Dealing With Salinity

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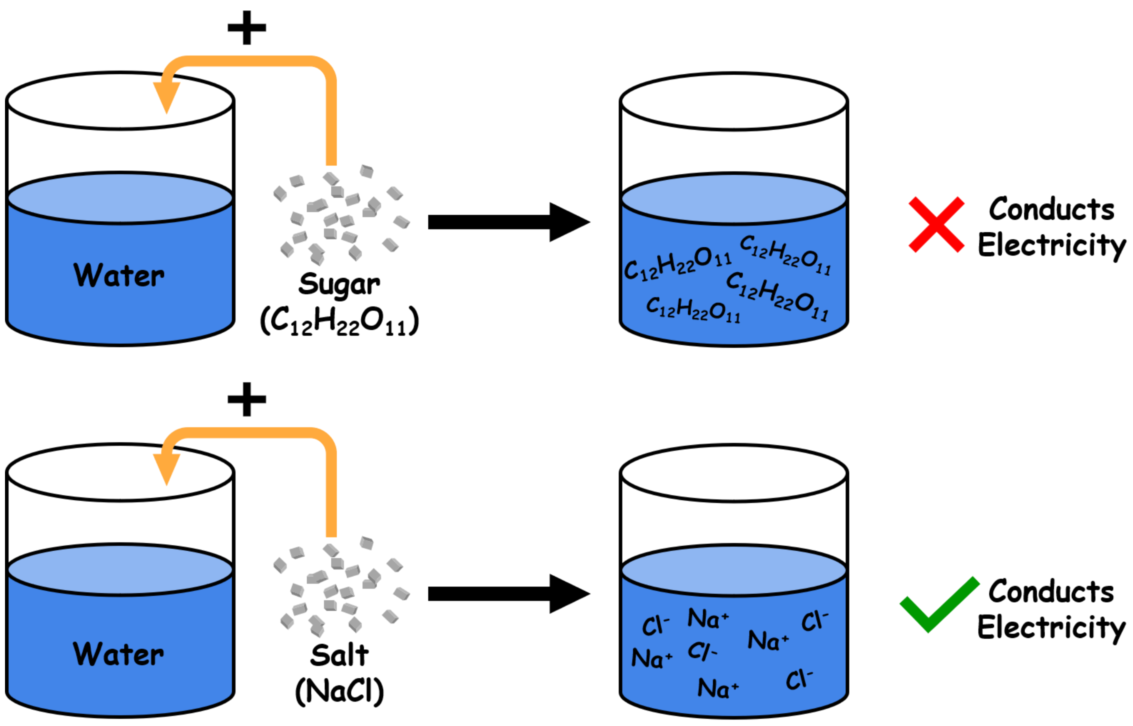
About Me

- Agricultural Data Scientist for CSU Ag Water Quality Program (AWQP)
- Certified Crop Advisor (CCA)
- My areas of research are
  - Data science in water resources
  - Irrigation science
  - Soil salinity
  - Environmental sensing technology
- Grew up on a farm in Rocky Ford, CO

What are salts and why do we care?

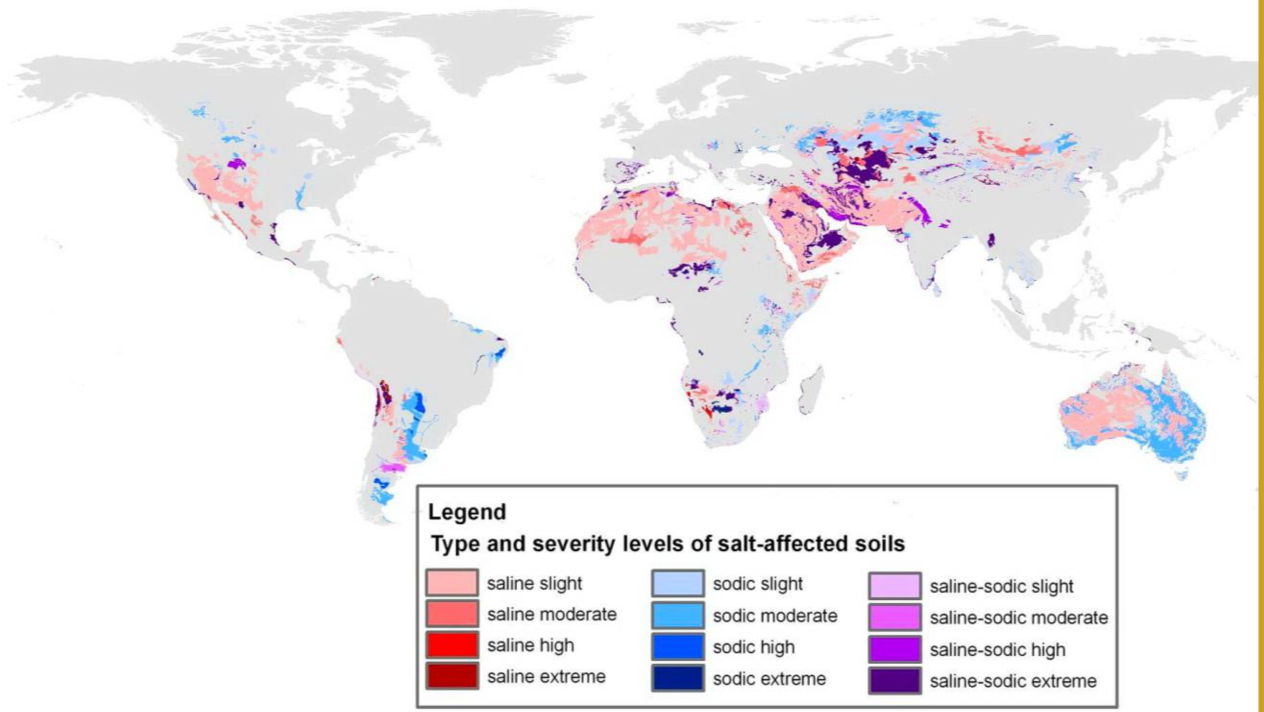
What are salts?

- A salt is **a chemical compound** made of **positively** charged and **negatively** charged ions, resulting in **no overall electric charge (e.g., table salt; NaCl)**.
- They are also **electrolytes**, meaning they conduct electricity after dissolving in water (think Gatorade!)



Why do we care?

- Salt is a major threat to food security
- ~$27 Billion USD annual impact, globally
- 3.7 million acres lost each year
- Extremely costly (time, money, energy) to treat in soils and water



Where does it come from?

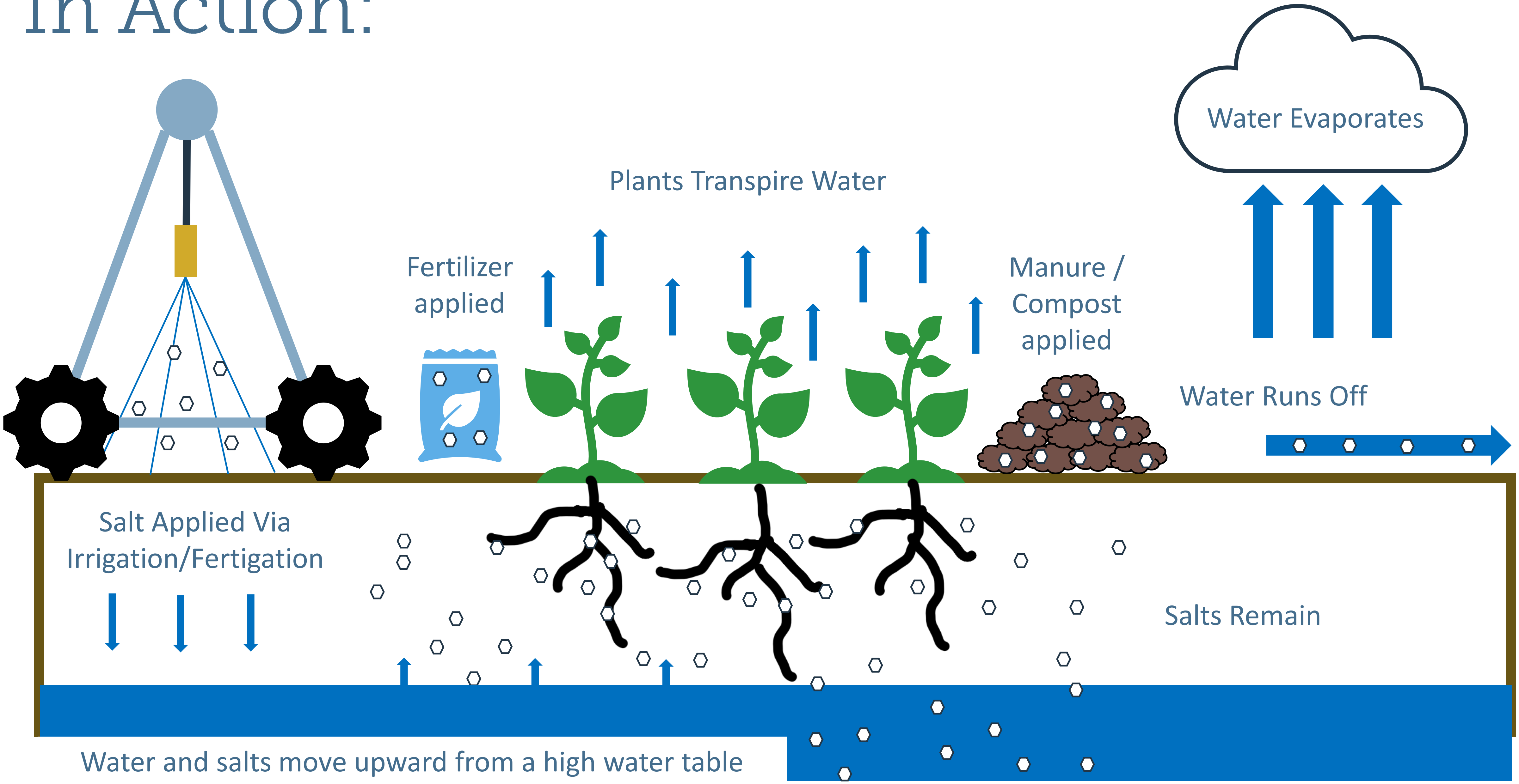
Origins of salts

- **Geology:** weathering of primary minerals, marine sediments, etc
- **Climate:** evaporation exceeds precipitation
- **Reuse:** ‘pure’ water evaporates with each use, salts remain
- **Human activity:** manure, fertilizer, road deicing, WWTP, oil and gas activity (CBM) or urban runoff
- **Water table:** near soil surface, bringing up salts and preventing leaching

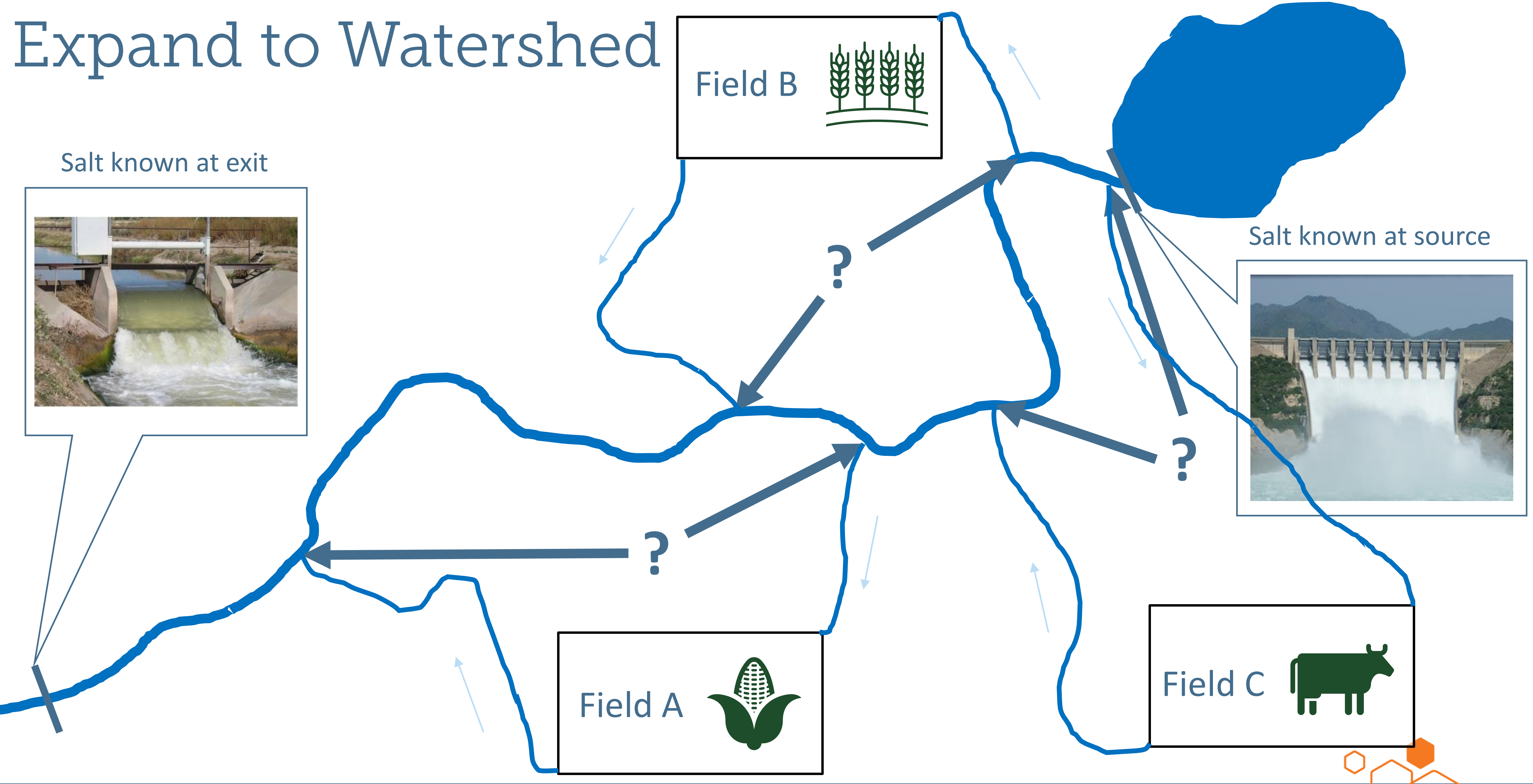
Salinity Accumulation 101:

1. All natural waters contain varying amounts of salts, as well as the soil.
2. Salt accumulation in soil and water is inevitable in climates where ET > precipitation
3. Thus, drainage and clean water, either natural or artificial, is essential to manage salts

In Action:


Water Evaporates
Plants Transpire Water
Fertilizer applied
Manure / Compost applied
Water Runs Off
Salt Applied Via Irrigation/Fertigation
Salts Remain
Water and salts move upward from a high water table

Expand to Watershed



How do we measure it?

How do we measure salinity?

Electrical Conductivity (EC)

- Bulk (ECa)
- Pore Water (ECpw)
- Applied Water (ECw)
- Saturation Extract (ECe)
- Gravimetric Extract (EC1:1, EC1:5)

Total Dissolved Solids (TDS)

- Parts per million of dissolved salts

= sum of all individual salt ions in solution

Saturated paste extract method (ECe): Attempts to mimic saturated soil; NOT the same as EC1:1 or EC1:5 as reported by most labs

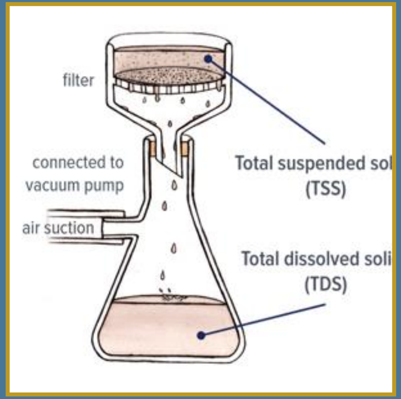
Lab Strategies

EC sensors

- Measures all salts in the form of EC
- Can be done in-field
- Is proxy for specific salts and TDS

Spectrometry

- For individual salt types in a solution (sum to get TDS)
- Done only at commercial and university labs



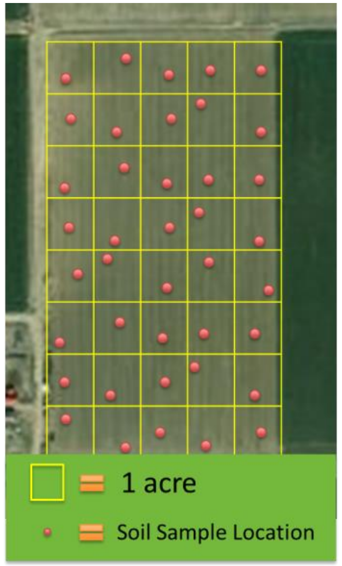
Evaporation for TDS

Let’s talk about the soil lab results

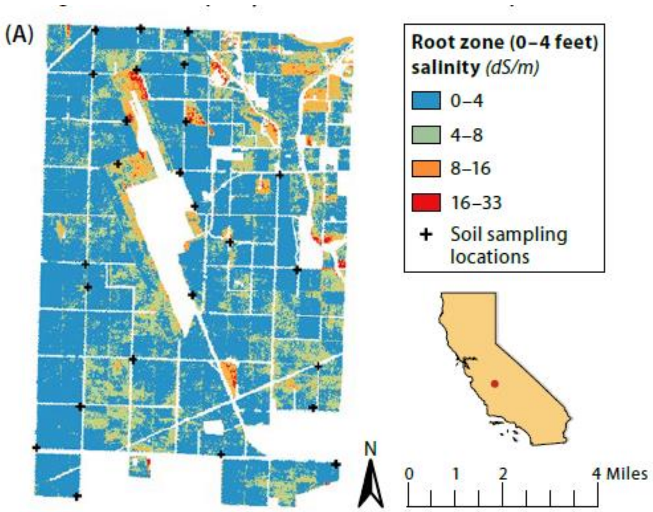
- Soil labs often report EC1:1 and **NOT** ECe (what we need)
- When you are trying to make decisions related to soil salinity on your field(s), here are two important things to remember:
  - Take composite samples over the whole root zone depth, often 1 – 4’ deep
  - Request to your agronomist or soil lab to return ECe and not EC1:1 (i.e., saturated paste EC and not 1:1 EC)
- If you only have EC1:1, the USDA recommendation is to multiply it by 3 to be safe, but often it’s somewhere between 1-3.

Field Strategies

- Electromagnetic Induction
  - EM38 or Veris
- Remote Sensing
  - Ground data coupled with satellite or drone Imagery
- Soil Sensors
  - Great for temporal observation
- Soil Sampling Regimes
  - Extremely costly



Traditional Soil Sampling regime



Satellite image from: Scudiero et al. (2017)

Common salts of concern

Salt compound	Cation (+)	Anion (-)	Common Name
NaCl	sodium	chloride	halite (table salt)
Na_2SO_4	sodium	sulfate	Glauber's salt
$MgSO_4$	magnesium	sulfate	epsom salts
$NaHCO_3$	sodium	bicarbonate	baking soda
Na_2CO_3	sodium	carbonate	sal soda
$CaSO_4$	calcium	sulfate	gypsum
$CaCO_3$	calcium	carbonate	calcite (lime)
$NaNO_3$	sodium	nitrate	none, but often in fertilizer

Different salts impact: **Soils**, **Water**, and **Plants** differently

Soil Impacts

Sodic vs. Saline

SODIC (THINK "SODIUM")

- Loss of soil structure
- Crusting
- Reduced infiltration
- Increased runoff and erosion
- Dark powdery residue on soil surface
- Higher pH impacting nutrient uptake/imbalances
- Hurts microbes

Photo credit: Jacob Makens, Las Cruces, NM

SALINE (THINK "EVERYTHING ELSE")

- Increased structure*
- Crusting
- Increased infiltration*
- White powdery residue on soil surface and in aggregates
- Higher pH impacting nutrient uptake/imbalances (but needs much more abundance than NaCl)

Often called "Alkali"

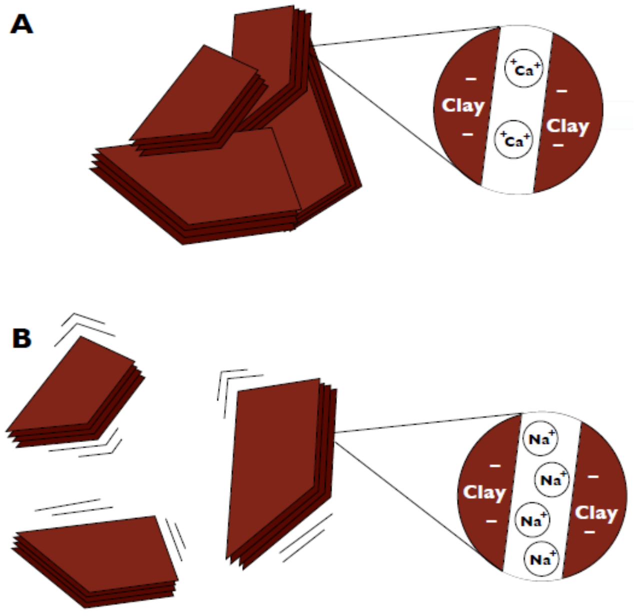
Classification	EC_e (dS/m)	SAR	Soil pH	Physical Condition
Saline	≥4.0	<13	<8.5	Normal
Sodic	<4.0	≥13	>8.5	Poor
Saline-Sodic	>4.0	≥13	<8.5	Normal

Problem	Potential Symptoms
Saline Soil (B)	white crust on soil surface, water stressed plants, species changes, leaf tip burn
Sodic Soil (A)	crusting or hardsetting, low infiltration rate; runoff and erosion, dark powdery residue on soil surface, stunted plants with leaf margins burned
Saline-Sodic Soil	generally, same symptoms as saline soil

Soil Diagnosis

SAR = Sodium Adsorption Ratio

- Used to diagnose a sodium-specific issue



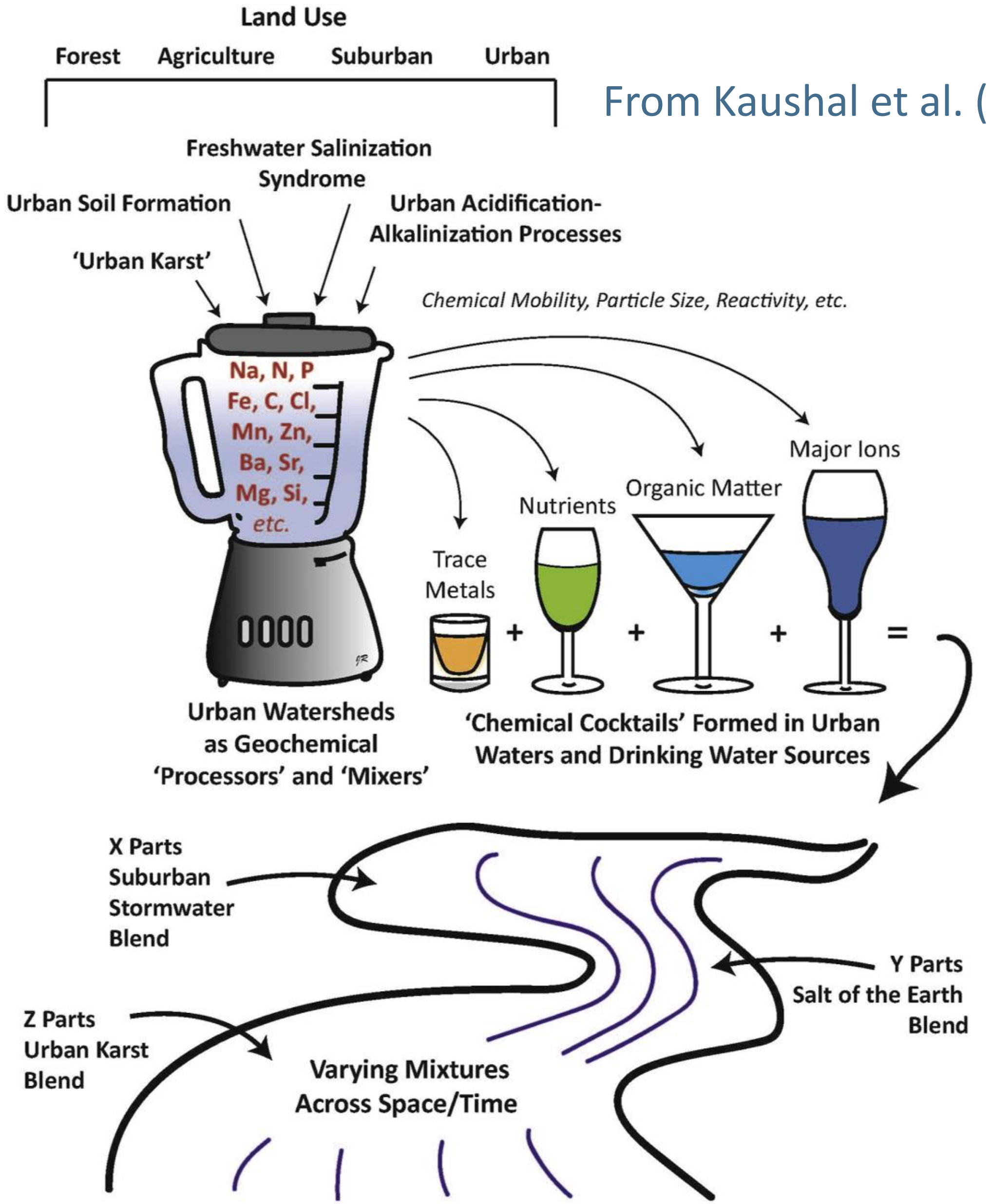
$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

Note how there is also a **Saline-Sodic** option! It's the worst of both worlds.

Water Impacts

What can salts do to our water?

- Can harm aquatic life, both vertebrates and invertebrates
- Pollutes drinking water sources
- Damage infrastructure
- Cause other pollutants to concentrate and mobilize in soil, groundwater, surface water, and pipes (freshwater salinization syndrome)



From Kaushal et al. (2020)

Water Diagnosis with ECw alone

Can be purchased on Amazon for $35 – $75
https://a.co/d/cbYdKBt

Classes of water	TDS	Electrical Conductivity
	(mg/l)	(dS/m)*
Class 1, Excellent	<1,000	≤0.25
Class 2, Good		0.25 - 0.75
Class 3, Permissible[1]	1,000 – 2,000	0.76 - 2.00
Class 4, Doubtful[2]		2.01 - 3.00
Class 5, Unsuitable[2]	>2,000	≥3.00

*dS/m at 25ºC = mmhos/cm
[1]Leaching needed if used.
[2]Good drainage needed and sensitive plants will have difficulty obtaining stands.

Water Diagnosis Considering SAR (Preferred)

TO COLLECT A SAMPLE:

- Label bottle (datetime, site)
- Use plastic bottle and rinse 3 times in water
- Sample on 4th fill
- Screw on cap tightly
- Refrigerate until shipping
- Get it to the lab < 28 days!

Potential for Water Infiltration Problem

Irrigation water SAR	Unlikely	Likely
	————EC_w[2] (dS/m)———-	
0-3	>0.7	<0.2
3-6	>1.2	<0.4
6-12	>1.9	<0.5.
12-20	>2.9	<1.0
20-40	>5.0	<3.0

[2]Modified from R.S. Ayers and D.W. Westcot. 1994. Water Quality for Agriculture, Irrigation and Drainage Paper 29, rev. 1, Food and Agriculture Organization of the United Nations, Rome.

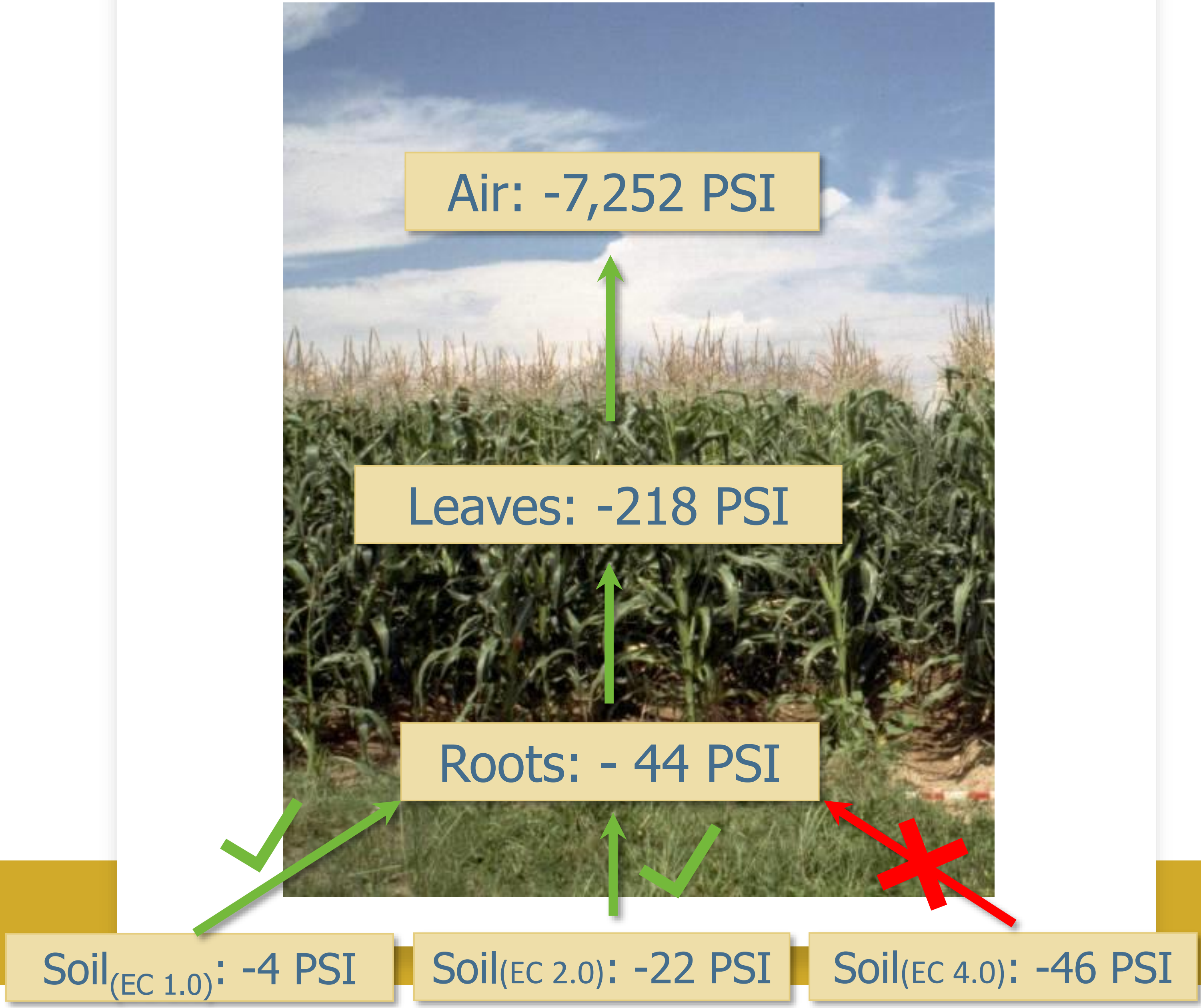
Crop Impacts

Salinity Impacts

- Symptoms
  - Drought stress (even in wet conditions!)
  - Specific ion toxicity
  - Leaf burn
  - Nutrient uptake interferences
- Impacts
  - Reduced yield
  - Reduced water uptake (ET)
  - Malnourishment
  - Plant death

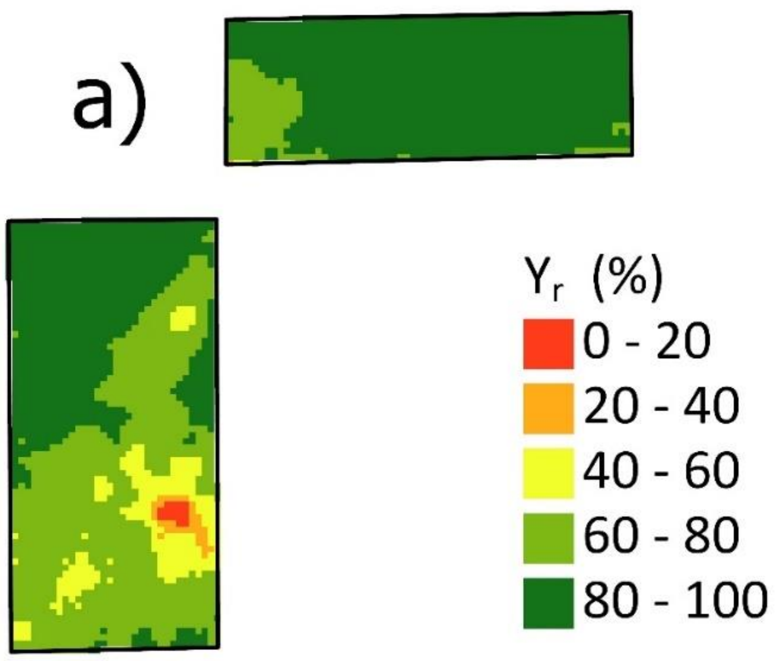
How Salts Hurt Crops: Drought Stress

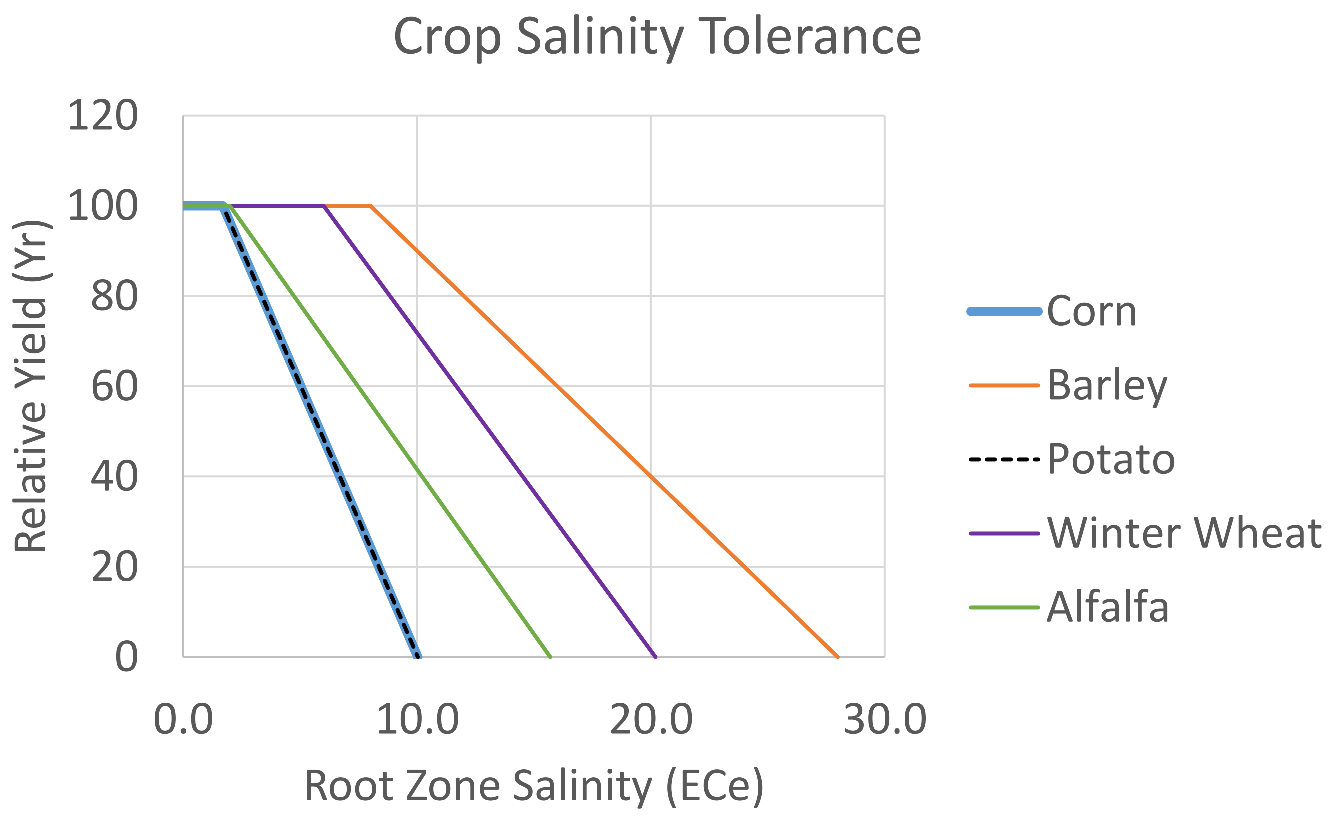
- Plants ‘suck’ on water just like we do through a straw. This suction can be measured in units, like PSI for example
- Plants will adjust their suction to accommodate for salinity at the cost of yield and growth.
- This phenomena is often the #1 stress cause, followed by nutrient toxicity



Crop Salt Tolerance: Visual Representation

- Yr = relative crop yield (0-100%)
- FAO tolerance datasheet <-click this link!





Management Strategies

Management Categories

Soil-centric

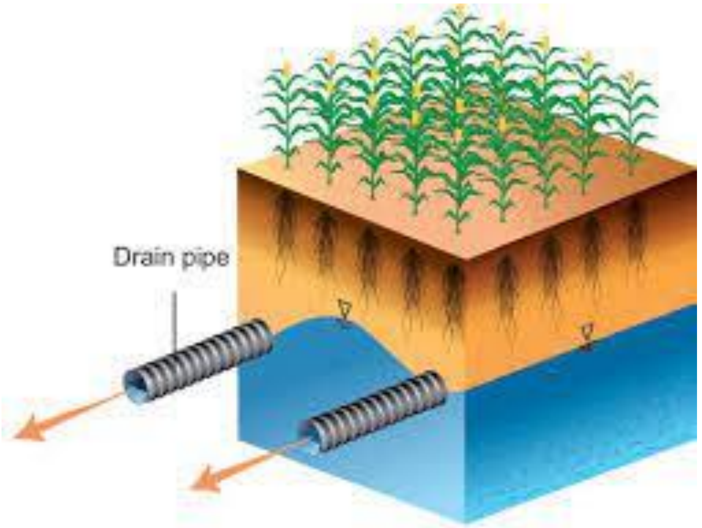
focuses on improving soil structure and quality

Crop-centric

focuses on imparting plant tolerance and enhancing growth

Soil-Centric Methods

- Soil leaching (in season)
  - Irrigating extra during the growing season to flush out salts
- Pre-post season flushing or Reclamation Leaching
  - Applying water pre-post growing season to flush out the seasonal salt accumulation
- Tillage to improve drainage
  - E.g., field levelling, drainage ditches
- Drainage tile installation
  - Ceramic or PVC perforated tile to remove water from roots
- Chemical amendments
  - Gypsum on sodic soil to improve soil structure
  - Sulfur on carbonate soil




Gypsum Application

Crop-Centric Methods

- **Switching to a more salt tolerant crop**
  - From corn to wheat to barley, for example
- **Afforestation**
  - establish deep rooted forests to tap into ground water and improve soil

Crop Salt Tolerance By Species

Sensitive	Moderately Sensitive	Moderately Tolerant	Tolerant
almond	**alfalfa**	olive	**barley**
apple	broccoli	red beet	**Bermuda grass**
avocado	cabbage	**ryegrass**	cotton
bean	corn	safflower	date palm
carrot	cucumber	soybean	sugar beet
grapefruit	grape	wheat	**Wheatgrass, tall**
lemon	lettuce	**Wheatgrass, crested**	
okra	peanut	**wildrye**	
onion	potato	**Sorghum sudangrass**	
orange	radish		
peach	rice		
plum	sugarcane		
strawberry	tomato		

I created an Excel Workbook to perform these three calculations for you. Open this QR code and download the excel file to your own computer.

Here's a tool to help

BONUS: Salinity and Livestock

Impacts: Overgrazing on Soil

- **Continuous grazing** often leads to soil compaction, reduced infiltration, and increased surface runoff, which can exacerbate salt accumulation.
- **Grazing can increase evaporation rates**, leading to the upward movement of salts from deeper soil layers to the surface.
- **Long-term manure application** increases soil salinity

Photo Credit: Phil Brink

Impacts: Salty Soil on Livestock

Direct Impacts

- **Water quality** – usually degrades due to poor soil and water salinization
- **Forage quality** – reduced biomass production, lower protein content, decreased palatability

Indirect Impacts

- **Soil structure and erosion** – lack of sustainable production
- **Vegetation composition** – shifts composition towards salt-tolerant species, which aren't always as nutritious or palatable

Salinity BMPs for Livestock

Rotational Grazing

- Allows for rest periods that allow soil and vegetation to become resilient

Grazing Exclusion

- Periodic grazing exclusion allows soil and vegetation to recover (reducing compaction, improving OM, soil structure, etc.)

Vegetative cover management

- Maintain cover to prevent erosion and reduce evaporation; it’s often best to have living roots in the ground

Soil amendments

- Same as previously mentioned cropping system approaches; often too costly for rangelands

Hydrological management

- Drainage drainage drainage!

Thank You

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