# Irrigation and Salinity Management in Forage Production Systems

## Alfalfa and Forage Field Day

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# Overview:

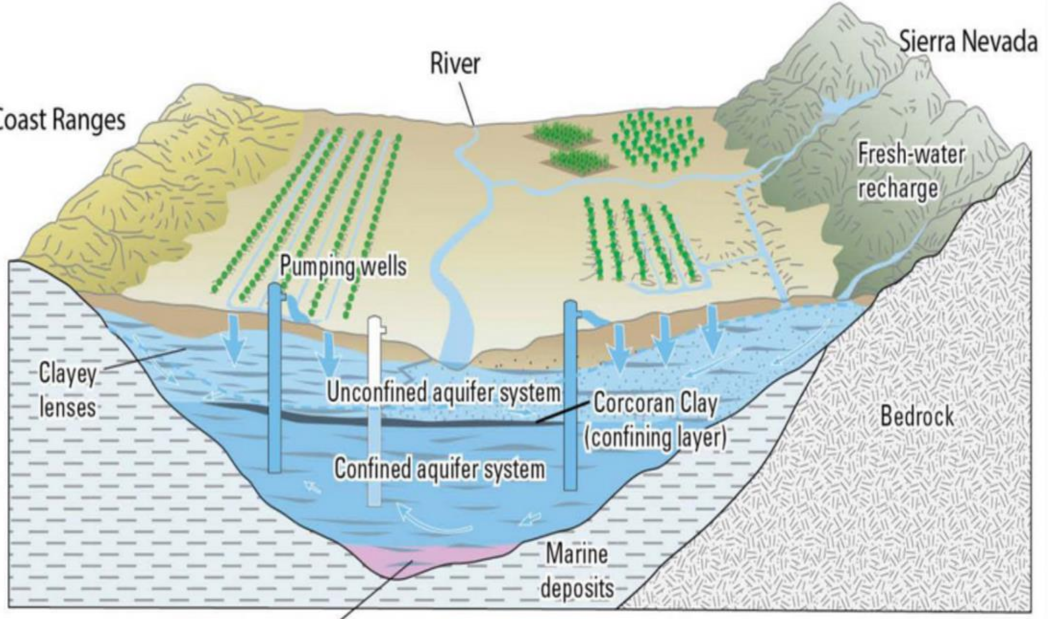
- Salinity origins and accumulation in soils
- Salinity tolerance in forage crops
- Water quality and balance
- Irrigation management and leaching

# Sources of Salts in Soils

- Native salts
  - dissolution of primary and secondary soil minerals
  - Atmospheric deposition
  - Groundwater influence
  - Irrigation has often removed
- Fertilizer and composts
- Irrigation water
  - Surface or groundwater?

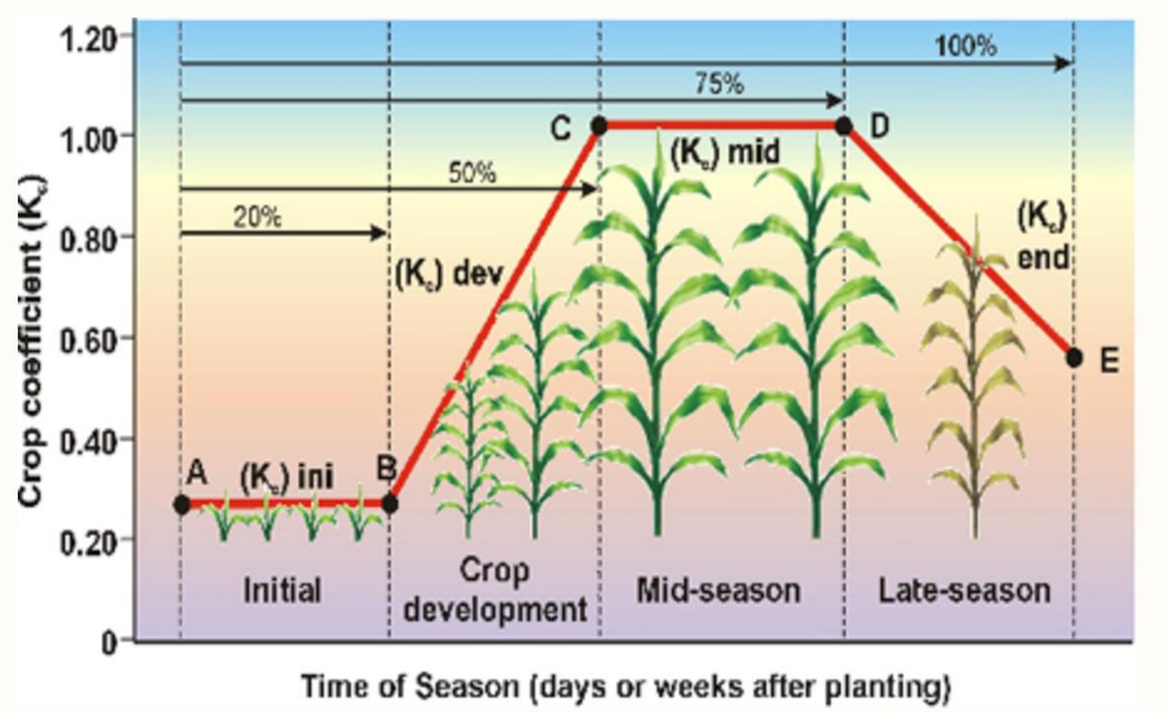
*BMP:*
*Water analysis should be conducted to know the quality of water!*

# Water quality varies throughout the San Joaquin Valley




- Groundwater quality dynamics are complex
- TDS is generally however:
  - Upper east valley positions; 100 to 500 ppm
  - Lower valley fan positions;  400 to 1,800
  - Above the Corcoran clay; 2,000 to 3,000 ppm
  - Below the Corcoran clay; 600 ppm to 1,800 ppm
  - Other issues; distance to canal, river, soil
    - Eastside surface water; 25 and 150 ppm
    - Westside San Luis Unit); 200 to 450 ppm

# Soil Salinity Buildup




EC of 1.0 dS/m → 1,740 lbs. for every ac ft applied

5 ac ft for a crop, equates to 8,700 lbs./ ac/yr (4.4 tons)

# Irrigation Water Guideline

| | Degree of Restriction | | |
|---|---|---|---|
| Specific Ion | None | Increasing | Severe |
| Sodium (ESP) | < 3.0 | 3 - 9 | > 9.0 |
| Chloride (meq/l) | < 4.0 | 4 - 10 | > 10.0 |
| Boron (mg/l) | < 0.5 | 0.5 - 3.0 | > 3.0 |

# 2017 XXXX Farms Well Water Analysis

| Drip Potential | pH | ECw | Ca+Mg | Na | Cl | CO3+HCO3 | SAR | Adj SAR | B | NO3-N | Mn | Fe |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (dS/m) | <---------------------- meq/l | | | ------------------> | | | <------------------ ppm | | | -----------------> |
| Yes | 7.9 | 1.6 | 0.6 | 15.4 | 9.0 | 3.6 | 28.1 | 24.5 | 1.87 | 10 | 0.000 | 0.020 |
| | | | | | | | | | | Della | 0.01 | 0.08 |
| Yes | 7.9 | 2.8 | 2.7 | 25.5 | 21.0 | 4.8 | 21.9 | 24.3 | 2.18 | 12 | 0.001 | 0.016 |
| No | 8.0 | 2.2 | 2.2 | 21.4 | 16.0 | 4.0 | 20.4 | 21.3 | 2.2 | 15 | 0.001 | 0.035 |
| | | | | | | | | | | Della | 0.02 | 0.10 |
| Yes | 8.1 | 2.0 | 1.8 | 19.1 | 12.0 | 3.6 | 20.1 | 20.1 | 1.82 | 8 | | |
| Yes | 8.1 | 1.5 | 2.2 | 14.1 | 7.5 | 4.0 | 13.4 | 14.6 | 2.01 | 2 | 0.001 | 0.039 |
| No | 8.4 | 1.6 | 2.3 | 13.9 | 7.0 | 4.8 | 13.0 | 14.5 | 1.53 | 6 | 0.002 | 0.491 |
| Yes | 8.0 | 1.1 | 3.0 | 9.1 | 2.0 | 1.2 | 7.4 | 6.2 | 1.48 | 11 | 0.003 | 0.000 |
| No | 7.4 | 1.2 | 3.8 | 8.6 | 1.0 | 1.2 | 6.2 | 5.5 | 0.90 | 5 | | |
| Yes | 7.3 | 1.2 | 4.5 | 0.8 | 1.5 | 0.4 | 5.9 | 3.9 | 0.55 | 2 | 0.002 | 0.000 |

# Well Water Analysis: Interpretation

| Sample | pH | Ecw (dS/m) | Ca (meq/L) | Mg | Na | HCO3 (meq/L) | SO4 | Cl | SAR | SARadj | B (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| High | 7.79 | 2.88 | 10.10 | 14.4 | 12.0 | 4.71 | 26.8 | 4.55 | 3.43 | 8.13 | 0.77 |
| | | | | | | | | | | | |
| UC | <7.0 | <1.1 | | | SAR | | | <4.0 | <3.0 | | <0.5 |

Acidifying water will drop adjusted SAR closer to reported SAR

pH dependent: Indicates that $Ca^{2+}$ or $Mg^{2+}$ will not remain free in soil solution

**Water is too hot!**

# Lowering pH of Irrigation Water

**Why?**

Can increase water penetration, soil structure

Can improve mineral nutrition

- Titration for water must be performed to determine amounts needed.
- Send water plus acid of choice to a local lab.

# Determining Acid Rates

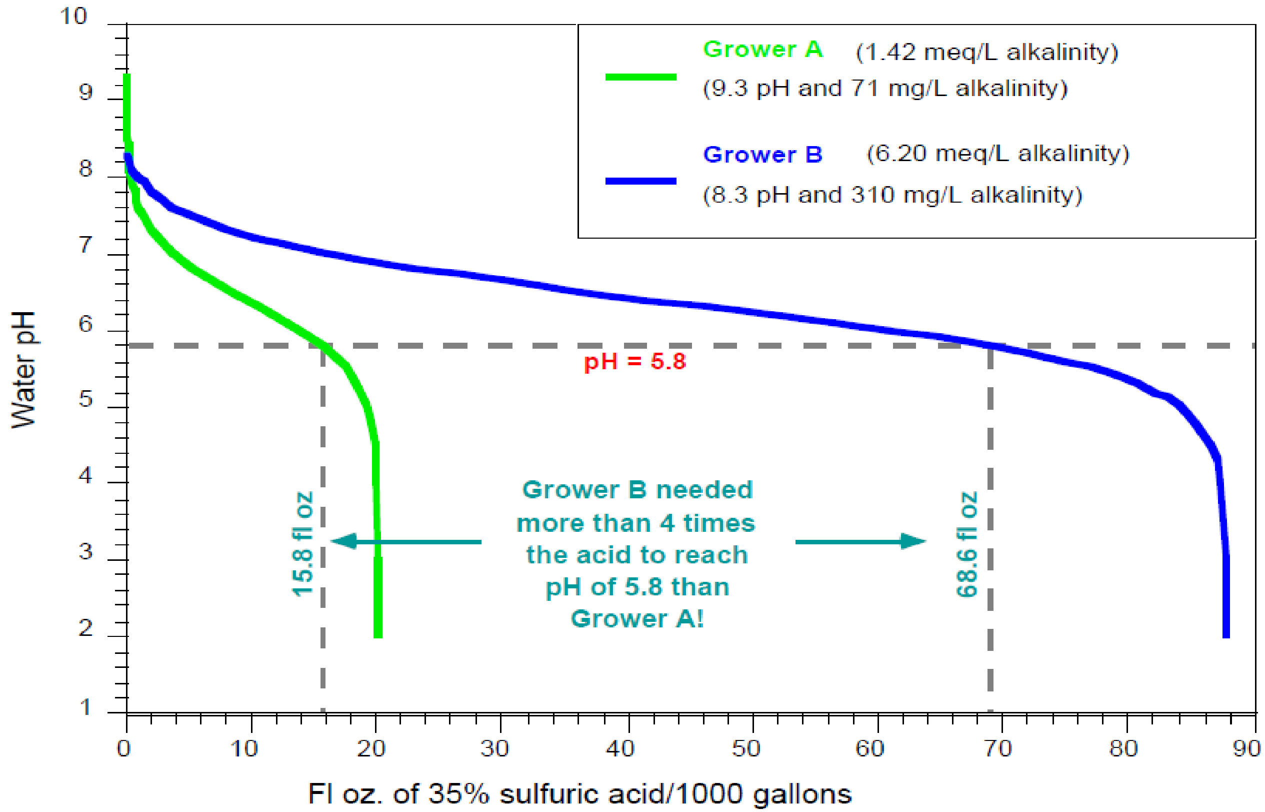



*Figure 2. Titrations of two different waters with sulfuric acid. Notice that although the beginning pH of Grower A water is a full unit higher than Grower B water, it takes more than 4 times the acid to drop Grower B water to pH 5.8, due to the greater alkalinity in Grower B water.*

**Table 1. Acids commonly used to acidify irrigation water and their properties.**

| Acid | Formulation and density (d) or formula weight (FW) | Amount of acid to add for each meq/L of alkalinity to result in a water pH of approximately 5.8* | Concentration of nutrient provided by one fl oz. of acid per 1000 gallons water** | Cost per meq/L per 1000 gal*** | Relative safety**** |
|---|---|---|---|---|---|
| Citric acid (2-Hydroxy-1,2,3-propanetricarboxylic acid) $H_3C_6H_5O_7$ | 99.5% (w:w) granular FW = 192.1 | 9.1 oz/1000 gals | none | $0.59 | can cause minor skin and eye irritation |
| | 50% (w:w) liquid d = 1.21 | 14.5 fl. oz/1000 gals | none | $0.96 | can cause minor skin and eye irritation |
| Nitric acid $H_2NO_3$ | 67% (w:w) liquid d = 1.42 | 6.6 fl oz/1000 gals | 1.64 ppm N | $0.26 | use extreme caution; very caustic and dangerous; avoid contact with fumes as well as acid |
| Phosphoric acid $H_3PO_4$ | 75% (w:w) liquid d = 1.58 | 8.1 fl oz/1000 gals | 2.88 ppm P | $0.44 | slightly caustic; can cause skin and eye irritation as well as damage clothing |
| Sulfuric acid $H_2SO_4$ | 35% (w:w) liquid d = 1.26 | 11.0 fl oz/1000 gals | 1.14 ppm S | $0.16 | slightly caustic; can cause skin and eye irritation as well as damage clothing |

*Add this amount for each meq/L of alkalinity present. For example, if your water report indicates an alkanity of 3 meq/L and you choose to use sulfuric acid, you would add 33 fl oz. of 35% sulfuric acid per 1000 gallons of water (11 fl oz/meq/L × 3 meq/L = 33 fl oz). Calculations based on the following dissociation values: 2.07 meq $H^+$ per 3 meq $H_3C_6H_5O_7$, 1 meq $H^+$ per 1 meq $H_2NO_3$, 1.02 meq $H^+$ per 3 meq $H_3PO_4$, and 1 meq $H^+$ per 1 meq $H_2SO_4$.

**In the above example, the acid would supply 38 ppm S at each irrigation ( 33 fl oz × 1.14 ppm S/fl oz. = 33 ppm S).

***Acid cost to neutralize 1 meq/L alkalinity per 1000 gallons of water. Based on the following costs: $1.04/lb of 99.5% citric acid; $8.45/gal of 50% citric acid; $5.00/gal of 67% nitric acid; $7.00/gal of 75% phosphoric acid; $1.90/gal of 35% sulfuric acid.

****Use caution with ALL acids. Wear eye protection, acid-resistant gloves, and an acid-resistant apron when handling any acid.

# Adding Calcium to Irrigation Water

**Why?**

- To lower SAR and increase EC
  - Can increase water penetration
  - Can improve soil structure
- To reduce toxic ion effects (Cl, Na)

# Adding Calcium to Irrigation Water

| Salt | Formulation | Solubility (distilled water @20°C, at ph=7) | | Soil Rxn and effect on pH |
|---|---|---|---|---|
| | | (g/100 mls) | General rating | |
| Calcium nitrate | $Ca(NO_3)_2$ | 121 | Highly soluble | Gradual, Neutral |
| Calcium chloride dihydrate | $CaCl_2 \cdot 2H_2O$ | 98 | Highly soluble | Gradual, Neutral |
| Calcium chloride | $CaCl_2$ | 74 | Highly soluble | Gradual, Neutral |
| Calcium acetate | $C_4H_6CaO_4$ | 34.7 | Highly soluble | Increase pH of acid soils |
| Gypsum | $CaSO_4 \cdot 2H_2O$ | 0.26 | Moderately soluble | Gradual, Neutral |
| Dolomite | $CaMg(CO_3)_2$ | 0.03 (depends on soil ph) | Low solubility | Increase pH of acid soils |
| Lime | $CaCO_3$ | 0.005 (depends on soil ph) | Very low solubility | Increase pH of acid soils |
| By-product ash | CaO or $Ca(OH)_2$ | Variable (depends on soil pH) | Very low solubility | Increase pH of acid soils |

*Source: CRC Handbook of Chemistry and Physics, 56th Edition*

# Adding Calcium to Irrigation Water

- In solution: ~ 250 lbs of gypsum/acre ft to increase one meq/l of calcium
- Land grade applications made monthly


# Saturated Soil Extract Guide

| | Degree of Restriction | | |
|---|---|---|---|
| Specific Ion | None | Increasing | Severe |
| Sodium (ESP) | < 5.0 | 5 - 15 | > 15.0 |
| Chloride (meq/l) | < 5.0 | 5 - 15 | > 15.0 |
| Boron (mg/l) | < 0.5 | 0.5 - 3.0 | > 3.0 |

# Well Water Analysis: Interpretation Boron

| Sample | pH | Ecw (dS/m) | Ca (meq/L) | Mg | Na | HCO3 (meq/L) | SO4 | Cl | SAR | SARadj | B (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| High | 7.79 | 2.88 | 10.10 | 14.4 | 12.0 | 4.71 | 26.80 | 4.55 | 3.43 | 8.13 | 0.77 |
| OK | 7.89 | 1.20 | 4.33 | 3.5 | 6.42 | 1.77 | 10.1 | 0.99 | 3.25 | 5.44 | 0.46 |
| ??? | 7.66 | 0.86 | 1.91 | 2.9 | 4.48 | 6.3 | 0.36 | 1.69 | 2.91 | 6.74 | 2.6 |
| | | | | | | | | | | | |
| UC | <7.0 | <1.1 | | | SAR | | | <4.0 | <3.0 | | <0.5 |

| | Degree of Restriction | | |
|---|---|---|---|
| | None | Increasing | Severe |
| Boron (mg/L) | <0.5 | 0.5-3.0 | >3.0 |

# Crop Salt Tolerance

Total Salinity (dS/m)

Yield= 100 – M(ECe – A)

M= slope, ECe= Avg. RZ Salinity, A= Threshold

- Plant genetics play a primary role in the various mechanisms governing crop salt tolerance.

| Crop | M | Threshold |
|---|---|---|
| Wheat | 6.1 | 3.8 |
| Barley | 8.0 | 5.0 |
| Corn(for.) | 1.7 | 7.4 |
| Sorghum | 6.8 | 16.0 |
| Alfalfa | 2.0 | 7.3* |
| Beans | 1.0 | 19.0 |
| Almond | 1.5 | 19.0 |

# Salinity Tolerance of Alfalfa

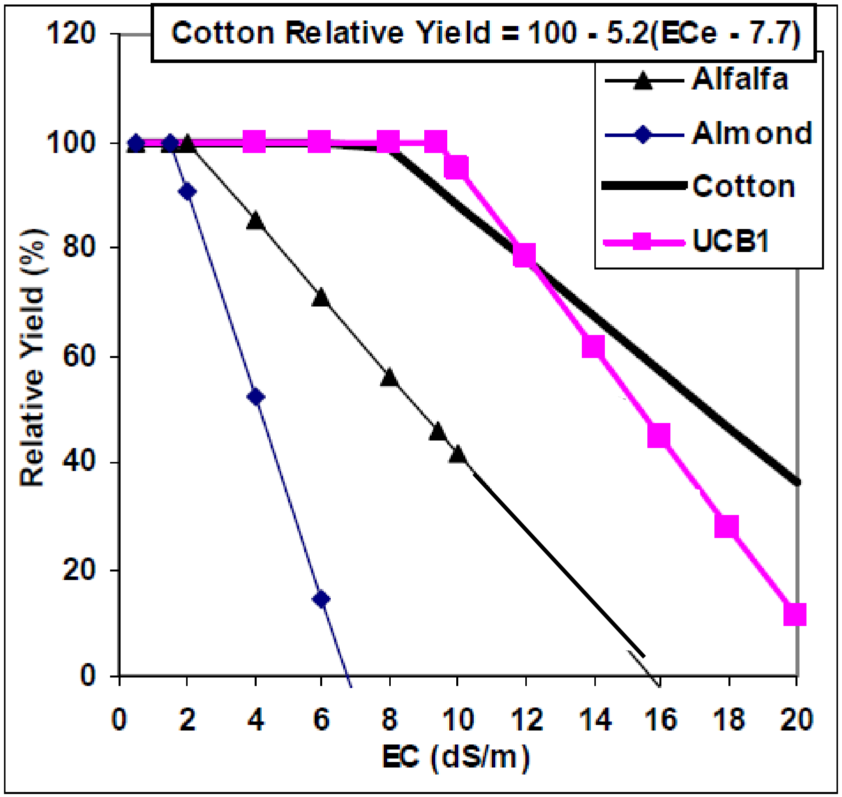



Fig. 2. Relative yield (RY) of various crops as a function of soil $EC_e$ (Sanden, et al., 2004).

How Tough is alfalfa?

- Variety dependent
- Slightly to moderately tolerant
- Know your variety!

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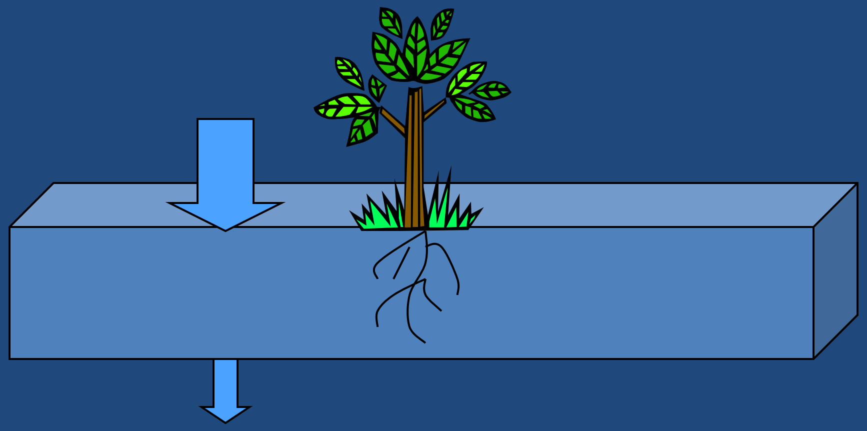
# Salt tolerance is based on soil salinity (ECe)

How does this help with my irrigation water quality report that gives me ECw?

# Leaching Fraction (LF)

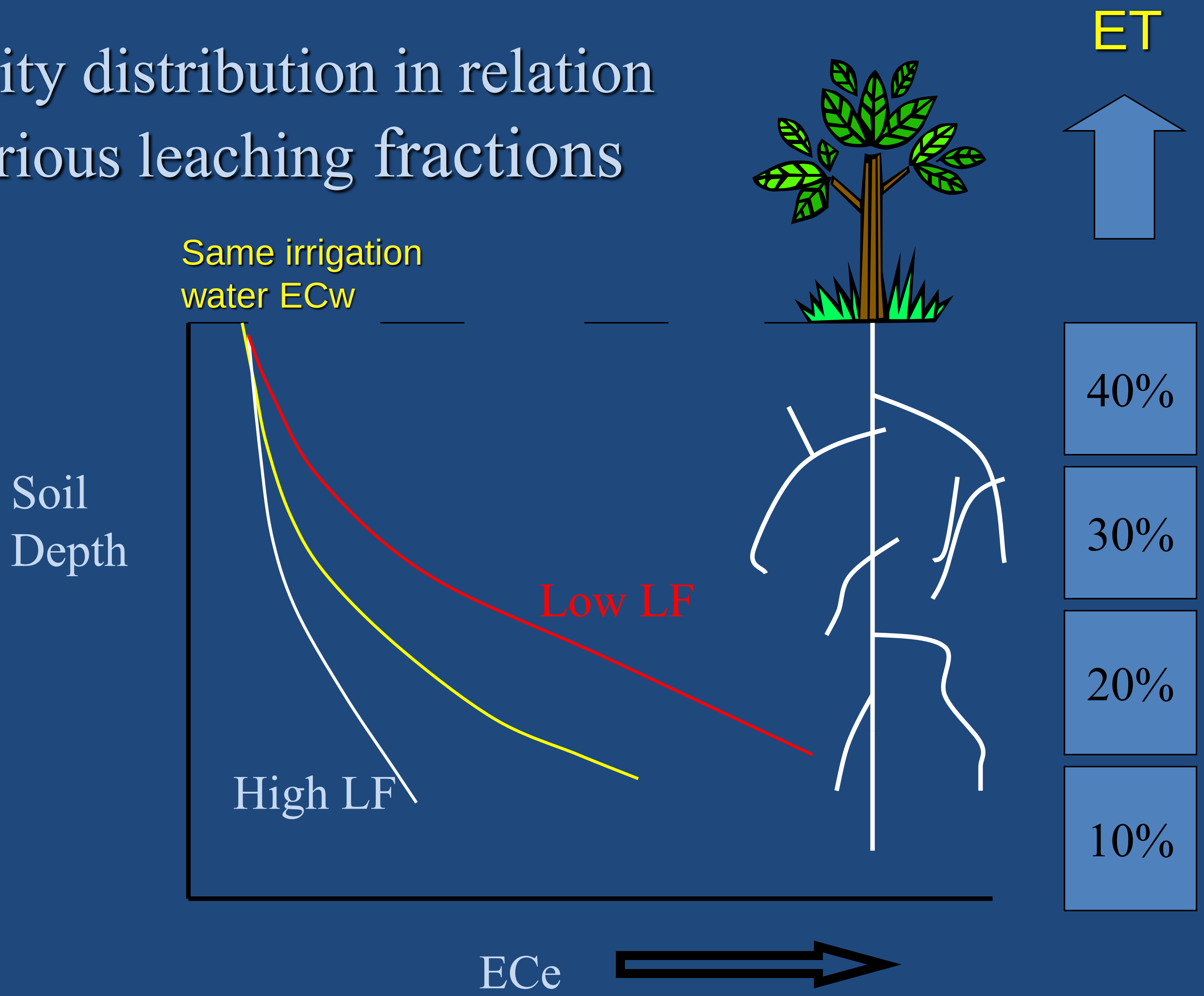


LF = volume of drainage water/volume of infiltrated water

LF = depth of drainage water/depth of infiltrated

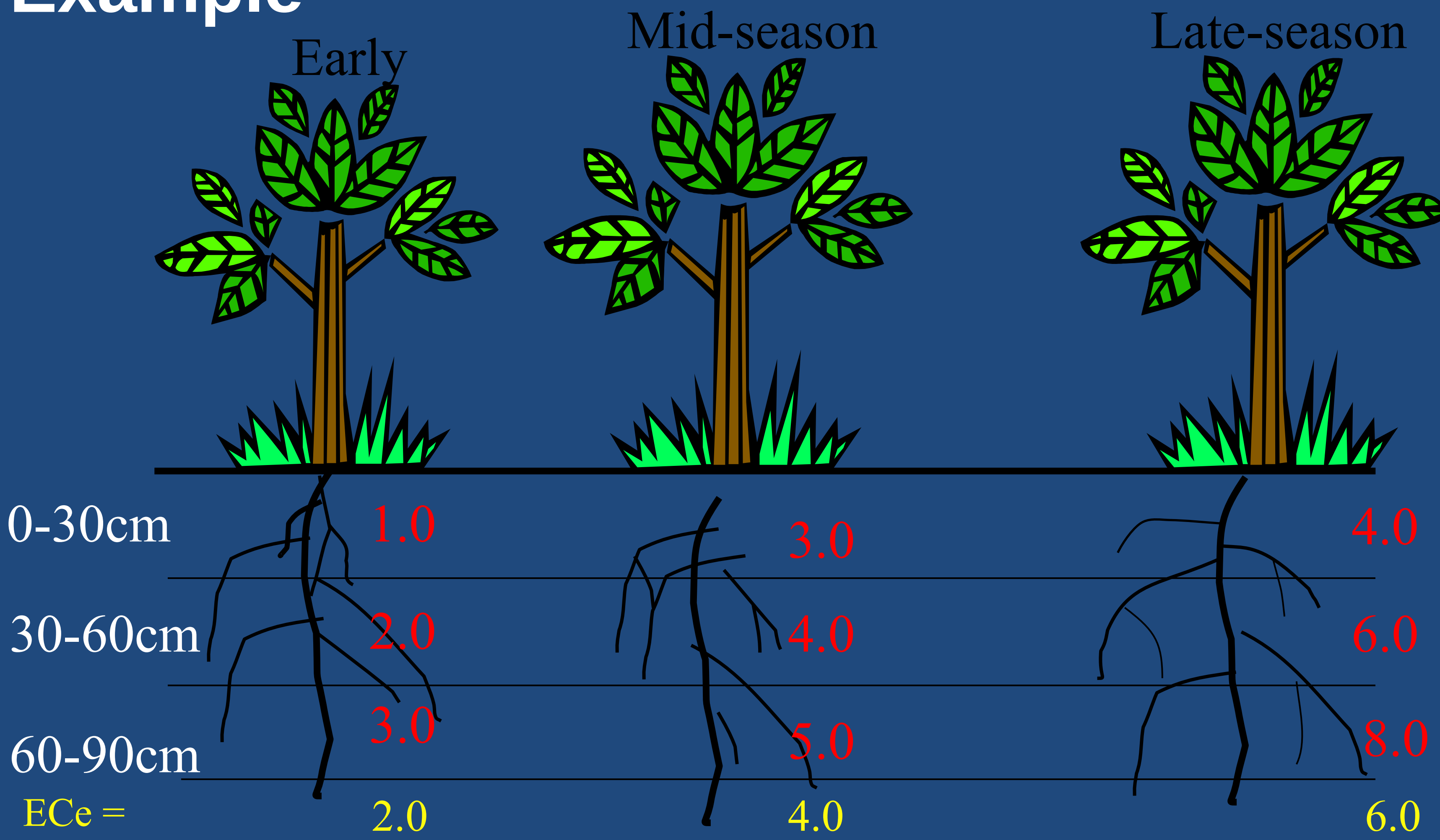
LF = ECdw/ECw x 100; Cldw/Clw,

# Salinity distribution in relation to various leaching fractions



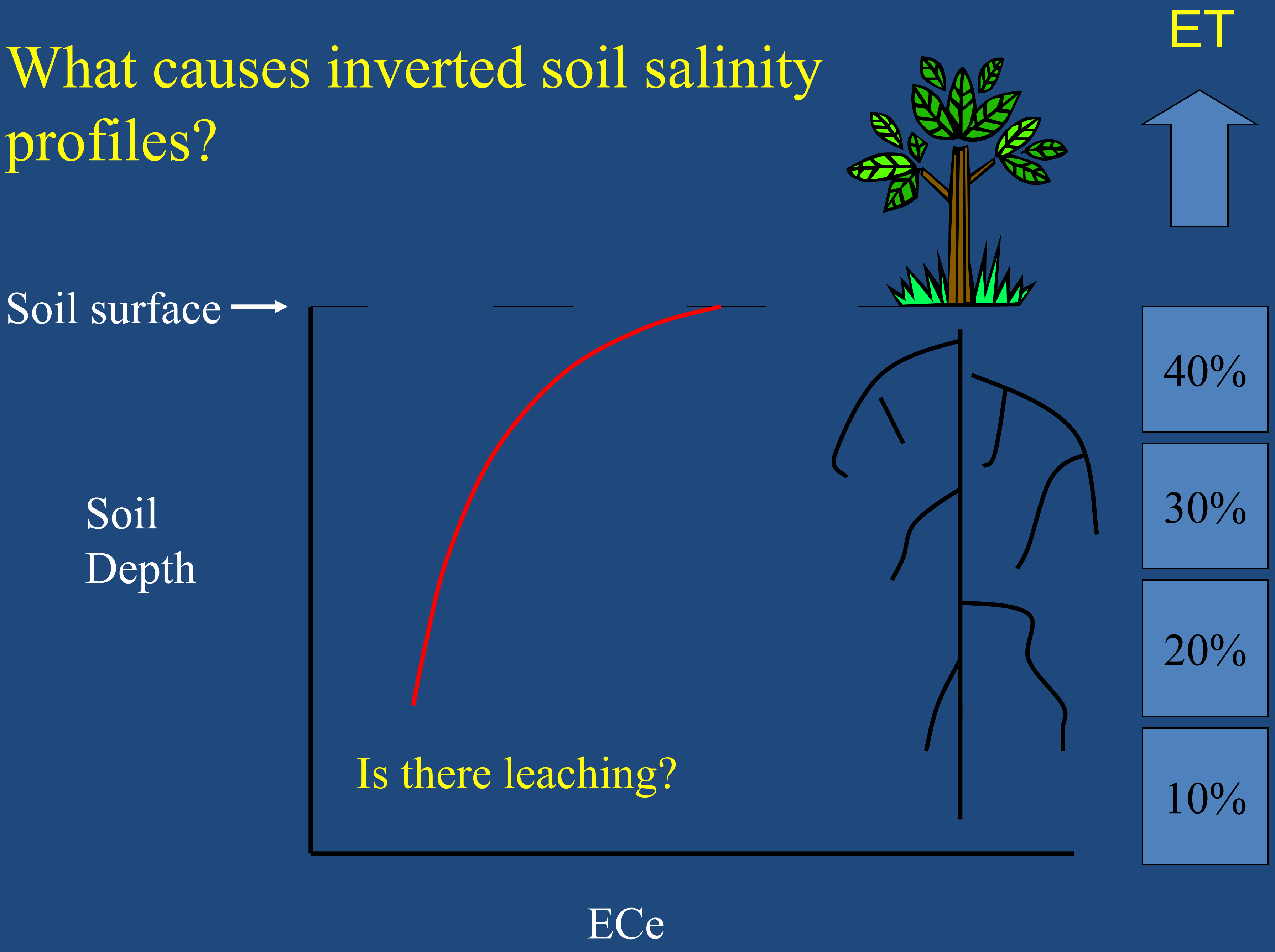
# Seasonal average rootzone salinity (ECe)

## Example

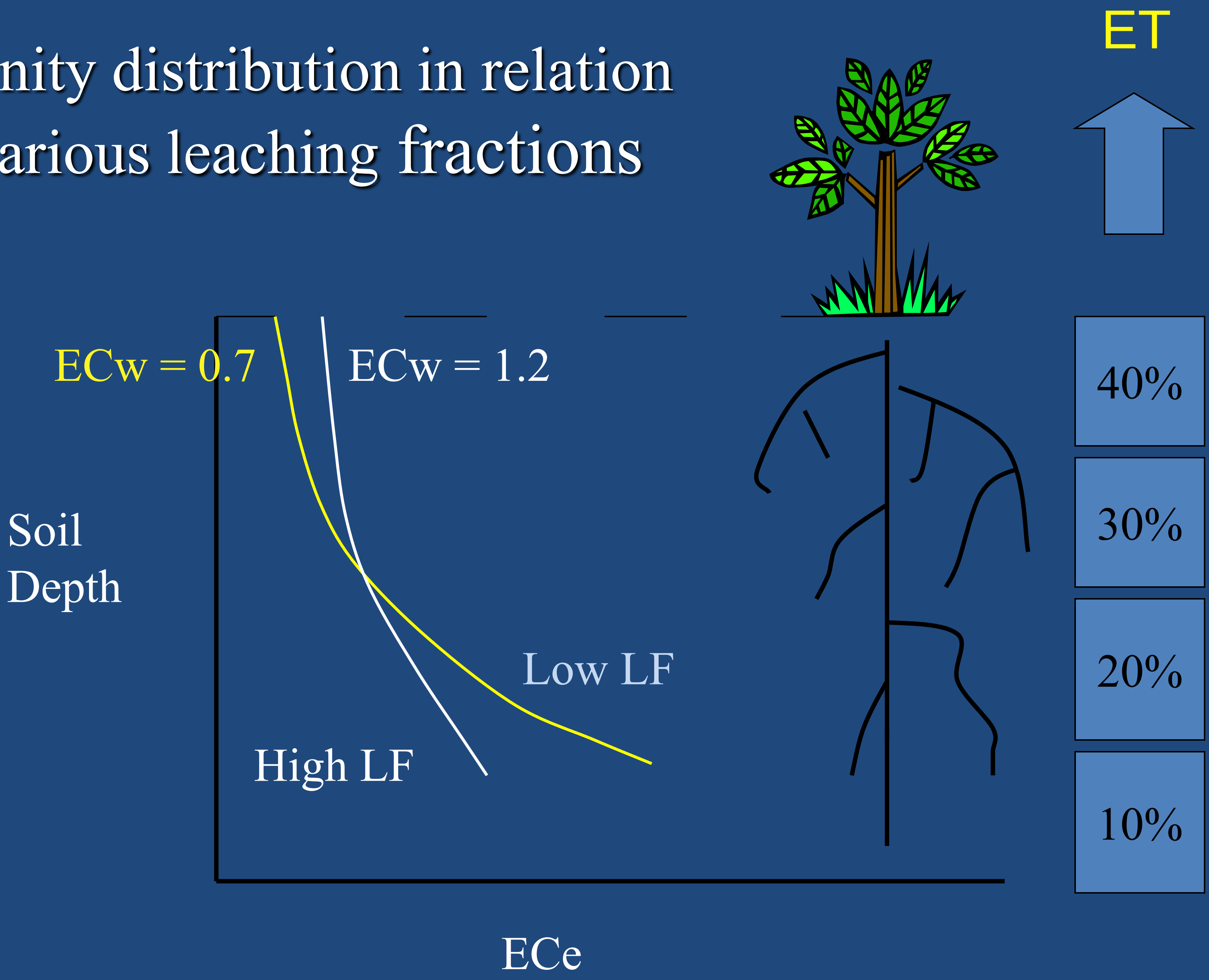


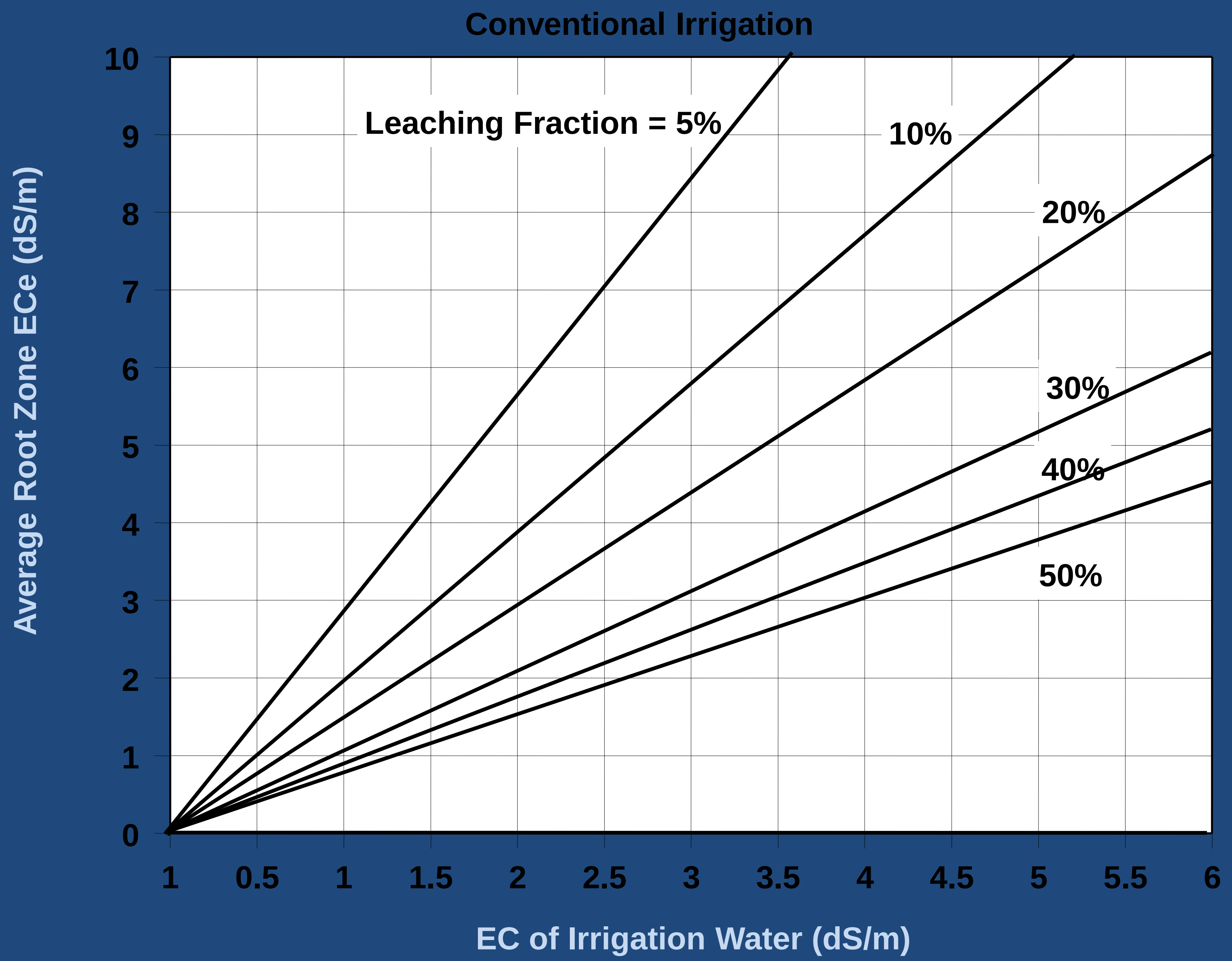

$\overline{ECe}$ = 2+4+6/3 = 4 dS/m  Season average

# What causes inverted soil salinity profiles?



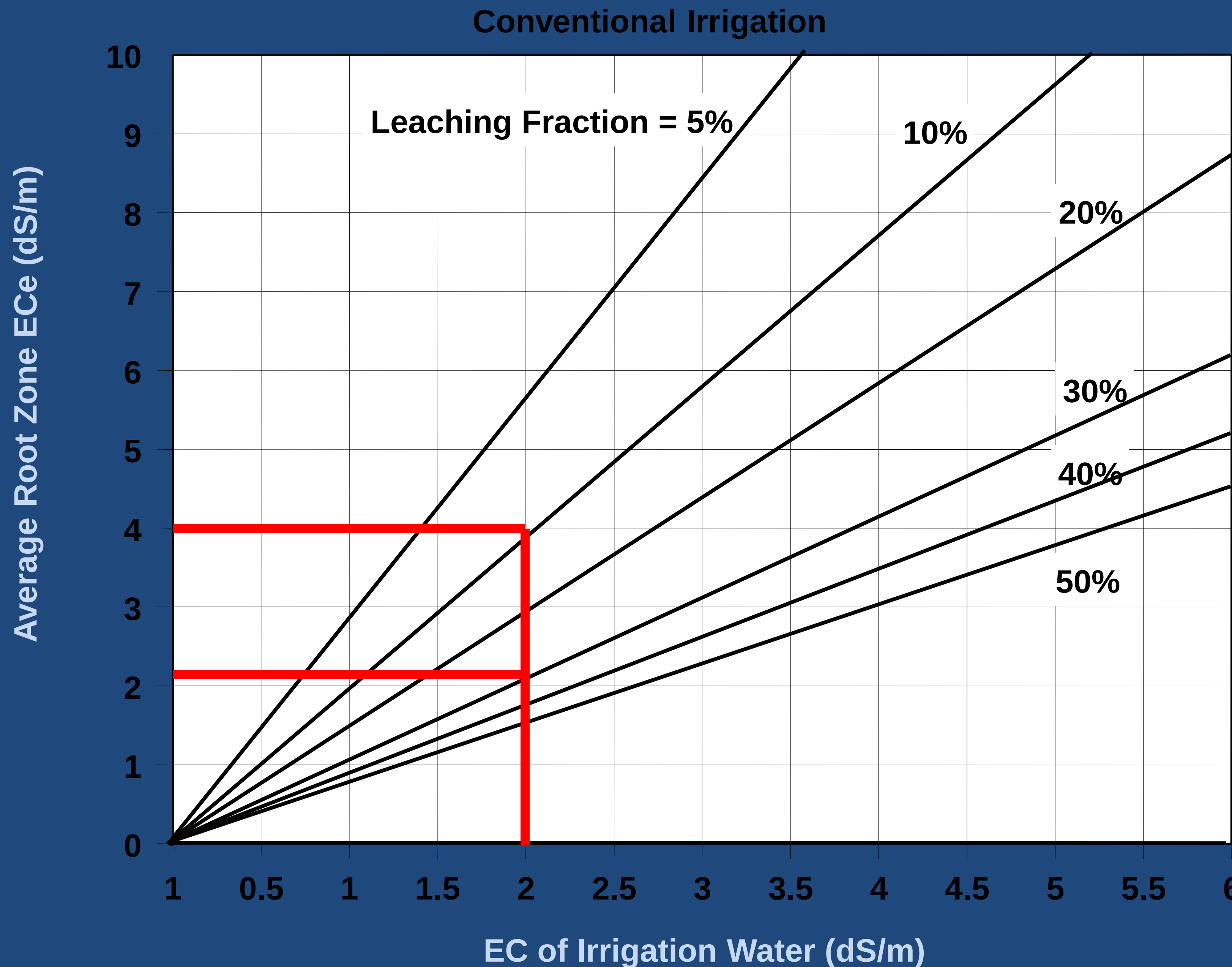
# Salinity distribution in relation to various leaching fractions



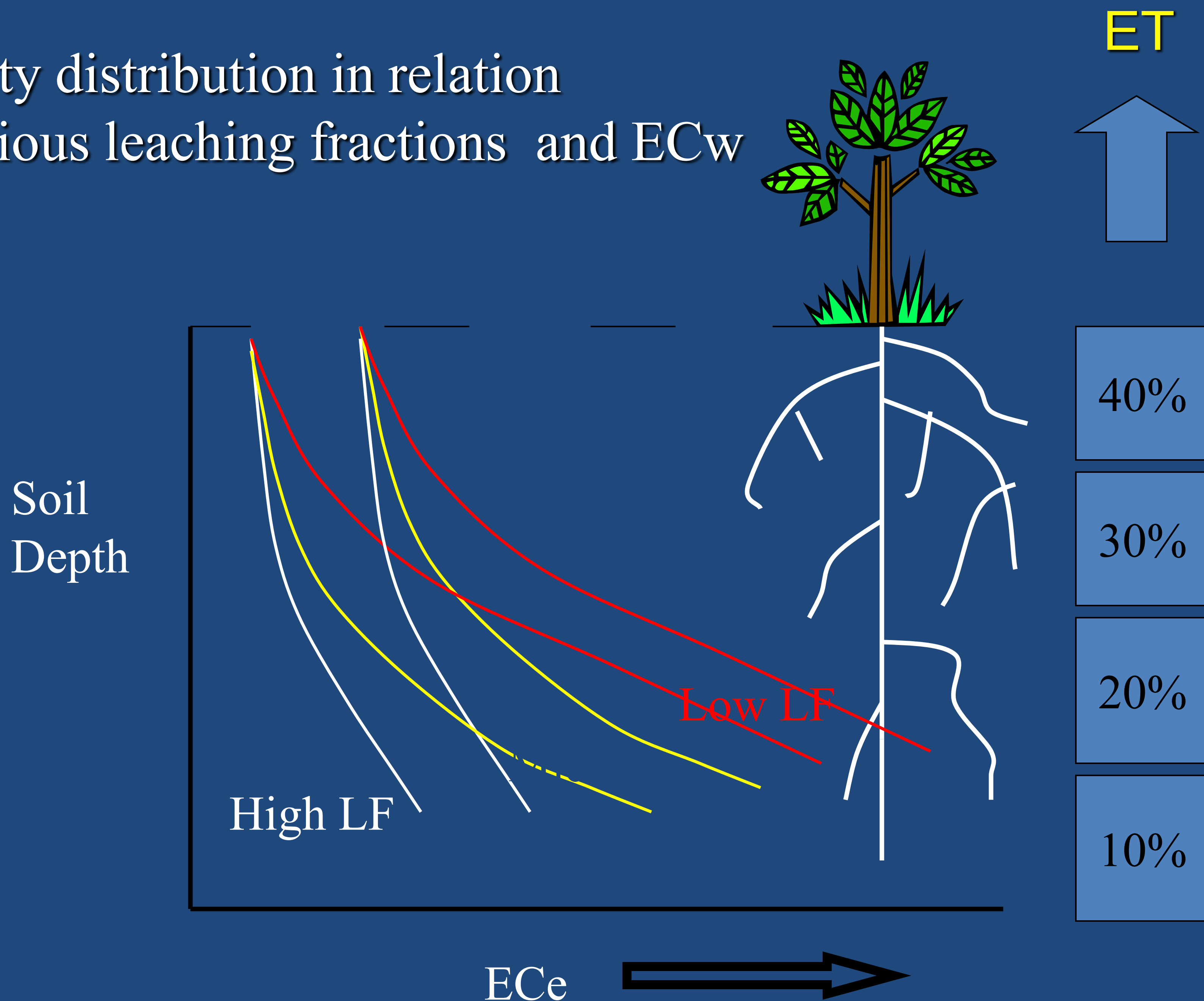


Conventional Irrigation
Leaching Fraction = 5%
10%
20%
30%
40%
50%
10
9
8
7
6
5
4
3
2
1
0
1
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
Average Root Zone ECe (dS/m)
EC of Irrigation Water (dS/m)

# What is ECe if ECw is 2.0 dS/m and the LF is either 40 or 10 %?



# Salinity distribution in relation to various leaching fractions and ECw

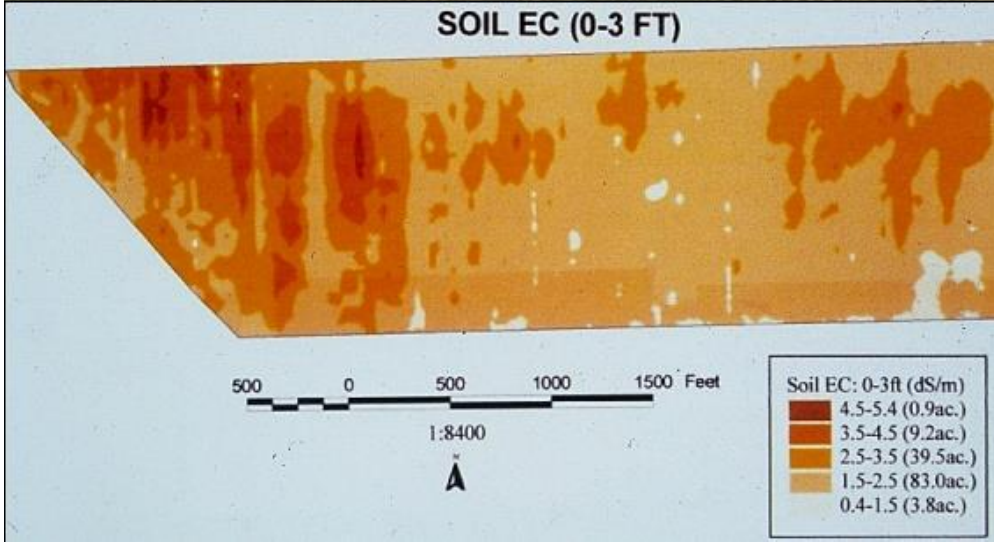


# Final Thoughts

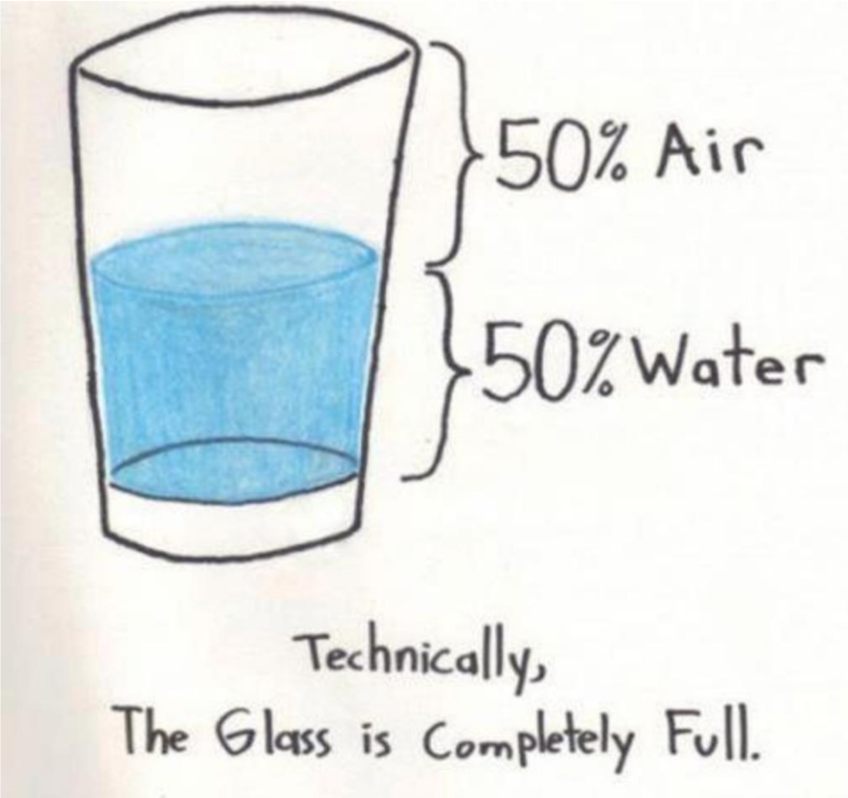
- **Know your system!**
  - Water quality options (well 1 vs. well 2)
  - Do you have recent soil and water data (adequate?)
  - What is your critical root zone? (alfalfa vs. forage)
- Do you have (get) a windfall in water?
  - Leaching with high quality irrigation water *can* erase years of salinity buildup.

# Final Thoughts

- Field variability
- Does your irrigation system accommodate your agronomic system needs?
  - System DU
  - Ability to be efficient **and** Ability to leach
- Know your water, soil, and utilize a leaching fraction



# Thank you!



# Well Water Analysis: Interpretation

| Sample | pH | Ecw (dS/m) | Ca (meq/L) | Mg | Na | HCO3 (meq/L) | SO4 | Cl | SAR | SARadj | B (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| High | 7.79 | 2.88 | 10.10 | 14.4 | 12.0 | 4.71 | 26.8 | 4.55 | 3.43 | 8.13 | 0.77 |
| | | | | | | | | | | | |
| UC | <7.0 | <1.1 | | | SAR | | | <4.0 | <3.0 | | <0.5 |

**Water is not ideal!**

| | Degree of Restriction | | |
|---|---|---|---|
| | None | Increasing | Severe |
| SAR | <3.0 | 3-9 | >9.0 |
| Chloride (meq/l) | <5 | 5-15 | >15 |

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

# Salinity distribution in relation to various leaching fractions and ECw