# Salinity

- Concentration of Total Dissolved Solids (TDS)
  - Units: milligrams/liter (mg/L) or parts per million (ppm)
  - 1mg/l = 1 ppm
- Electrical Conductivity (EC)
  - Units: deciSiemens per meter (dS/m)
  - 1 dS/m = 1 millimho/cm = 1000 micromhos/cm
- Approximate relationship: TDS = 640 (EC)
  where TDS is in mg/L and EC is in dS/m
- Commonly measure $EC_e$
  (EC of the extract taken from a saturated soil)

*Example 7.1*

An irrigation source contains 500 mg of dissolved salt per liter of water. How much salt is applied to a 50-acre corn field if 15 in. of irrigation water are applied?

Given: Salt concentration of irrigation water ($C_i$) = 500 mg/L,
Depth of irrigation water ($d_g$) = 15 in, and
Field size (A) = 50 acres.

Find: Amount of salt applied (W).

Solution:

$$W = C_i \, d_g \, A \qquad (7.1)$$

$$W = 500 \frac{mg}{L} x\, 15\, inches\, x\, 50\, acres$$

$$W = 500 \frac{mg}{L} x \frac{10^5 \ L}{acre \ inch} x \frac{ton}{9 \ x \ 10^8 \ mg} x \ 15 \ inches \ x \ 50 \ acres$$

W = 42 tons

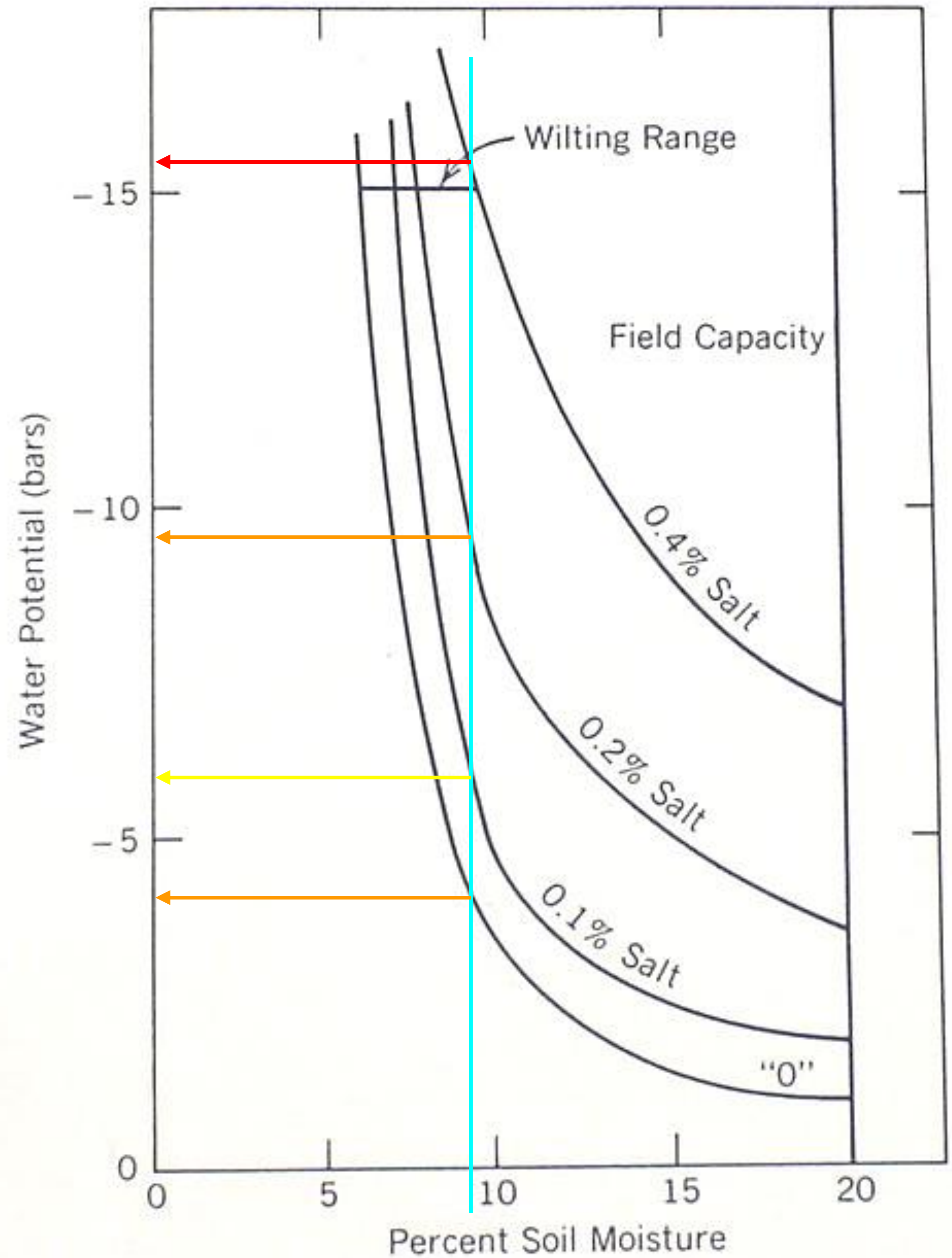
# Causes of Salinity

- All soils and irrigation waters contain salt
- ET tends to increase salt concentrations
- In humid regions, rainfall provides dilution and flushing below the root zone
- In arid regions, salts tend to concentrate much more over time, especially at the soil surface

# Salinity Effects

- Reduced water availability to plants (osmotic effect)
- $\psi_T = \psi_M + \psi_G + \psi_O$
- More difficult for roots to extract water from the soil because increased osmotic potential raises total water potential the plant must generate to extract water from the soil

# Salinity and Soil Water Potential




## Salt Concentrations

0.1% = 1000 mg/l

0.2% = 2000 mg/l

0.3% = 3000 mg/l

0.4% = 4000 mg/l

# Salinity Effects:  Part 2

- Yield impacts depend on the soil salinity level and the crop's sensitivity to it
- $Y_r = 100$    for $EC_e < T$
- $Y_r = 100 - S\,(EC_e - T)$    for $EC_e > T$    (Eq. 6.4)
- $Y_r$= relative yield, (%)
- T= threshold salinity where yield is first reduced, (dS/m)
- S= slope of yield-salinity relationship, (%/dS/m)
- Minimum value for $Y_r$ is 0

# Threshold, T, and Slope, S, Salinity Values

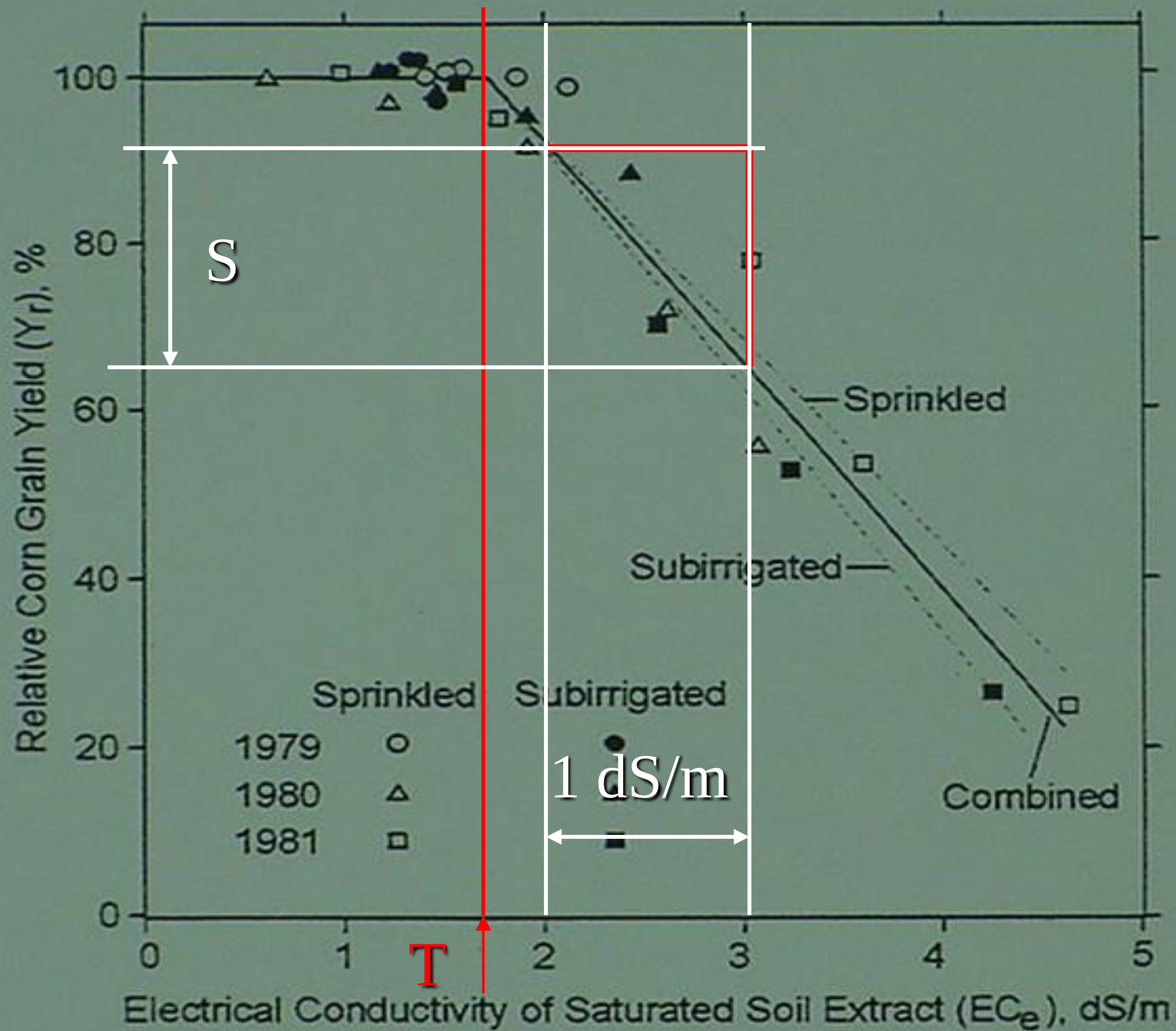



Figure 7.7. Relative grain yield of corn grown in the Sacramento-San Joaquin Delta of California as a function of soil salinity (adapted from Hoffman et al., 1983).

Table 7.2. Salt tolerance of major crops (adapted from Maas and Hoffman, 1977).

| Crop | Salt Tolerance Threshold (T) dS/m | Percent Yield Decline (S) %/(dS/m) | Qualitative Salt Tolerance Rating |
|---|---|---|---|
| **Grain Crops** | | | |
| Barley | 8.0 | 5.0 | T |
| Corn | 1.7 | 12 | MS |
| Cowpea | 4.9 | 12 | MT |
| Rice | 3.0 | 12 | S |
| Sorghum | 6.8 | 16 | MT |
| Soybean | 5.0 | 20 | MT |
| Wheat | 6.0 | 7.1 | MT |
| **Fiber, Sugar and Oil Crops** | | | |
| Cotton | 7.7 | 5.2 | T |
| Flax | 1.7 | 12 | MS |
| Peanut | 3.2 | 29 | MS |
| Sugar Beet | 7.0 | 5.9 | T |
| Sugar Cane | 1.7 | 5.9 | MS |
| **Grasses and Forage Crops** | | | |
| Alfalfa | 2.0 | 7.3 | MS |
| Bermuda Grass | 6.9 | 6.4 | T |
| Clover | 1.5 | 12 | MS |
| Fescue | 3.9 | 5.3 | MT |
| Orchard Grass | 1.5 | 6.2 | MS |
| Ryegrass | 5.6 | 7.6 | MT |
| Trefoil, Birdsfoot | 5.0 | 10 | MT |
| **Vegetables and Fruit Crops** | | | |

*Example 7.2*

A saline area of a field has an average salt concentration of 3000 mg/L. Calculate the relative yield of corn in this salt-affected soil. If the non-saline portion of the field produces 180 bushels per acre, what is the actual yield of the saline area in the field?

<u>Given:</u> C = 3000 mg/L

Non-saline corn yield = 180 bushels/acre, and

S = 12% / (dS/m) and T = 1.7 dS/m (Table 7.2 for corn)

<u>Find:</u> Relative ($Y_r$) and actual ($Y_a$) corn yields in the saline area

<u>Solution:</u> EC = C/640 = 3000/640 = 4.7 dS/m (Equation 7.3)

$Y_r = 100 - S\ (EC_e - T)$ (Equation 7.4)

$Y_r = 100 - 12\ (4.7 - 1.7)$

$Y_r = 64\%$

$Y_a = Y_r \times Y_{max}$

$Y_a = .64\ (180\ \text{bu/acre})$

$Y_a = 115\ \text{bu/acre}$

# Sodicity

- Sodicity: sodium level in water or soil, particularly in relation to the levels of calcium and magnesium
- Effects:
  - Clay particles swell and aggregates disperse (soil structure)
  - Reduced infiltration and percolation
  - Poor tilth and aeration
  - “Slick spots” (Black alkali soils)
  - (when calcium and magnesium dominate, soil structure is much better)

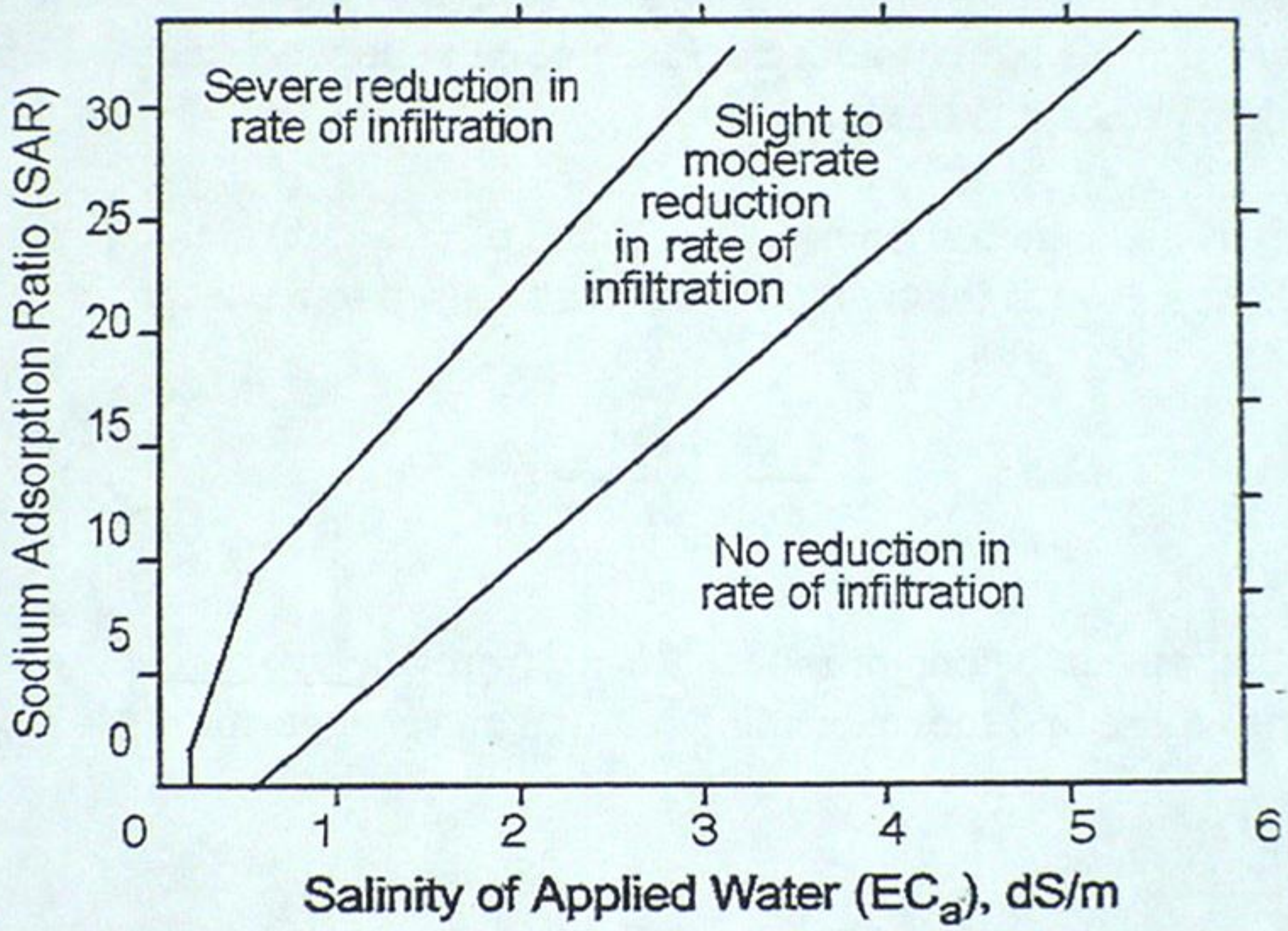
# Sodicity Measurement

- Sodium Adsorption Ratio (SAR)

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

- C's have units of moles of charge per cubic meter (meq/L ÷ valence)

# Potential for infiltration problems due to high $Na^+$ water.



*Example 7.3*

Water from an irrigation well in Arizona has an electrical conductivity of 0.4 dS/m at 25°C and the concentration of sodium is 33 meq/L. The concentrations of calcium and magnesium are 24 and 8 meq/L, respectively. Determine if this irrigation water will create a sodicity hazard.

<u>Given:</u> $C_{Na} = 33$ meq/L, $C_{ca} = 24$ meq/L, $C_{Mg} = 8$ meq/L, and $EC = 0.4$ dS/m.

<u>Find:</u> Will water cause a sodicity hazard.

<u>Solution:</u>
$C_{Na} = (33\ \text{meq})/\text{L}/1 = 33\ \text{mol}_c/\text{m}^3$
$C_{Ca} = (24\ \text{meq})/\text{L}/2 = 12\ \text{mol}_c/\text{m}^3$
$C_{Mg} = (8\ \text{meq})/\text{L}/2 = 4\ \text{mol}_c/\text{m}^3$

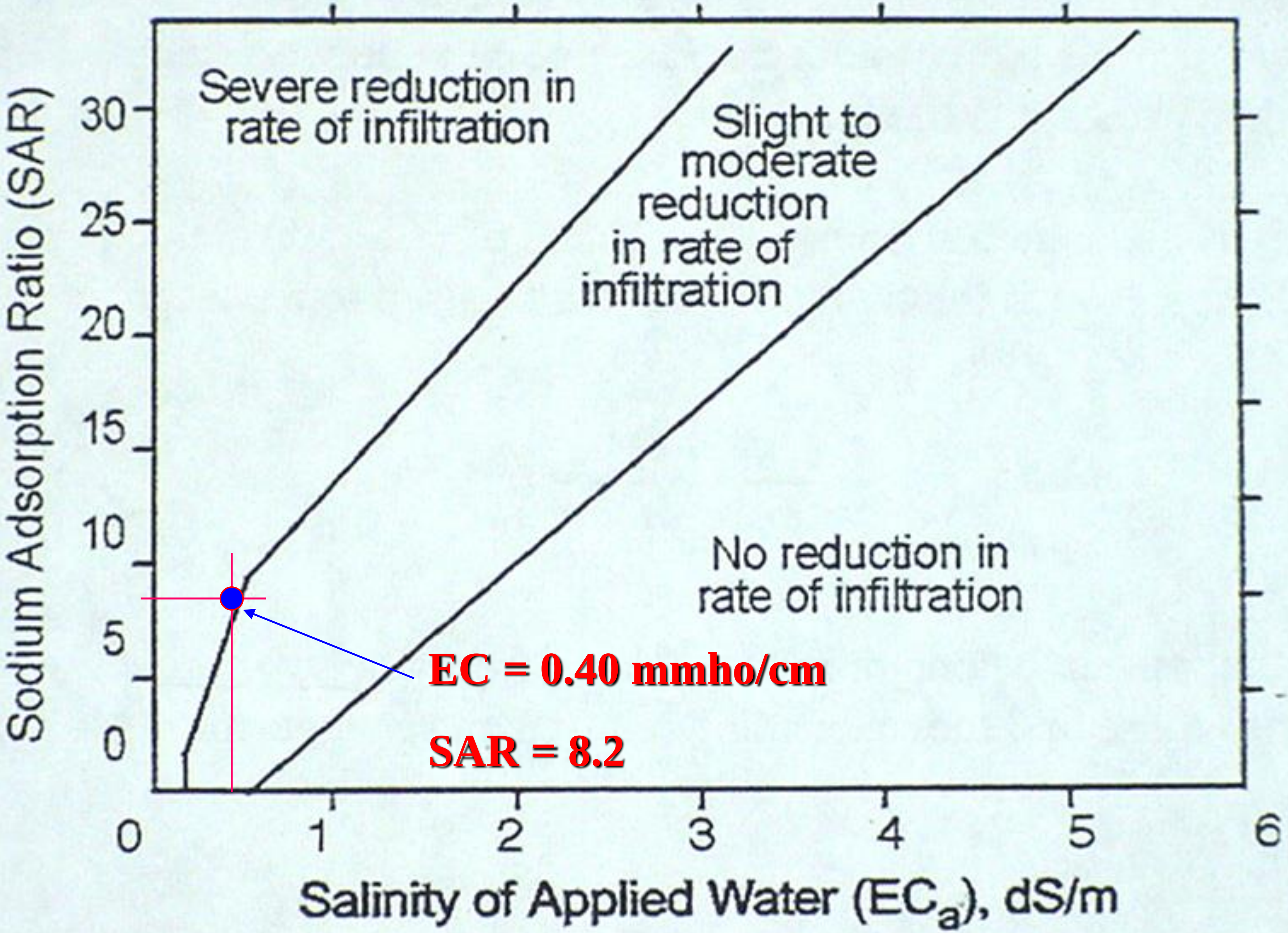
$$SAR = C_{Na} / \sqrt{C_{Ca} + C_{Mg}}$$

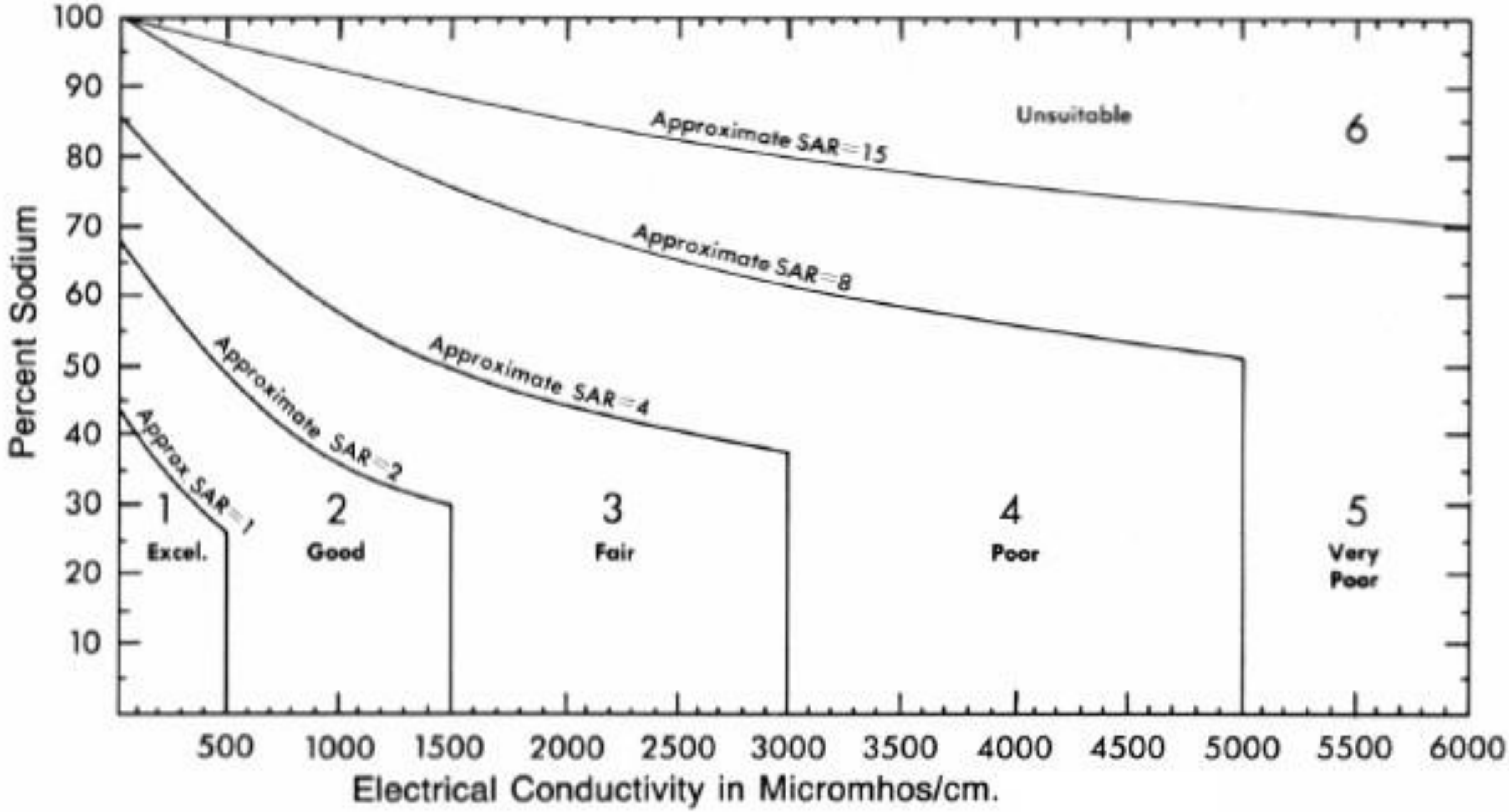
$$SAR = 33 / \sqrt{12 + 4}$$

$SAR = 8.2\ (\text{mol}_c/\text{m}^3)^{1/2}$

From Figure 7.10, the intersection of lines extended from an SAR of 8.2 and an EC of 0.4 dS/m indicates that water penetration will probably be decreased due to excess sodium.

# Potential for infiltration problems due to high $Na^+$ water.





Percent Sodium
100
90
80
70
60
50
40
30
20
10
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
Electrical Conductivity in Micromhos/cm.
Approximate SAR=15
Approximate SAR=8
Approximate SAR=4
Approximate SAR=2
Approx SAR=1
Unsuitable
6
1
Excel.
2
Good
3
Fair
4
Poor
5
Very Poor

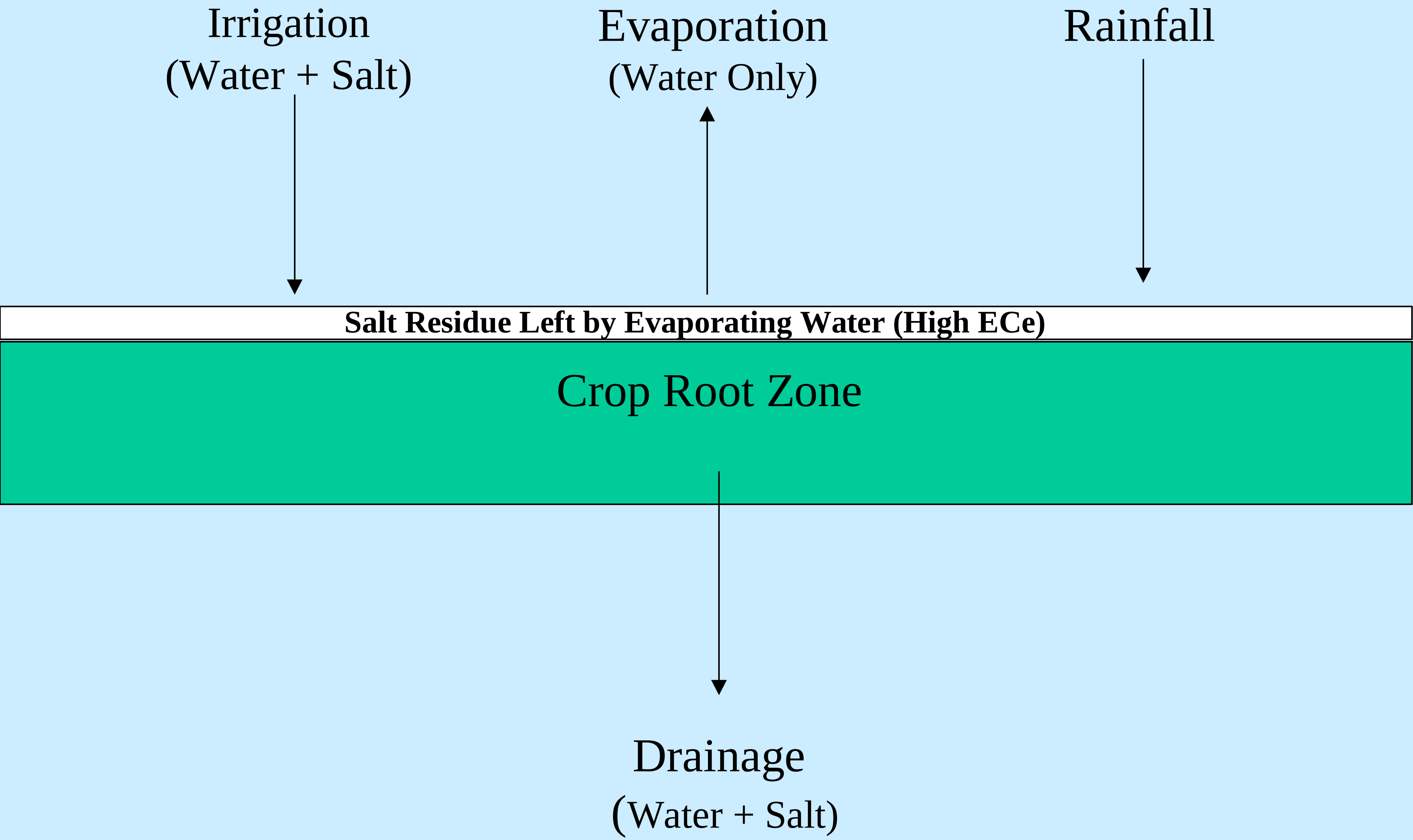
# Mineral Toxicity

- Plant damage resulting from the uptake and accumulation of certain ions
- Examples:  boron, chloride, sodium
- Evidence of toxicity usually appears as burning on margins of mature leaves
- Generally not a problem with most irrigation waters

# Leaching

- Leaching:  Addition of excess water which will wash accumulated salts below the root zone
- Occurs naturally in humid regions due to heavy rainfall
- Artificial leaching in arid regions through over-irrigation
- Either method requires good drainage

# Salt and Water Balance in the Root Zone



# Leaching Fraction, L

$$L = D_d/D_i = C_i/C_d = EC_i/EC_d$$

L = Leaching fraction

D = Water depth

C = Water mineral concentration (TDS)

EC = Water electrical conductivity

$_i$ = Irrigation water (consistent units: in/in,

$_d$ = Drainage water ppm/ppm, dS/m/dS/m)

*Example 7.4*

What is the annual leaching fraction of a soil if 300 mm of rain fell during the year and 250 mm infiltrated into the soil and 300 mm of irrigation were applied. The electrical conductivity of the irrigation water was measured to be 0.5 dS/m at 25° and the electrical conductivity of the soil water draining below the root zone was found to be 2.5 dS/m.

<u>Given:</u> $C_d = 2.5$ dS/m, $C_i = 0.5$ dS/m, and
$d_g = 300$ mm, $d_r = 250$ mm.

<u>Find:</u> The leaching fraction (L) for this condition.

<u>Solution:</u>

$$C_a = \frac{C_i\, d_g + C_r\, d_r}{d_g + d_r}$$

$$C_a = \frac{0.5\ (300) + 0\ (250)}{300 + 250}$$

$$C_a = 0.27\ dS/m$$

$$L = \frac{C_a}{C_d}$$

$$L = \frac{0.27}{2.5}$$

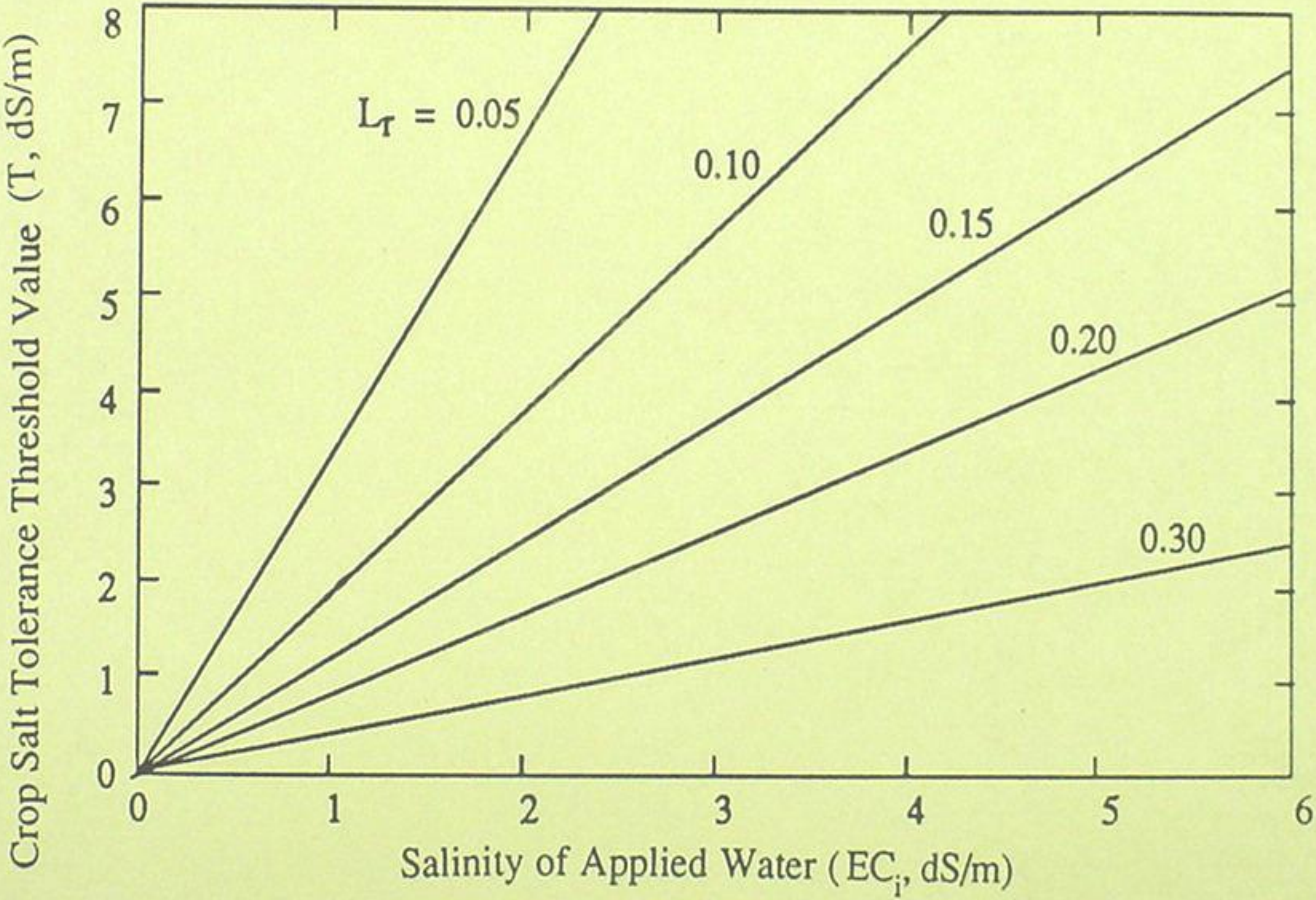
$$L = 0.11$$

# Leaching Requirement, $L_r$

$L_r$ = Leaching requirement
(i.e., the leaching fraction *required*)

There are simple models which estimate the amount of leaching required to maintain an acceptable level of soil salinity, based on a linear distribution of accumulated salts in the root zone.

# Leaching Requirement as a function of $EC_i$ and T



*Example 7.5*

Determine the leaching requirement for tomato if the salinity of the irrigation water is 3 dS/m with 16 inches of irrigation water and 4 inches of rainfall contributing to the crop water requirement.

<u>Given:</u> $EC_i$ = 3 dS/m,
$d_i$ = 16 in,
$d_r$ = 4 in, and
T for tomato is 2.5 dS/m from Table 7.2.

<u>Find:</u> Leaching requirement for tomato under the specified conditions.

<u>Solution:</u> From Equation 7.8

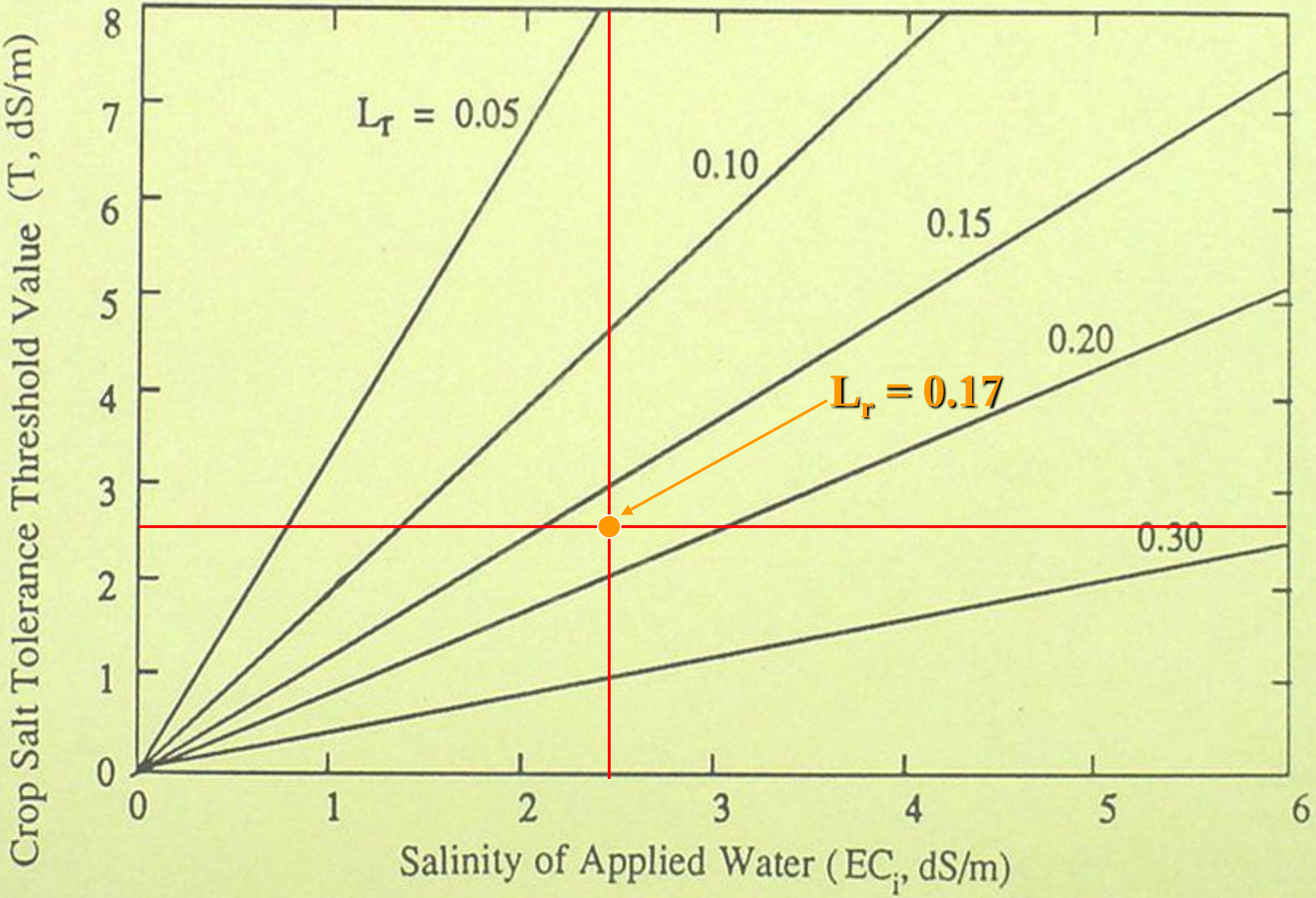
$$C_a = \frac{C_i\, d_g + C_r\, d_r}{d_g + d_r}$$ is equivalent to $$EC_a = \frac{EC_i\, d_g + EC_r\, d_r}{d_g + d_r}$$

$$EC_a = \frac{3\ dS/m\ (16\ inches) + 0\ (4\ inches)}{16\ inches + 4\ inches}$$

$$EC_a = \frac{48}{20} = 2.4\ dS/m$$

From Figure 7.11 for an $EC_a$ of 2.4 dS/m and a salt tolerance threshold value of 2.5 dS/m, the leaching requirement is 0.17.

# $L_r$ when $EC_i$ = 2.40 dS/m and T = 2.5 dS/m



# Reclamation of Saline Soils

- Salinity
  - Natural leaching with rainfall
  - Artificial leaching with excess irrigation
  - Good drainage through root zone required
- Sodicity
  - Addition of soil amendments (Calcium)
- Reclamation should be done whenever salt levels reach an economic threshold (Crop yield is significantly affected)

# Water Law

- Riparian Doctrine: "a landowner contiguous to a stream is entitled to have water of the stream flow by his/her land undiminished in quantity and unpolluted in quality"
  - Based on English common law
  - Ground water context: ownership of overlying land
  - Doctrine is often modified to the concept of "reasonable use"
- (Prior) Appropriation Doctrine: "diverting water and putting it to a beneficial use creates a water right"
  - Early miners' claims: "first in time is first in right"

# Beneficial Uses

- Domestic
- Industrial
- Irrigation
- Livestock
- Power generation
- Recreation
- Aquatic life

# Water Rights
## (cornerstone of the Appropriation Doctrine)

- Water is owned by the public
- State can grant the right to use water
- Certain quantity, certain use, certain point of diversion
- Priority is very important (senior vs. junior rights)
- Can be bought and sold
- No guarantee of water
- Non-use forfeits the right
- Normally administered through a permit system

# Oklahoma Water Rights

- Combination of Riparian and Appropriation Doctrines (like most western US states)
- Owning land over groundwater or by a stream grants domestic use by Riparian Doctrine
  - Household use
  - Irrigate 3 acres or less (for any purpose)
  - Water free range livestock at normal stocking rate
- All other uses require a permit under Appropriation Doctrine (OK Water Resources Board)