

Salinity in Irrigated Agriculture: *Management Issues & Strategies*

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Salt-Affected Soils: where do the salts come from?

- **Parent Material of the soil** (varies widely with region) - examples
 - Westside SJV: marine sediments
 - Eastside SJV- granitic materials, not contributing much salinity
- **Irrigation water**
 - Imperial Valley– basins draining to Colorado River water have significant salt, drains to river, which is used for irrigation.
 - Westside SJV– large volumes of low salt surface water added. More recently, higher salinity ground water has been applied.
- **Fertilizers, manures, other amendments** – can contribute salts
- **Shallow groundwater** – saline in many areas
- **Sea spray or seawater intrusion (coastal areas)**

Across all these situations, inadequate drainage and limited plans or ability to put in drains and export salt are common.



How much salt added with irrigated agriculture?

$EC (dS/m)^* \times 640 = TDS (mg/L)$ – generally applies if EC of water $< 5 dS/m$

*milligram (mg) / $10^6 =$ kilogram (kg) 1 kg = 2.20 lbs.

1 gallon = 3.785 liters

1 acre-ft = 325,850 gal.

EXAMPLE (moderate quality irrigation water):

If irrigated with 1.5 dS/m water (about double average for the CA Aqueduct), how much salt would be added?

For one acre foot:

$$1.5 \text{ dS/m} \times \frac{640 \text{ mg}}{\text{L}} \times \frac{3.785 \text{ L}}{\text{gal}} \times \frac{\text{kg}}{10^6 \text{ mg}} \times \frac{2.2 \text{ lbs.}}{\text{kg}} \times \frac{325,850 \text{ gal.}}{\text{acre-ft.}}$$

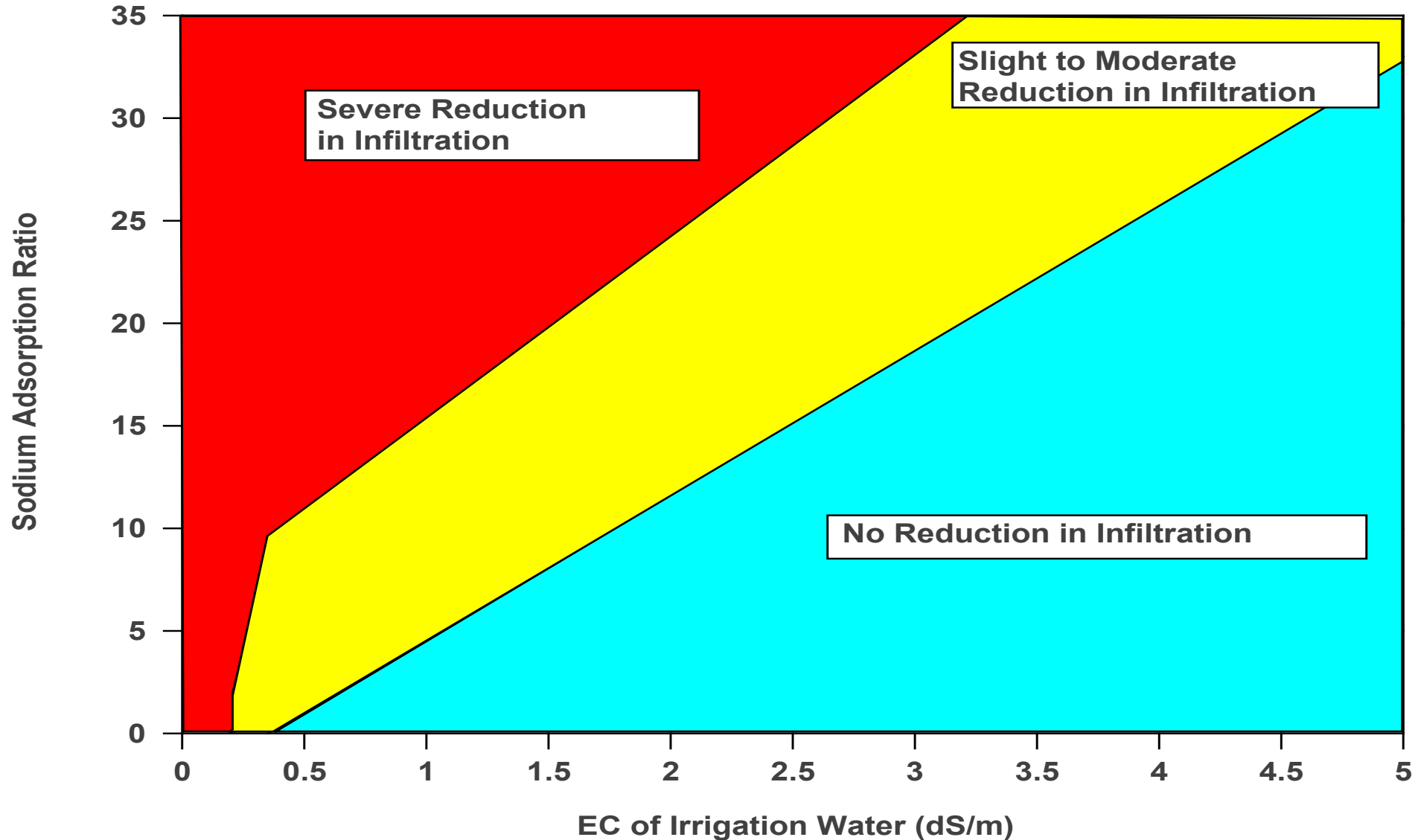
= 2605 lbs salt per acre-foot of water applied

Or about 10,420 lbs per acre if applied 4 feet of this irrigation water


PRACTICES NEEDED: to manage salt-affected soils

- 1) **Irrigation water analysis**- *how much total salt and specific ions (Na, Cl, B) are contributed by each source. If necessary to use a more saline water source, when in season is best?*
- 2) **Soil samples/analysis** (representative of field or zones) - *is it saline, saline-sodic or sodic?*
- 3) **Soil mapping** (EM-38, drone or satellite imagery)- *should the field be treated uniformly or are there areas of the field more saline or sodic?*
- 4) **Leaching Salinity Management**: *reclamation or maintenance?*
- 5) **Amendments** (gypsum, or sulfur/acid if free lime is present)- *only if sodicity a problem*
- 6) **Appropriate irrigation management** to *avoid water-logging, esp. if infiltration problem*
- 7) **Suitable crop/variety** for salinity level existing in field (MH salinity tolerance tables). *How much yield loss is acceptable? Are there known differences in salinity tolerance at different growth stages (ie. Seedling germination/emergence versus established plants?)*

For irrigation water, relationship between sodicity (SAR) & salinity (EC) influences its ability to infiltrate into soil.



Example: Irrigation water analysis

		EC	Ca	Mg	Na	SAR	Adj SAR	Cl	HCO ₃ + CO ₃	SO ₄	B	NO ₃ -N	pH	TDS	
		ds/m	meq/L	meq/L	meq/L			meq/L	meq/L	meq/L	mg/L	mg/L	unit	mg/L	
001	0.5 ds/m	0.47	1.38	0.67	1.2	1.1	1.8	0.3	2.5	0.1	0.03	19.1	8.3		
002	5 ds/m	6.51	7.16	7.48	53.2	19.7	43.1	30.0	3.6	37.6	10.9	23.3	9.1		
General Ag Levels		Total Salts	Calcium	Magnesium	Sodium	Sodium Abs. Ratio		Carbonates &			Boron	Nitrate	pH		
						SAR	Adjusted	Chloride	icarbonate	Sulfate					
Low		<0.50	<4.00	-	-	-	-	-	-	-	-	-	<6.5		
Normal		0.60-1.50	5.0-10.0	1.1-5.0	<4.0	0.1-4.0	0.1-4.0	0.1-1.5	0.1-2.5	0.1-5.0	0.01-0.40	0.1-5.0	6.8-7.9		
High for Sensitive Crops		1.51-2.20	> 10.00	> 5.0	4.1-7.0	4.1-9.0	4.1-9.0	1.6-3.5	2.5-3.5	-	0.41-0.59	5.1-7.0	8.0-8.4		
High for Tolerant Crops		> 2.20	-	-	> 7.0	> 9.0	> 9.0	> 3.5	> 3.5	-	> 0.60	> 7.0	> 8.4		
Many of the above parameters need specific adjustment for crops, uses, irrigation procedures, etc. Check report for specifics.												Black = Normal			
When sodium is greater than calcium (or high SAR), the water is considered sodic or "alkali".												Red = High		Green = Sl. Low	
												Orange = Sl. High		Blue = Low	

WHAT TO MEASURE?

Test	Information Provided	How use for Management?
Electrical conductivity (EC)	Measures soil solution electrical conductance, related to quantity of salts that impact conductance	Relative indicator of the quantity of salts , dissolved ions in the soil. Higher EC levels (>3-4 dS/m) often associated with reduced seedling germination and survival, growth reductions.
pH	Relative indicator or soil acidity, alkalinity	Can be an indicator of a sodic soil (if pH>8.5) , impacts solubility of some nutrients , minerals. When pH approaches or exceeds 8.2 to 8.5, more attention is needed to monitoring Na, Ca, Mg to identify problematic ESP and SAR levels
Calcium Carbonate Equivalent	Amount of undissolved calcium carbonate in soil	If calcium carbonate amounts are relatively high, can help with decisions to use acid (sulfuric or others) or elemental S instead of gypsum

Test	Information Provided	How use for Management?
<p>Cation levels (Na, Ca, Mg, K) & CEC (cation exchange capacity)</p>	<p>Cations in soil, relative concentration impacts ion adsorption & some soil properties. With >CEC, generally harder to remove salts.</p>	<p>Determines dominant cations (Na, Ca, Mg). CEC is total quantity of cations that can be exchanged (Ca, Mg, K, Na, H, Al). When both known, ESP values can be determined as well as gypsum requirement.</p>
<p>Sodium Absorption Ratio (SAR)</p>	<p>Relative indicator of sodium ion concentrations relative to calcium, magnesium (in soil or irrigation water)</p>	<p>Measure of relative sodium hazard (SAR>13) in irrigation water and associated with Na in sodic & saline-sodic soils. >Na levels & high SAR produce damage to soil structure, reduced infiltration capacity.</p>
<p>Exchangeable Sodium Percentage (ESP)</p>	<p>Sodium as a percentage of cation exchange sites in soil</p>	<p>ESP used in determining gypsum application amounts for sodic soils.</p>

Problems with Different Types of Salt-Affected Soils

(ways of characterizing salt-affected soils):

Saline Soils - high enough soluble salts to injure plants, reduce growth, reduce availability of water to plants, sometimes direct specific ion toxicity issues as well

Saline-Sodic Soils – high in multiple soluble salts, including specifically sodium (Na)
Differs from saline soils in proportion of Na to Ca & Mg (Na much higher). High EC irrig water would result in better soil structure, but more high salinity impacts on crop. For reclamation, 1st deal with sodicity, increase Ca/Mg levels & reduce Na levels.

Sodic Soils – can be low to moderate in total soluble salts, but have relatively high amounts of sodium adsorbed onto soil particles. This results in dispersed soil particles and generally poor tilth and low water permeability, aeration issues, high pH.

Soils affected by **sodicity** have reduced infiltration due to sodium dispersion of clays (breaks down soil structure) – *Benes et al*

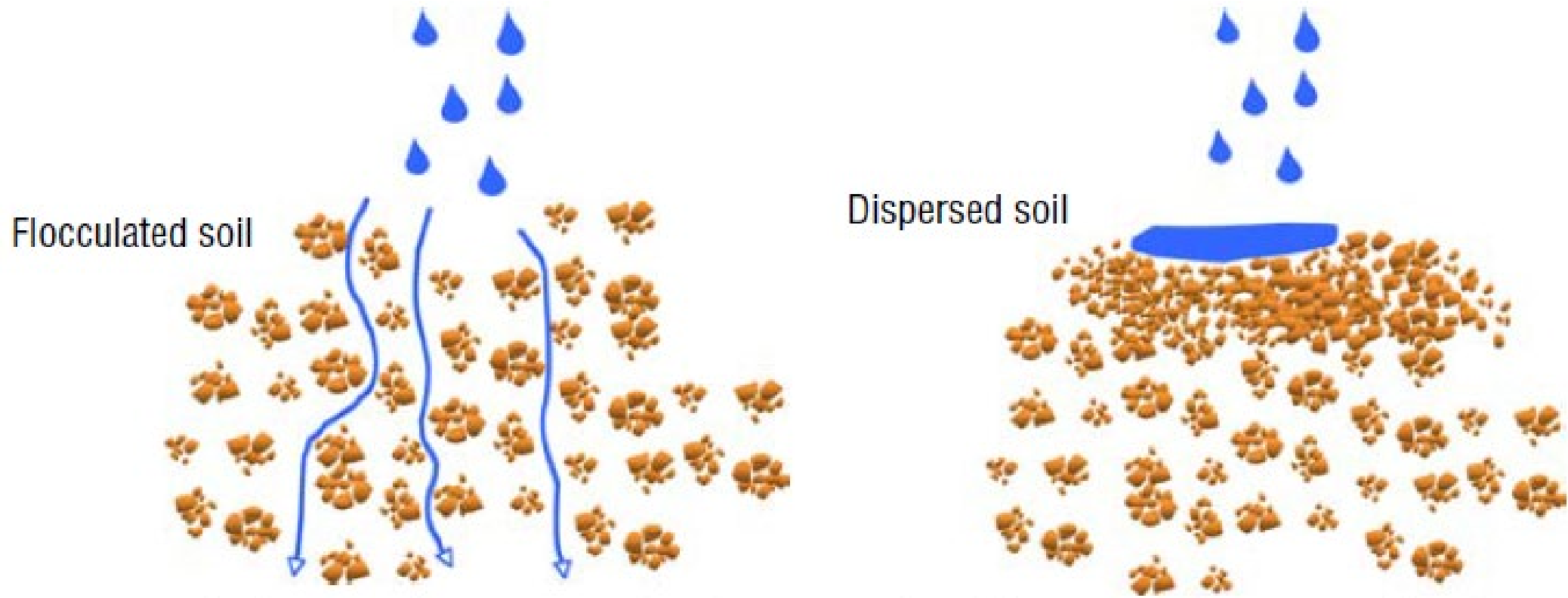


Figure 1.—The difference between flocculated (aggregated) and dispersed soil structure. Flocculation (left) is important because water moves through large pores and plant roots grow mainly in pore space. Dispersed clays (right) plug soil pores and impede water movement and soil drainage in all but the sandiest soil.

SALT-AFFECTED SOIL CLASSIFICATIONS *(NRCS & USDA-ARS Salinity Lab)*

Salt-affected soil classification	Electrical conductivity (EC)	Sodium Absorption Ratio (SAR)	Exchang. Sodium Percentage (ESP)	Soil pH	Resulting Soil Physical / Soil Structure Conditions
Not salt-affected	< 4	Below 13	Below 15	< 8.5	Flocculated
Saline	> 4	Below 13	Below 15	< 8.5	Flocculated
Sodic	< 4 typically	Above 13	Above 15	> 8.5	Poor - Dispersed
Saline-sodic	Greater than 4	Above 13	Above 15	< 8.5	Impacted but Flocculated

Can “assign” soils a certain classification, but salinity issues can change over time, so there can be changes or a progression from “not salt-affected” to some level of salinity impact

PRACTICES NEEDED: to manage salt-affected soils

- 1) **Soil samples/analysis** (representative of field or zones) - *is it saline, saline-sodic or sodic?*
- 2) **Irrigation water analysis**- *how much total salt and specific ions (Na, Cl, B) are contributed by each source. If necessary to use a more saline water source, when in season is best?*
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Sodic Soil Management – *amendments as part of process*

- ✓ Can be difficult and costly to reclaim a truly sodic soil (*need amendements, effective leaching and potential for downward movement or drainage of salts*)
- ✓ Steps to improve water infiltration rates in sodic soils?
 - ✓ Ca levels need to be increased, Na decreased for sodic soil reclamation, this displaces Na & reduces ESP
 - ✓ Practices help reduce Exch. Sod. Percentage (reduction needed to increase infiltration depends on soil texture & irrigation method)
- ✓ In some situations, can utilize tillage and organic matter additions to help break up high-sodium layers affecting soil structure & infiltration – can be difficult perennial crops except prior to seeding

- ✓ It is important to know some details of soil and irrigation water chemistry, since a focus with sodic soils will be on sodium (Na), not just Ca and Mg salts.
- ✓ **SALINE – SODIC SOIL MANAGEMENT** (some differences from sodic soils):
 - ✓ For reclamation, **treat these soils first for sodicity problems** (addition of amendments that impact Na displacement 1st, followed by leaching)
 - ✓ If try to leach with good quality water first, while Na still high (relative to Ca + Mg) and not very soluble, will likely :
 - ✓ Reduce salinity to a limited degree (depends on if water infiltrate)
 - ✓ Increase sodicity problems since you haven't removed Na, and
 - ✓ Make soil structure and infiltration problems worse

Sodic Soil Management – amendments as part of process

GYPSUM:

- ✓ Common choice to supply Calcium for sodic soil reclamation, also high in S
- ✓ Dissolves well at high pH; quantity needed can be quite high, so often recommend split applications or only treat worst –affected areas

ELEMENTAL S: *(can also consider adding sulfuric acid directly for similar affect)*

- ✓ Adding S does not add Calcium – it oxidizes to form sulfuric acid, which can dissolve free lime (CaCO_3) present in many arid-zone soils (same process w/ acid)
- ✓ It helps speed process & you treat more soil volume if S can be incorporated

Amount to treat one ft soil (Tons/acre)	Exchangeable Sodium you want to replace with Calcium (meq Na / 100 g soil)			
	1	2	4	6
Gypsum	1.75**	3.5	7	10.5
Elem. Sulfur*	0.325	0.65	1.3	1.95
Sulfuric acid*	0.99	1.98	3.96	5.95

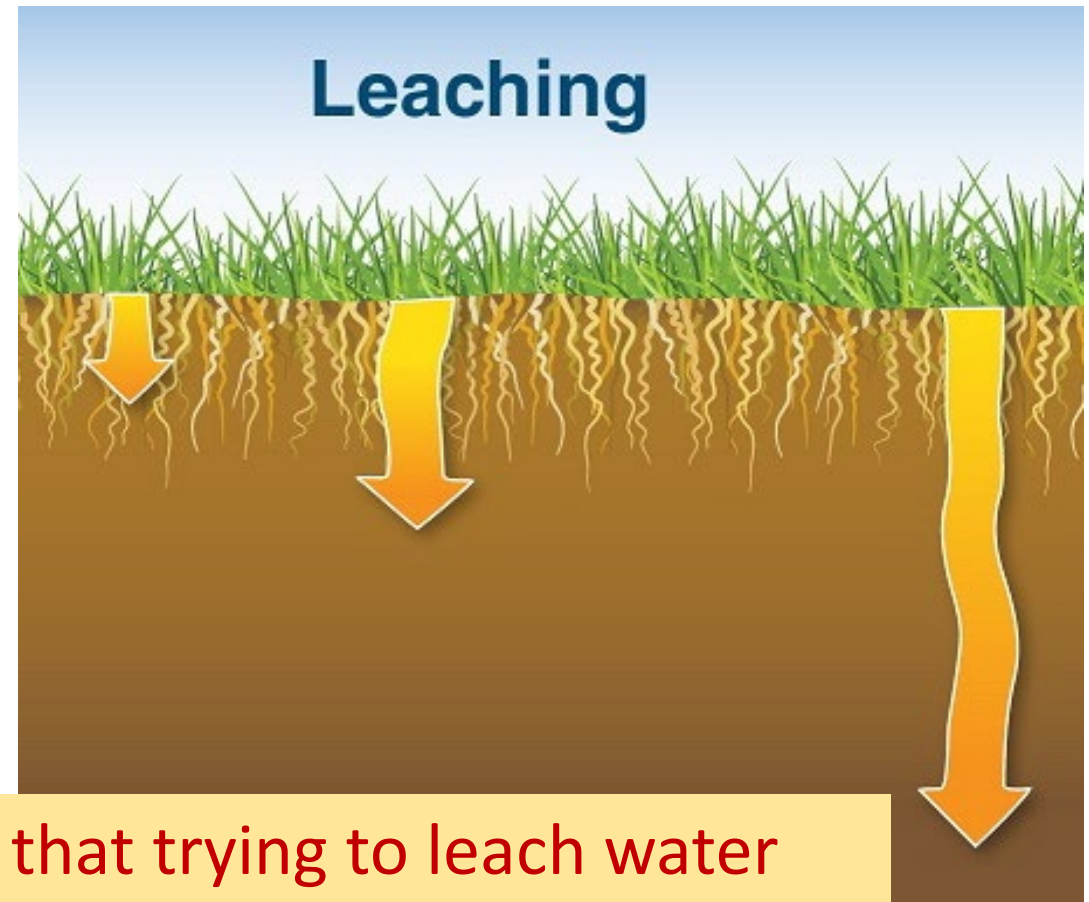
**assumes soil contains adequate amounts of free lime ** split amounts higher than 2T/ac into separate applications*

Leaching Requirement (LR)

- Fraction of water infiltrating the soil that must move beyond the root zone to prevent soil salinity from exceeding a specified value

$$LR = \frac{ECa}{5ECe * - ECa}$$

Traditional LR model is based on steady-state approach.



Note that trying to leach water also assumes that some drainage is an option no drainage creates other problems

Generalized Table for LEACHING FRACTIONS (LF) - based on the approach described
(Ayers and Westcot, 1985) - UCCE Kern Co. bulletin Sanden, B., Fulton, A.E., Ferguson, L.

Irrig Water EC (dS/m)	Desired Average Rootzone Salinity (ECe) (dS/m)					
	1	2	3	4	5	6
0.5	10	3	2			
1.0	33	10	5	3	2	2
1.5		20	10	7	5	3
2.0		33	17	10	7	5
3.0			33	20	14	10
4.0				33	23	17
5.0					33	24

In General:

For soil ECe to remain about=ECiw, LF = **33 %**

For ECe to end up 2 times ECiw, LF = **10 %**

For ECe to end up 3 times ECiw, LF = **< 5 %**

Re-evaluation of Leaching Requirement Calculations

Steady-state equations (for maintenance leaching) **may over-estimate water required for leaching**, especially if ET (crop water need is ↓'d by salinity

$$LR = \frac{EC_w}{5 EC_{e(100\%)}^* - EC_w} \times 100$$

**EC_e = crop's estimated yield loss threshold (100% yield). Conservative approach- never surpass yield loss threshold which itself may be too low.*

Use EC_{e90%} instead? Growers may accept a 10% yield loss if water supplies limited.

Future: move to transient state models: estimate root zone salinity real-time and calculate appropriate leaching requirements within season

-- still a challenge for growers or consultants to work with these

CSUID (Colorado State University Irrigation Drainage) model

- 3-dimensional model
 - I-D version currently be used to reduce run times
- Tracks the crop root zone over time
 - estimating salinity impacts to crop yield at various crop growth stages
- Decision support tool for guiding growers with the optimum leaching requirement (LR)
- Site-specific inputs (*soil texture, *initial salinity, *crop ET, irrigation volume/ frequency, rain, crop & harvest cycle)

Nigel Quinn, UC Berkeley National Laboratory

Leaching Fraction Calculator

File Model Setting Help

2. Simulation

3. Data

1. Topolog v recan

Time & Space Discretization

Number of Vertical Layers: 50 Choose Depths info, First

Start Date: 01-Jan-2015 11:00:00 Select

End Date: 31-Jan-2015 11:00:00 Select

Number of Plantings: 1

Leach: 4. Models

Hoffman's Model Settings Input

CSUID Model Settings CSUID Solver

Simulation

Choose Simulation Type

5. Simulation

6.

Output

Manage and Visualize Model Outputs

Land Surface (ft): 0.0

Root Zone Depth (ft): 6.00

Groundwater Depth (ft): 8.00


Lower Boundary Depth (ft): 9.00

Leaching Flow

<- Don't hit this

Soil Salinity and Leaching Management


The Soil Salinity Leaching Management (SSLM) website was developed to help growers and decision makers for better management of soil salinity for sustainable agriculture production. This online tool can be used to determine the leaching requirement, predict the soil salinity, predict relative yield and also provide management options for leaching practices.



Crop

Corn ▾

Cumulative ET: 600



Irrigation Water Quality

Irrigation Water EC: 2.5

Rain to Appl.Water: (%)



Soil Texture

Silty Clay Loam ▾



Irrigation System

Furrow ▾

On-line tool developed by Laosheng Wu & Hossein Shahrokhnia. Available soon.

Leaching: *Different approaches*

Reclamation Leaching

- Salinity has accumulated in the root zone
- Periodic, heavier applications, to reclaim soil
- More realistic approach if irrigation water supply is limited

Maintenance Leaching

- Assumes that level of soil salinity is not excessive (not beyond level with significant damage to the crop), and small changes in soil salinity can be managed over time
- ***Objective is to apply sufficient water so that salts do not accumulate (proactive approach). LR (leaching requirement) calculations refer to this one— extra water you need to apply each time***



OPTIONS: In-Season Leaching vs Dormant-Season – *some pros & cons*

In-Season Leaching:

Pros:

- ✓ leaching tied to weekly ETc
- ✓ If effective, lower salt & trace element exposure during peak growth periods

Cons:

- ✓ Some soils can't infiltrate full amounts to meet ETc + leaching requirements
- ✓ localized soil volumes can be under conditions of anoxia – possible direct plant damage, disease impacts
- ✓ Increase potential for fertilizer nutrient leaching

Dormant Season Leaching:

Pros:

- ✓ Leaching in low water use time of year, potentially more effective leaching
- ✓ Potentially more effective for Boron, Chloride leaching
- ✓ Avoids anaerobic conditions during more active growth, less disease???
- ✓ Better separation from timing of soluble nutrient applications

Cons:

- ✓ soil water content must be brought back up to field capacity for leaching to occur (can be an issue low rainfall year)

Consider Salt Tolerance, Growth Stage Sensitivity of Crop

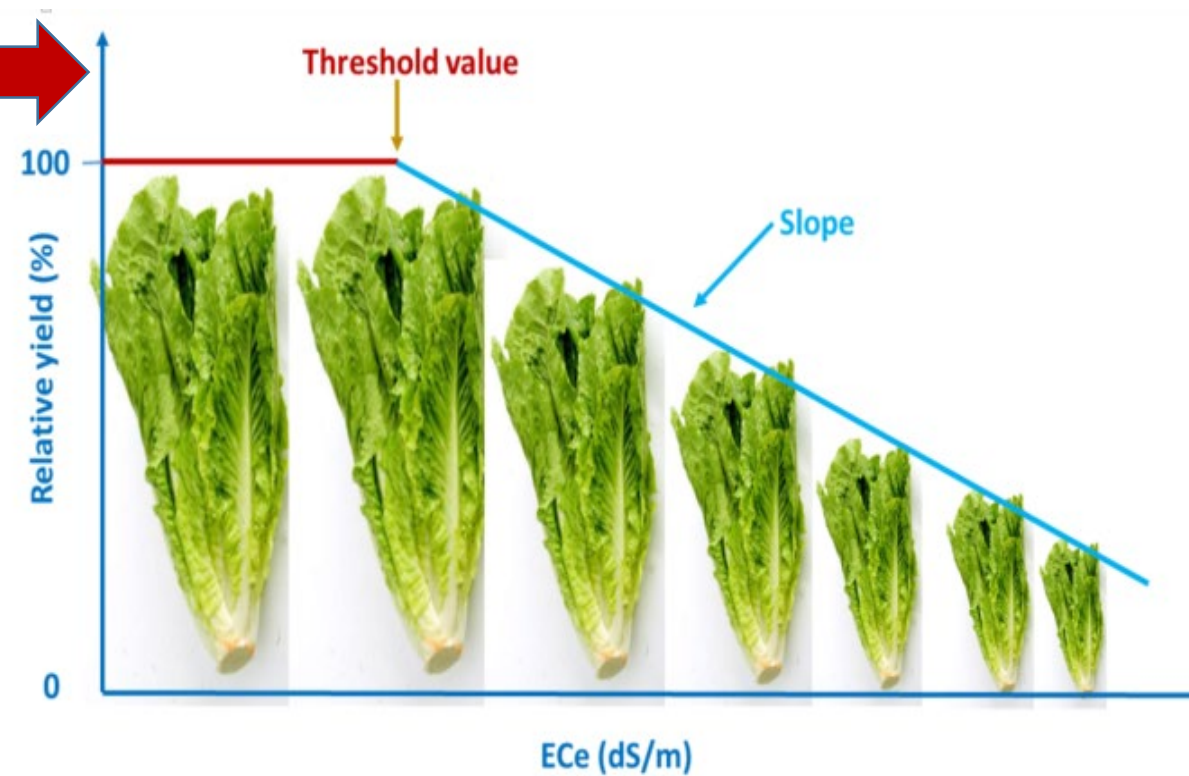
Maas & Hoffman salinity tolerance curves (1977) are often the “standard” for comparison

Alfalfa - more sensitive to salinity than some other species but is high-yielding and can be profitable.

- **Published threshold = 2.0 dS/m ECe, slope = 7.3;**
- **New varieties can be more salt tolerant. Yield loss may not begin until 6-8 dS/m ECe...** unless sodicity leads to crusting, poor infiltration & drainage, losses related to water-logging.

Tall wheatgrass

- threshold = 7.5 dS/m ECe; slope = 4.2. Can still produce growth at very high soil salinities (10-15+ dSm ECe)



- **Threshold:** the EC of soil saturated extract (ECe) when yield starts decrease.
- **Slope:** % of yield decrease when ECe increased by 1 dS/m.

http://ucanr.edu/sites/Salinity/Salinity_Management/Effect_of_soil_salinity_on_crop_growth/Crop_salinity_tolerance_and_yield_function/

Field Evaluations – Putnam, Benes et al (*UC West Side REC (western Fresno County)*)

Trial 1: Basin irrigation. $EC_w \sim 5.5$ to 7.0 dS/m applied over 3 years.

- 24 alfalfa varieties planted into non-saline soil, replicated field trial
- **Equivalent yields or losses of 5% or less (as % of CUF-101 yield). No Low Salinity (LS) trt**

 ***Trial 2: Basin irrigation. $EC_w \sim 7-10$ dS/m (HS)**

- 21 alfalfa varieties, replicated field trial in two basins (HS and LS).
- **Avg. yield reduction (HS) = 11 %**

Trial 3: Subsurface drip irrigation (SDI). $\sim 7-10$ dS/m (HS)

- **SDI to deliver water more directly to the plant;** avoid excess wetting & drying of soil
- 34 varieties replicated in eight blocks (four HS and four LS)
- Acidification of irrigation water to reduce alkalinity. TDR soil moisture sensors.
- Assessment of spatial variability in soil salinity underway.

Saline Irrigation in the field

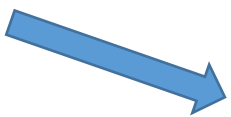


- Salt composition representative of western SJV
- Achieve uniformity in water and salt application & distribution in the field

Alfalfa Yields:
Trial 2 (flood) -
1 dS/m versus 7-10 dS/m water

Spatial variability in soil salinity with saline irrigation (7-10 dS/m) did not allow us to rank cultivars for salt tolerance

HOWEVER ...
 average 3-year yield reduction with use of higher EC water was 11%



Variety	Yield (t/A)									
	2015		2016		2017		3-year Avg.		Cum. Yield	
	LS	HS	LS	HS	LS	HS	LS	HS	LS	HS
SW9812	6.54	7.37	8.36	10.89	9.44	12.01	8.12	10.09	24.35	30.27
SW 9813	7.94	7.22	9.27	10.16	9.25	12.78	8.82	10.05	26.47	30.16
FG R914W259S	8.32	7.61	9.97	9.38	10.47	10.62	9.59	9.20	28.76	27.61
AmeriStand 915TS	7.60	7.03	8.73	9.28	8.99	10.74	8.44	9.02	25.32	27.05
SW 8421- RRS	7.78	7.31	10.40	8.54	12.12	10.18	10.10	8.68	30.30	26.03
Saltana	7.35	6.85	9.65	8.74	11.53	10.42	9.51	8.67	28.54	26.00
AmeriStand 901TS	7.34	6.35	9.70	8.67	11.53	10.36	9.52	8.46	28.57	25.38
FG R814W257S	7.69	6.39	8.80	9.64	9.28	9.09	8.59	8.37	25.77	25.12
CUF101	7.84	6.98	9.92	9.02	10.60	8.78	9.46	8.26	28.37	24.79
9R100	7.79	6.99	9.68	8.25	10.39	9.40	9.28	8.21	27.85	24.64
SW9215	6.95	6.90	8.02	8.15	10.88	9.39	8.62	8.14	25.85	24.43
Sun Quest	7.39	6.63	9.78	7.63	12.41	9.87	9.86	8.04	29.58	24.13
AZ- 90NDC-ST	7.91	6.15	9.90	8.38	10.59	9.42	9.47	7.98	28.40	23.95
CW050085	7.82	6.32	9.88	7.98	10.41	9.29	9.37	7.86	28.12	23.59
FG R814W258S	7.01	6.52	9.30	8.30	11.07	8.49	9.13	7.77	27.39	23.31
AZ-88NDC	7.42	6.29	9.29	7.75	9.53	8.46	8.75	7.50	26.24	22.50
SW 9215-RRS	7.58	6.23	10.29	7.39	10.56	8.40	9.48	7.34	28.43	22.02
CW058071	8.00	6.17	9.02	7.45	9.50	8.28	8.84	7.30	26.52	21.89
Desert Sun 8.10RR	7.49	6.43	8.55	7.39	9.81	7.97	8.62	7.26	25.86	21.79
SW 9106	8.34	5.87	11.19	7.41	12.59	7.93	10.71	7.07	32.13	21.22
SW 8421-S	7.69	6.06	9.06	6.36	9.29	8.11	8.68	6.85	26.04	20.54
Average	7.61	6.65	9.47	8.42	10.49	9.52	9.19	8.20	27.56	24.59
CV (%)	10.91	23.54	19.59	28.20	30.96	30.30	21.82	25.80	27.13	30.69
LSD (P = 0.05)	1.17	2.21	2.62	3.36	4.59	4.08	0.26	0.27	2.02	2.04
<i>Yield loss due to salinity</i>	13%		11%		9%		11%		11%	

Conclusions: Potential for Saline Irrigation of Alfalfa

- **Avg. yield penalty (Trial 2): ~11% with saline waters of ~9.5 dS m⁻¹ EC_w. Little effect on stand persistence observed**
- Data from sand tank, greenhouse and field **studies suggest much higher salinity tolerance in alfalfa than previously reported**
- Yield reductions more likely to begin in the 6-8 dS/m EC_e range (vs. EC_e 2.0, published)
- **Yields under high salinity were still economically viable**
- Interactions of salinity with soil properties (crusting, infiltration rate, saturation of soils, inability to provide adequate water) may be more critical than salinity effects on plants per se. **Management issues will be very important to mitigate water quality problems.**
- ***Alfalfa is tolerant of higher salinity levels than previous guidelines indicated***

Key principles

- **Soil salinity is dynamic, & salts can redistribute. Soil texture & properties can influence distribution, extent surface salinity.**
 - *temporal & spatial variability, “root zone averaged salinity”*
- **Not all salinity is the same**
 - Sodium and chloride salts are more damaging than are calcium and sulfate salts
 - Saline-sodic (or Sodic) conditions are a different situation, requiring other mgmt
- **Manage in the root zone**– reduce salinity via leaching; change cation composition
- **“Salt Tolerance” in crops is a relative term** (*growth stage effects, specific ions*)
- **Amount of salt taken up by the plant is negligible relative to the amount of salt in the soil.** Can't expect highly salt tolerant plants (halophytes) to “clean up” saline soils

Understand Limits to Salt Mgmt – *dependence on sources*

Do you have any control over continuing salt additions?

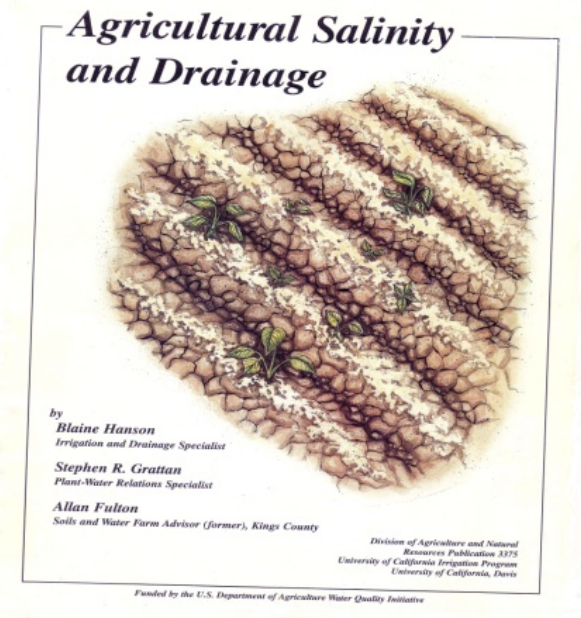
- ✓ Salt origins from salt-containing irrigation water
 - ✓ Did accumulations occur over long time with low/moderate salinity waters?
 - ✓ Or ... result from short-term use of high salinity waters?
 - ✓ Is there more moderate salinity water available for reclamation?

- ✓ Salt origins associated with shallow groundwater
 - ✓ Can you exert some control over water table depth at specific times of year through drainage, or with other crops able to use shallow groundwater?
 - ✓ Or ... is shallow groundwater control/depth mostly out of your local control ... a recurring issue in high rainfall years, etc.?

Useful references

- **Hanson, Grattan, Fulton (2006)**

“Ag Salinity & Drainage”. Div. Agriculture & Natural Resources (ANR), Univ. California. Pub. #3375
<http://anrcatalog.ucdavis.edu/SoilsWaterIrrigation/>



- **Ayars & Westcot, FAO 29 (1985)** FAO #29 Irrig. & Drainage series.

“Water Quality for Agriculture

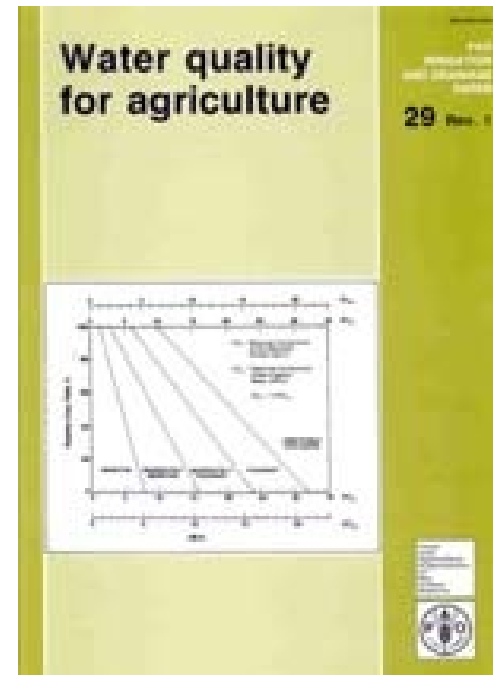
www.fao.org/DOCREP/003/T0234E/T0234E00.HTM

- **Rhoades et al., FAO#48 (1992)**

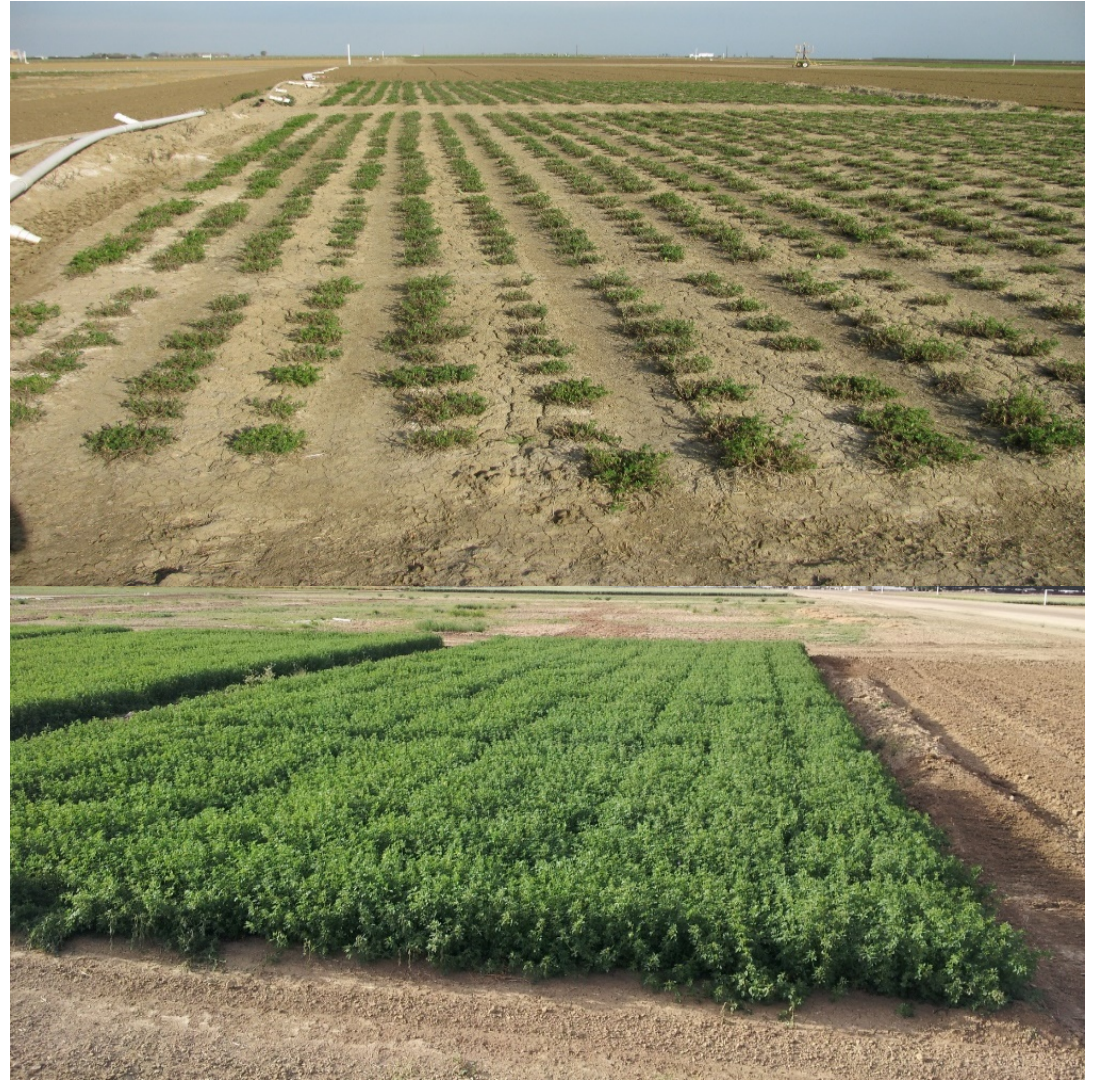
Irrig. & Drainage Series

“Use of Saline Waters for Crop Production”

<http://www.fao.org/docrep/T0667E/T0667E00.htm>



Thank you



Summary – *Suggested Approaches*

- ✓ sample irrigation waters & have basic chemical suitability analyses done for all water sources
- ✓ Depending on salinity, sodicity & trace element issues, sample soils periodically to assess developing problems & impacts of leaching or amendment treatments
- ✓ Consider basic limits of salt and trace element tolerance issues for the crops grown (ie. what can you get away with & for how long?)
- ✓ Adjust leaching & amendment application practices (gypsum, acid, S, etc.) for type / combination of conditions in salt-affected ground
- ✓ When soil type & chemistry produce poor water infiltration, **consider dormant-season** (winter +) **leaching** to reduce plant damage assoc. with anoxia, & reduce chances of nutrient leaching.

Primary methods to Remediate Salt Affected Soils.

- Leaching (apply water in excess of evapotranspiration):
 - Principle approach is to add enough low-salt content water to dissolve portion of salts and begin to move them through soil and below crop root zone.
 - Leaching will not likely be effective if soil tests indicate a sodic or saline-sodic soil, since you must 1st deal with high soil Na content issues and their impacts on soil structure and water infiltration
 - Leaching methods & efficacy in reducing soil salinity are influenced by soil type, soil structure & ability to infiltrate water, particularly if crop is present.
 - Winter / cool season leaching (crop dormant or no crop present, lower ETc time of year) is often more effective in moving salts, with reduced risk of damage to crop and applied water more effective in leaching.
 - Soils with higher salinity (or deeper levels of salt accumulations in profile) are most effectively leached using multiple smaller irrigations with low salinity water (adequate amounts to move into soil, not just wet the soil surface)

Primary methods to Remediate Salt Affected Soils (continued)

Improve drainage (if possible) to allow for removing salt-loaded soil water

- Deep tillage can at least temporarily break up hardpans or plow pans to help remove some restrictions to downward water flow
- Where possible, install semi-permanent drain lines to provide longer-lasting drainage, provided there is a means to deal with drain flow in significant volumes
- Reduce Evaporation
 - through application of crop residues or other mulch materials
- Apply chemical treatments (mostly needed in sodic or saline-sodic soils)
 - In saline-sodic and sodic soils, chemical treatments needed for remediation, since Na problems impact soil structure and make it difficult to leach salts in soil profile
 - Goal of chemical applications (gypsum, acid, sulfur) is to reduce the exchangeable Na concentrations, typically replacing Na with Ca to improve soil structure, improve aggregation & gradually increase the ability to leach water and move soluble salts through the soil profile and out of the primary root zone.

Saline Soil Management - *timing, impacts of amendments*

- ✓ Drainage out of surface layers needed - Leaching over time required to manage saline soils, provided that either drainage is available to carry away higher salinity drainage waters, or shallow gw buildups can be managed
- ✓ For many crop species, plants are most sensitive to salinity during germination & seedling development For this reason, use of better quality water at this time is best (if an option)
- ✓ Soil amendments (elemental S, gypsum, other Ca-amendments) can actually add salts, and can make some salt-affected situations worse. Make sure you know composition of manures, composts and what you are adding.
- ✓ Problems with sodicity are a different situation