Matching the soil, water, and crop system in saline and sodic conditions

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Understanding the Components of Salinity Control

- To move into a sound program of salinity control on a farm field, one must ask oneself:

  What is cause of my salinity problem?

  Is there adequate leaching of salts beyond the root zone?

  Does irrigation water quality threaten soil permeability and tilth?

  Am I making the best of the irrigation conditions I have?

  Am I growing crops which are tolerant to the salt levels in my soil and irrigation water?

  Are there other methods to correct/prevent the problem?

My soils are saline and/or sodic, what is the cause?

- **Naturally saline/sodic soils**
  - **Soils with marine deposit parent material**
  - **Low-lying soils in contact with sea water along the sea coasts.**
  - **Geologic or other discontinuities in the landscape**

- **Salt accumulation in root zone**
  - Poor drainage
    - **High groundwater table or perched aquifer**
      - Drainage of water carrying salts away from uplands to lowlands
      - Fluctuating water table and ET
      - Irrigation of low-land adjacent to streams
    - **Low permeability soils**
      - Fine soils or impermeable layer
      - Textural Discontinuity
  - Saline Irrigation Water
    - **Naturally saline/sodic water**
    - **Secondary saline/sodic water**

Soil Chemistry Responses to Saline Water

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MSU Graduate Research
Under Dr. Jim Bauder

Objective: Determine how valley soils react to irrigation with saline water

Sampling locations within Powder River watershed, Prairie County Conservation District, and Buffalo Rapids Irrigation District.

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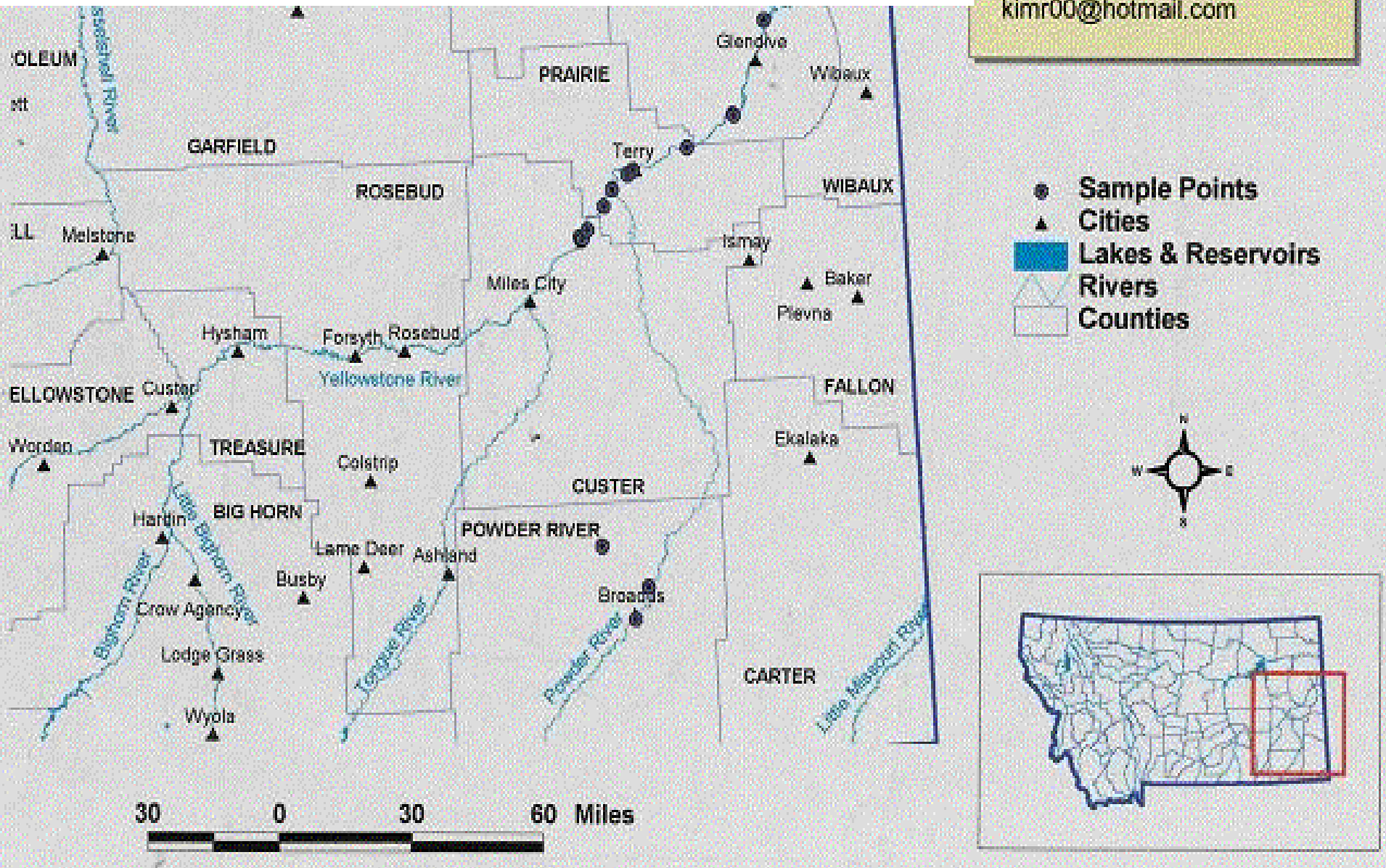


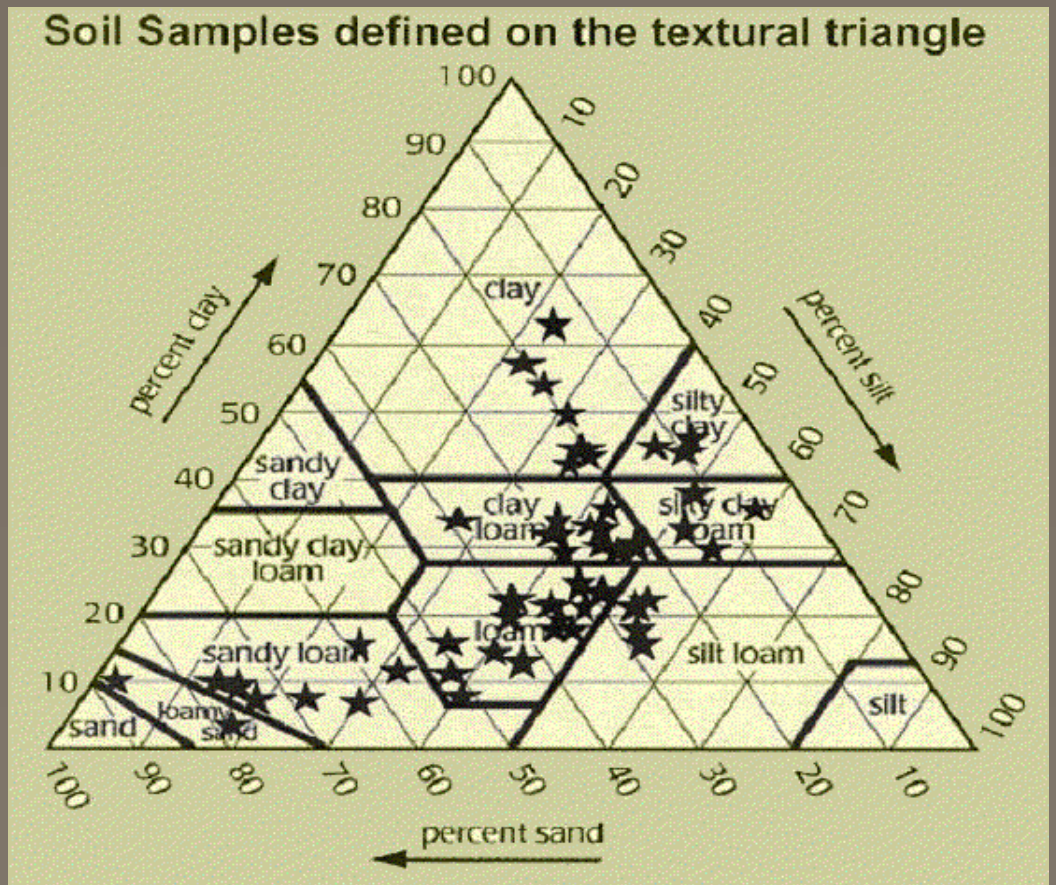
TEXTURAL CLASSES

1- Clay % 0-11% - Loamy Sand, Sandy Loam, Loam

2- Clay % 12-22% - Sandy Loam, Loam, Silt Loam

3- Clay % 23-33% - Loam, Clay Loam, Silty Clay Loam

4- Clay % 34+ - Silty Clay Loam, Silty Clay, Clay



Wetting Regime

- Water Quality

  low salinity x low sodicity

  - **EC = 1.6 dS/m SAR = 4.5 pH = 8.0**

  moderately (saline x sodic)

  - **EC = 3.1 dS/m SAR = 13.0 pH = 8.0**

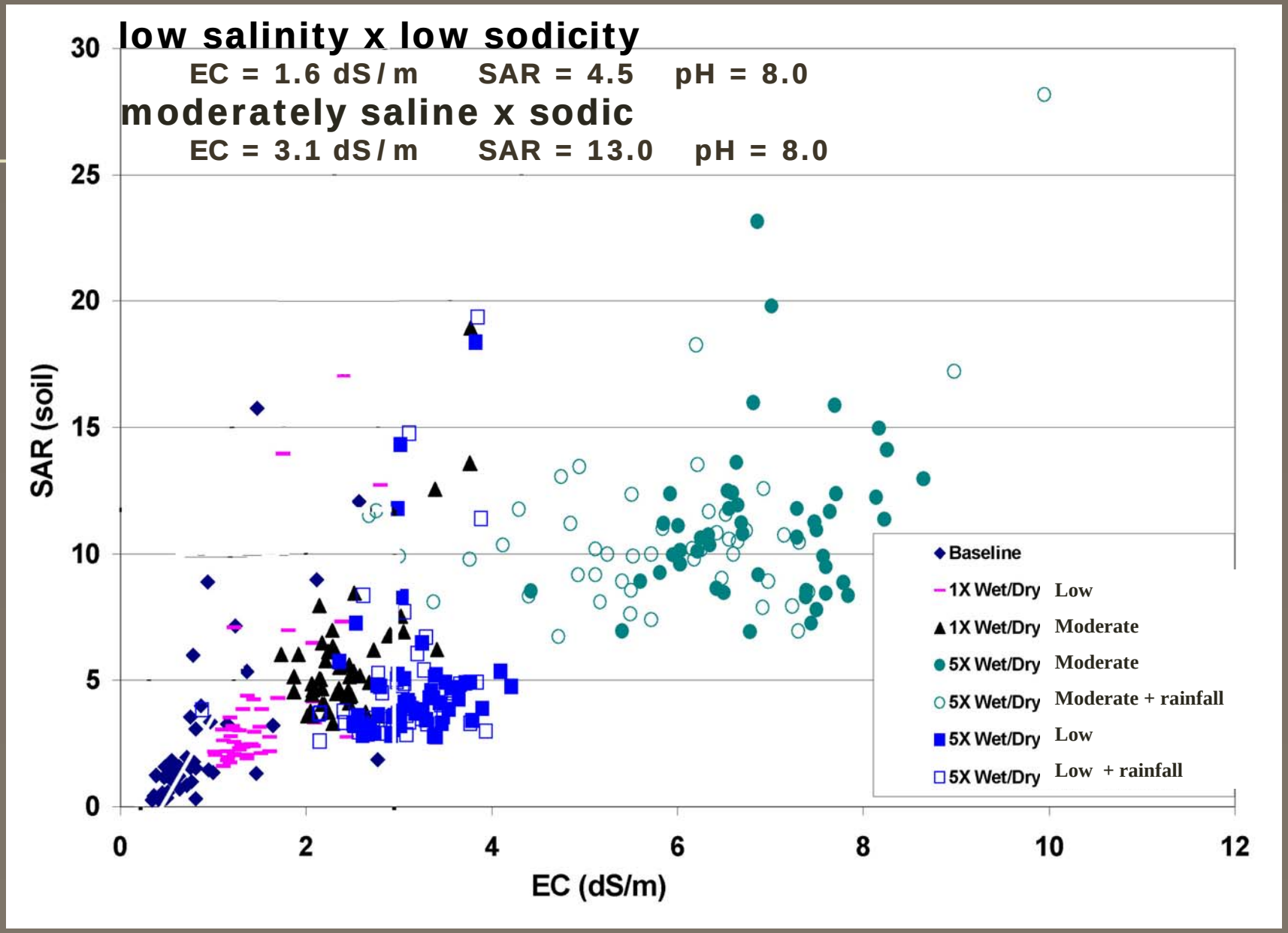
- 3 Different Wetting Regimes

  low salinity x low sodicity

  1x 5x 5x then simulated rainfall

  moderately (saline x sodic)

  1x 5x 5x then simulated rainfall


low salinity x low sodicity
EC = 1.6 dS/m SAR = 4.5 pH = 8.0
moderately saline x sodic
EC = 3.1 dS/m SAR = 13.0 pH = 8.0
SAR (soil)
EC (dS/m)
0
5
10
15
20
25
30
0
2
4
6
8
10
12
Baseline
1X Wet/Dry Low
1X Wet/Dry Moderate
5X Wet/Dry Moderate
5X Wet/Dry Moderate + rainfall
5X Wet/Dry Low
5X Wet/Dry Low + rainfall

Soil Chemistry Conclusions

- Repeated irrigation with saline water is likely to result in elevated soil salinity levels higher than published tolerance thresholds for some irrigated crops unless:
  - there is adequate leaching
  - there is a supplemental source of better quality water
- Soils may not become excessively saline from use of saline water in a single irrigation season.
- Leaching salts from the root zone is essential in controlling soil salinity.

Is there adequate leaching of salts beyond the root zone?

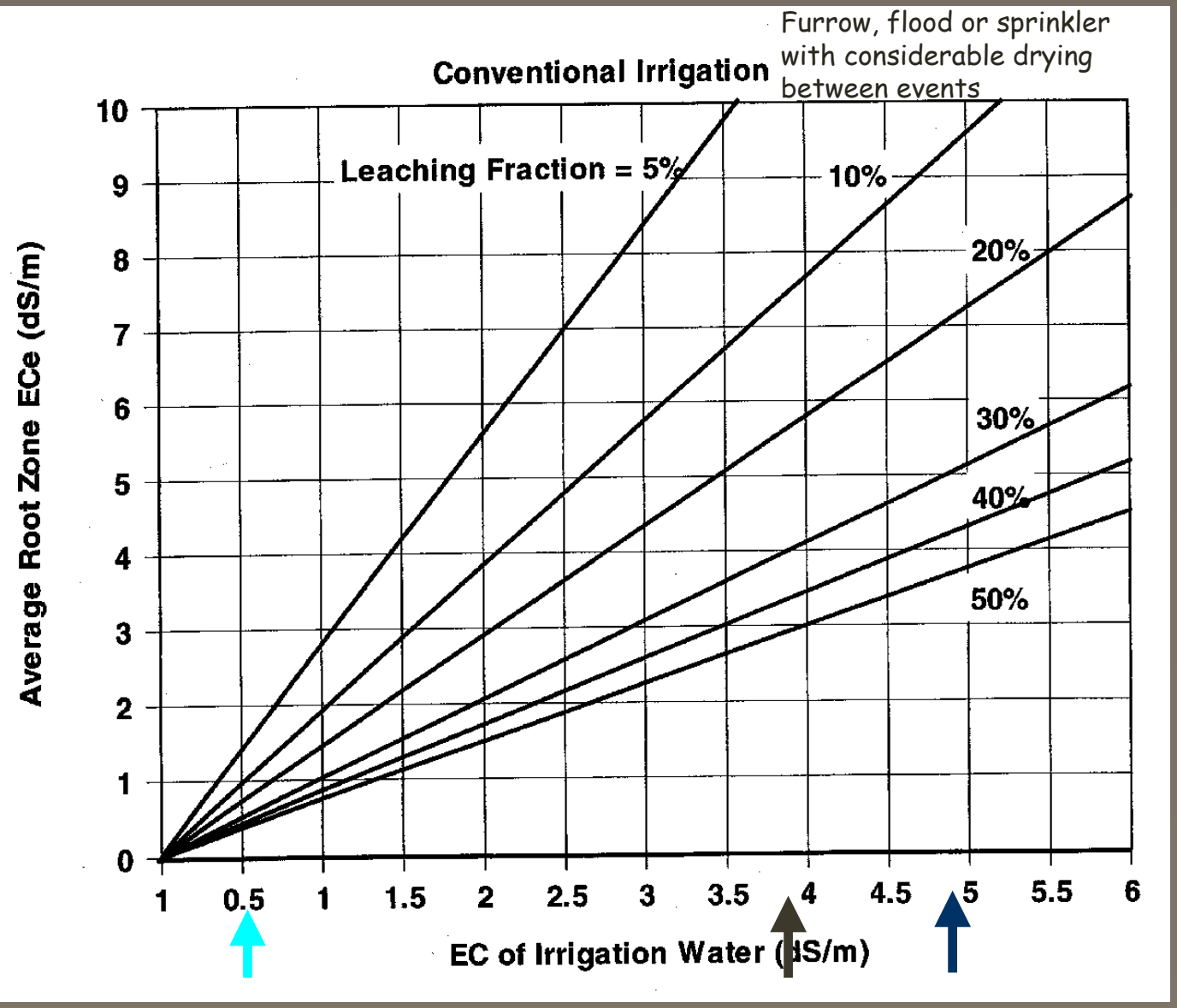
- The net downward movement of water and salt controls salt accumulation in the root zone.
  - The higher the irrigation water salinity, the higher the leaching requirement to keep root zone salinity below toxic levels to crops.
- Crop water uptake distribution is 40:30:20:10% for each quarter of the root zone.

Saline:
- Irrigation water
  - EC = 4.8 dS/m
  - SAR = 4.2
- Soil
  - EC = 3.8 dS/m
  - SAR = 2.6
- Sandy loam, low lime
- Continuous Corn
- Sprinkler

Sodic:
- Irrigation water
  - EC = 0.5 dS/m
  - SAR = 3.7
- Soil
  - EC = 3.5 dS/m
  - SAR = 20.5
- Clay loam, low lime
- forage, furrow

Saline Sodic:
- Irrigation Water
  - EC = 3.7 dS/m
  - SAR = 0.4
- Soil
  - EC = 4.2 dS/m
  - SAR = 18.2
- Sandy clay loam
- High lime
- Corn, beets, barley
- Furrow

Figure 1. Assessing the maintenance leaching fraction under conventional irrigation methods.



Source: Agricultural Salinity and Drainage, by Hanson, Grattan, and Fulton

Additional Guidance about Leaching

Oster (1994) and Shalhevet (1991) conclude that leaching may not be necessary until soil salinity reaches levels hazardous to crops.

Since the rate of salt accumulation in the soil depends on the amount of saline water applied, water applied should not exceed the water requirement of the crop.

In cases where the sodicity of irrigation water is a hazard to soil infiltration, hydraulic conductivity and tilth, more frequent leaching may be necessary to maintain soil-physical properties.

- The only way to be certain adequate leaching is being done is to periodically test the soil.

Does irrigation water quality threaten soil permeability and tilth?

- Sodic irrigation water causes soil crusting and impairs soil hydraulic conductivity - affecting water availability and aeration, important to crop growth and yield.

  Upon wetting soils with swelling clay, sodium causes the degree of swelling in the clay to increase, causing dispersion and migration of clay particles.

  Oster (personal com.) observed crusting, poor soil tilth, hardsetting and aggregate failure on a sandy loam soil irrigated with water EC ~ 1, SAR ~ 7.

  Minhaus (1994) saw irreversible and severe reduction in infiltration on sandy loam soil with long term irrigation under high SAR water followed by monsoon rain.

REDUCED HYDRAULIC CONDUCTIVITY -Shainberg and Letey, 1984

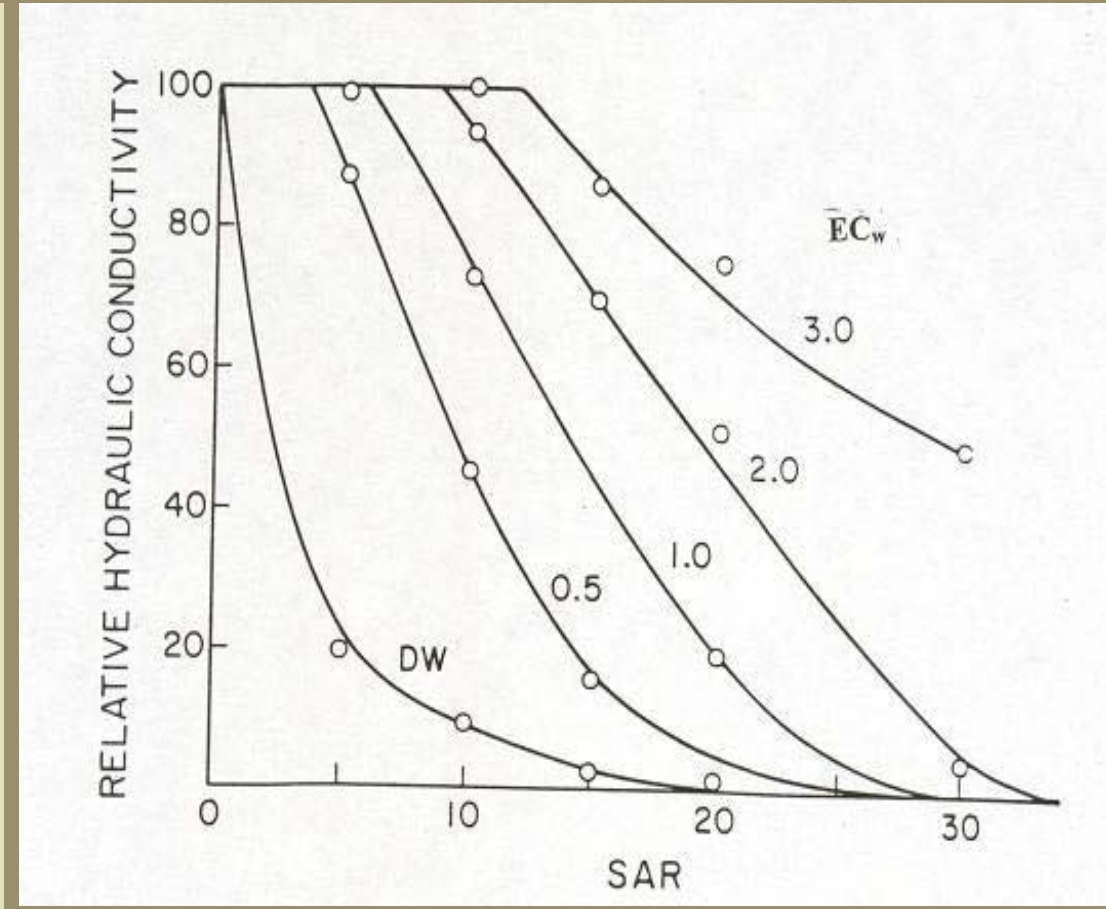
- The hazard of irrigation water sodium on soil hydraulic conductivity *must* be determined from the SAR/EC interaction.

- To minimize problems with hydraulic conductivity:

  Enough calcium must be on the cation exchange complex relative to sodium.

  OR

  Salinity must be high enough to maintain flocculation and aggregation (inhibits swelling and subsequent migration of clay).



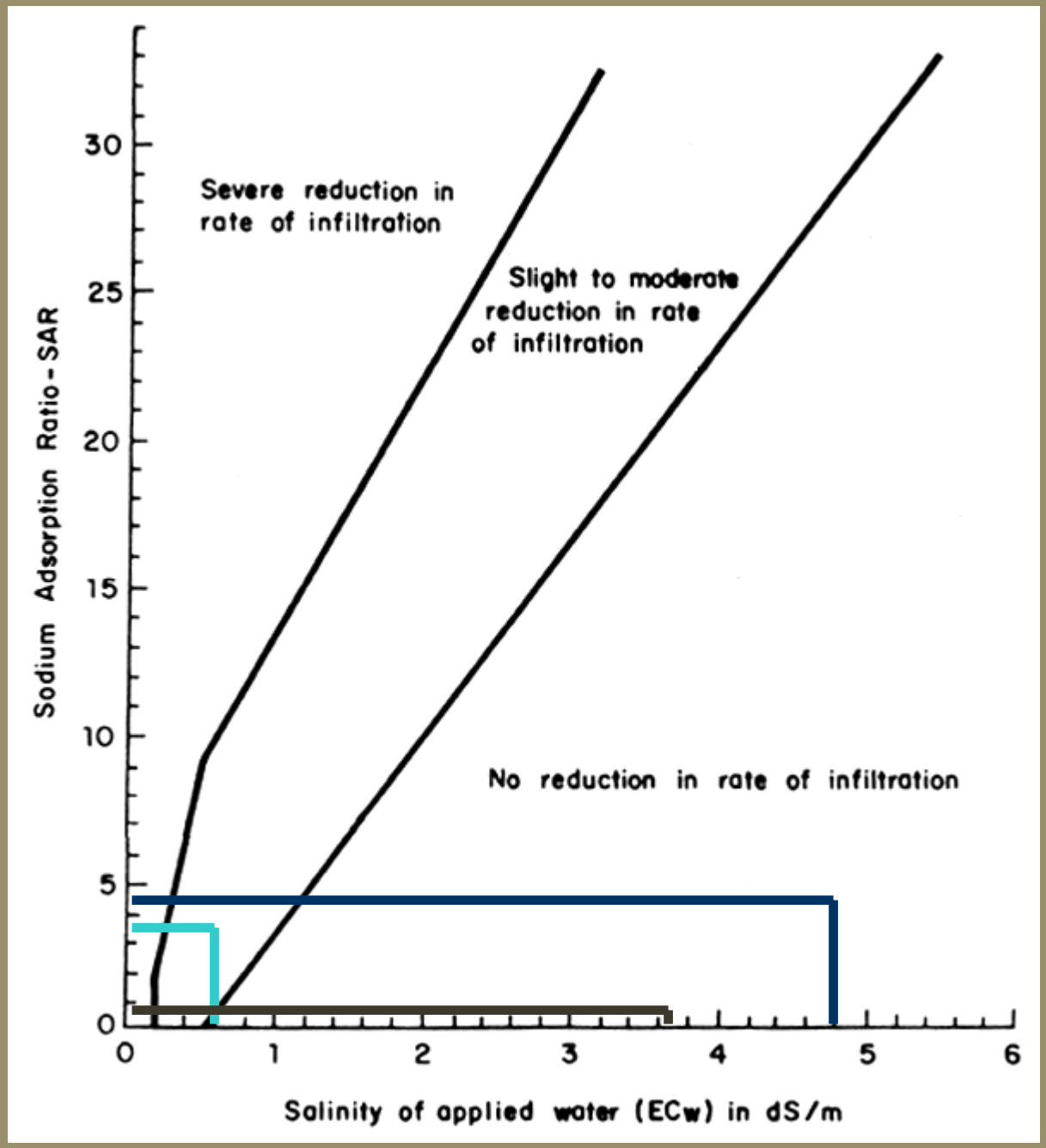
The hazard of irrigation water sodium on soil infiltration *must* be determined from the SAR/EC interaction.

Rainfall or irrigation with non-saline water on soils previously irrigated with saline sodic water can increase the sodium hazard.

Saline:
Irrigation water
EC = 4.8 dS/m SAR = 4.2
Soil
EC = 3.8 dS/m SAR = 2.6

Sodic:
Irrigation water
EC = 0.5 dS/m SAR = 3.7
Soil
EC = 3.5 dS/m SAR = 20.5

Saline Sodic:
Irrigation Water
EC = 3.7 dS/m SAR = 0.4
Soil
EC = 4.2 dS/m SAR = 18.2



Ayers & Wescot, 1985

Using soil type for recommendations using EC/ SAR Relationship

Recent publications provide variations of the Ayers and Wescot diagram giving EC and SAR guidelines for infiltration rates based on soil texture. These are guidelines only and other circumstances have been observed.

- **Oster observed crusting problems, poor soil tilth, hardsetting and aggregate failure on irrigated sandy loam soils using water quality of EC = 1.0–1.5; SAR = 7.**
- **There are many factors in addition to soil texture that affect infiltration rates:**
  - Mineralogy, lime, sesquiozides, organic matter content, cultivation, irrigation method, wetting rate, antecedent water content and time since cultivation

Am I making the best with the irrigation conditions I have?
Water Quality Variability

- The only way to be certain of the impacts of saline irrigation water on the soil is to periodically sample and test the irrigation water and the soil.

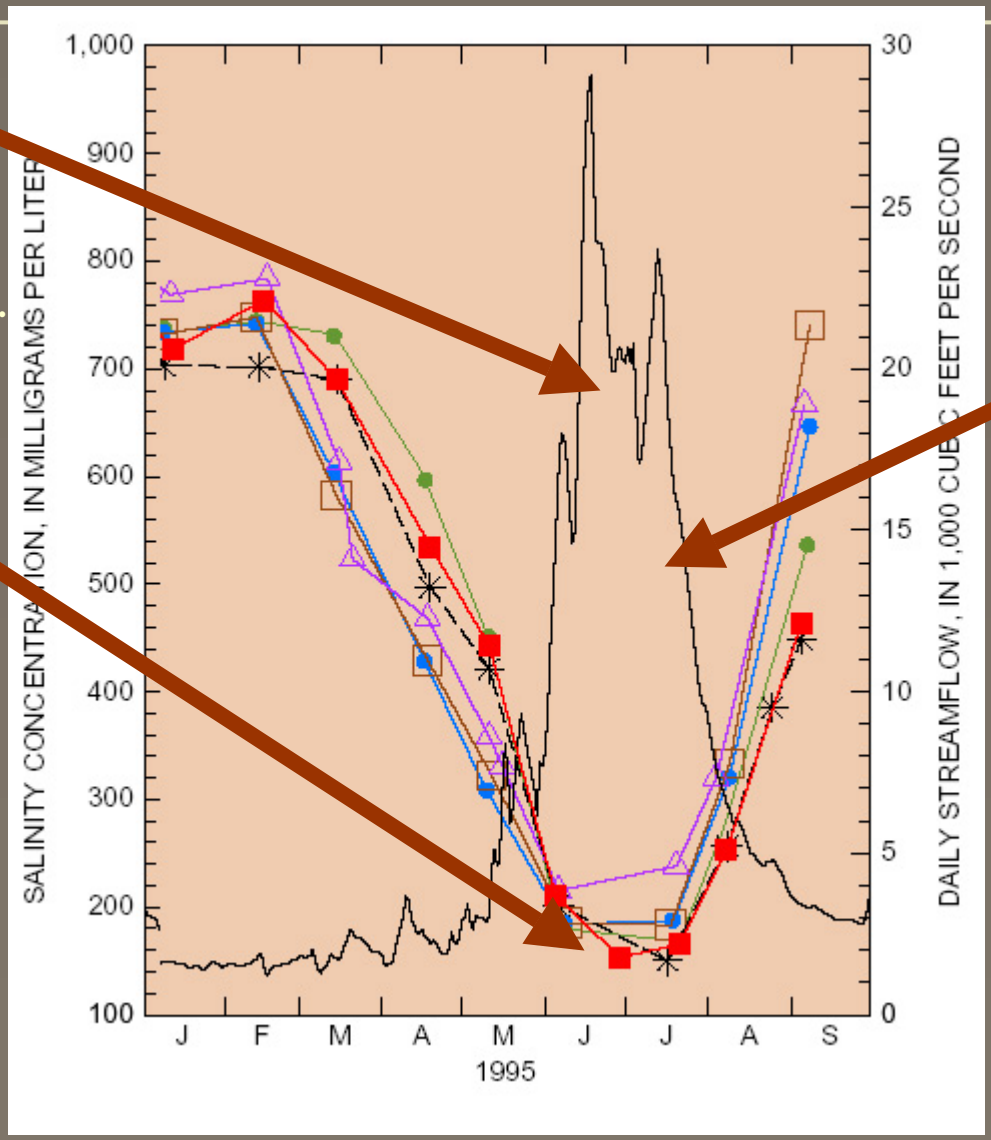
- Groundwater quality can change with time and surface water quality changes seasonally; surface water tends to become more saline as stream flow declines.
  - The amount of water flowing in the stream is influenced by:
    - Geographic location
    - Climatic conditions
    - Time of year
    - Degree of human influence
  - Stream discharge may dictate when is the best time to irrigate.

Making the best with the irrigation conditions I have:

salinity and stream discharge

Sediment load usually heaviest during snowmelt runoff (high flow).

Salinity and SAR decreases dramatically with dilution from snowmelt runoff.



Sediment load, salinity, and SAR tend to be lowest after the river level has risen to its maximum and is now falling.

Colorado River in the Grand Valley, Western CO.

U.S.G.S. Data taken monthly at 6 sites along the river.

Making the best with the irrigation conditions I have:

Irrigation Frequency

- Because salinity affects available water in the root zone, it would seem one should irrigate more frequently to increase the available soil moisture.

  Studies show beyond threshold soil salinity levels, crop transpiration decreases due to increasing osmotic stress which results in:

  - less crop water use
  - no advantage to adding more water each irrigation event
  - less moisture depletion in the soil between irrigation events
  - no advantage to higher irrigation frequency; in fact some research proves the contrary
    - i.e. risk of leaf injury is higher under sprinkler irrigation the more frequent the irrigation and the higher the temperature.

Additional Guidance about Irrigation Frequency

- Shani & Dudley (2001) looked at yield response of melon, corn, and alfalfa under simultaneously imposed drought and salt stress.

  Under salinity conditions ranging over an order of magnitude (EC 1.2 – 9), there was no significant difference in crop yield when irrigation was below that which produced maximum yield.

  Salt tolerance increased as irrigation water became more limited. Therefore, the use of poor quality water during drought may not be an additional concern for yield loss.

Making the best with the irrigation conditions I have: Irrigation Frequency

Source: Agricultural Salinity and Drainage, by Hanson, Grattan, and Fulton

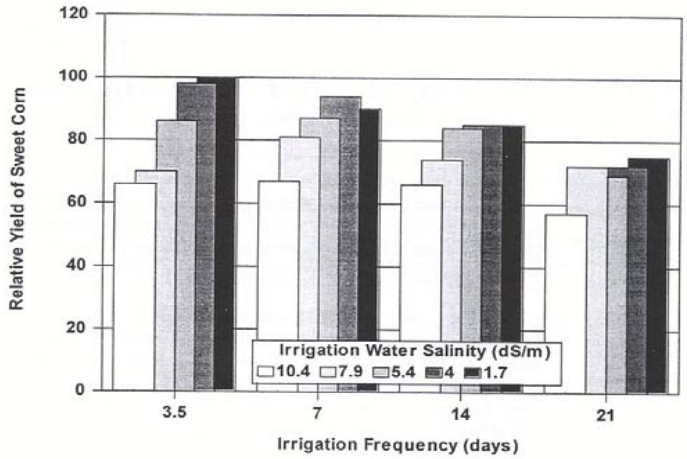


Figure 1. Relationship between relative yield, irrigation frequency, and irrigation water salinity on sweet corn.

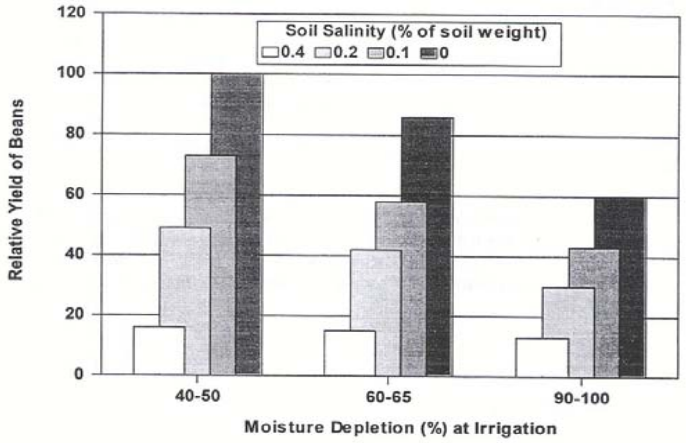


Figure 2. Relationship between relative yield, irrigation frequency, and irrigation water salinity on dry beans.

Am I growing crops which are tolerant to the salt levels in my soil and irrigation water?

There are 2 key issues with crop tolerance to salinity:

Response to osmotic potential created by salt levels in soil

Physiological response

- Examples:
- Legume nodulation
- Foliar injury

- Choosing the appropriate crop is based on salt tolerance of the crop and irrigation water salinity

Relative Salt Tolerance of Various Crops

Intercept:

Crop threshold salinity level

Slope:

The severity of % loss in yield with each unit increase in salinity

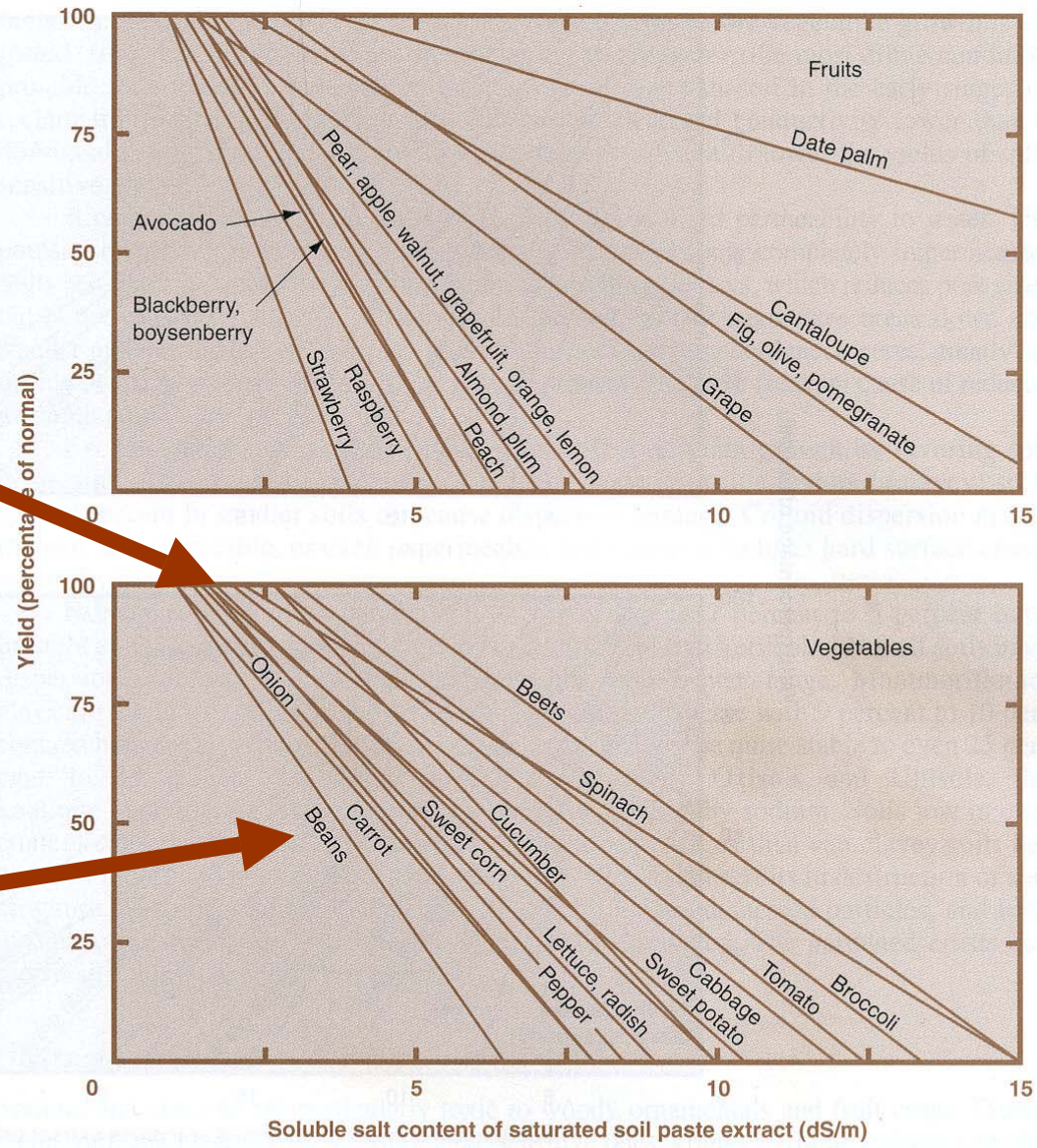


FIGURE 9-3 Yield reduction of fruit and vegetable crops by soluble salts in soils. Notice that this salt scale is expanded more than that of Figure 9-4. (*Source:* Drawn from data in *Soil Survey Investigations for Irrigation,* FAO Soils Bulletin 42, Food and Agriculture Organization of the United Nations, Rome, 1979, 72–74. Courtesy of Raymond W. Miller.)

FAO Soils Bulletin 42

Relative Salt Tolerance of Various Crops at Emergence and During Growth to Maturity (FAO irrigation and drainage paper 48)

These data serve only as guidelines to relative tolerances among crops. Absolute tolerances vary, depending upon:

- climatic and soil conditions
- agronomic management
- irrigation management
- crop variety
- stage of growth

Saline:
Soil
EC = 3.8 dS/m SAR = 2.6
Sandy loam, low lime
Continuous Corn Sprinkler

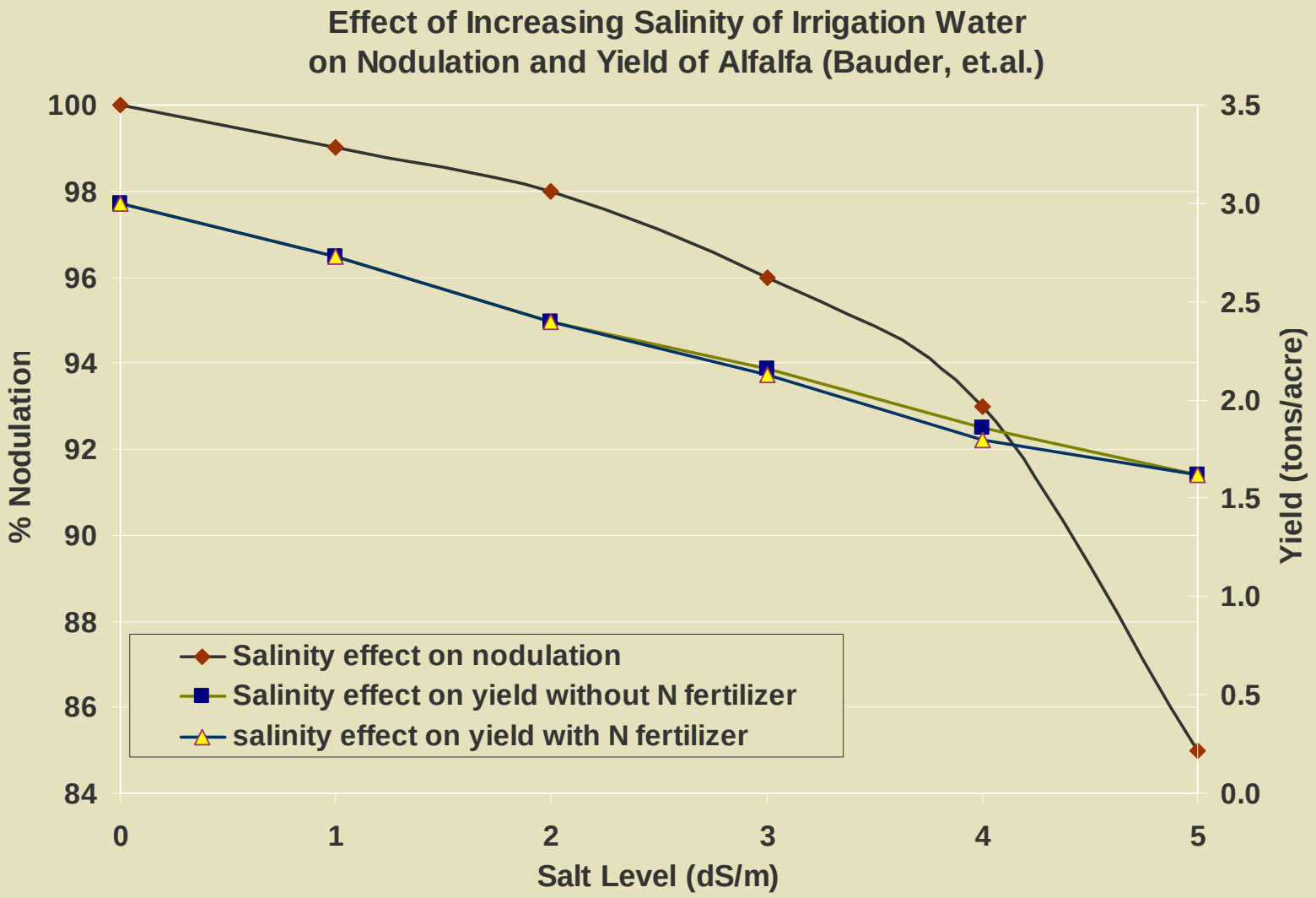
Sodic:
Soil
EC = 3.5 dS/m SAR = 20.5
Clay loam, low lime
forage, furrow

Saline Sodic:
Soil
EC = 4.2 dS/m SAR = 18.2
Sandy clay loam High lime
Corn, beets, barley Furrow

	Electrical conductivity of saturated soil extract dS/m		
Common Name	Threshold	50% yield	50% emerge[2]
Barley	8.0	18	16-24
Cotton	7.7	17	15
Sugarbeet	7.0	15	6-12
Sorghum	6.8	15	13
Safflower		14	12
Wheat	6.0	13	14-16
Beet, red	4.0	9.6	13.8
Cowpea	4.9	9.1	16
Alfalfa	2.0	8.9	8-13
Tomato	2.5	7.6	7.6
Cabbage	1.8	7	13
Maize	1.7	5.9	21-24
Lettuce	1.3	5.2	11
Onion	1.2	4.3	5.6-7.5
Rice		3.6	18
Bean	1.0	3.6	8

[2] Emergence percentage of saline treatments determined when non-saline treatments attained maximum emergence.

How does saline water affect alfalfa growth?



Susceptibility ranges for selected crops to foliar injury from saline sprinkler water

	--------Na or Cl concentration (mg/L) causing foliar injury----------			
	Apricot Plum Tomato	Pepper Potato Corn	Alfalfa Barley Sorghum	Sugar beet Sunflower
Na concentration	<46	46-230	231-460	>460
Cl concentration	<175	175-350	351-700	>700

Foliar injury is influenced by cultural and environmental conditions. These data are presented only as general guidelines for daytime irrigation.
Source: Mass (1990) Crop salt tolerance. In: Agricultural Assessment and Management Manual. K.K. Tanji (ed.). ASCE, New York. pp. 262-304.

Summary

- **What is cause of my salinity problem?**
  Saline soils, poor drainage, saline irrigation water

- **Is there adequate leaching of salts beyond the root zone?**
  Soils may not become excessively saline from use of saline water in a single irrigation season.

  Leaching may not be necessary until soil salinity reaches levels hazardous to crops.

- **Does irrigation water quality threaten soil permeability and tilth?**
  The hazard of irrigation water sodium on soil infiltration and hydraulic conductivity *must* be determined from the SAR/EC interaction.

- **Am I making the best of the irrigation conditions I have?**
  Periodically sample and test the irrigation water and the soil.

  Surface water tends to become more saline as stream flow declines.

- **Am I growing crops which are tolerant to the salt levels in my soil and irrigation water?**
  Choosing the appropriate crop is based on salt tolerance of the crop and irrigation water salinity

- **Are there other methods to correct/prevent the problem?**