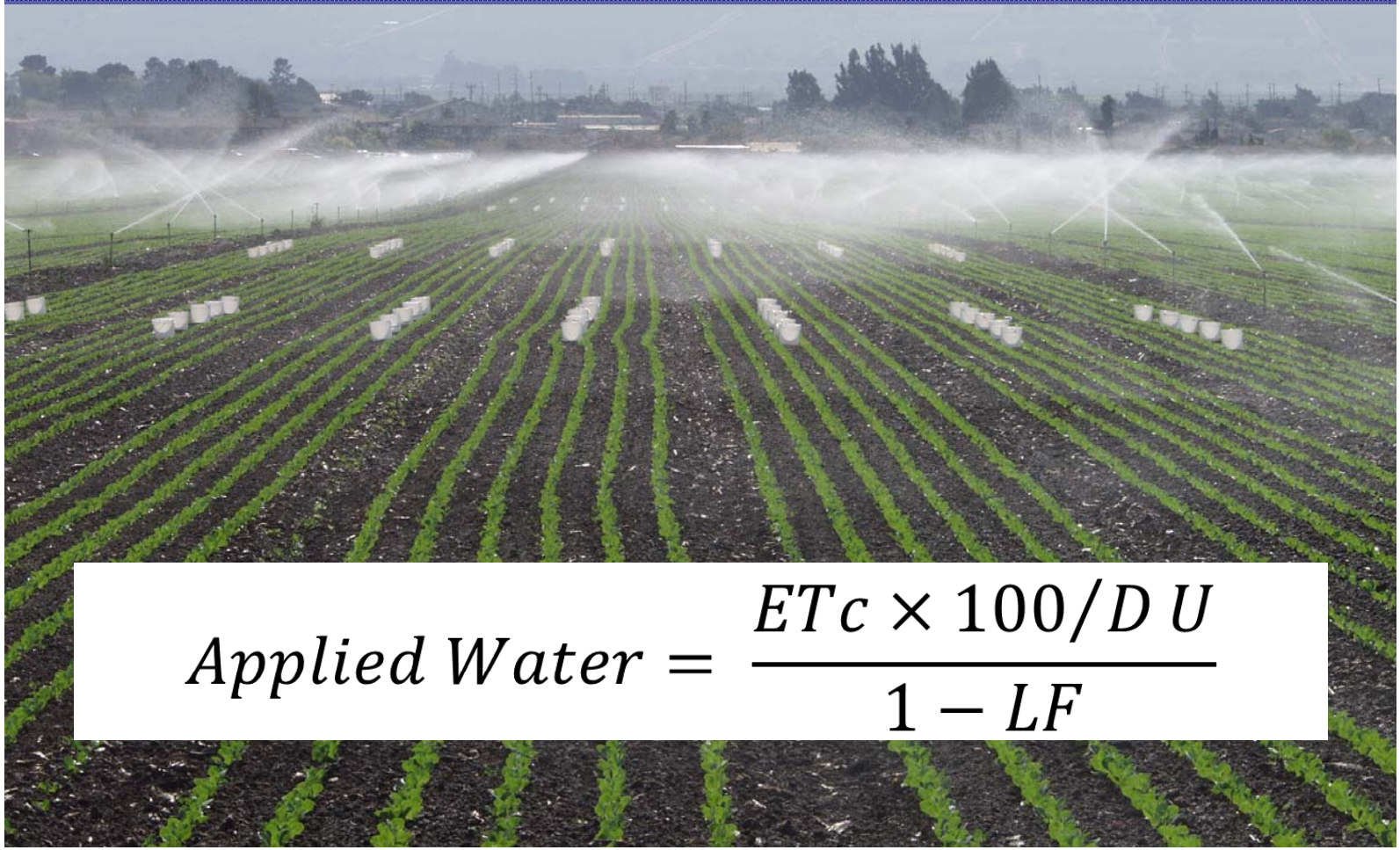
$$Applied\ Water = \frac{15\ inches}{1-0.3} = 21.4 \text{ inches}$$

A 30% Leaching Fraction: Applied water = 143% of Crop ET

Leaching Fraction	Applied Water as a Percentage of Crop ET
--------- %	----------
5	105
10	111
15	118
20	125
25	133
30	143
35	154
40	167
50	200
60	250
70	333
80	500

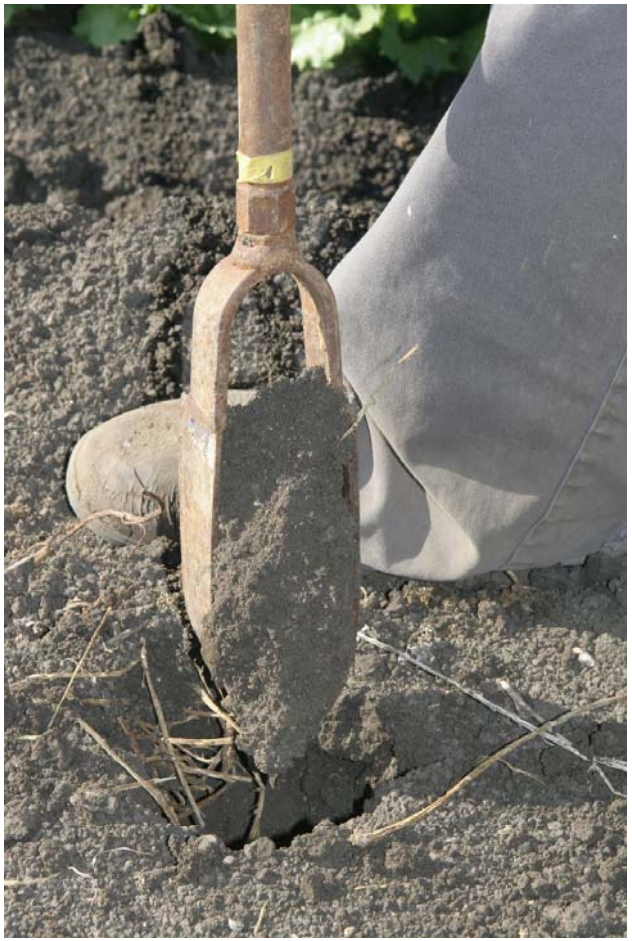
$$LF = \frac{D}{ET + D}$$

Should you factor in irrigation uniformity into Leaching Requirement?



$$Applied\ Water = \frac{ETc \times 100/D\ U}{1 - LF}$$

Field Assessment of Leaching Fraction



1. Sample soil from 3 to 4 layers of depth in root zone
2. Measure ECe of soil from each layer
3. Calculate the average ECe and compare to yield threshold ECe
4. Measure irrigation water salinity (ECw)
5. Calculate the actual Leaching Fraction

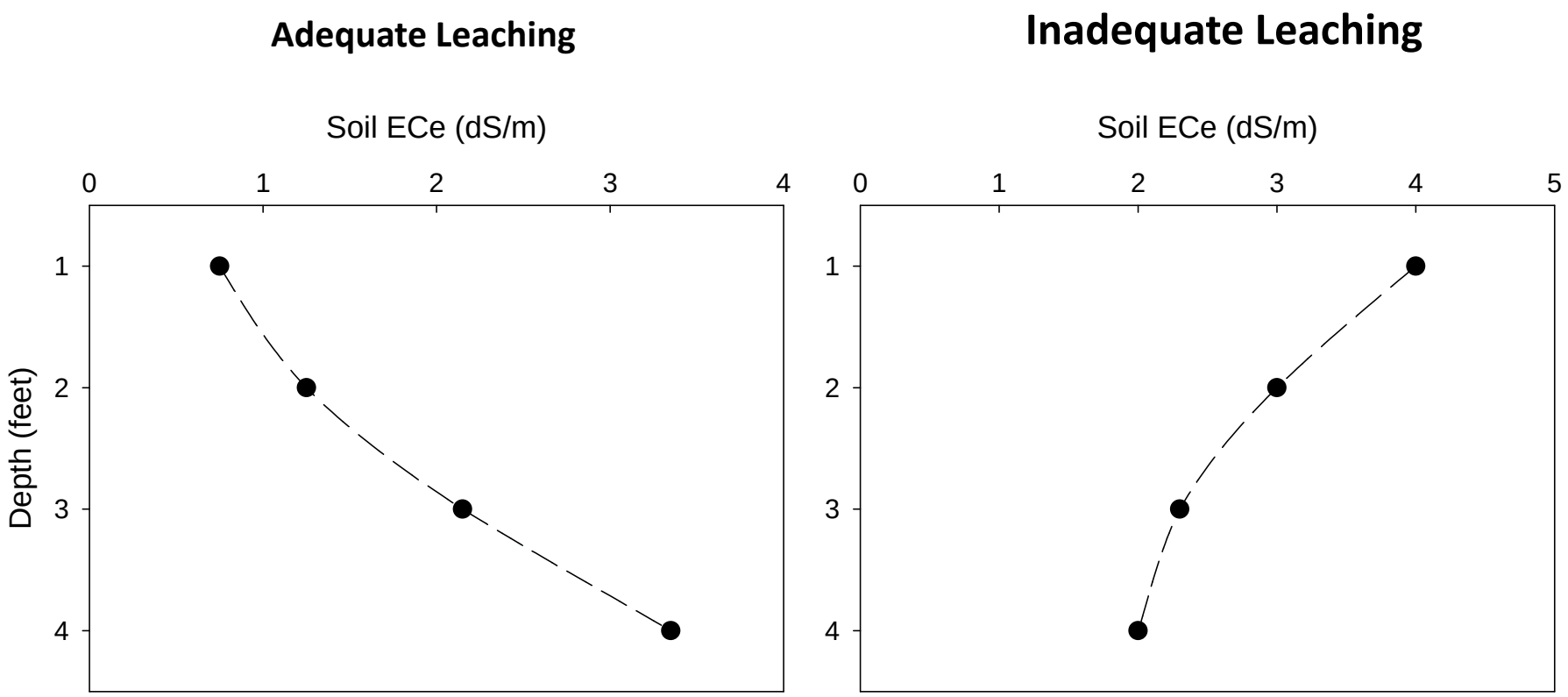
<u>Example:</u>

Water ECw = 1.0 dS/m

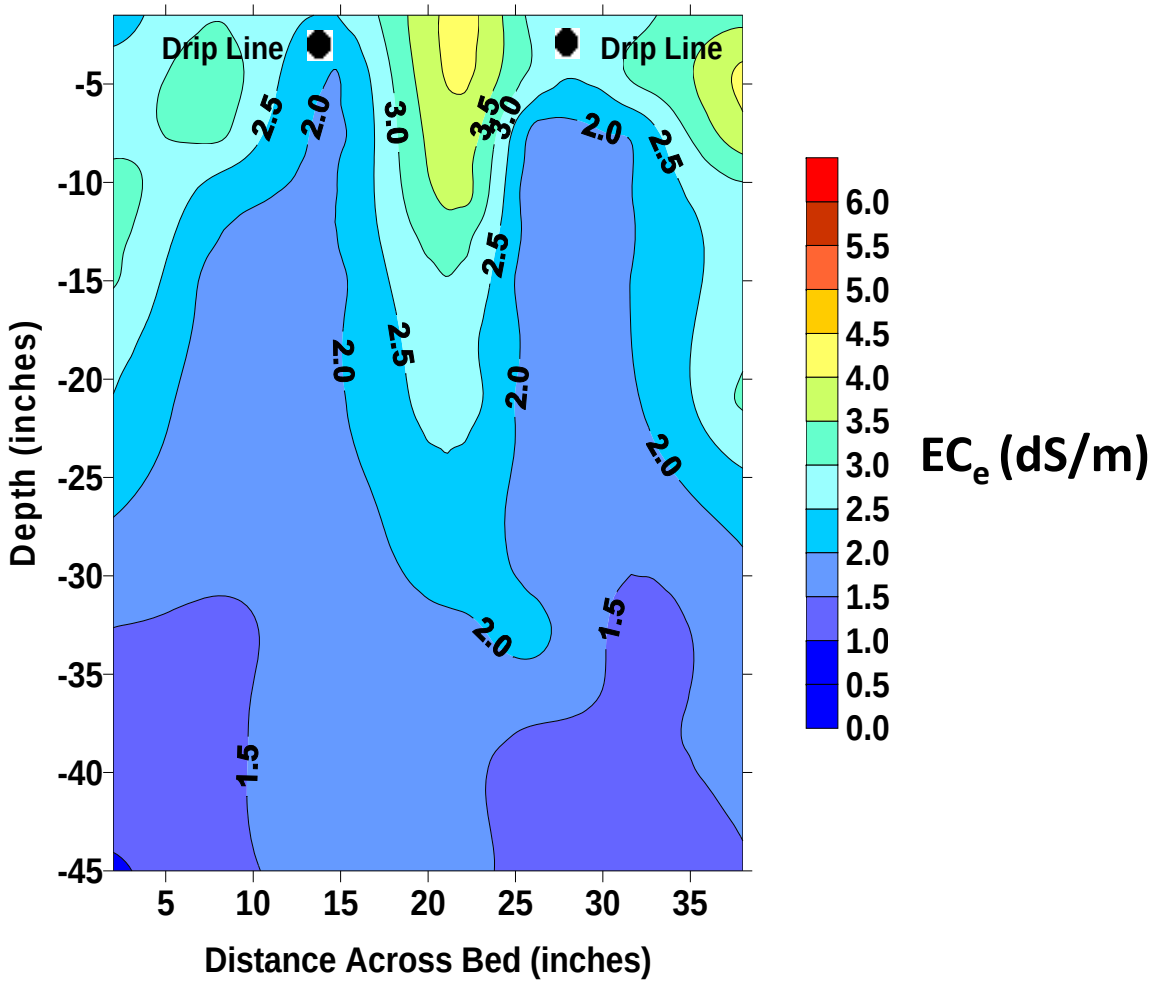
Average ECe = 2.0 dS/m

$$\frac{1.0\ ds/m\ *100}{(5*2.0\ ds/m)-1.0}=11\%$$

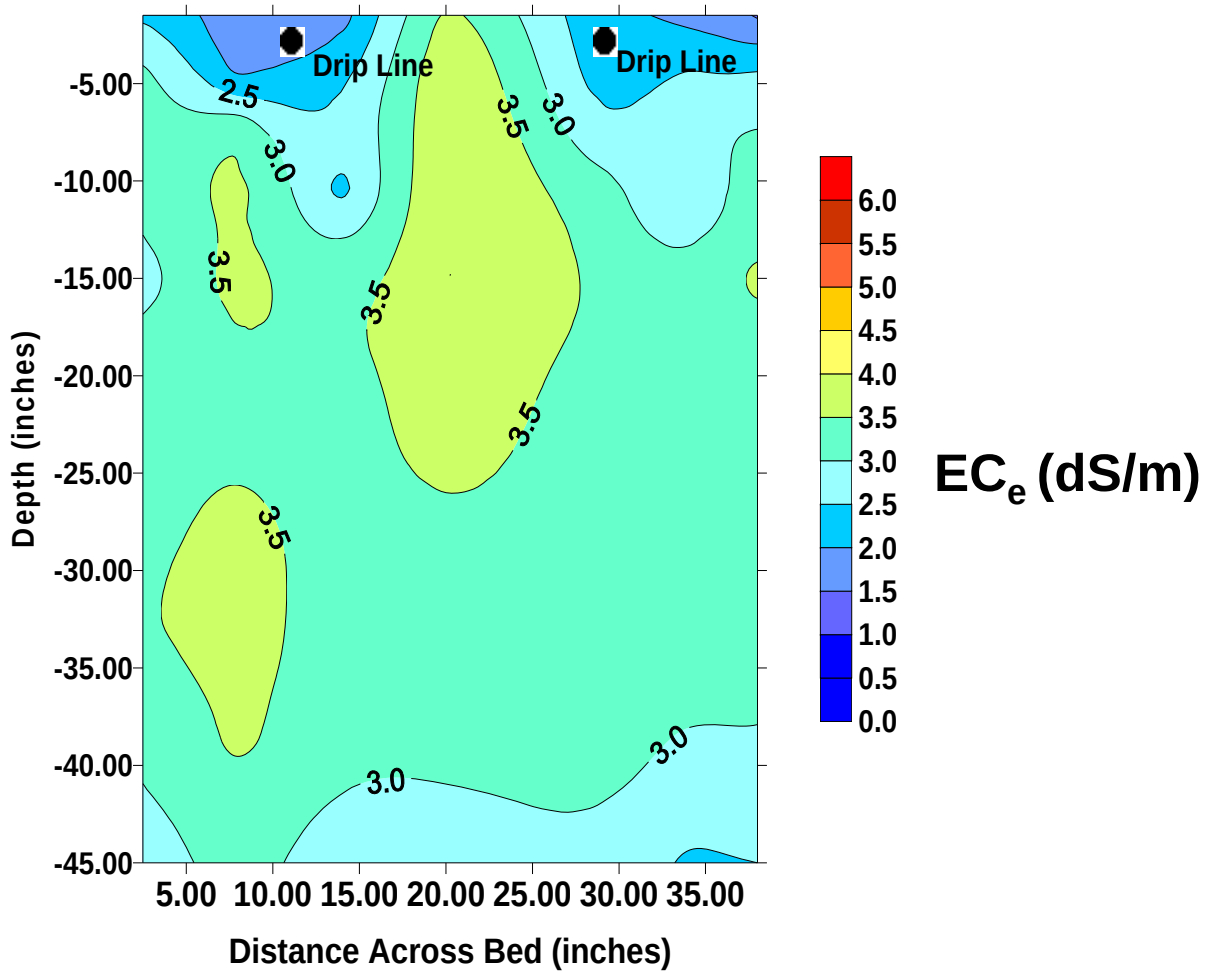
Field Assessment of Leaching Fraction



High Leaching Fraction under Drip in Strawberry



Low Leaching Fraction under Drip in Strawberry



Field measurements of salinity:

EM 38

Soil Salinity Probe

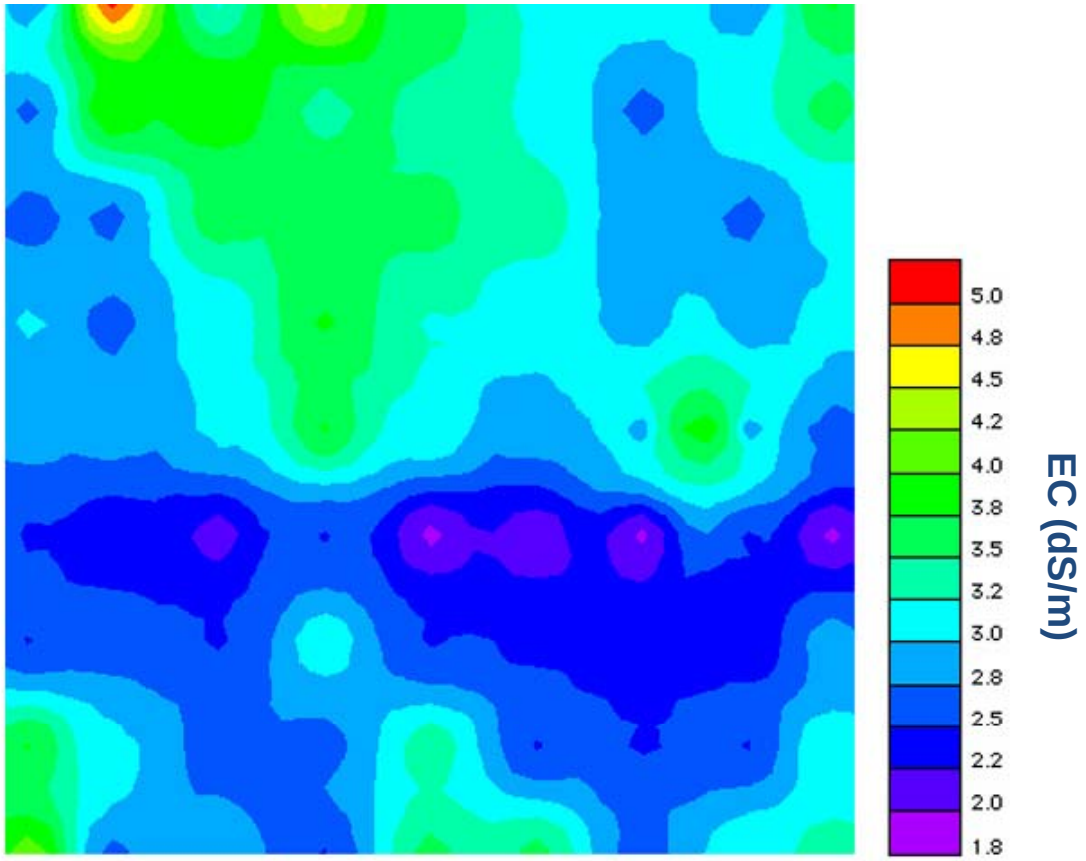
Suction lysimeter

$$\mathrm{LF} = \frac{ECw}{ECsw}$$

Direct measurements of soil salinity: Decagon 5TE probe

- Measures: ECa, Soil temp, volumetric moisture
- Calibration for ECsw
- Good for assessing relative differences within a field
- Differences in soil moisture and bulk density will still interfere with readings

Bulk EC Map Using an EM38



Readings affected by:

- **Soil Salinity**
- **Soil Compaction (porosity)**
- **Soil Texture (clay content)**
- **Soil Moisture Content**
- **Soil Temperature**
- **Depth of penetration**

Managing Salinity under Drought Conditions

- Less rainfall, higher ET, ground water may be saltier
- Use an appropriate leaching fraction
- Credit all rainfall, pre-irrigation and germination water
- Maximize application uniformity
- Irrigate more frequently
- Monitor soil and water salinity