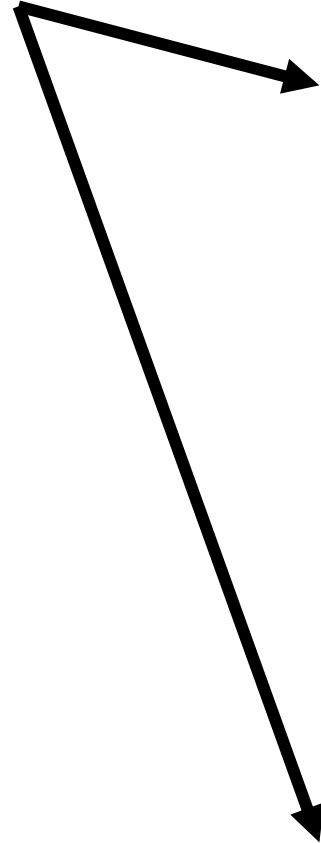




Soil Salinity, Sodicity, Etc.

Matt Yost

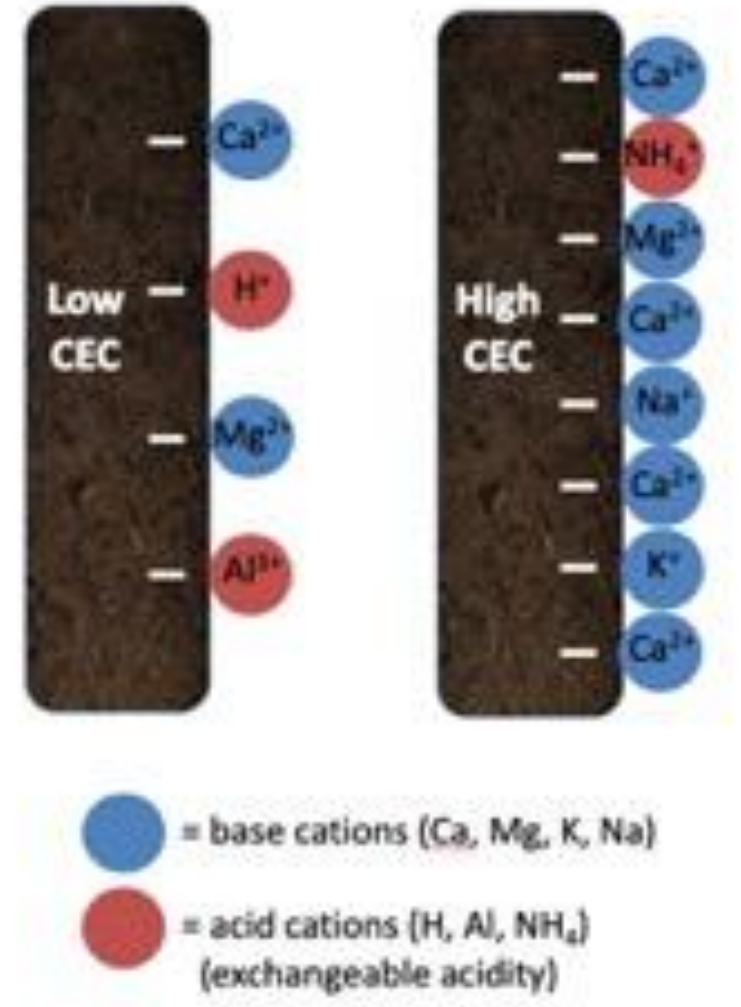
CEC and Base Saturation



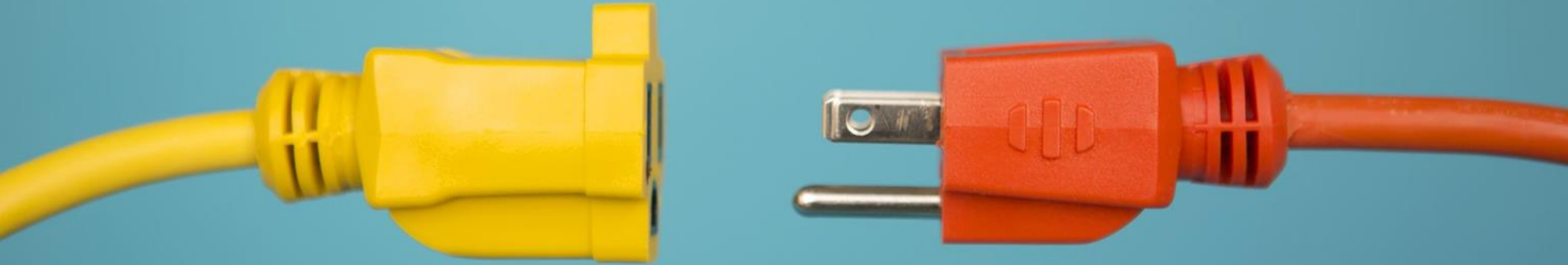
<u>SOIL TEST DATA</u>	<u>Sample 1</u>	<u>Sample 2</u>	<u>Sample 1</u>	<u>Sample 2</u>
pH	7.9	H	Grower	USU
Salts, mmhos/cm	1.0	L	Sample Identity	
Chlorides, ppm	4	VL	Crop	ALFALFA
Sodium, meq/100g	0.20	VL	Yield Goal	6 T
CEC, meq/100g	16.4	M	Acres	
Excess Lime, %	20.0	VH	Prev Crop T/Acre	ALFALFA
Organic Matter, %	1.77	M	Manure T/Acre	
Organic N, lb/Acre	70	M	Prev Applied Nut	
Ammonium - N, ppm	4.0	VL	<u>RECOMMENDATIONS, lbs Nutrients or Units per Acre</u>	
Nitrate - N, ppm	14	M	Nitrogen	0
Phosphorus, ppm	18	M	P ₂ O ₅ - Phosphate	145
Potassium, ppm	125	L	K ₂ O - Potash	90
Calcium, meq/100g	11.9	H	Calcium	0
Magnesium, meq/100g	3.9	H	Magnesium	0
Sulfate - S, ppm	9	L	Sulfate - Sulfur	50
Zinc, ppm	2.2	H	Zinc	0
Iron, ppm	10.5	H	Iron	0
Manganese, ppm	2.2	L	Manganese	4
Copper, ppm	0.9	M	Copper	0
Boron, ppm	0.91	M	Boron	0
			Elemental Sulfur	0
			Gypsum	0
			Lime	0
<u>Base Saturation, %</u>			<u>Relation of CEC to Soil Texture</u>	
Potassium (Ideal 3 - 6)	2.4	L	0-5 Sand	18-24 Silt Loam
Calcium (Ideal 65 - 80)	72.6	M	5-12 Loamy Sand	24-36 Clay Loam
Magnesium (Ideal 15 - 25)	23.8	M	12-18 Sandy Loam	36+ Clay
Sodium (Ideal < 3)	1.2	M		
<u>Comments</u>				
Crop / Yield 1	Excessively Calcareous soils respond to 100-200 lbs/ac of Elemental Sulfur or Acid forming fertilizers.			
Crop / Yield 1	Examples of acid forming fertilizers are: 21-0-0/Thio-Sul/Nitro-Sul and Disintegrating Sulfurs.			

Cation Exchange Capacity

- Ability of soil to hold exchangeable cations (NH_4 , Ca, Mg, K, Na, H, Al).
- Hard to change
- Affected by soil texture – increases with more clay
- Buffers soil acidification



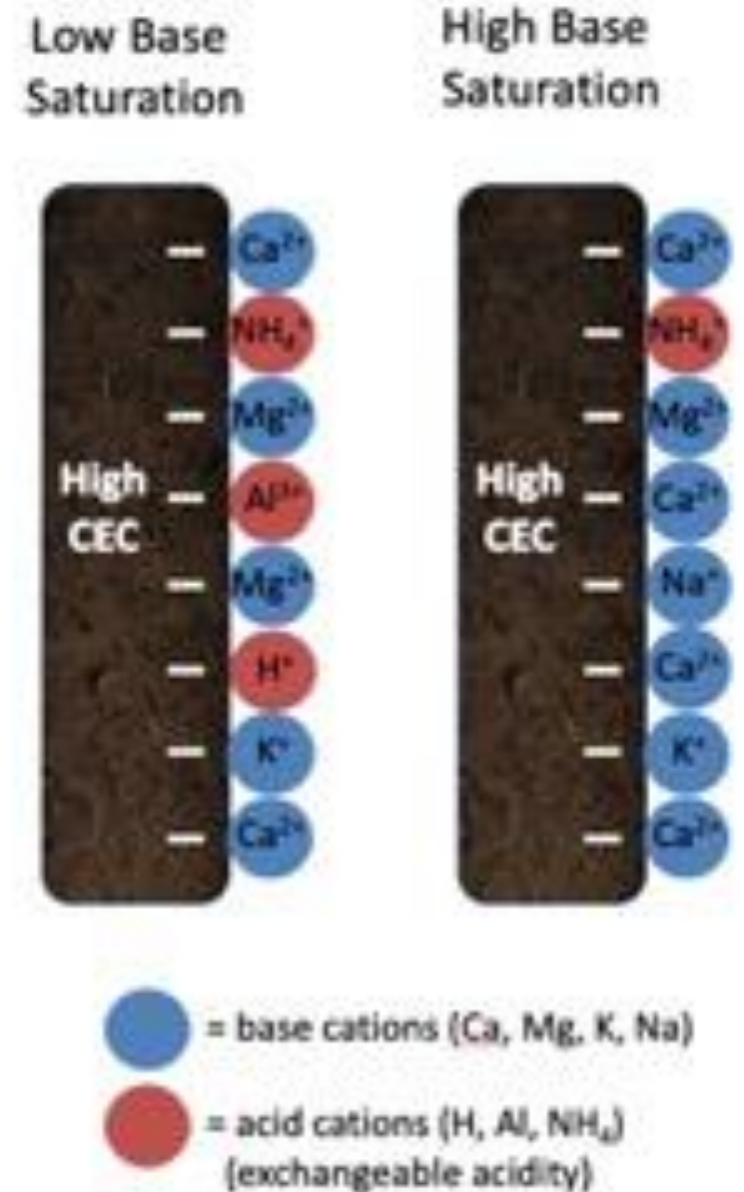
How to use CEC?



- Liming recommendations
- Fertilizer adjustments (K and N timing) – low CEC can leach more
- Sodicity management

Base Saturation

- Developed from research in 1940's in New Jersey and Missouri
- Balance of cations for an “ideal” soil of:
 - 65% Ca
 - 10% Mg
 - 5% K



Base Saturation

- Developed from research in 1940's in New Jersey and Missouri
- Balance of cations for an “ideal” soil of:
 - 65% Ca
 - 10% Mg
 - 5% K

A Review of the Use of the Basic Cation Saturation Ratio and the “Ideal” Soil 2007

Peter M. Kopittke*

Neal W. Menzies

School of Land and Food Sciences

The Univ. of Queensland

St. Lucia, Qld

Australia 4072

The use of “balanced” Ca, Mg, and K ratios, as prescribed by the basic cation saturation ratio (BCSR) concept, is still used by some private soil-testing laboratories for the interpretation of soil analytical data. This review examines the suitability of the BCSR concept as a method for the interpretation of soil analytical data. According to the BCSR concept, maximum plant growth will be achieved only when the soil's exchangeable Ca, Mg, and K concentrations are approximately 65% Ca, 10% Mg, and 5% K (termed the *ideal soil*). This “ideal soil” was originally proposed by Firman Bear and coworkers in New Jersey during the 1940s as a method of reducing luxury K uptake by

chemical, physical, and biological fertility can a range of cationic ratios. Indeed, McLean, who worked with Albrecht in Missouri during the 1940s, stated that, on the whole, “there is no ‘ideal’ basic cation saturation ratio or range” (Eckert and McLean, 1981), and that “emphasis should be placed on providing sufficient, but not excessive levels of each basic cation rather than attempting to attain a favorable basic cation saturation ratio which evidently does not exist” (McLean et al., 1983). The data do not support the claims of the BCSR, and continued promotion of the BCSR will result in the inefficient use of resources in agriculture and horticulture.

Salt, Salinity, EC

<u>SOIL TEST DATA</u>	<u>Sample 1</u>	<u>Sample 2</u>	<u>Sample 1</u>	<u>Sample 2</u>
pH	7.9	H	Grower	USU
Salts, mmhos/cm	1.0	L	Sample Identity	
Chlorides, ppm	4	VL	Crop	ALFALFA
Sodium, meq/100g	0.20	VL	Yield Goal	6 T
CEC, meq/100g	16.4	M	Acres	
Excess Lime, %	20.0	VH	Prev Crop T/Acre	ALFALFA
Organic Matter, %	1.77	M	Manure T/Acre	
Organic N, lb/Acre	70	M	Prev Applied Nut	
Ammonium - N, ppm	4.0	VL	<u>RECOMMENDATIONS, lbs Nutrients or Units per Acre</u>	
Nitrate - N, ppm	14	M	Nitrogen	0
Phosphorus, ppm	18	M	P ₂ O ₅ – Phosphate	145
Potassium, ppm	125	L	K ₂ O - Potash	90
Calcium, meq/100g	11.9	H	Calcium	0
Magnesium, meq/100g	3.9	H	Magnesium	0
Sulfate - S, ppm	9	L	Sulfate - Sulfur	50
Zinc, ppm	2.2	H	Zinc	0
Iron, ppm	10.5	H	Iron	0
Manganese, ppm	2.2	L	Manganese	4
Copper, ppm	0.9	M	Copper	0
Boron, ppm	0.91	M	Boron	0
			Elemental Sulfur	0
			Gypsum	0
			Lime	0
<u>Base Saturation, %</u>			<u>Relation of CEC to Soil Texture</u>	
Potassium (Ideal 3 - 6)	2.4	L	0-5 Sand	18-24 Silt Loam
Calcium (Ideal 65 - 80)	72.6	M	5-12 Loamy Sand	24-36 Clay Loam
Magnesium (Ideal 15 - 25)	23.8	M	12-18 Sandy Loam	36+ Clay
Sodium (Ideal < 3)	1.2	M		
<u>Comments</u>				
Crop / Yield 1	Excessively Calcareous soils respond to 100-200 lbs/ac of Elemental Sulfur or Acid forming fertilizers.			
Crop / Yield 1	Examples of acid forming fertilizers are: 21-0-0/Thio-Sul/Nitro-Sul and Disintegrating Sulfurs.			

How much is too much?

Table 1. *General Soil Salinity Classifications*

Soil extract electrical conductivity (ds/m)	Salinity class	Crop sensitivity
0 - 2	Nonsaline	Suitable for most crops
2 - 4	Very slightly saline	Salt-tolerant vegetables, many grains, and forages
4 - 6	Slightly saline	Highly salt-tolerant plants
8 - 16	Moderately saline	Not suitable for crops
> 16	Strongly saline	Not suitable for crops

Sources: Natural Resources Conservation Service (1990) and Tables 3 and 4.

Where does salt come from?

Where does salt come from?

30 inches =
4.4 tons/acre

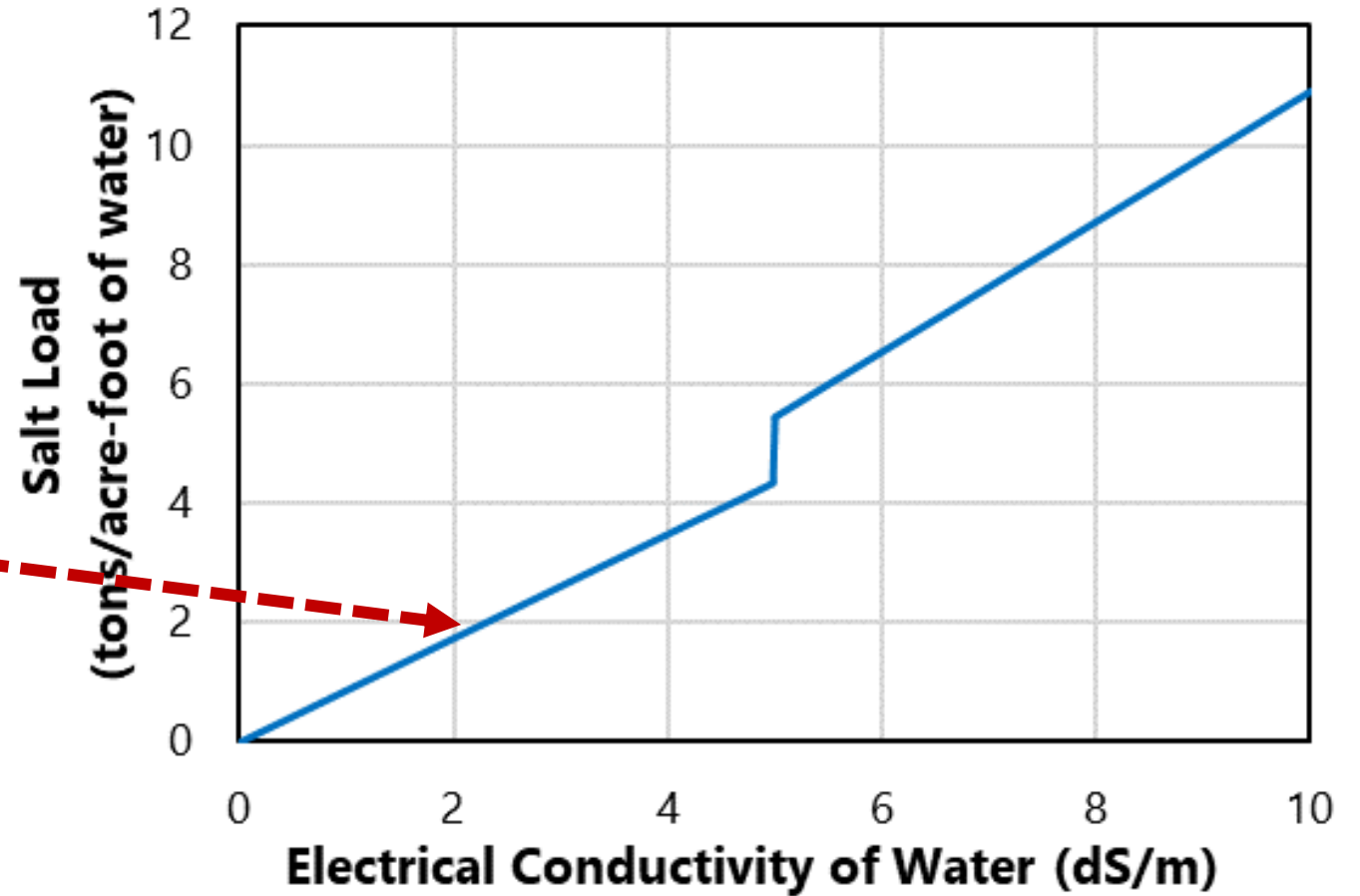


Figure 2. *Approximate Salt Load in Irrigation Water*

Where to Sample?

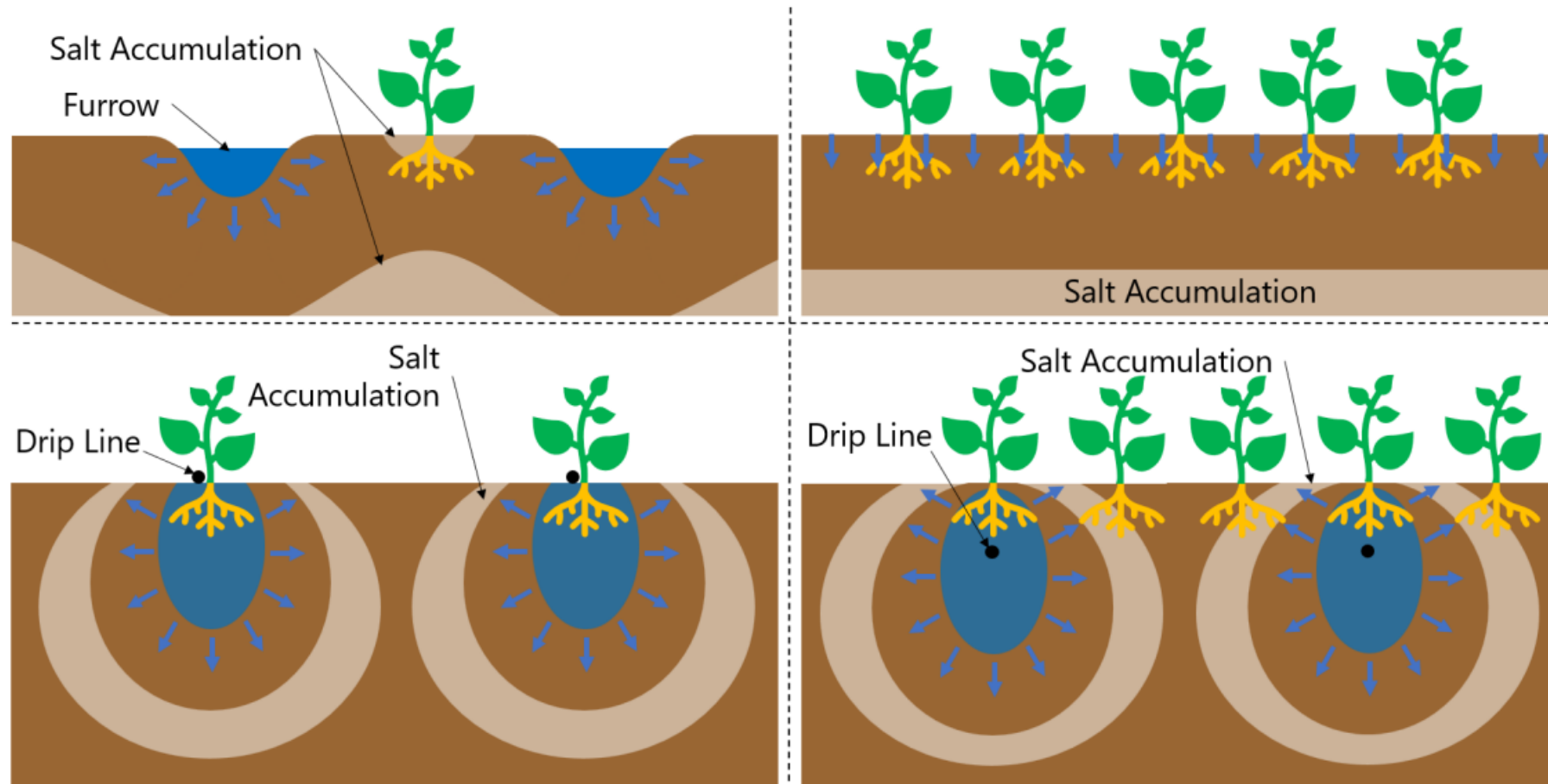


Figure 6. Generalized Locations of Salt Accumulation With Different Irrigation Systems: Furrow Irrigation (top left); Sprinkler, Basin, Border, and Flood Irrigation (top right); Surface Drip Irrigation (bottom left); and Subsurface Drip Irrigation (bottom right)

Credit: Based, in part, on Ayers and Westcot (1997).



**What to
do about
it?**



Over-Irrigate: Constant Leaching

~30
inches =

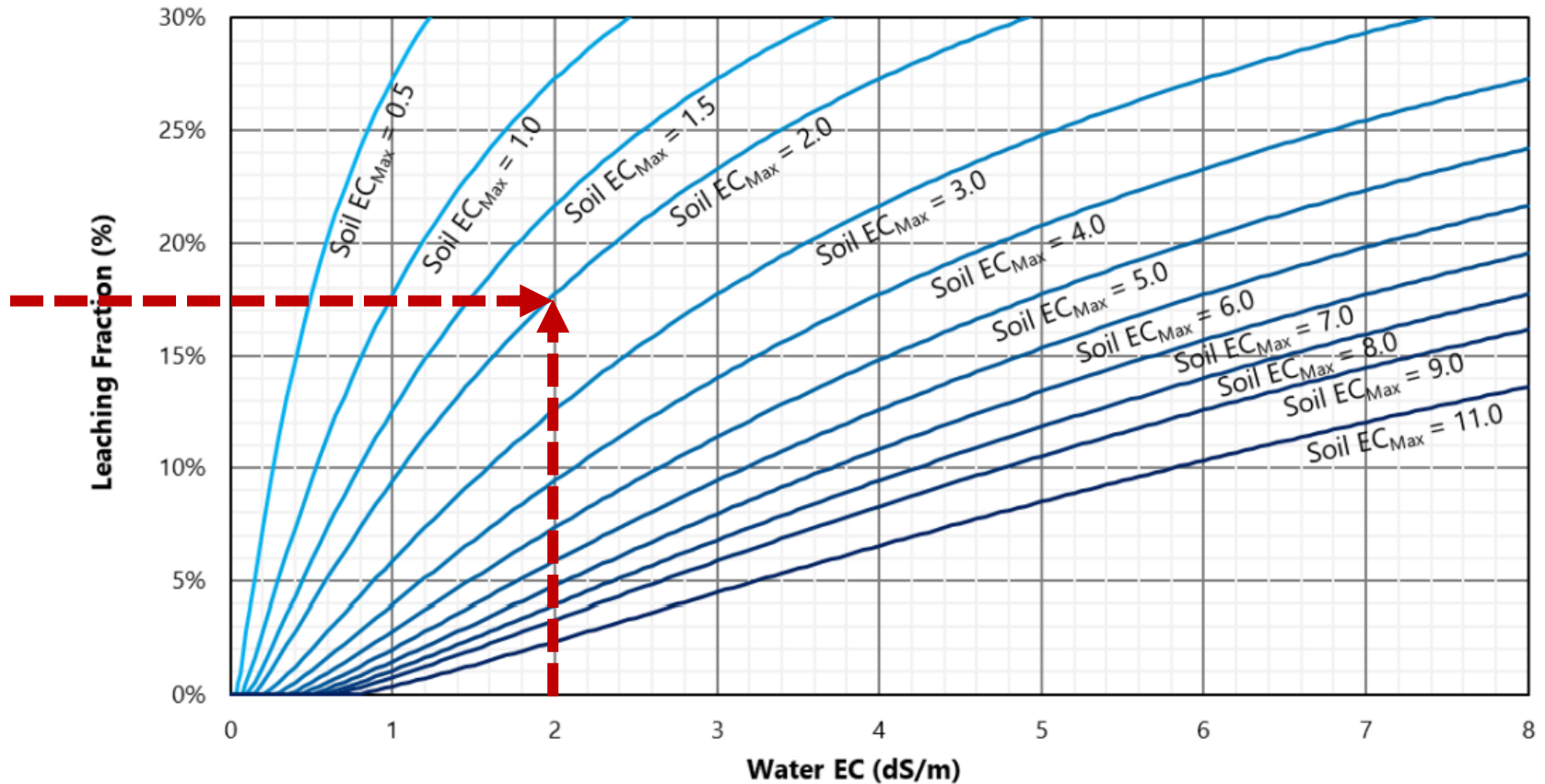


Figure 9. The Leaching Fraction Given the Irrigation Water Electrical Conductivity and Maximum Desired Soil Electrical Conductivity (EC_{Max}) for a 1-Meter (3.3-Foot) Deep Root Zone (Hoffman & Shalhevet [2007])

Over-Irrigate: Reclamation

Extra 22
inches =

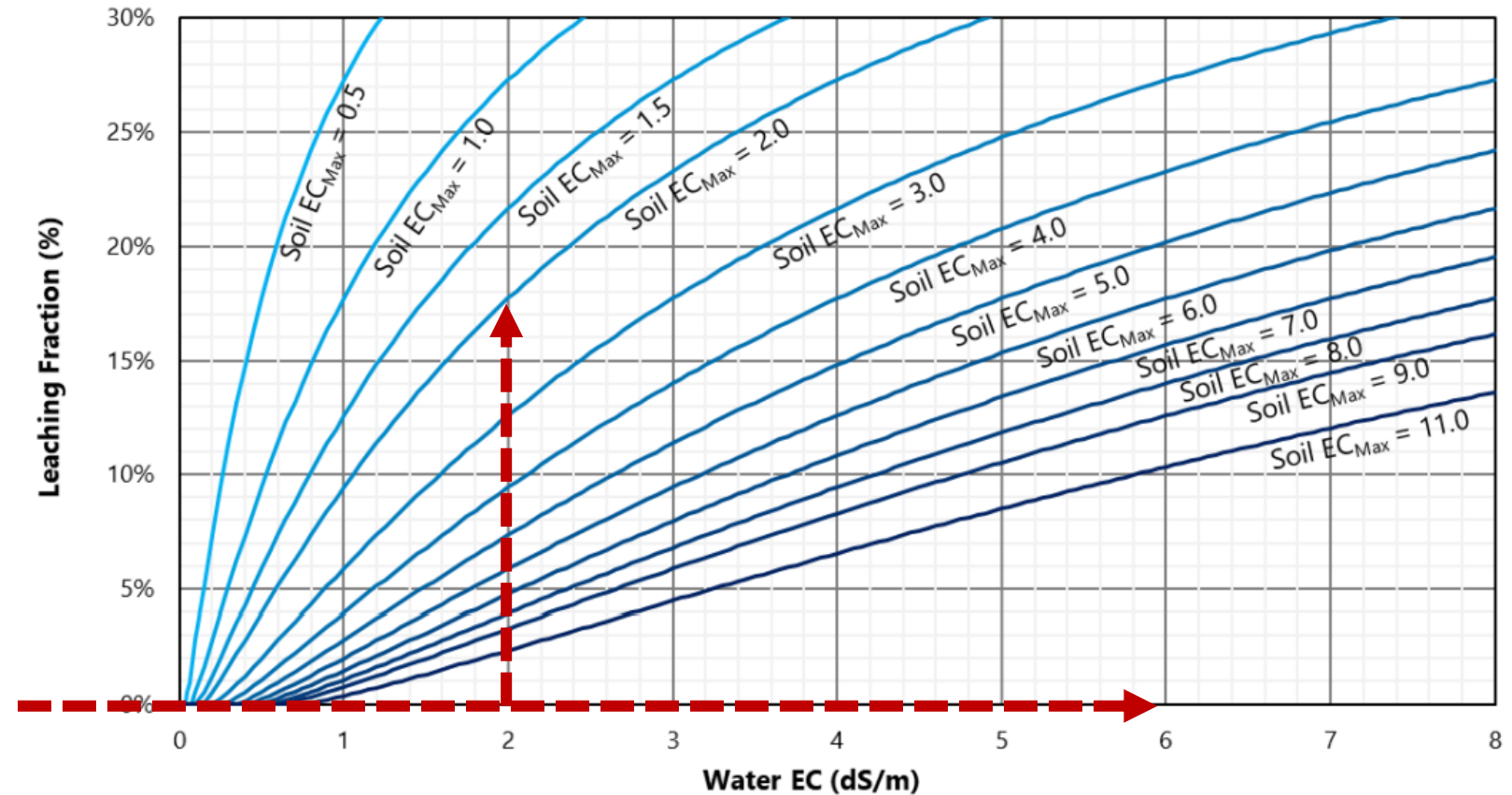


Figure 9. The Leaching Fraction Given the Irrigation Water Electrical Conductivity and Maximum Desired Soil Electrical Conductivity (EC_{Max}) for a 1-Meter (3.3-Foot) Deep Root Zone (Hoffman & Shalhevet [2007])

Switch Crops



Table 4. Soil Salinity Tolerance of Some Agronomic Crops in Utah

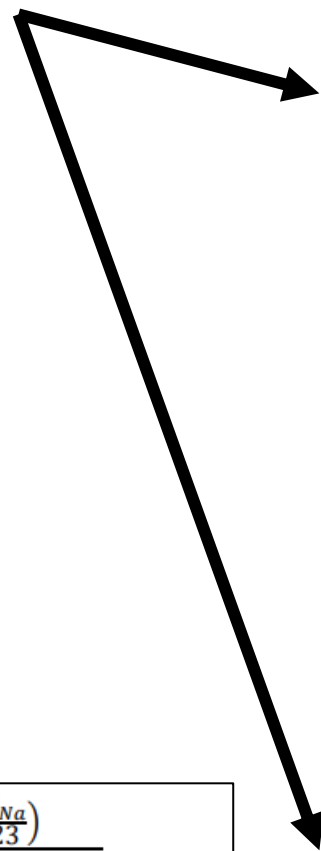
Crop and sensitivity	Potential yield reduction	
	0%	10%
	Maximum soil extract EC (dS/m)	
Moderately sensitive		
Alfalfa	2.0	3.4
Clover - red	1.5	2.3
Corn - grain	1.7	2.5
Corn - silage	1.8	3.2
Orchard grass	1.5	3.1
Moderately tolerant		
Barley - forage	6.0	7.4
Brome - mountain & smooth	3.0-6.0*	4.3-7.8*
Perennial ryegrass	5.6	6.9
Safflower	3.0-6.0*	4.3-7.8*
Sorghum - grain	4.0	5.1
Sudangrass	2.8	5.1
Sunflower - seed	4.8	6.8
Tall fescue	3.9	5.5
Wheat - grain	6.0	7.4
Wheatgrass - crested	3.5	6.0
Tolerant		
Barley - grain	8.0	10.0
Oats - grain	6.0-10.0*	7.8-12.2*
Oats - forage	6.0-10.0*	7.8-12.2*
Triticale - grain	6.1	8.1
Wheatgrass - tall	7.5	9.9

Sources: Grieve and others (2012); Hoffman & Shalhevet (2007)

Notes. Shading indicates relative salt tolerance (lighter = more sensitive, darker = less sensitive).

*Approximated range from sensitivity group; using the lower end of the range is recommended.

Sodium Adsorption Ratio



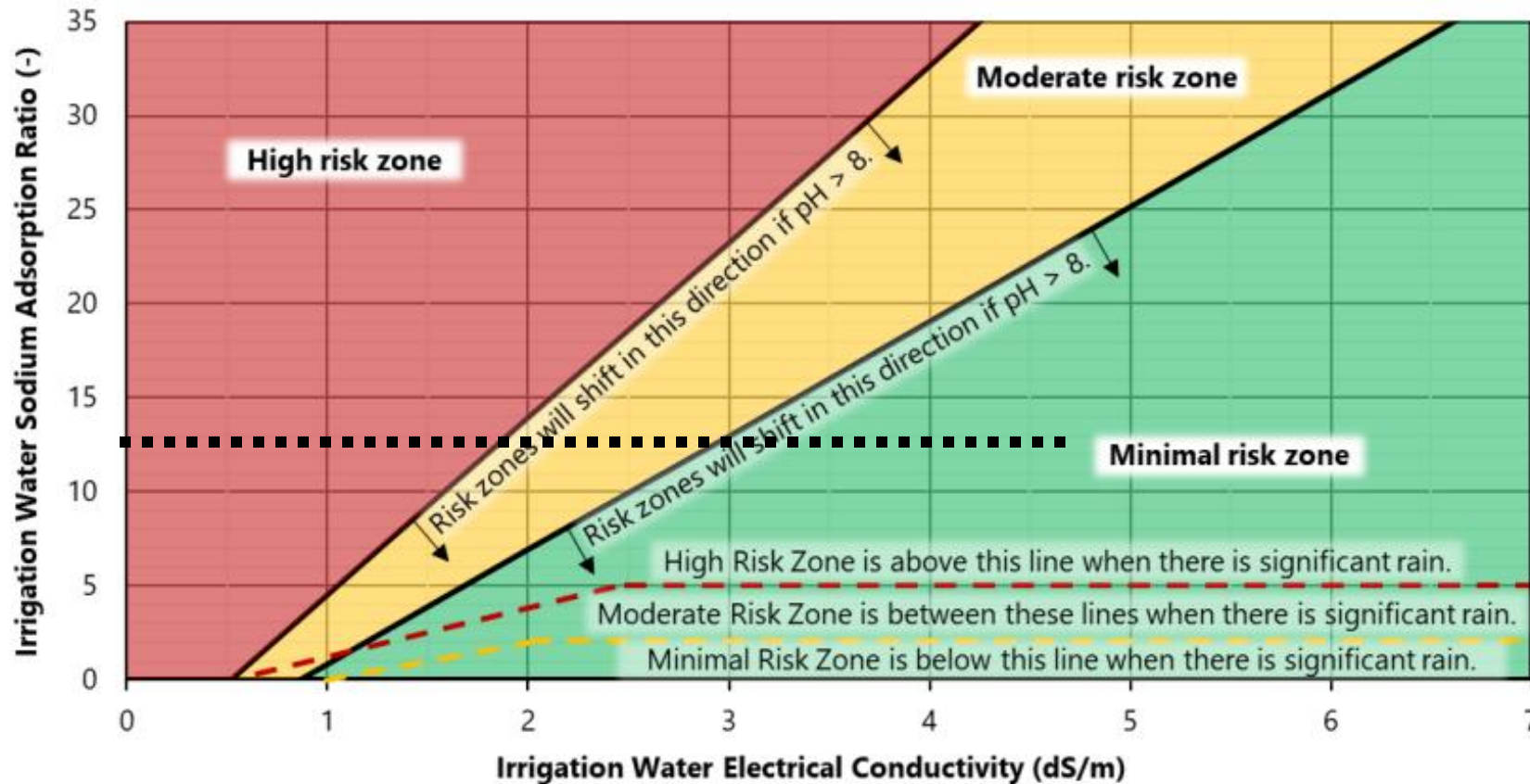
<u>SOIL TEST DATA</u>	<u>Sample 1</u>	<u>Sample 2</u>	<u>Sample 1</u>	<u>Sample 2</u>
pH	7.9	H	Grower	USU
Salts, mmhos/cm	1.0	L	Sample Identity	
Chlorides, ppm	4	VL	Crop	ALFALFA
Sodium, meq/100g	0.20	VL	Yield Goal	6 T
CEC, meq/100g	16.4	M	Acres	
Excess Lime, %	20.0	VH	Prev Crop T/Acre	ALFALFA
Organic Matter, %	1.77	M	Manure T/Acre	
Organic N, lb/Acre	70	M	Prev Applied Nut	
Ammonium - N, ppm	4.0	VL	<u>RECOMMENDATIONS, lbs Nutrients or Units per Acre</u>	
Nitrate - N, ppm	14	M	Nitrogen	0
Phosphorus, ppm	18	M	P ₂ O ₅ - Phosphate	145
Potassium, ppm	125	L	K ₂ O - Potash	90
Calcium, meq/100g	11.9	H	Calcium	0
Magnesium, meq/100g	3.9	H	Magnesium	0
Sulfate - S, ppm	9	L	Sulfate - Sulfur	50
Zinc, ppm	2.2	H	Zinc	0
Iron, ppm	10.5	H	Iron	0
Manganese, ppm	2.2	L	Manganese	4
Copper, ppm	0.9	M	Copper	0
Boron, ppm	0.91	M	Boron	0
			Elemental Sulfur	0
			Gypsum	0
			Lime	0
			<u>Relation of CEC to Soil Texture</u>	
			0-5 Sand	18-24 Silt Loam
			5-12 Loamy Sand	24-36 Clay Loam
			12-18 Sandy Loam	36+ Clay
			<u>Base Saturation, %</u>	
Potassium (Ideal 3 - 6)	2.4	L		
Calcium (Ideal 65 - 80)	72.6	M		
Magnesium (Ideal 15 - 25)	23.8	M		
Sodium (Ideal < 3)	1.2	M		
			<u>Comments</u>	
Crop / Yield 1	Excessively Calcareous soils respond to 100-200 lbs/ac of Elemental Sulfur or Acid forming fertilizers.			
Crop / Yield 1	Examples of acid forming fertilizers are: 21-0-0/Thio-Sul/Nitro-Sul and Disintegrating Sulfurs.			

$$SAR = \frac{\left(\frac{C_{Na}}{23}\right)}{\sqrt{\left(\frac{C_{Ca}}{40}\right) + \left(\frac{C_{Mg}}{24}\right)}}$$

where

- C_{Na} = Concentration of sodium (mg/L).
- C_{Ca} = Concentration of calcium (mg/L).
- C_{Mg} = Concentration of magnesium (mg/L).

Step 1: Determine infiltration risk



SAR is measured in both soil extracts and irrigation water. Monitor both regularly to manage sodicity effectively. Soils with a SAR > 13 are considered sodic (Garcia, 2014; Davis et al., 2003). There may be no visual evidence of sodicity. However, soils with sodicity problems will often have trouble with water infiltration; they may also have soil structure problems resulting in low load-bearing capacity.

Figure 8. Irrigation Water Infiltration Impairment Based on Irrigation Water Sodium Adsorption Ratio and Electrical Conductivity

Step 2: Amend with Gypsum / ES

$$\text{Gypsum rate} = \frac{\text{soil depth} \times \text{bulk density} \times \text{CEC} \times (\text{SAR measured} - \text{SAR desired})}{85.4}$$

OR

$$\text{Elemental Sulfur} = \text{gypsum rate} \times 0.19$$

Example:

$$2 \text{ tons / acre} = 2 \times 1.4 \times 10 \times (14 - 8) \div 85.4$$

$$760 \text{ \# / acre} = 2 \text{ tons} \times 0.19$$