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COOPERATIVE EXTENSION

Salinity, Sodicity, & Water Management in Desert Crop Production Systems

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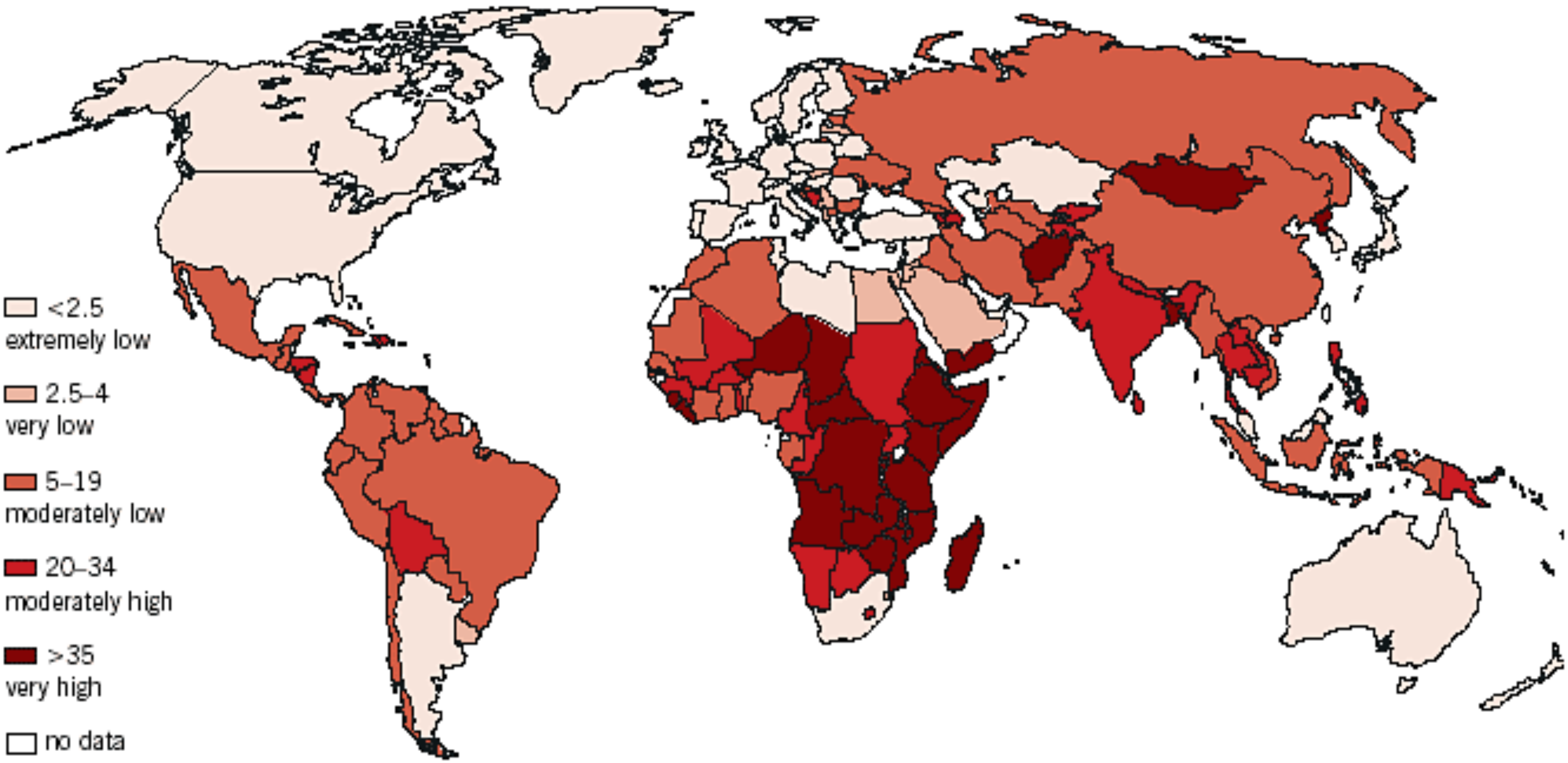
BLUF
(bottom line up front)

- Salinity is a common problem in arid land agriculture for many centuries.
- Sustainable management in arid lands dependent upon:
  - Water quality
  - Soil type
  - Crops being grown
  - Management
- Irrigated crop systems require extra water for leaching above crop growth requirements.

World Hunger



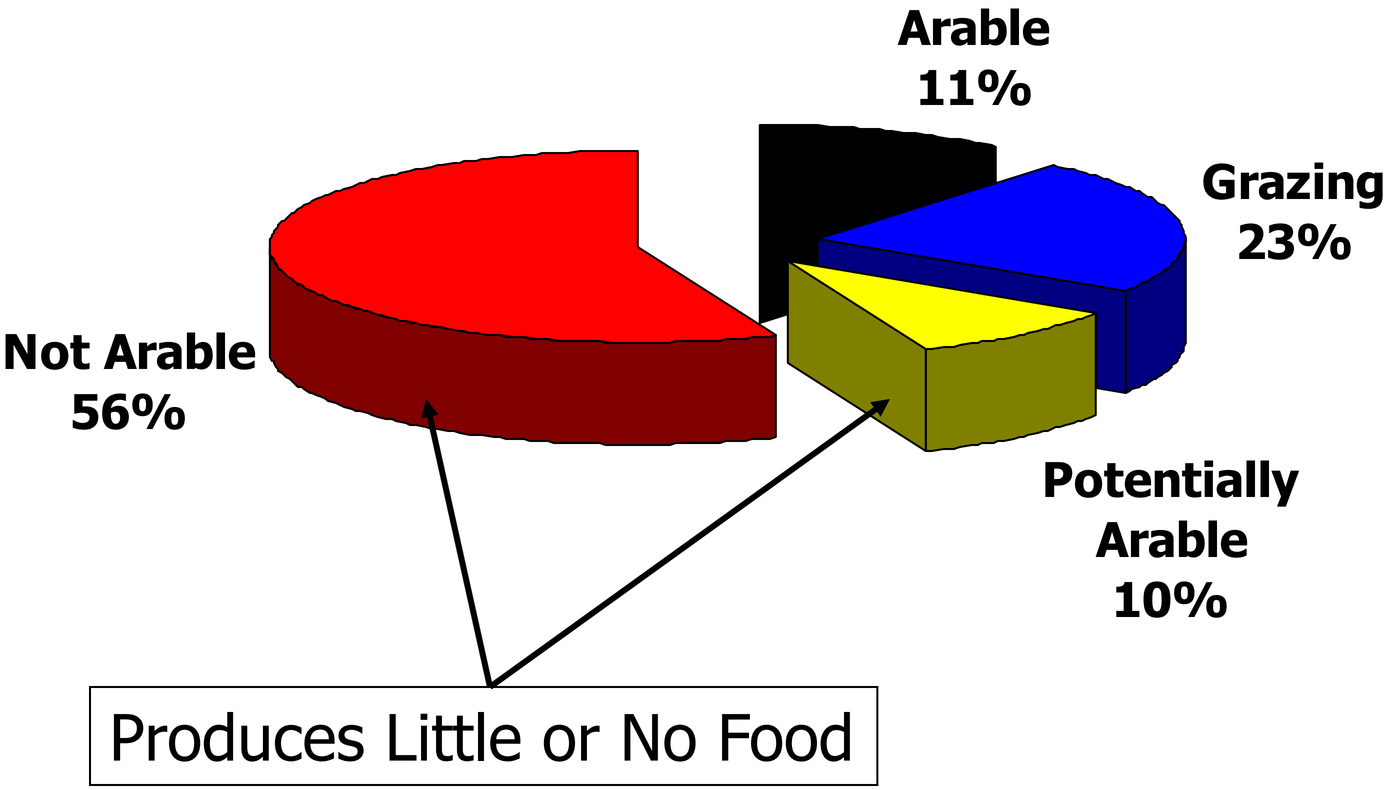
Challenges

Earth resources are finite (land, water,…)

- **~32.5 B acres of land on earth (total)**
- ~1/2 of total land area is completely non-arable (16.25 B acres)
- ~1/4 of total land area is “potentially” arable

  (~8.1 B acres)
  - most potentially arable land is currently under cultivation (>5.0 B acres)
  - remaining land (potentially arable) is extremely marginal in nature
  - focus for development in recent years

World Land Use



Challenges

Earth resources are finite (land, water,…)

- **Arable land covers less than 10%** of the world's surface
  - **Most productive arable land ~ 3% of world's surface**
  - continually being converted into urban areas.
    - One hectare of productive land is estimated to be lost every 7.67 seconds.
- With current global trends in diets and population, 60% more food will be needed in 2050.

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Land Resources - Losses

- Urbanization
  - >6,000 acres/year in Arizona
- Soil salinization
  - >6 M ha (14 M acres) of land lost each year due to drainage and salinization problems
  - Important aspect of soil mgt. in desert SW
- Soil erosion
  - Worldwide problem – soil degradation
  - Major issue in many parts of China
- Deforestation impacts
  - South America (Brazil)

Dry Regions

~ 50% of global land is classified as arid or semi-arid

~ 40% of global population

~ 40-45% global food production

~ 65% of global grain production

~ 70% of global fresh water supplies used by agriculture

- increasing competition between ag. and domestic water use.

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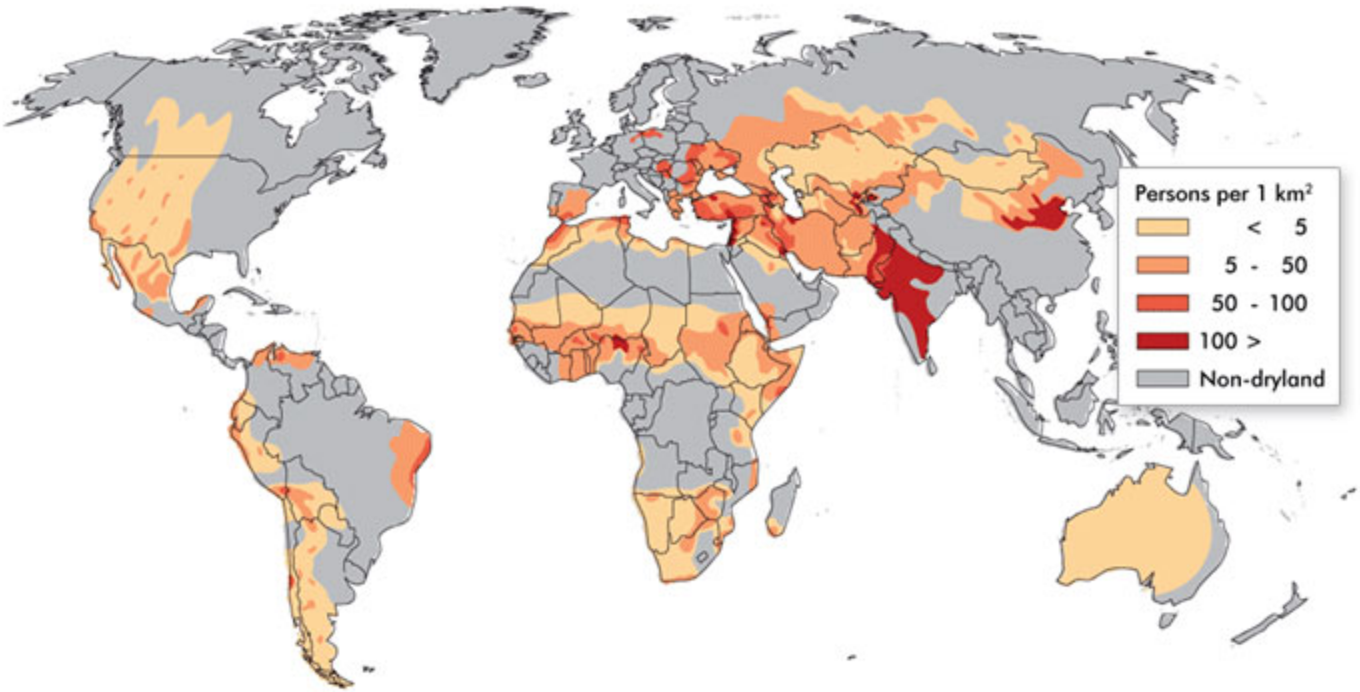
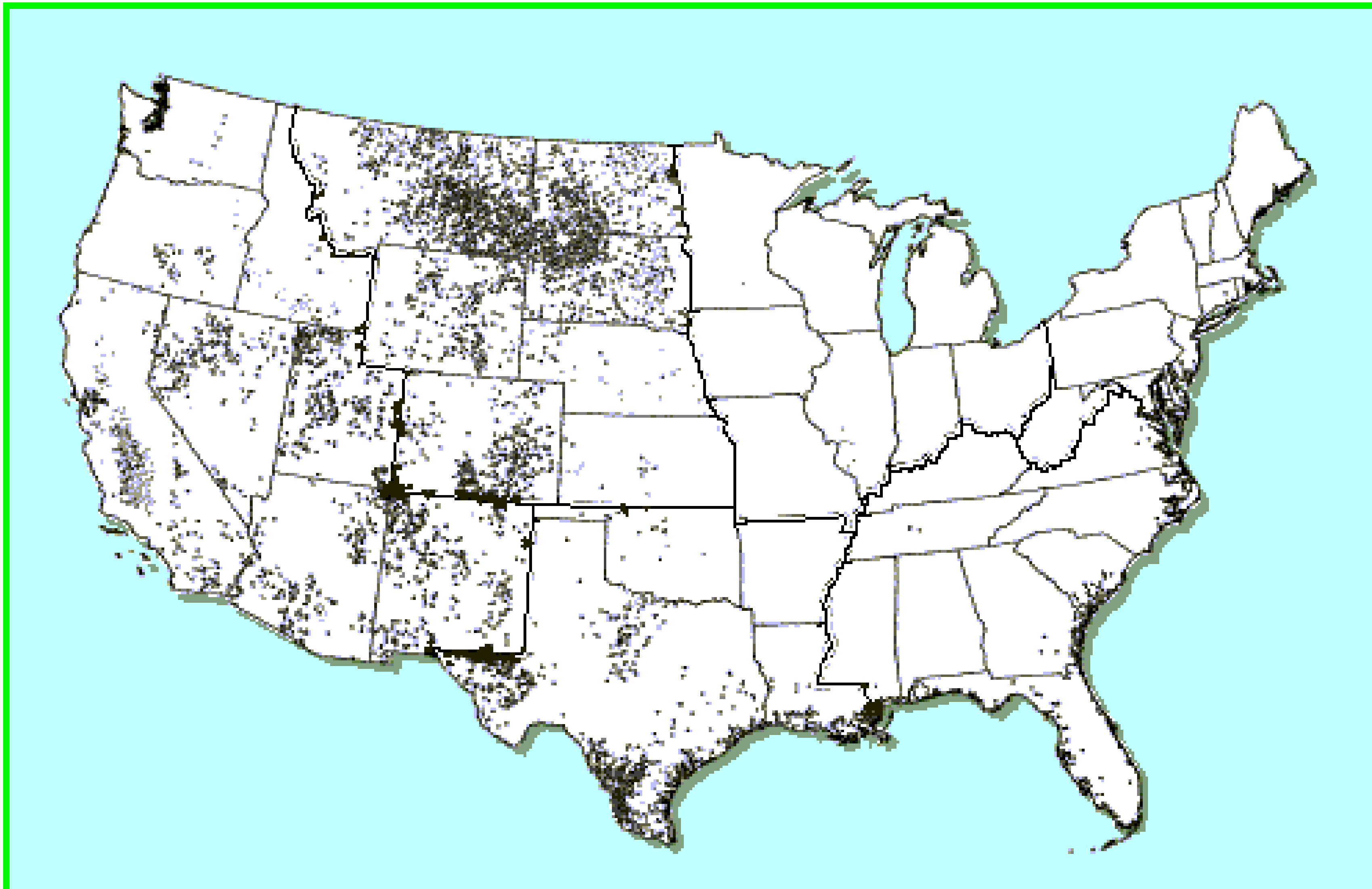
Population Density in Drylands



- >50% of the world's land mass
- nearly 40% of the human population
- relatively understudied systems

Population density in drylands of the World,
http://maps.grida.no/go/graphic/population-density-in-drylands-of-the-world



Distribution of salt-affected soils in the U.S.

Brady and Weil

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Limiting Factors
Terrestrial Ecosystems

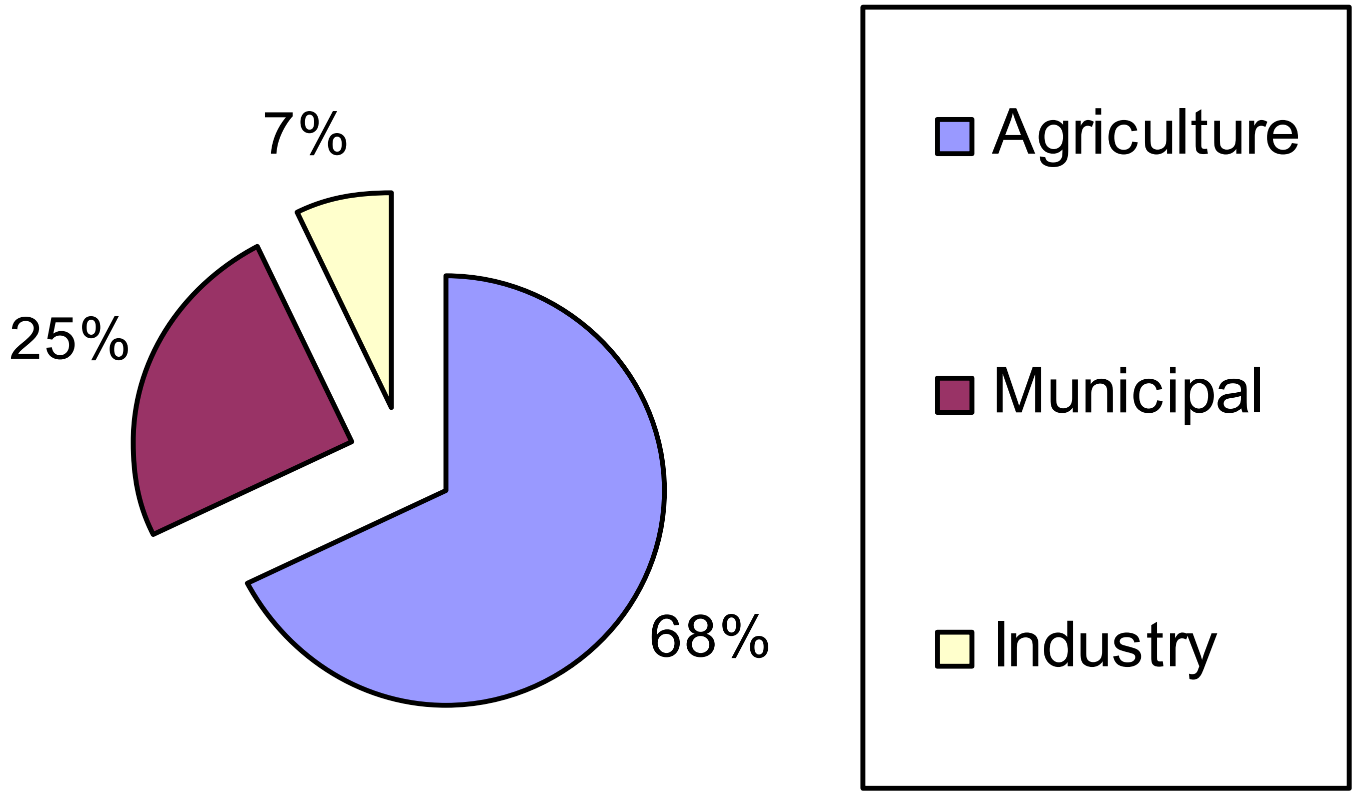
1. Sunlight
2. Water
3. Bio-Available Nitrogen

Global Freshwater Use

70% - Agriculture

- supports 40% of total crop production
- approximately 65% of global grain production
- supports ~ 40-45% of global population
- mostly in arid and semi-arid regions

Arizona Water Allocations



The Bottleneck (E.O. Wilson, Harvard University)

1. Maximum human population levels
2. Maximum demand on natural resources
3. Maximum demand on human ingenuity to overcome these challenges

The need/demand for research, technology development, transfer, and education is **HUGE**.

General Overview (cont.)

- Soils in these regions have played a unique role in history
  - rise and fall of several ancient civilizations tied to irrigation and subsequent mismanagement
  - knowledge of previous mistakes of earlier civilizations can lead to prevention of repeating errors in management for the future

Carthage

"Carthago delenda est"

Marcus Cato

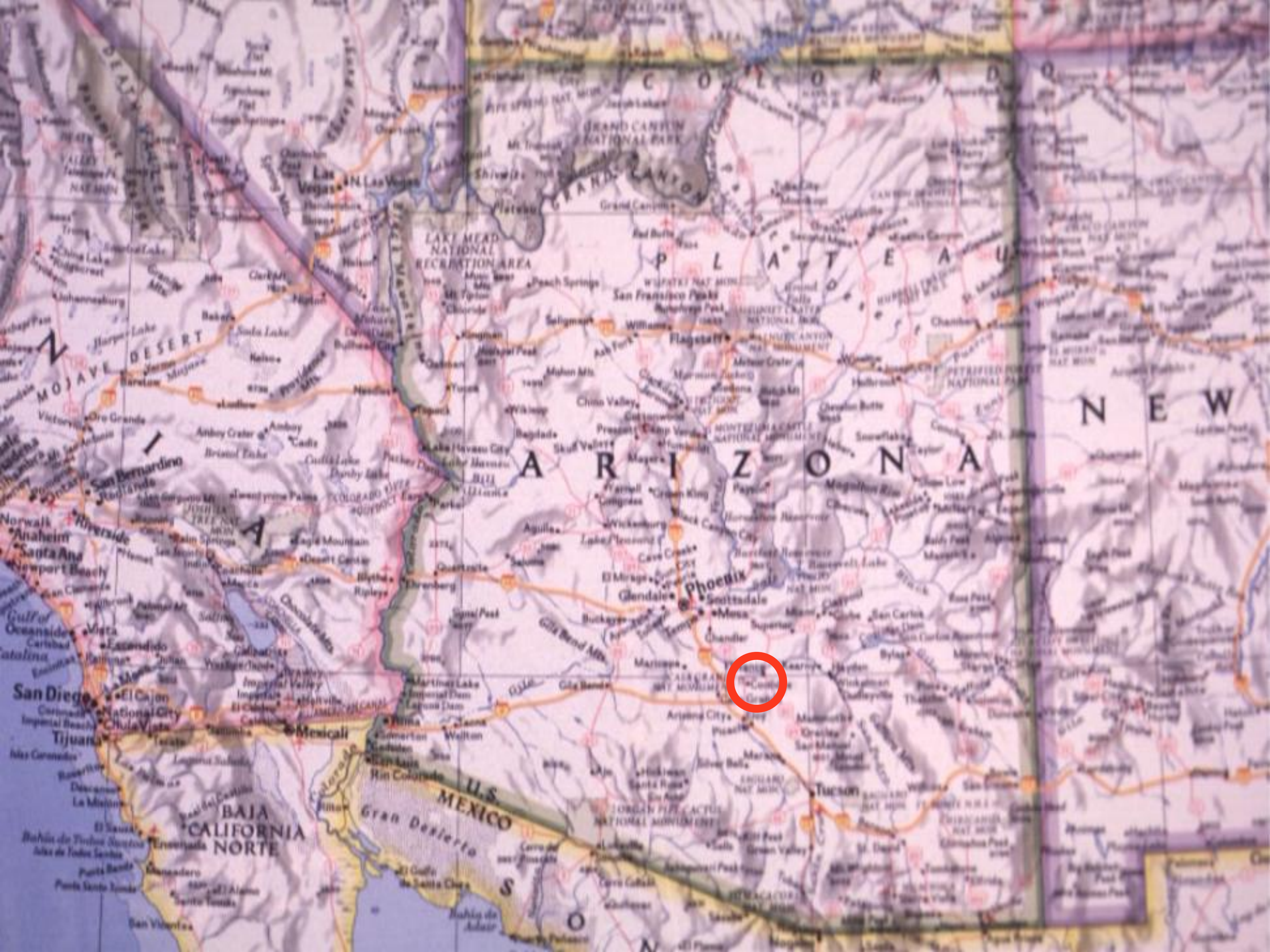
“Carthago delenda est” Marcus Cato

- “Carthage must be destroyed.”
- Carthage – Phoenician city state of N. Africa
  (present day Tunisia)
- Commercial competitors with the Romans
- Romans won the first two Punic Wars
  - The Punic Wars were a series of three wars fought between Rome and Carthage from 264 to 146 BC.

  - Romans suffered several losses and humiliations at the hand of the Carthagenians
- Romans defeated Carthage in the Third Punic War

  - survivors sold into slavery

  - fields/lands were sown with salt (legend?)


ARIZONA
NEW
PLATEAU
COLORADO
GRAND CANYON NATIONAL PARK
LAKE MEAD NATIONAL RECREATION AREA
MOJAVE DESERT
BAJA CALIFORNIA NORTE
MEXICO
U.S.
Gran Desierto
Phoenix
Scottsdale
Mesa
Chandler
Glendale
Tucson
Flagstaff
Williams
Kingman
Las Vegas
San Bernardino
Riverside
Anaheim
Santa Ana
Newport Beach
Oceanside
San Diego
El Cajon
National City
Chula Vista
Tijuana
Mexicali
Yuma
Gila Bend
Casa Grande
Coolidge
Florence
Payson
Sedona
Holbrook
Winslow
Wickenburg
Lake Havasu City
Blythe
Barstow
Needles
ORGAN PIPE CACTUS NATIONAL MONUMENT
PETRIFIED FOREST NATIONAL PARK
Tecate
Ensenada

Origin of Salt-Affected Soils

- Natural:
  - Poor soil drainage
  - High water table
  - Closed basin (no outlet for salts)
  - Arid climate (limited weathering and leaching of salts)
  - Coastal margins (salt spray)

Saline Soils (definitions)

- EC_e > 4 dS/m (saline conditions)
- ESP < 15
- $SAR_e \leq 13$

- crop growth can be adversely affected by excesses of both salt and Na

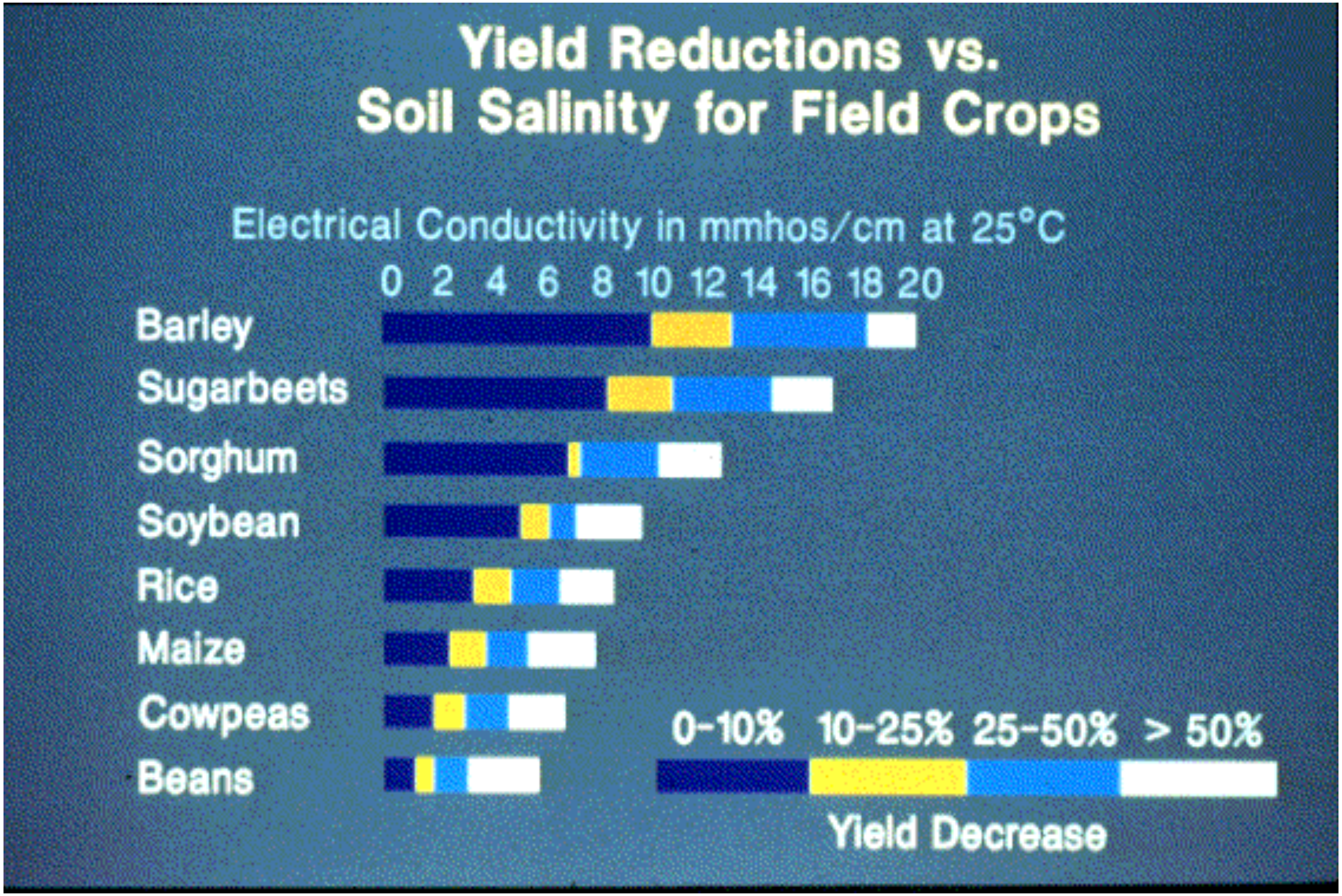
Salt-Affected Soils

Saline - excess salts
good structure
moderate pH

Saline-sodic
excess salts
excess Na
good structure
high pH

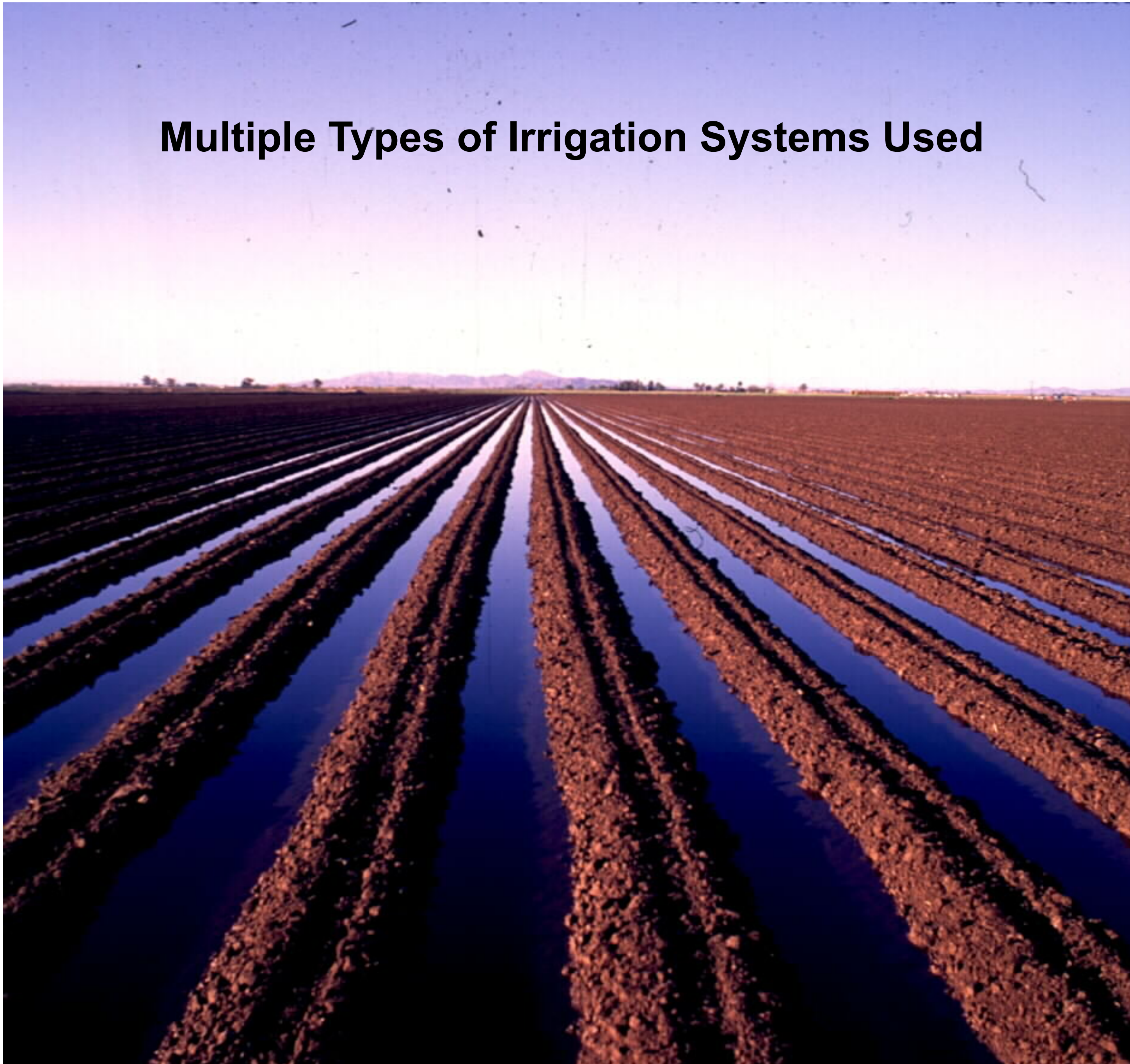
Sodic - excess Na
poor structure
high pH (>8.5)

Plant Salinity Tolerance




Arid Regions
- Water is Limiting and a Finite Resource -
Management is Critically Important

Multiple Types of Irrigation Systems Used



Multiple Crop Production Systems

Diagnostics in the Field

- Soil Conditions
- Water Quality
- Crop Conditions

Water Quality

- Quality of irrigation water is very important
  - can contribute significant amounts of salt
  - without proper drainage and management – soil salinity can increase to intolerable levels
  - leads to chemical and physical problems

"Successful irrigation schemes in arid regions carry seeds of their own demise"

(Gardner, 1985)

Classes of Irrigation Water Quality

Classification	Electrical Conductivity EC (µmhos/cm)	Gravimetric concentration (ppm)
Excellent	250	175
Good	250-750	175-525
Permissible	750-2,000	525-1,400
Doubtful	2,000-3,000	1,400-2,100
Unsuitable	> 3,000	> 2,100

*1,000 ppm ~ general crop management threshold

Saline Soils (cont.)

- Poor physical condition is commonly not a problem on saline soils
  - soluble salts help <u>prevent</u> dispersion
    - good aggregate stability and aeration

Crop Response to Salinity Similar to Crop-Water Stress

- Species dependent
  - Variety dependent
- Crop vigor
- Crop phenology
  - Track growth & development = f(HUAP)

Integration – System Management

- Understand crop phenology
  - Crop growth and development
- Establish growth guidelines as a function of heat unit accumulations
- Integration:
  - Crop development
  - Water use
  - Nutrient requirements

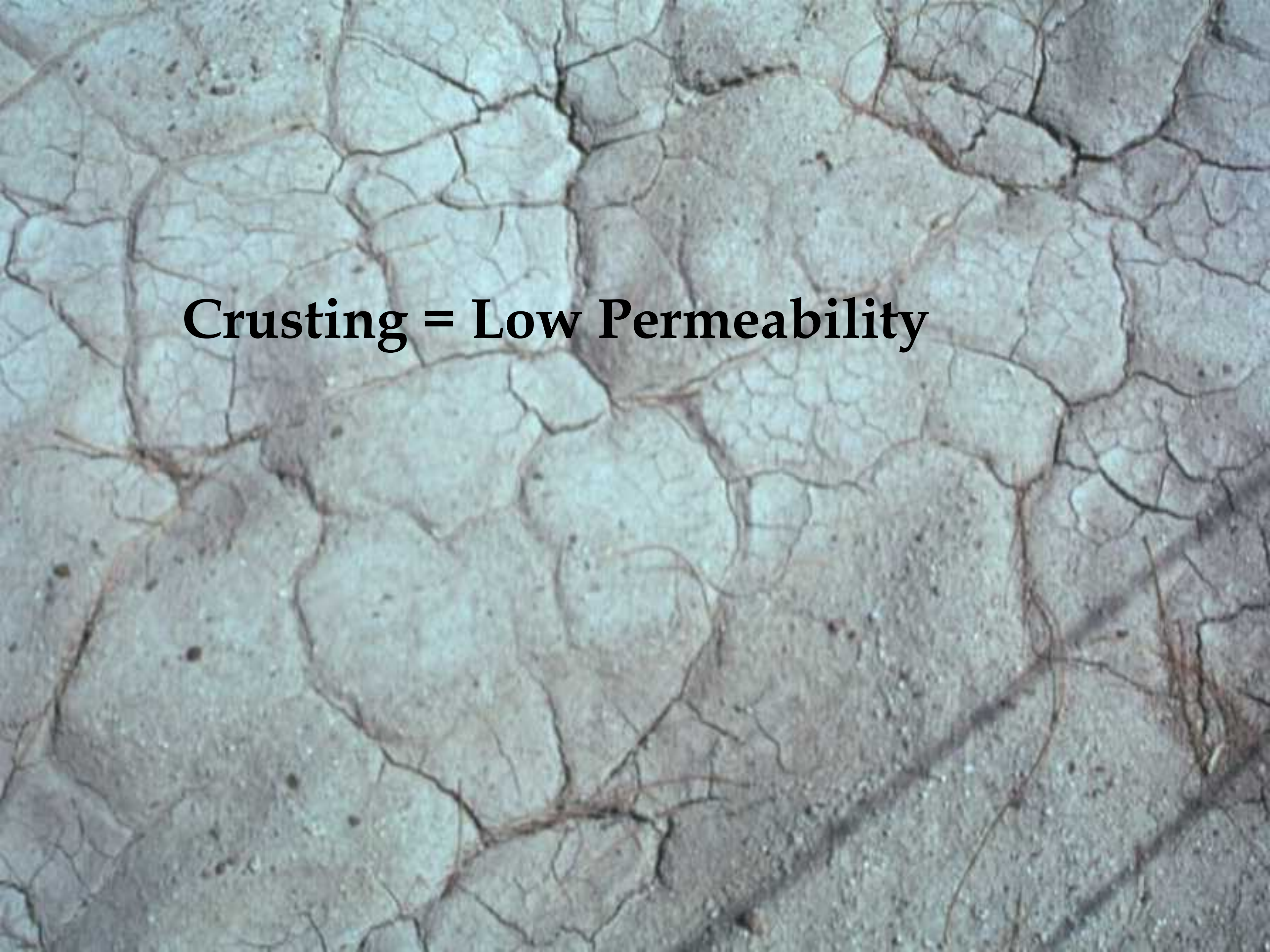
Crop System Monitoring

- Salinity problems develop slowly
- Need to monitor fields (plants, soil, water)
  - In season
  - Over time
  - Identify trends

Sodic Soils (definition)

- $EC_e \leq 4$ ds/m (non-saline)
- ESP > 15 (sodic)
- $SAR_e \geq 13$ (sodic)

- sodic soils are the most troublesome of the three basic conditions described here


Crusting = Low Permeability

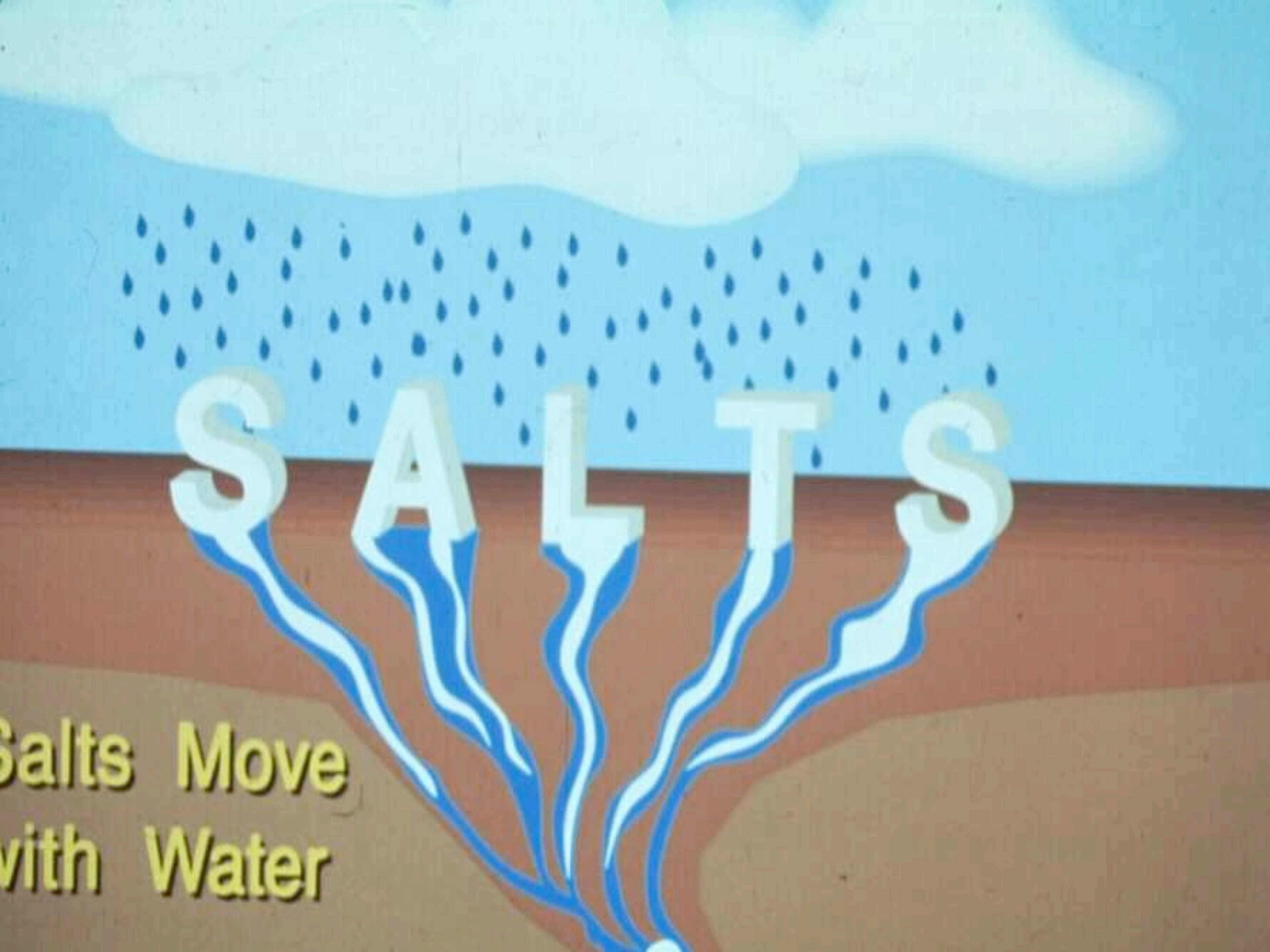
Low Water Permeability

Management of Saline and Sodic Soils - Fundamentals

- Must develop a salt balance approach
- understanding of amount and nature of mobile salts being added to and removed from soils
- must know about the quality of irrigation water
- quantity of irrigation water being applied
- soil drainage status

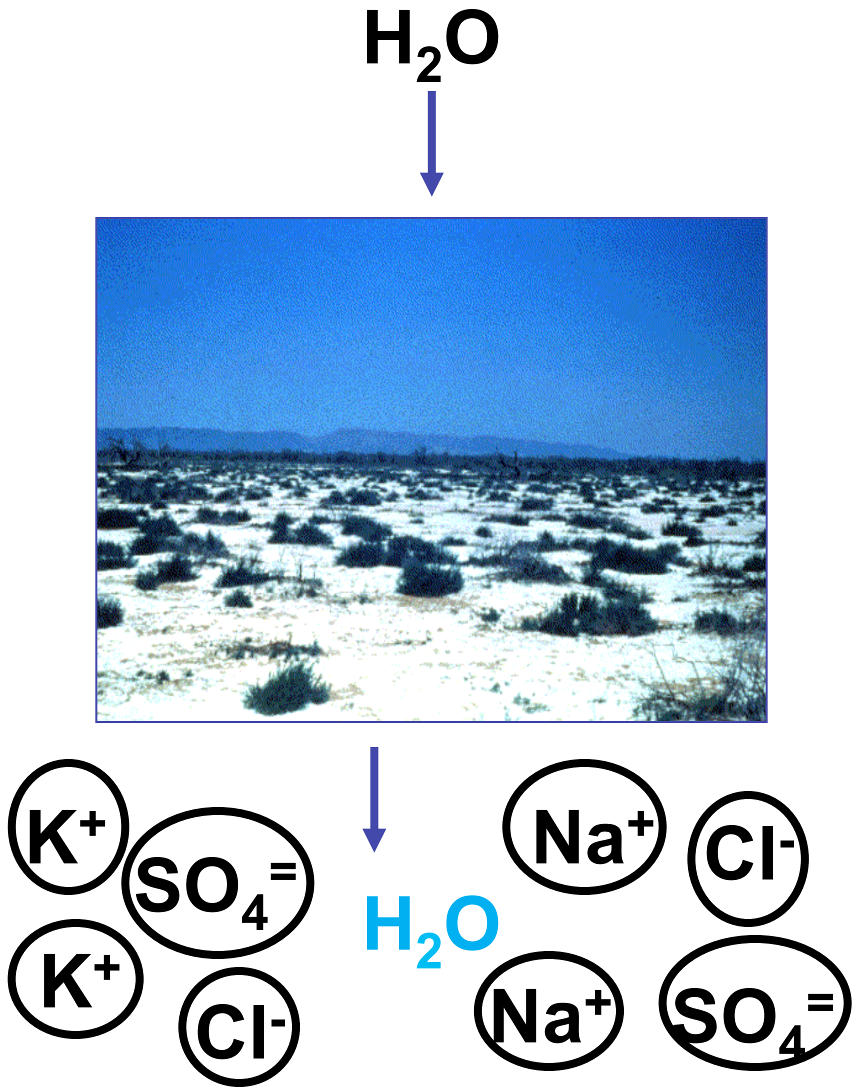
Managing Salty Irrigation

- The **only way to effectively manage salty irrigation water** is to apply extra water to prevent excessive salt buildup.
- The amount of extra water needed is called the *leaching requirement*. The leaching requirement depends on the irrigation water salinity and the tolerance of the plants to salt.


SALTS
Salts Move
with Water


Add enough irrigation water to leach
excess salts from the root zone.

Reclamation of Saline Soils



Leaching Requirement (LR)

- Leaching Requirement - amount of water needed to remove excess salts from saline soils
  - LR depends on:
    1. characteristics (tolerance) of crops being grown
    2. irrigation water quality
    3. soil characteristics

Leaching Requirement

- LR relationship is based upon the assumptions that a salt balance exists
  - Plants have specific salinity tolerance limits
  - Soil salinity develops in equilibrium to the salinity of the irrigation water and the total volume applied.

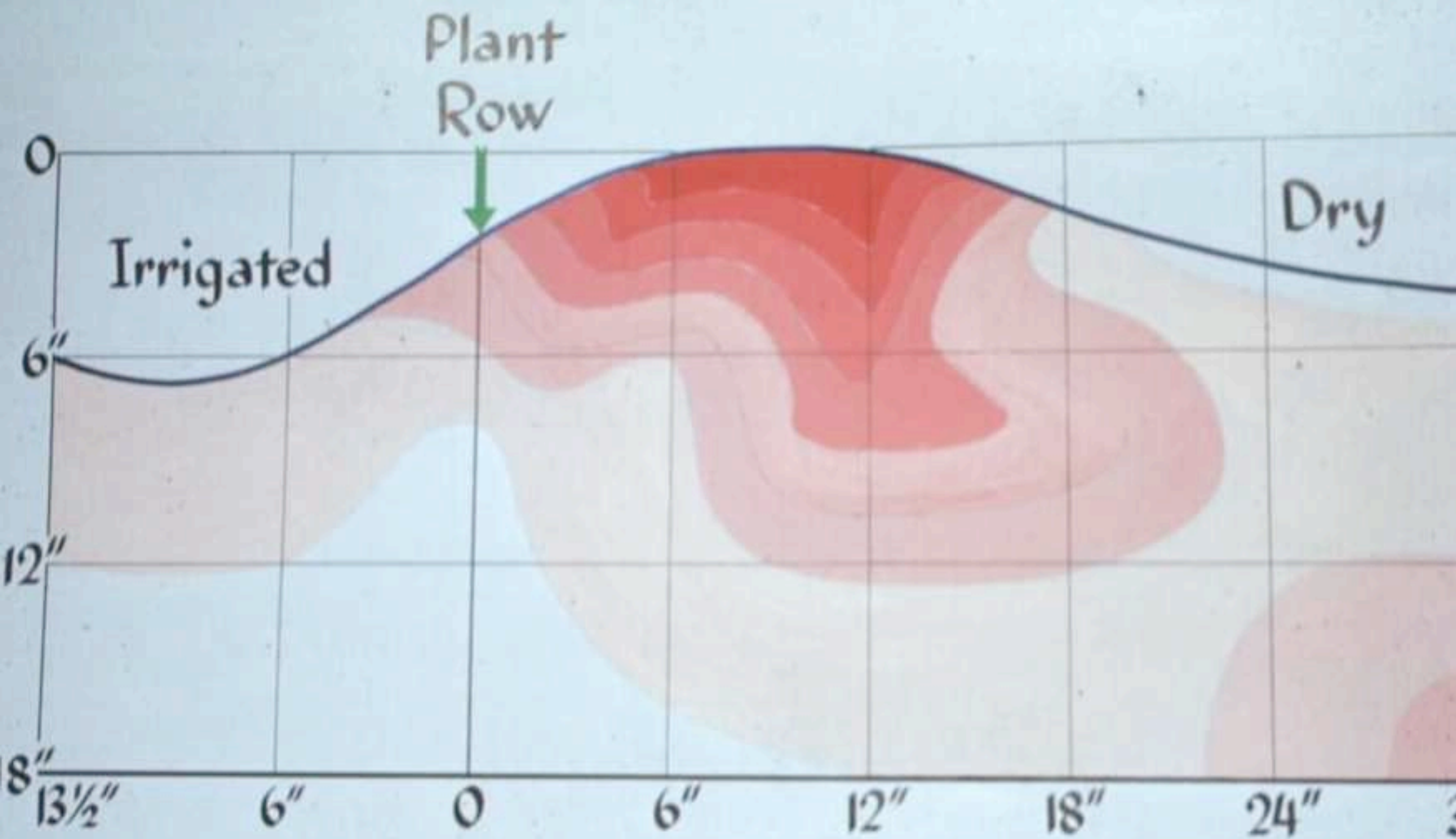
$$LR = \frac{EC_w}{5(EC_e) - EC_w}$$

Leaching Requirement

- **LR (0.45)** is multiplied by the amount of water needed to thoroughly wet the soil profile, or bring it to field capacity (FC).
  - Example - **8 cm of water (3.1 inches**) needed
  - **8cm * 0.45 = 3.6 cm water**
  - 3.6 cm of additional water would be needed to satisfy the leaching requirement
  - **8.0 cm + 3.6 cm = 11.6 cm water total**

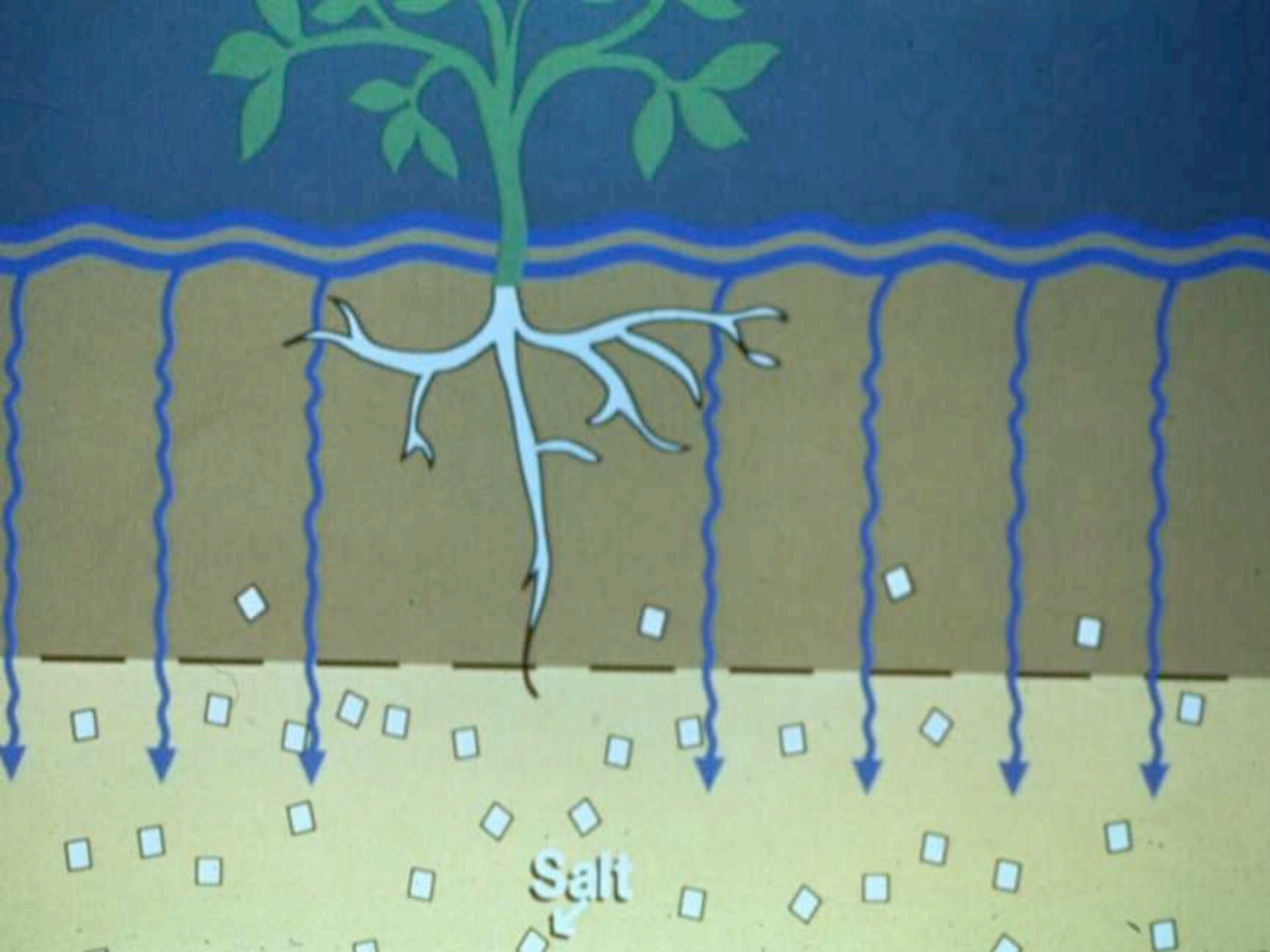
    (4.6 inches)
    - assume good uniformity in irrigation delivery
    - uniformity in soil conditions

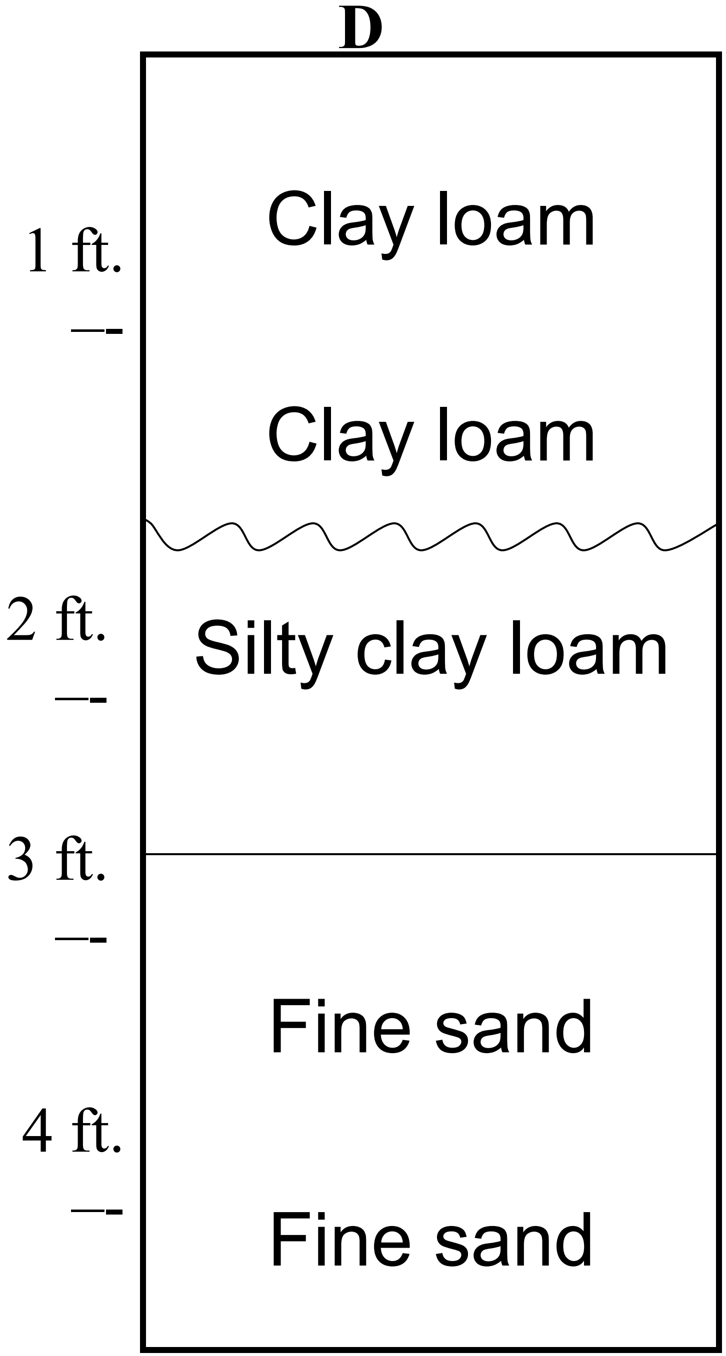
Irrigation Systems Designed for Salinity Management

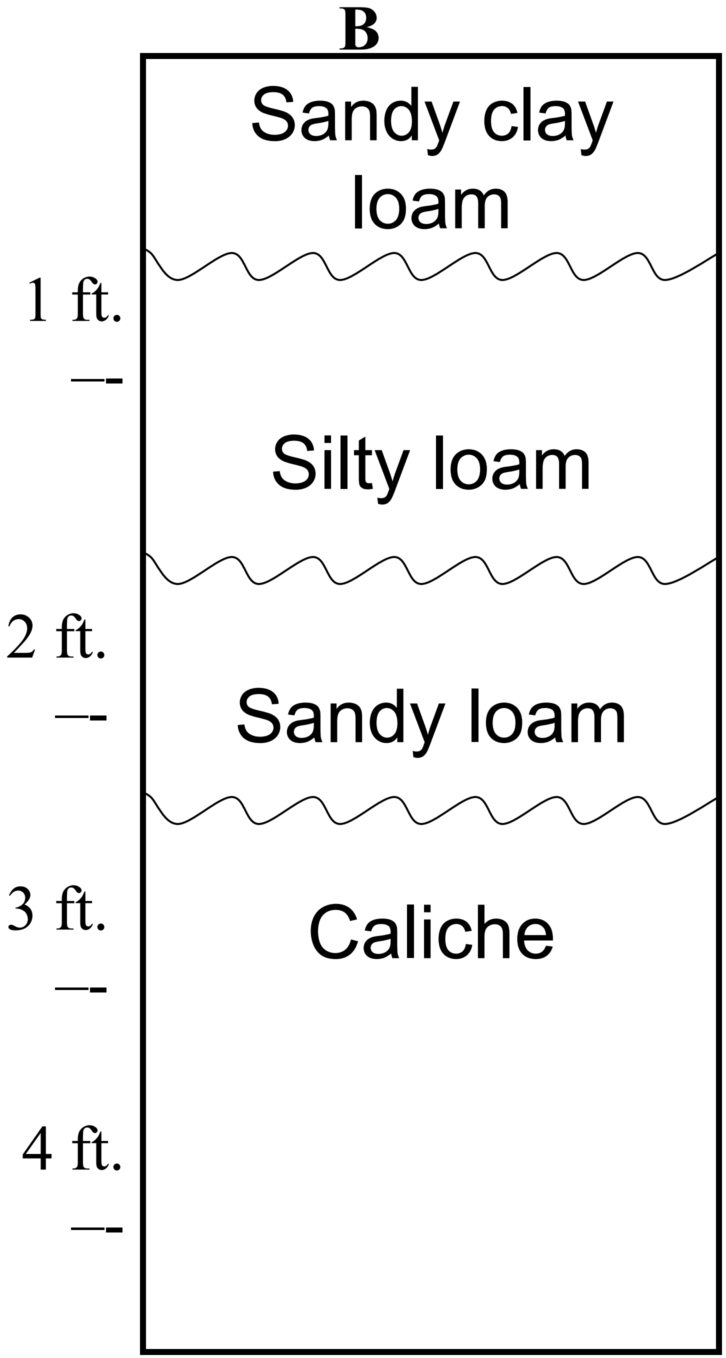


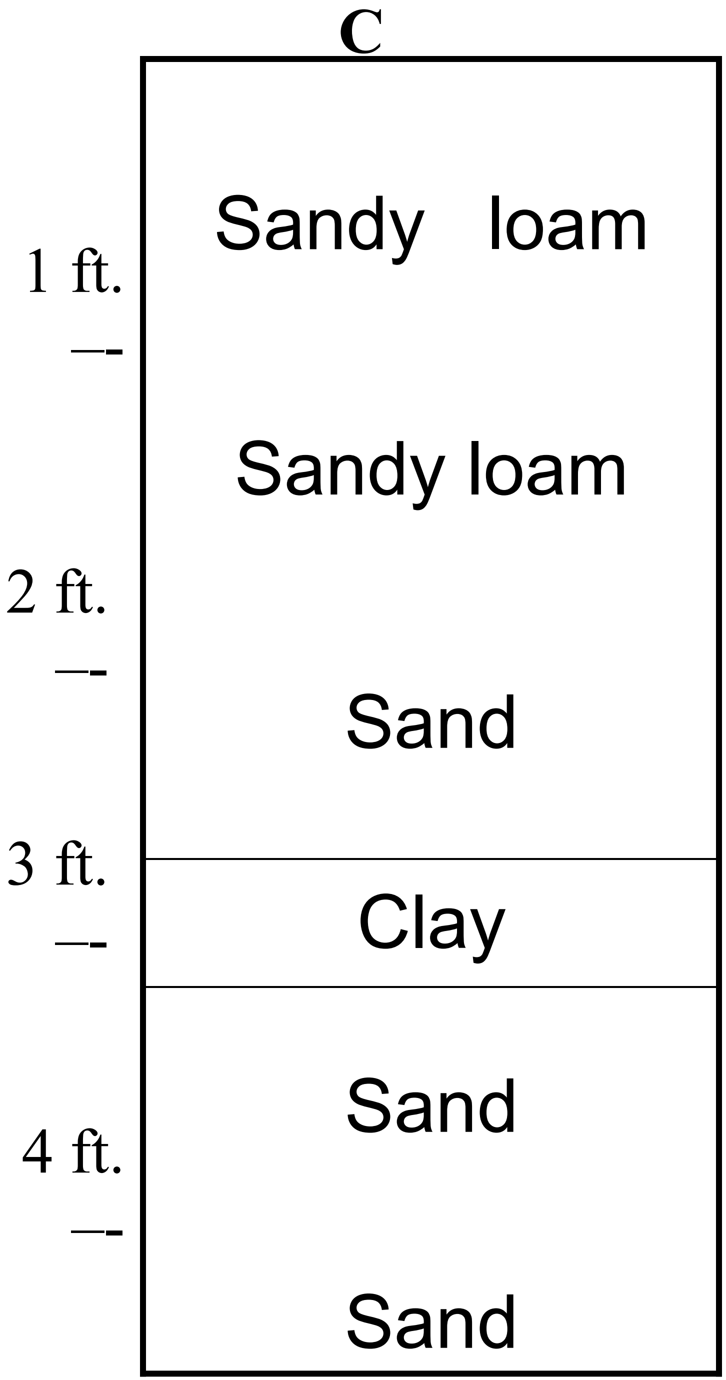
Salt Distribution in Bed Profile

VARIABLE ROW SPACING


Salt


D
1 ft.
2 ft.
3 ft.
4 ft.
Clay loam
Clay loam
Silty clay loam
Fine sand
Fine sand


B
Sandy clay loam
1 ft.
Silty loam
2 ft.
Sandy loam
Caliche
3 ft.
4 ft.


C
Sandy loam
1 ft.
Sandy loam
2 ft.
Sand
3 ft.
Clay
Sand
4 ft.
Sand

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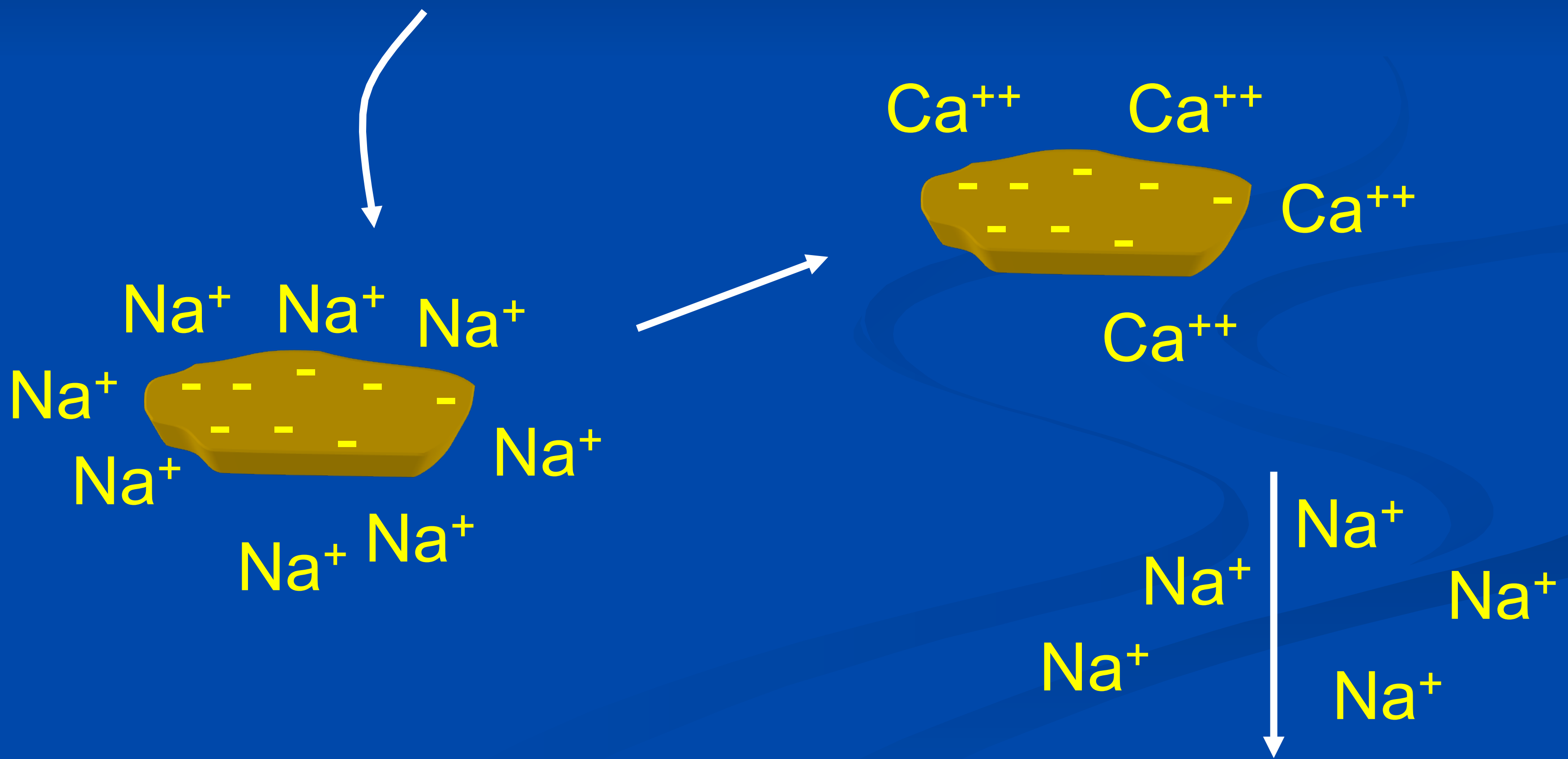
Reclamation of Sodic Soils

Gypsum Ca^{2+} SO_4^{2-}



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Bottom Line
(summary)

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- Sustainable management in arid lands dependent upon:
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- Irrigated crop systems require extra water for leaching above crop growth requirements.