University of California
Agriculture and Natural Resources

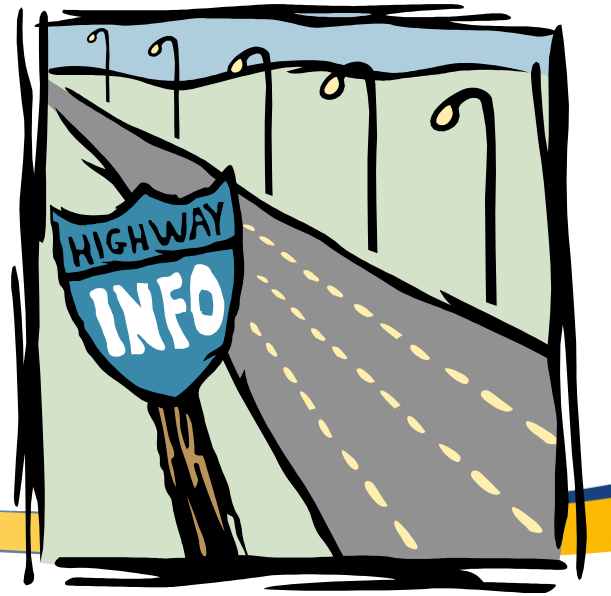
Pistachios are salt tolerant….right?

- Higher threshold than other tree crops but eventual decline in tree growth and yield
- Continual tree nutrition, soil, water monitoring and management is key!

ROAD MAP for Salinity Management

What to evaluate?

- **Crop salinity tolerance**
- Water supply and quality
- Soil quality/structure
- Salinity management options



Salinity impact on trees

Osmotic:

-Elevated salts require more energy to take in water

-ET decreases

-Growth limited

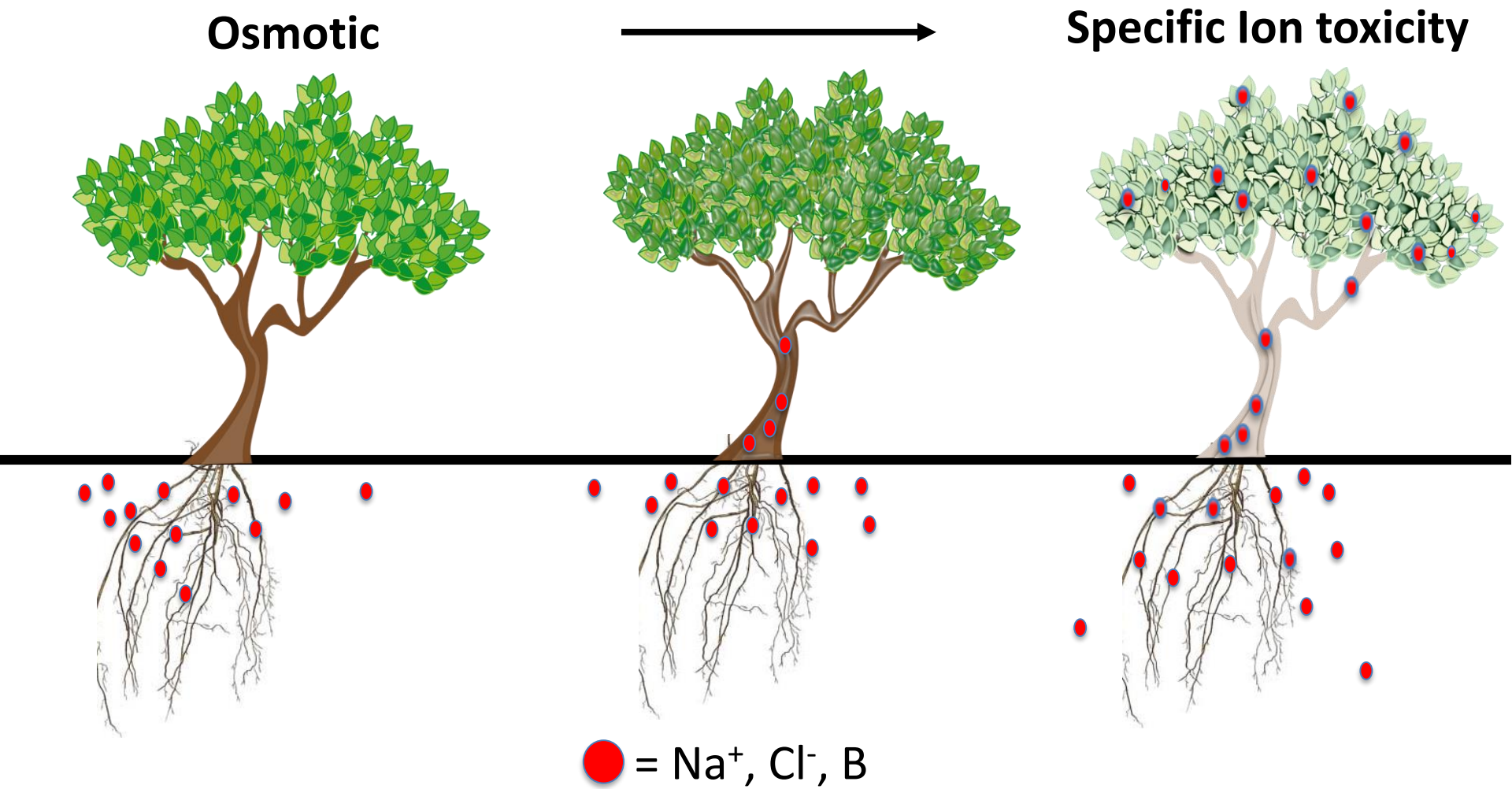
Specific Ion Toxicity:

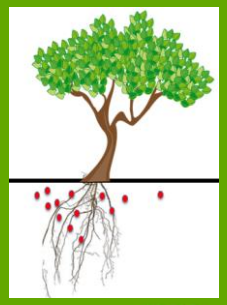
-Sodium (Na^+), Chloride (Cl^-) and Boron (B) absorbed by roots accumulate in leaves

-Leaf burn on margins

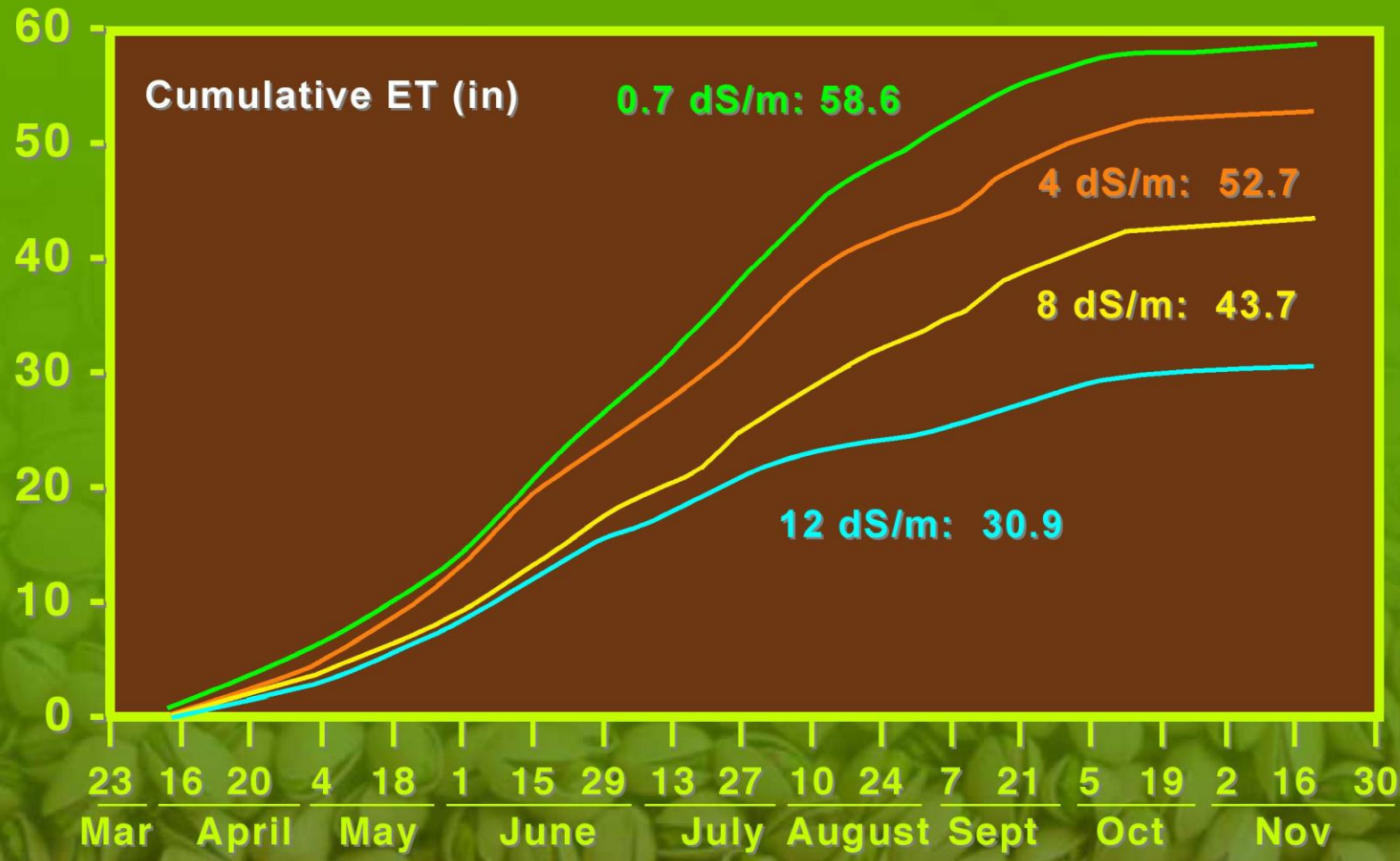
-Nutritional disorders

Tree sensitivity increases with time

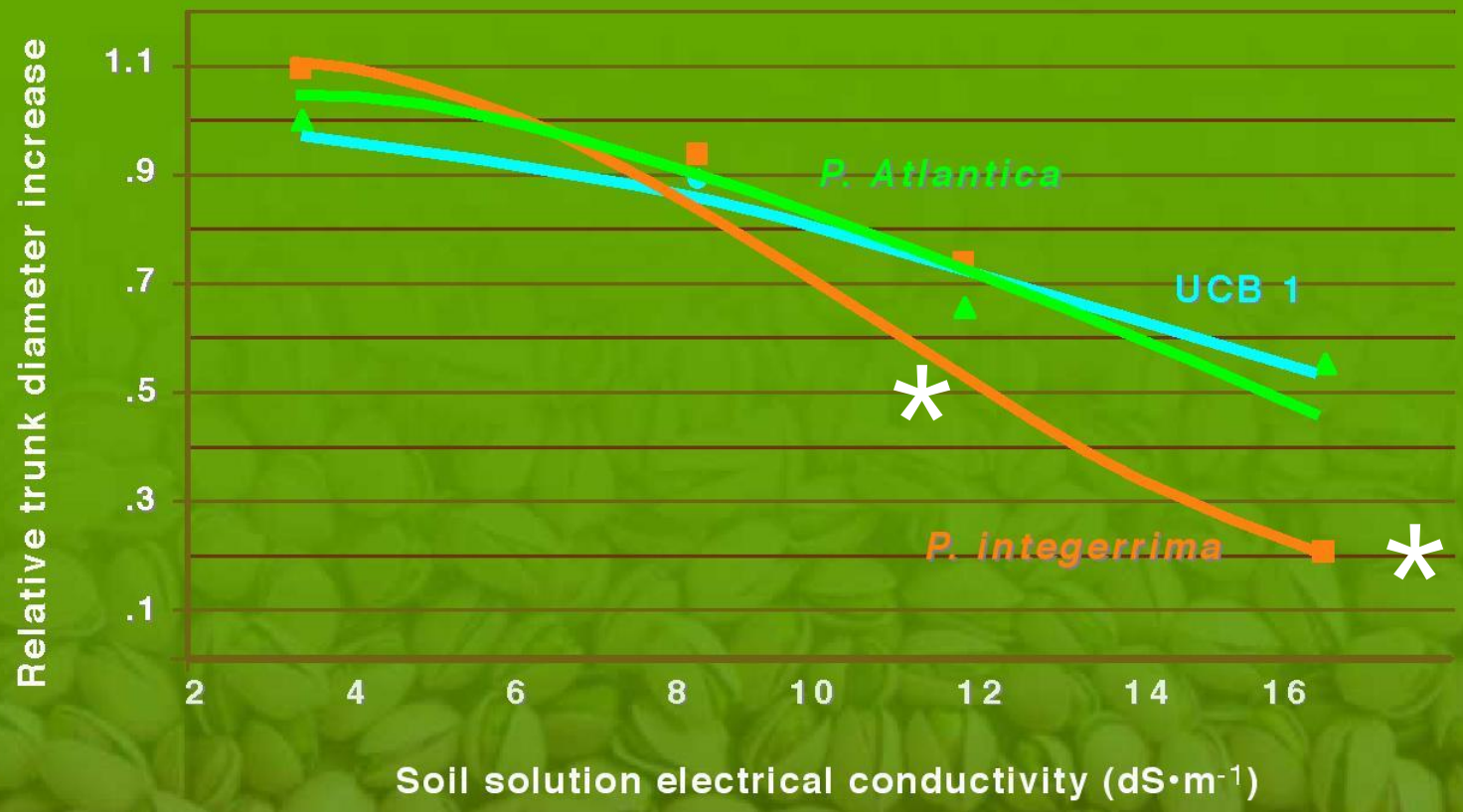




Osmotic impacts



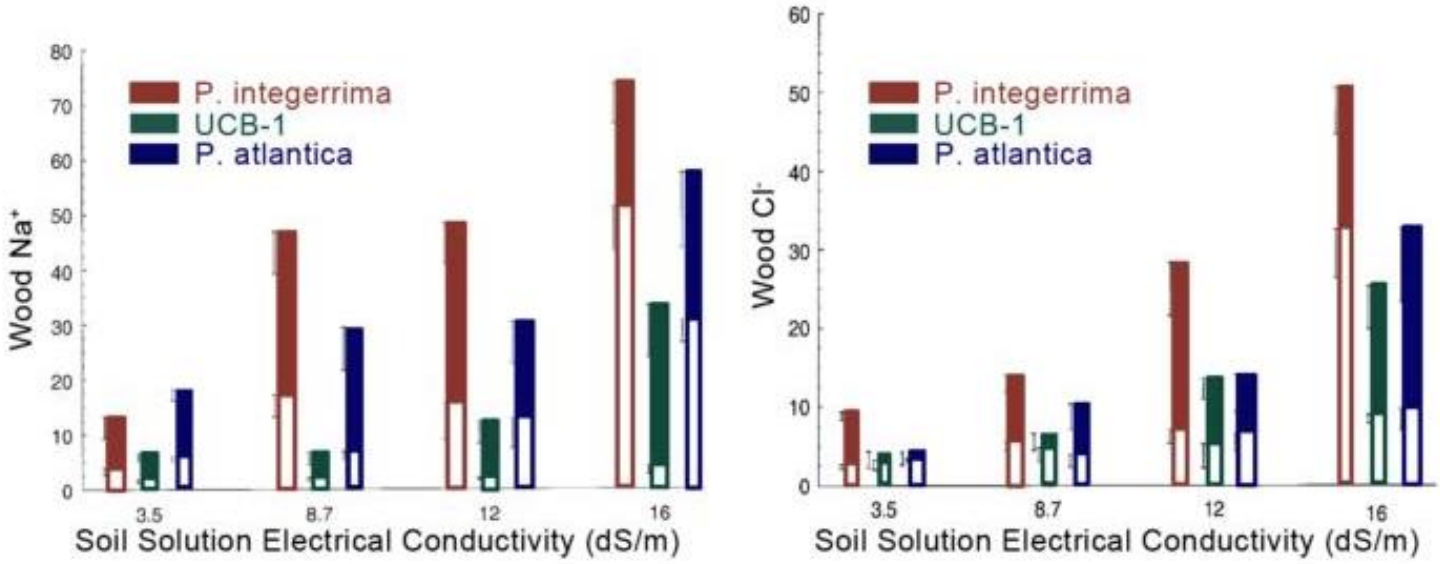
Osmotic impacts



Ferguson, Poss, Grattan, Grieve, Wang, Wilson, Donavan, Chao. 2002 JASHS 127 (2): 194-199

Specific ion damage

Na^+ and Cl^- ion partitioning between scion and rootstock



Ratio of rootstock (solid color) / scion (white) concentration of Na^+ and Cl^- with increasing salinity

Specific ion damage

B levels in leaf tissue of Kerman scion

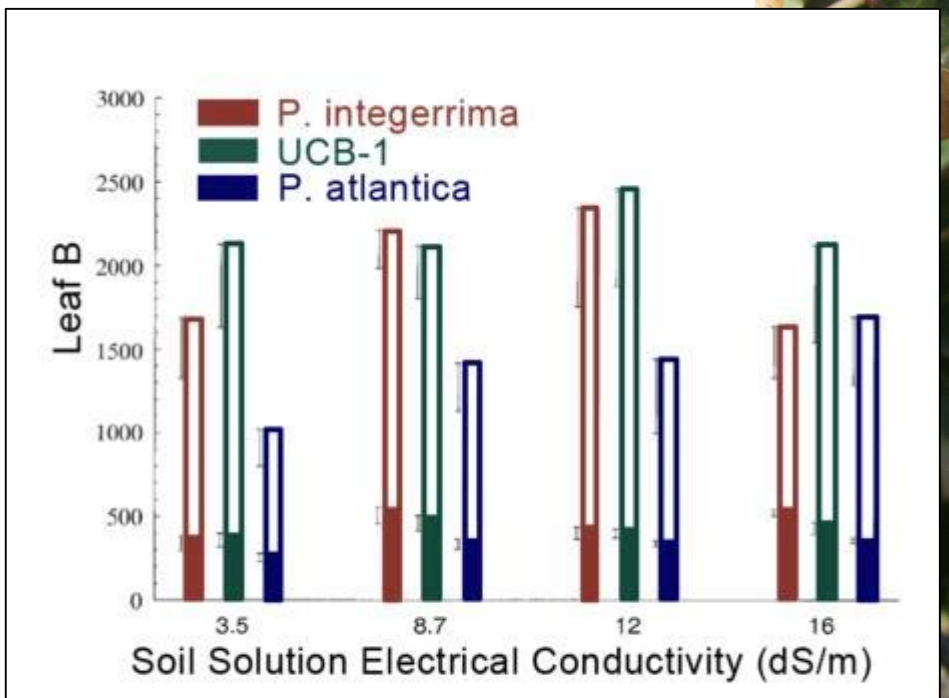
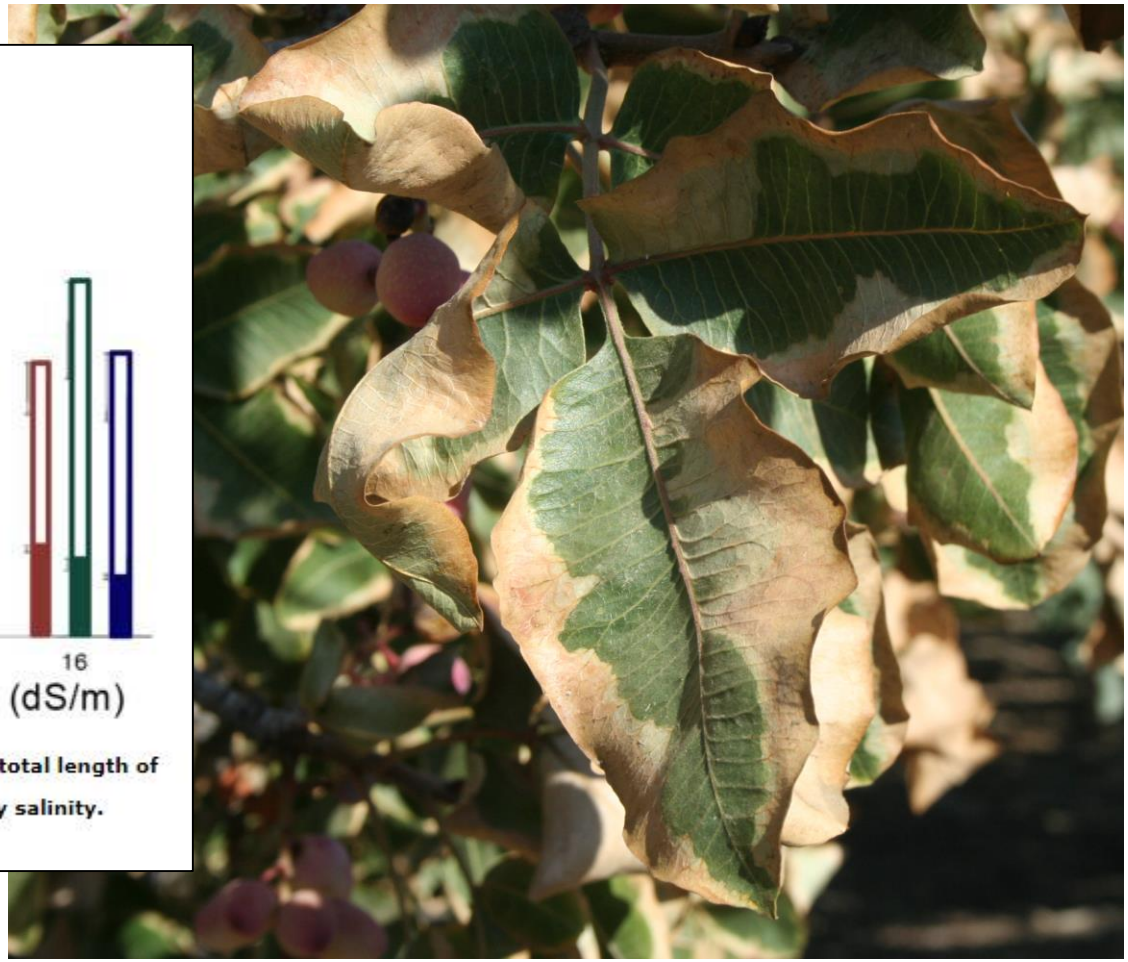


Figure 1. Boron in healthy (filled area of column) & injured (total length of column) leaves of scion on 3 rootstocks as influenced by salinity.



Specific ion tissue thresholds

Specific Ion	Degree of toxicity levels in leaf tissue		
	None	Increasing	Severe
Sodium (ppm)	< 100	100 - 200	> 200
Chloride (%)	< 0.2	0.2 - 0.4	> 0.4
Boron (ppm)	< 300	300 - 700	> 800

Critical levels of specific ions in pistachio leaf tissue (July/August tissue sample prior to harvest)

Source Adapted from Ayers and Westcot 1985.

Yield impacts

Sunburn

Nut shrivel

Non-splits

Photos: Themis Michailides

Yield Impacts

Summary of salinity impacts on Pistachio

- Osmotic effects > specific ion damage over time
- Difference among rootstocks in how they partition Na^+, Cl^-
- **Established trees** can be irrigated with saline water up to 8.4 dS/m
- **From planting to maturity** critical limit 6 dS/m
- Rootstock tolerance UCBI > PGI
  UCBI: 100 lb (1.4%) decline per 1 dS/m >6

  PGI: 236 lb (3.0%) decline per 1 dS/m >6

http://ucanr.edu/sites/psalinity

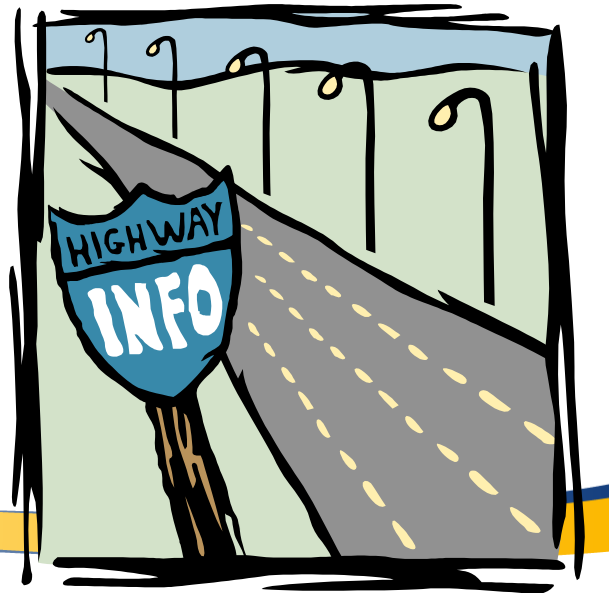
Pistachios are salt tolerant but….

4.5 to 6 dS/m EC irrigation water may not be sustainable

ROAD MAP for Salinity Management

What to evaluate?

- Crop salinity tolerance
- **Water supply and quality**
- **Soil quality/structure**
- **Salinity management options**
  - **Amendment and leaching dependent on quality of water available**



Soil salinity amendment and leaching calculations

Cnvrsn-Infilt-LeachCalc

http://cekern.ucanr.edu/Irrigation_Management/ANALYTICAL_CONVERSIONS_AND_LEACHING_CALCULATIONS/

Included in your files on thumbdrive received at end of course.

Water and Soil Quality

EC is concentration of salts in solution: dS/m

- Irrigation water: ECw
- Soil water: ECe

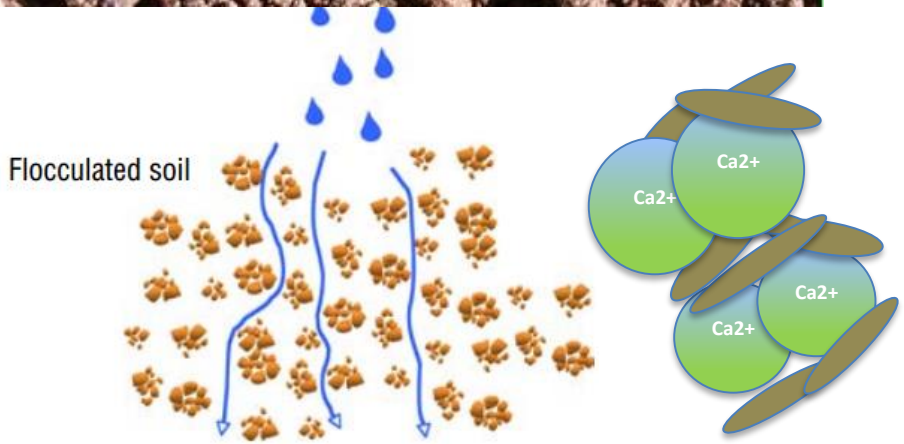
Analysis:

	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			

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

Sodicity: High SAR with low Ec_w = poor infiltration

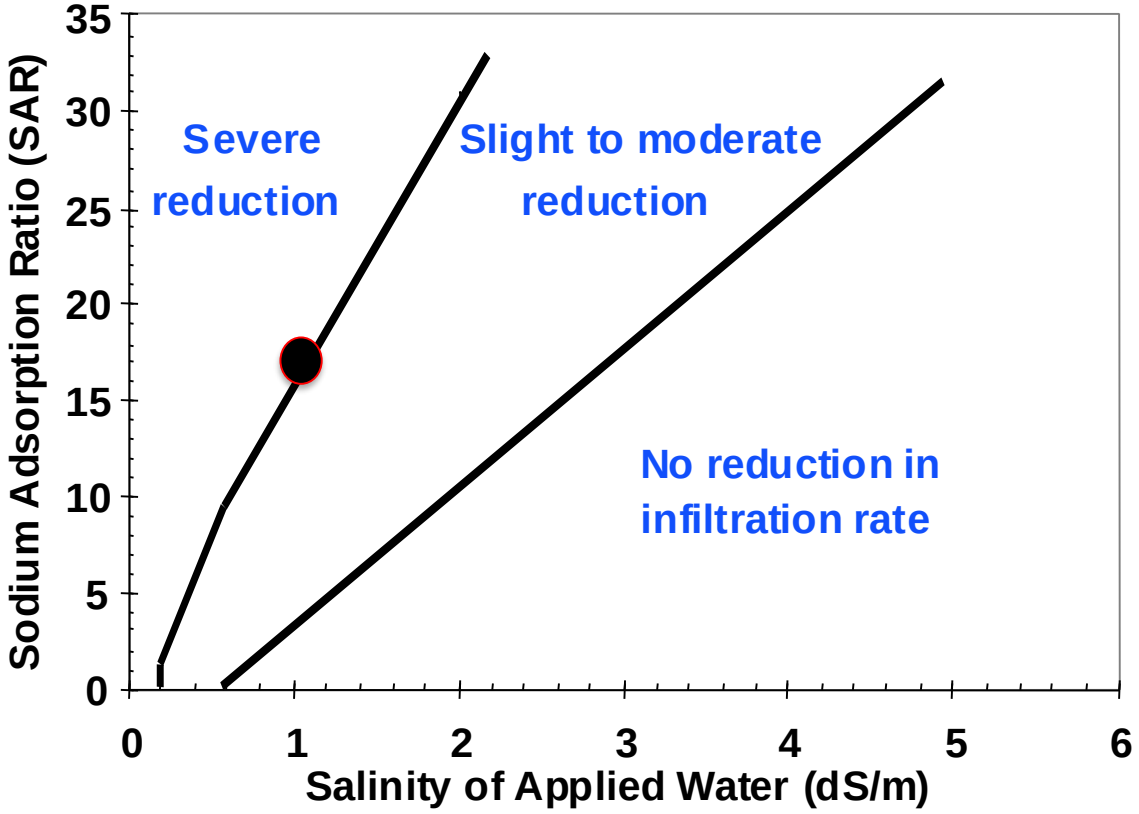
Normal or saline: low SAR with low or high EC_w= little to no infiltration problem



Soil ECe: average 7.1 dS/m

Low EC, high SAR ground water

Calculate Amendment Rates



Analysis:

	Well 1	
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	1.0	meq/l
Cl	**4.6**	**meq/l**
SO_4	0.1	meq/l
B	**0.7**	**mg/l**
NO_3	5.2	mg/l
SAR	**17.5**	
SAR_{adj}	16.6	

Na + Ca + Mg = 9.6 + 0.5 + 0.1 = 10.2 meq/l

EC = 10.2 ÷ 10 = 1.0 dS/m

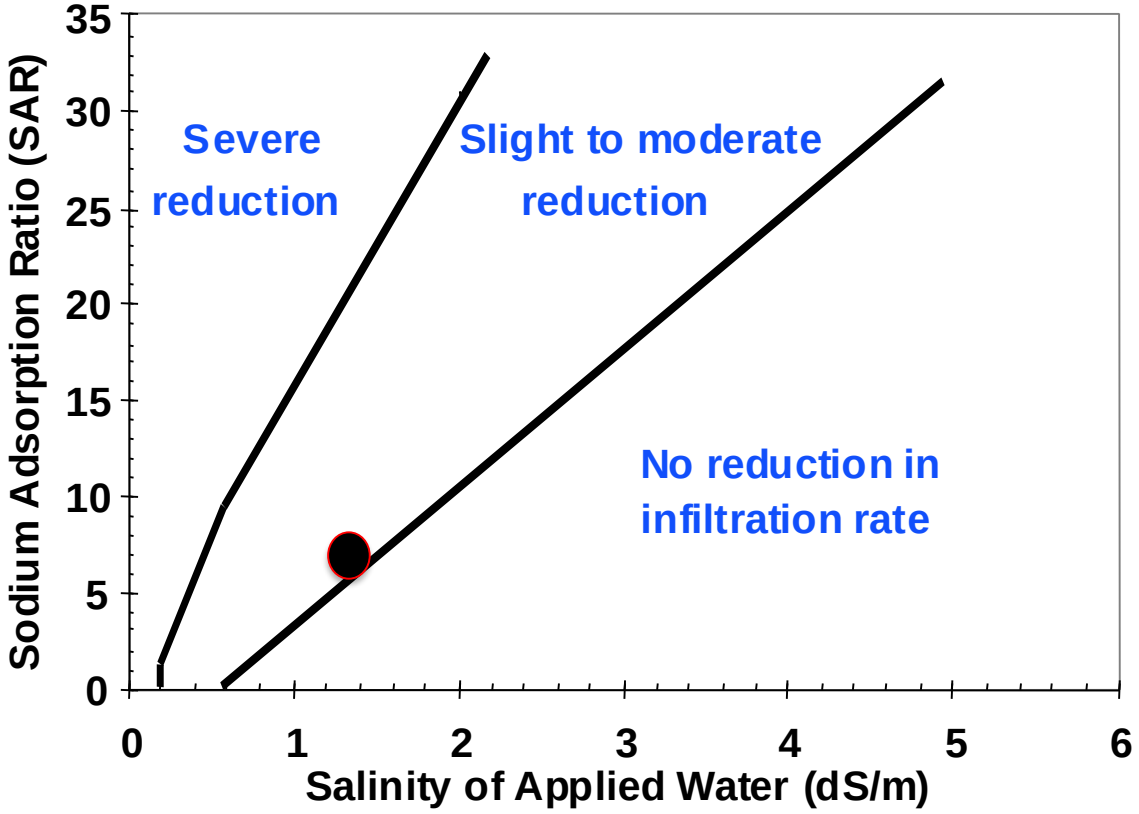
SAR = 9.6 ÷ ((0.5 + 0.1) ÷ 2)^0.5 = 17.5

Calculate Amendment Rates

	Pounds amendment per acre-foot/water				
meq Ca/l	*gypsum 100% pure*	*sulfuric acid (100% pure)*	*lime sulfur (23.3 % S)*	*nitro* sul (20% N, 40% S)*	*urea-sulfuric acid* (10% N, 55% acid)*
1.0	234	133	192	50	107
2.0	468	266	383	100	214
3.0	702	399	576	150	321
4.0	936	532	768	200	428
5.0	1170	665	959	250	535
6.0	1404	798	1151	300	642

** One mole of ammonium is assumed to replace two moles of sodium.*

Calculate Amendment Rates



Analysis:

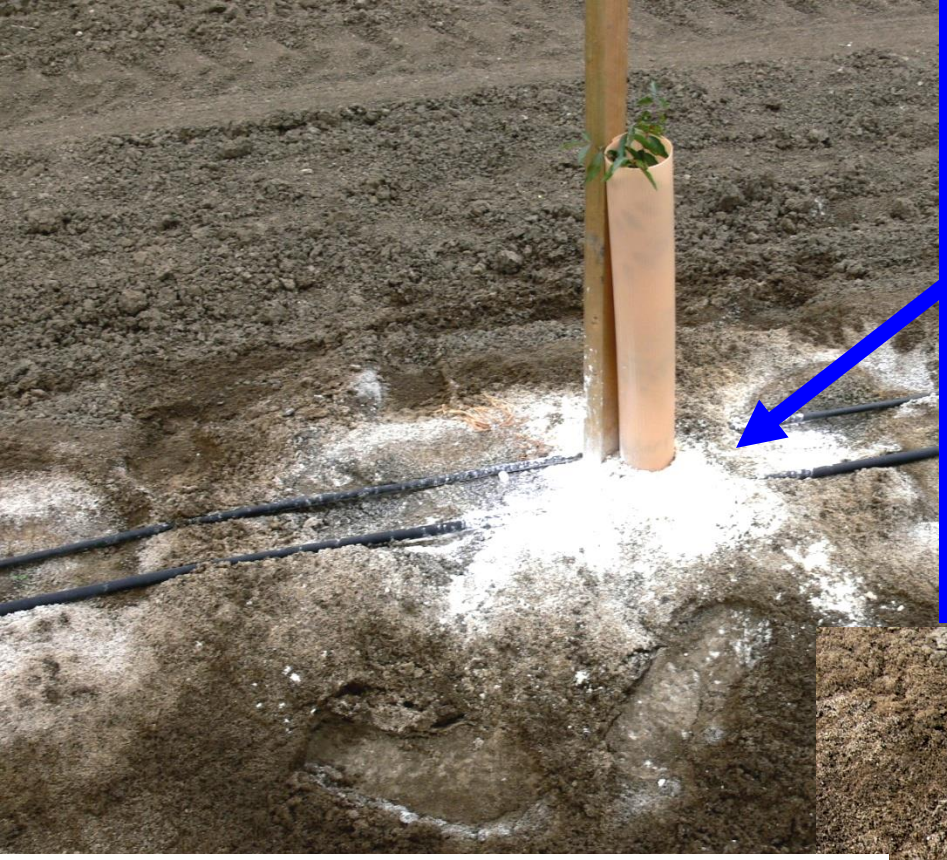
	Well 1
pH	8.4
EC_w	1.3
Ca	3.5
Mg	0.1
Na	**9.6**
HCO_3	4.2
CO_3	1.0
Cl	**4.6**
SO_4	0.1
B	**0.7**
NO_3	5.2
SAR	**7.2**

New Ca + Mg = 3.5 + 0.1 = 3.6 meq/l

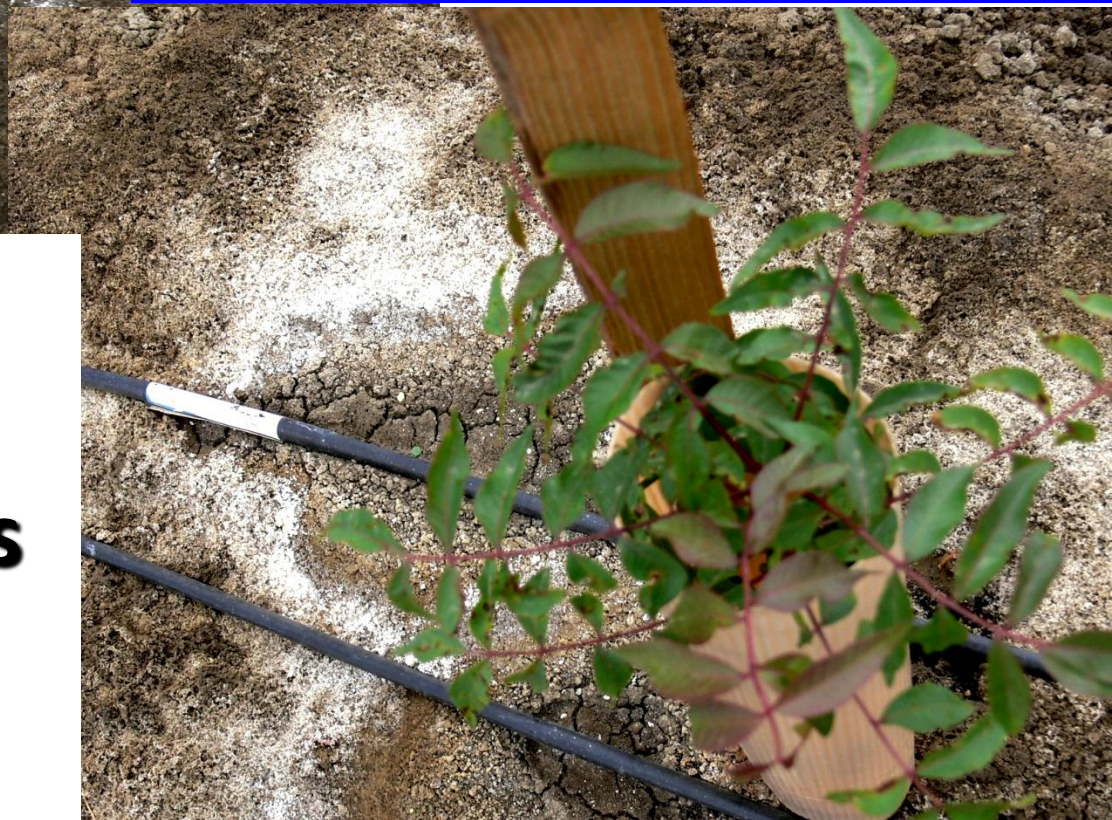
New cation concentration = 9.6 + 3.6 = 13.2 meq/l

New EC = 13.2 ÷ 10 = 1.3 dS/m

New SAR = 9.6 ÷ ((3.5 + 0.1) ÷ 2)^0.5 = 7.2



Broadcasting or injecting gypsum into the water is only necessary if: Sodium > 5*Calcium



Gypsum is a salt adds to osmotic pressure that limits water uptake through the roots

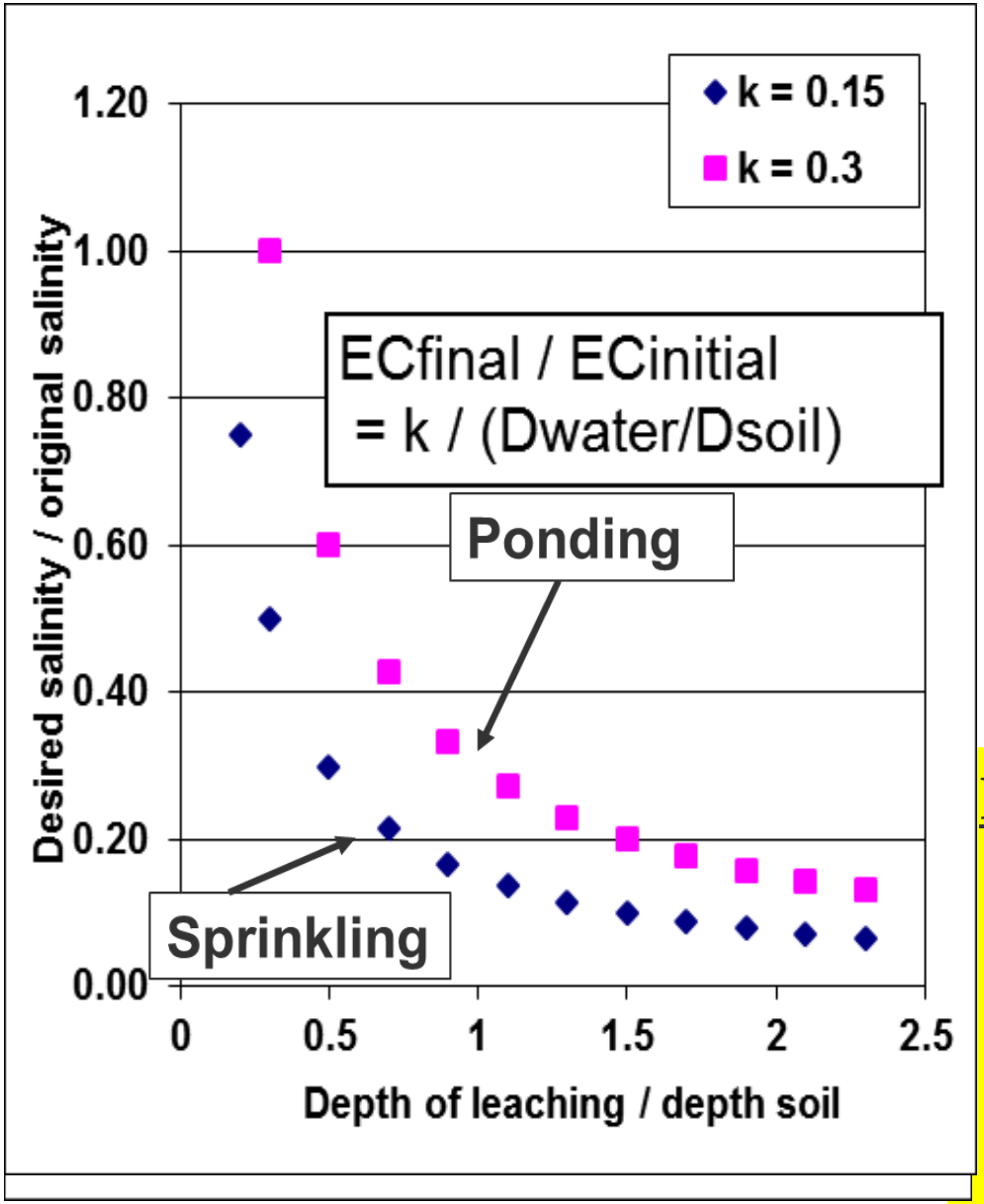
Soil ECe: average 6.6 dS/m
Low EC, high SAR ground water
Low EC, low SAR surface water

Calculate the leaching fraction

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	**CALCULATING LEACHING DEPTH TO ACHIEVE DESIRED**															
2		**SALINITY FOR SOIL RECLAMATION**														
3		(Using fresh water with EC <= 1 mmho/cm)														
4																
5			CALCULATING SAR, ESP AND DESIRED LEACHING DEPTH											Sprinkling / Drip to Leach Rootzone		
6		Sample	Data Required from Soil Extract Analysis													
7	EXAMPLE	Thickness	(%)		(dS/m)	(meq/l)						Desired	Dsrd/Orig	(ft water /	(inch water	
8	Depth	(inches)	SP	pH	EC	Ca	Mg	Na	SAR	ESP	EC/ESP	Salinity	EC	ft soil)	for sample)	
9	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	
10	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	
11	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	
12									TOTAL DEPTH OF LEACHING REQUIRED (inches):						11.70	
13																
14			ENTER YOUR DATA BELOW											Sprinkling / Drip to Leach Rootzone		
15	YOUR	Sample	Data Required from Soil Extract Analysis													
16	SOIL	Thickness	(%)		(dS/m)	(meq/l)						Desired	Dsrd/Orig	(ft water /	(inch water	
17	Depth	(inches)	SP	pH	EC	Ca	Mg	Na	SAR	ESP	EC/ESP	Salinity	EC	ft soil)	for sample)	
18									#####	#DIV/0!	#DIV/0!		#DIV/0!	#DIV/0!	#DIV/0!	
19									#####	#DIV/0!	#DIV/0!		#DIV/0!	#DIV/0!	#DIV/0!	
20									#####	#DIV/0!	#DIV/0!		#DIV/0!	#DIV/0!	#DIV/0!	
21									TOTAL DEPTH OF LEACHING REQUIRED (inches):						#DIV/0!	

http://cekern.ucanr.edu/Irrigation_Management/ANALYTICAL_CONVERSIONS_AND_LEACHING_CALCULATIONS/

Mass balance leaching for ponding vs sprinkling or intermittent ponding



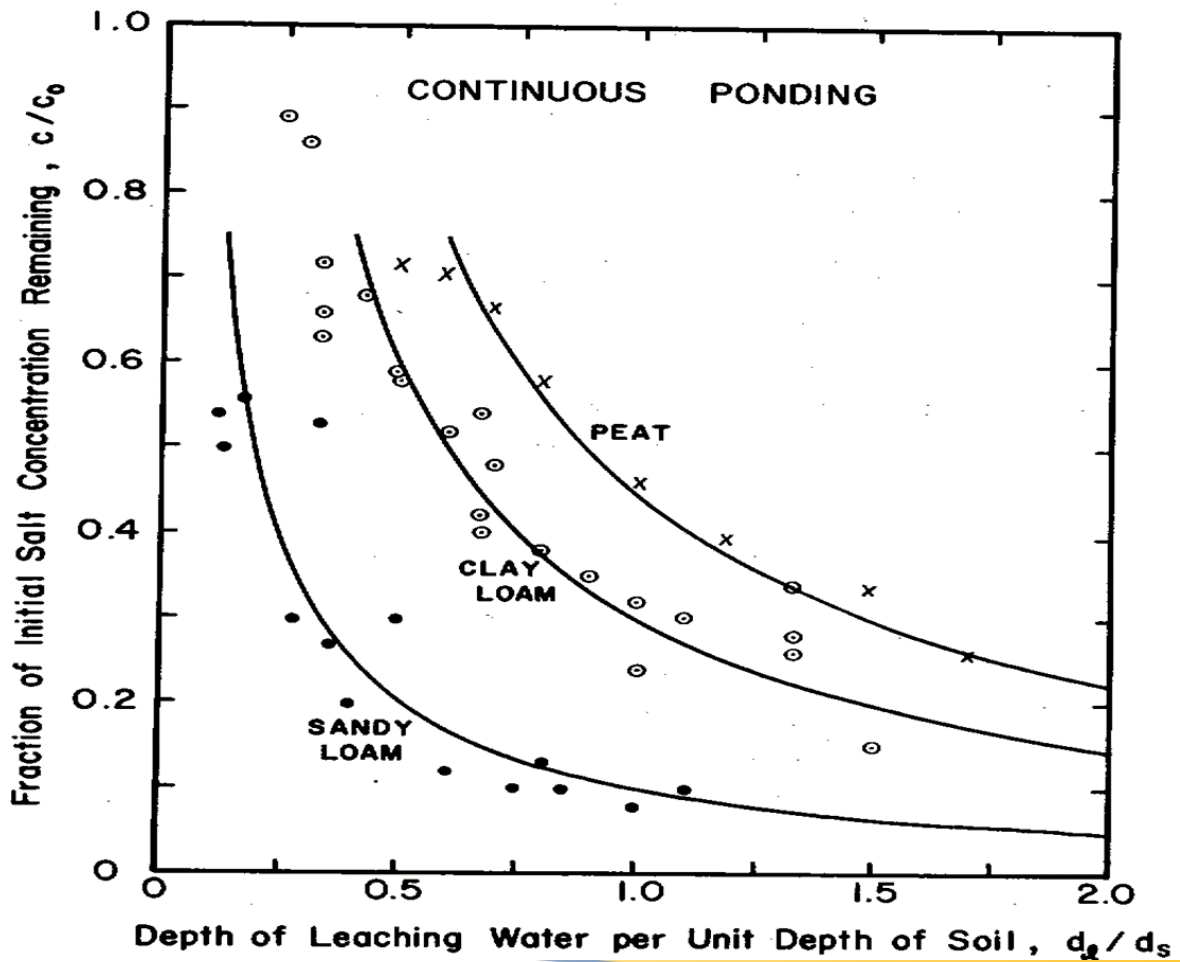
SPRINKLING RECLAMATION				
Desired Rootzone Salinity	*Inches of water/foot of rootzone Required to leach initial salinity of::			
dS/m	**4**	**8**	**12**	**16**
2	3.6	7.2	10.8	14.4
4	0	3.6	5.4	7.2
6	0	2.4	3.6	4.8

***Applicable for all irrigation waters less than 1.0 dS/m. Adapted from Hoffman, G.J. 1996. "Leaching fraction and root zone salinity control." Agricultural Salinity Assessment and Management. ASCE. New York, N.Y. Manual No. 7:237-247**

FIX: Apply appropriate depth of leaching to achieve rootzone salinity target.

About 11" to go from EC = 6 to EC = 3 to a depth of 3 feet.

Soil texture and depth of leaching water requirement



Calculate depth of water for reclamation

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

Required Leaching Ratio* (depth water/depth soil)
= K / (Desired EC/Original EC)

Use K factor of 0.15 for sprinkling, drip or repeated flooding. Use 0.3 for continuous ponding. Boron use 0.6 leaching coefficient 3x greater than other salts

* Assumes leaching water 1.0 dS/m

Calculate depth of water for reclamation

Required Leaching Ratio (depth water/depth soil)
= 0.15 / (Desired EC/Original EC)

(K factor of 0.15 for sprinkling, drip or repeated flooding. Use 0.3 for continuous ponding, Boron use 0.6 leaching coefficient 3x greater than other salts

Required Leaching Ratio (depth water/depth soil) =
0.15/(**3/6.5**) = 0.325

Actual depth of leaching water = 0.325 * 3 feet = **0.98 feet**

Calculated feet to hours

- Gallons to apply = depth of water (inches) x (trees per acre) X (0.622 gal/in. ft^2)
- Depth of water inches = 0.98 feet x 12 inches per foot = **11.8 inches**
- Acre inches per hour = (trees per acre) x (gph output per tree) ÷ 27,154 gallons per acre-inch)
- 128 trees x 8 gph ÷ 27,154 gallons = **0.038 acre in/hr**

11.8 inches ÷ 0.038 in/hr = 310 hours or 13 days

Table 3 CONCENTRATION FACTORS (X) FOR PREDICTING SOIL SALINITY (ECe)1 FROM IRRIGATION WATER SALINITY (ECw) AND THE LEACHING FRACTION (LF)

Leaching Fraction (LF)	Applied Water Needed (Percent of ET)	Concen-tration Factor (X)
0.05	105%	3.2
0.1	111%	2.1
0.15	118%	1.6
0.2	125%	1.3
0.25	133%	1.2
0.3	143%	1
0.4	167%	0.9
0.5	200%	0.8
0.6	250%	0.7
0.7	333%	0.6
0.8	500%	0.6

Applied water needed = 1/(1-LF)

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

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Determining Leaching Fraction to maintain desired rootzone salinity

Leaching fraction required over long-term irrigation with a given salinity of water to obtain a desired rootzone salinity. (Ignoring precipitation/dissolution reactions in the soil.)

Irrigation Water EC (dS/m)	Desired Average Rootzone ECe						
	1	2	3	4	5	6	7
0.1	0.01	0.00	0.00	0.00	0.00	0.00	0.00
0.4	0.07	0.02	0.01	0.01	0.01	0.00	0.00
0.8	0.23	0.07	0.04	0.02	0.02	0.01	0.01
1.2	0.44	0.14	0.07	0.05	0.03	0.02	0.02
1.6		0.23	0.12	0.07	0.05	0.04	0.03
2.0		0.33	0.17	0.10	0.07	0.05	0.04
2.4		0.44	0.23	0.14	0.10	0.07	0.06
2.8			0.29	0.18	0.13	0.09	0.07
3.2			0.36	0.23	0.16	0.12	0.09
3.6			0.44	0.27	0.19	0.14	0.11
4.0				0.33	0.23	0.17	0.13
4.4				0.38	0.26	0.20	0.15
4.8				0.44	0.30	0.23	0.18
5.2					0.35	0.26	0.20
5.6					0.39	0.29	0.23
6.0					0.44	0.33	0.25
6.4						0.36	0.28

SOLVING FOR DESIRED LEACHING FRACTION DIRECTLY:

Regressing the rootzone salinity concentration factors in FAO29 and rearranging to solve for Leaching Fraction (LF):

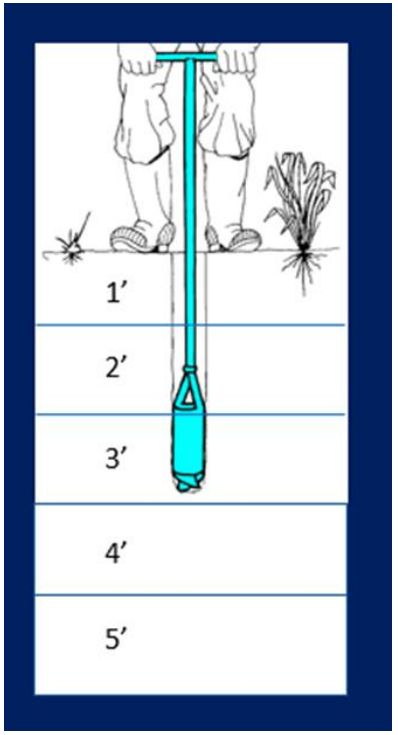
LF = 0.326 (Desired ECe/ECirr)^ -1.64

Dormant Season Salinity Management:

Replenish deep soil moisture, improve water penetration and leach enough salt for efficient use of water next season

https://www.luxviz.com/html-photography/landscape-photography-gallery-asia-bali.html

Salinity Management Timeline:



November:

Sample irrigation water and soil from 1' to 5'

Determine EC, pH, Na^+ (SAR), B

Calculate amendments: needed if SAR > 5x EC

Sodicity then Salinity!

Calculate leaching fraction: Determine depth of water (inches per foot depth soil) needed to achieve desired salinity

Determine timeline for completing leaching program

November to March:

Leach in dormant season

1st fill profile to field capacity (3-6 inches over 3-4 days), then 2-4 days drainage…..then begin leaching applications

March:

Re-sample irrigation water and soil from 1' to 5' to determine effectiveness of applied leaching and starting point for growing season

Tree health in saline conditions summary…..

- Pistachio is more tolerant than other tree crops but….
- Elevated salinity degrades soil structure, decreases water uptake, stunts growth, eventually accumulates salt in tissues and decreases nut crop quality

Tree health in saline conditions summary…..

- Keep soil salt levels below 4.5 dS/m
- Soil and water sample
- First address sodicity then salinity
  - Fall apply gypsum before rain and leaching
- Best approach: leach salts in dormant period -lowest ET and maximum salt accumulation post season
- If possible complete leaching before spring root flush


THANK YOU!