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Great Lakes Chapter

Toronto and Region Conservation for The Living City

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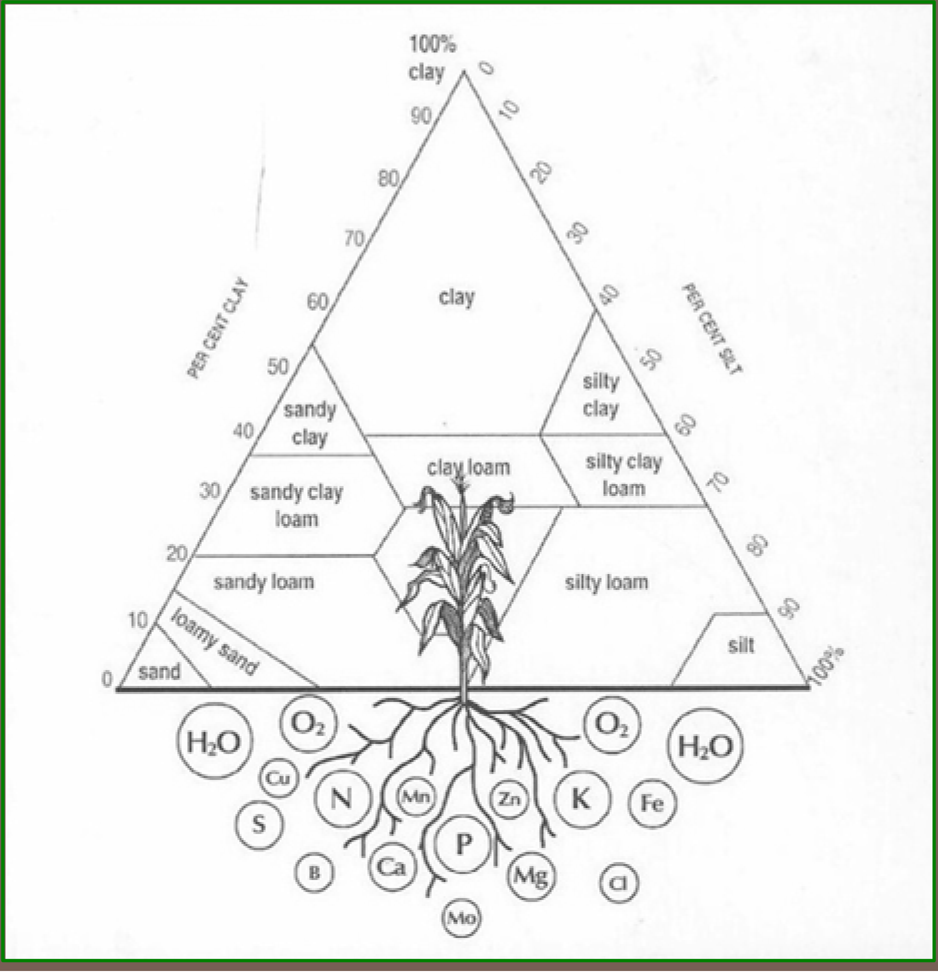
SOIL TESTING AS A KEY COMPONENT IN EROSION CONTROL PROJECTS



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VP – Business Development & Technical Services

Overview

Vegetation establishment is critical to erosion control success

- Soil tests
  - pH
  - Organic Matter
  - Cation Exchange Capacity
  - Salts and Soil Structure
    - Sodium Adsorption Ratio
    - Electrical Conductivity
- Soil sampling methodology

Benefits of a Soil Test

- Evaluate soil fertility
  - Measure soil's ability to supply essential elements
- Provide a basis for amendment recommendations
- Help ensure appropriate plant species selection
- Predict probability of desired outcome- optimal vegetation growth!

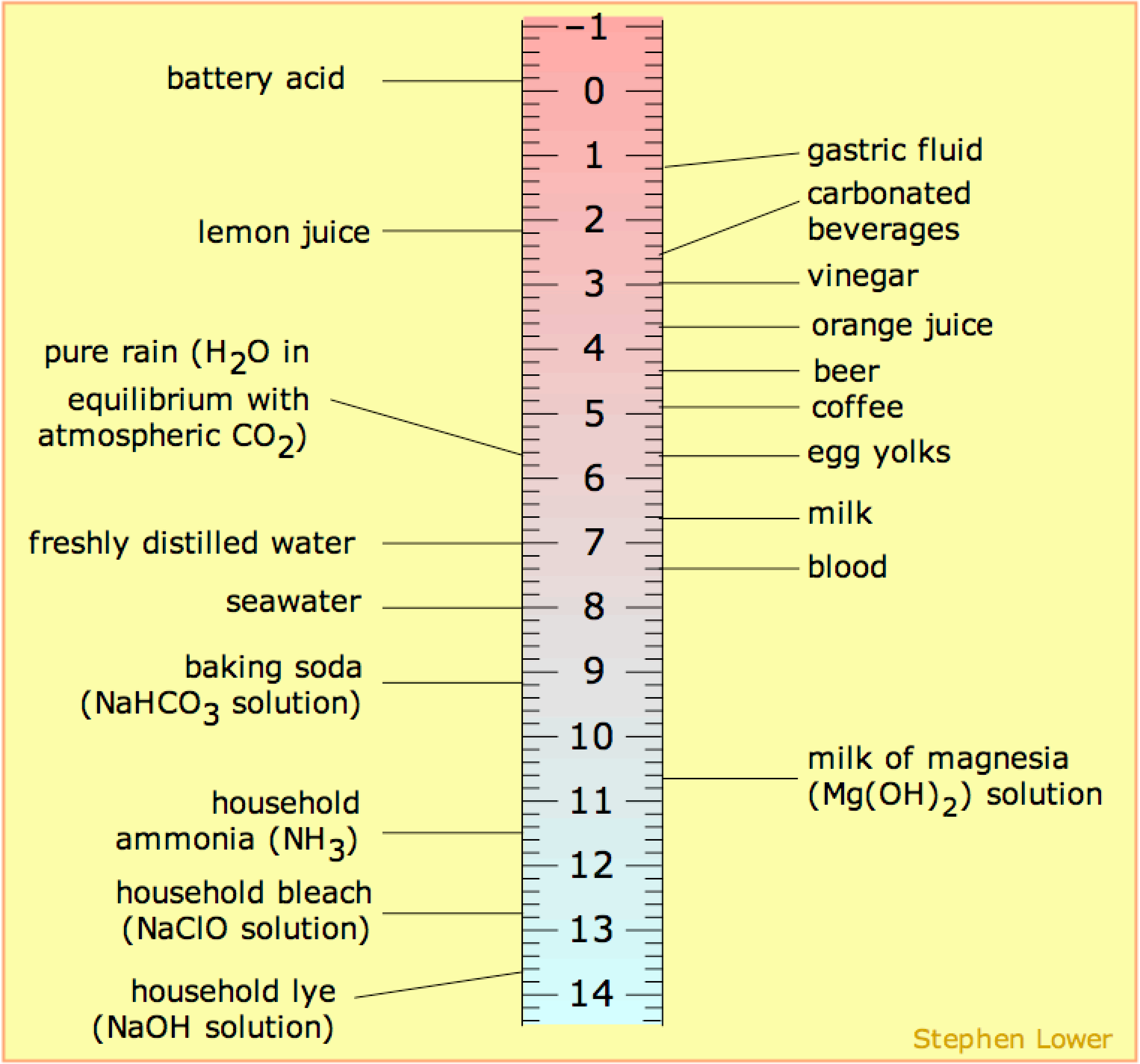
Soil Tests Based on Objectives

Test	Objective
Water, salt and buffer pH levels	Soil reaction and buffering requirement
Extractable elements:	
Major elements (P, K, Ca ,Mg, NO_3, SO_4)	Nutrient element availability
Macronutrients (B, Cl, Cu, Fe, Mo, Mn, Zn)	Nutrient element availability
Other elements (Al, Na)	Toxicity
Trace elements and heavy metals (As, Cd, Co, Cr, Cu, Mn, Pb, Ni)	Toxicity
Organic Matter Content	Physical and chemical characteristics
Soluble salts	Total salts in soil solution

What is pH?

- A small “p” is used in place of writing “– log10” and the “H” represents $[H^+]$, the concentration of hydrogen ions present in the soil solution
- pH measures the acidity or alkalinity of a solution
- pH of 7 is neutral
- Greater than 7 is basic
- Less than 7 acidic
- Each unit is 10 times that of the previous or next unit
  - A soil with a pH of 6 is 10 times more acidic than a soil with a pH of 7. A soil with a pH of 5 is 100 times more acidic than one with a pH of 7.

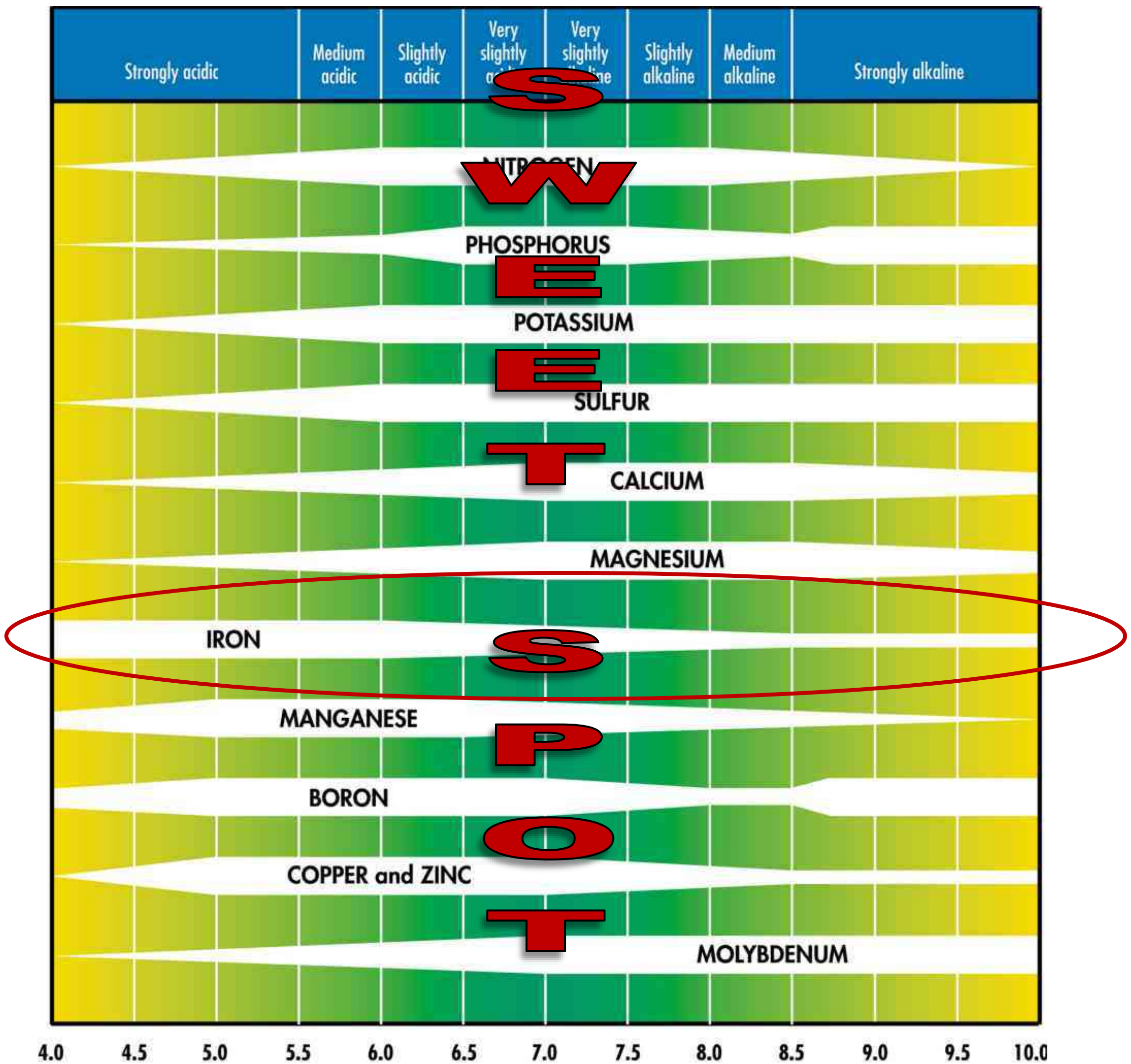
pH values of selected substances



pH

- As pH deviates farther away from neutral, either to the acidic or alkaline side, the less nutrients are available for plant uptake
- Stated another way, the farther pH deviates from neutral, the greater the potential for nutrients to be displaced and deposited into waterways

Nutrient Uptake

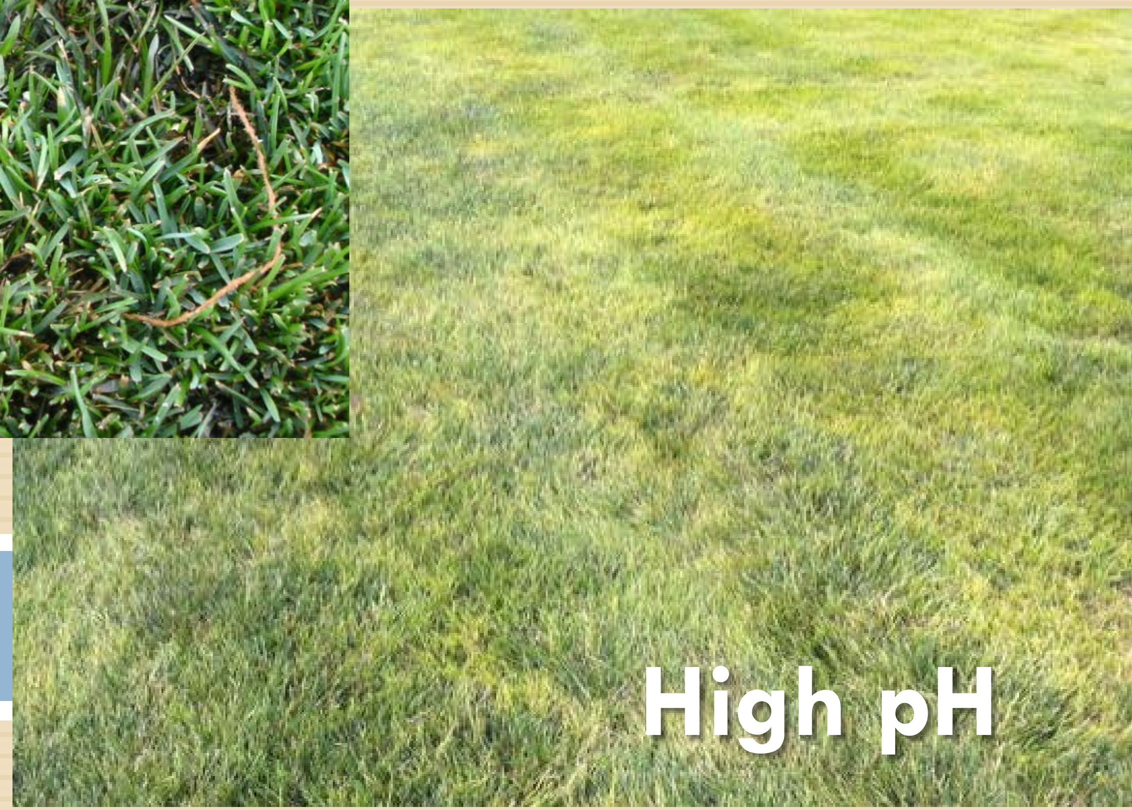


pH

Iron and Soil pH

- Micronutrient
- Essential for chlorophyll formation
- Availability decreases with increasing pH
- Insoluble in high pH

pH	Iron Concentration
7.5	3.5
7.0	35
6.5	350
6.3	1000



Finding the sweet spot with iron

Strongly Acidic Soils

- Calcium, Magnesium, Potassium uptake decreased
  - Less than 5.5
- Aluminum Toxicity-Root growth
  - Less than 5.0
- Manganese Toxicity – Plant Tissue
- Iron Toxicity– Stunted Growth

Turf Grass Species pH Tolerance

Species	Minimum pH	Maximum pH
Fescue	5.0	8.5
Bentgrass	5.0	7.5
Creeping Bentgrass	5.0	7.5
Bluegrass	5.0	8.4
Bermudagrass	5.0	8.0
Perrennial ryegrass	5.2	7.5

Soil pH and Buffer pH

- Soil pH
  - Measure of hydrogen ions in the soil solution
  - What the plant roots see
- Buffer pH
  - Ability of a soil to resist pH changes
- Neutralizer recommendation based on a soil's resistance to change

Buffer pH

- Clay and organic matter in the soil tend to hold on to the hydrogen ions
- Requires "effort" to raise the pH
- Two soils with the same active pH but vastly differing amounts of clay and/or organic matter would require vastly different amounts of lime to raise the pH
- Measured with a weak base that starts out at pH 8.0. Solution added to soils that have an "active" pH value of 5.8 or below. The more the solution decreases from pH of 8.0 the easier it will be to change the pH.

Benefits of Managing Acidic Soils

- Eliminates most major problems associated with acid soils
- Provides calcium and magnesium to the soil
- Phosphorus more available for plant growth
- Increases the availability of nitrogen by speeding up the decomposition of organic matter
- Liming materials are relatively inexpensive

Adding Lime

Adding Lime:

- Most efficient: Apply small amounts of lime every 1-2 years
- Typical: Add lime less often in large amounts
- With coarse lime granules change may require months, maybe longer
- Smaller granule lime will act within 7-10 days
- Combination of particles is best
- Maintenance applications required

Managing Acidic Soils

Raising the pH will:

- Improve the long-term fertility & vitality of soils
- Improve nutrient uptake by plants
- Stimulate germination & growth
- Help achieve denser vegetative cover
- ***Increase erosion control effectiveness!***

Basic Soils

- High pH can be an even bigger problem
- pH above 8.5 – plant has limited access to Nitrogen & Phosphorus
- pH of 10 – turf grasses can't survive
- Higher pH can make plants more susceptible to infection from pathogens

Managing Basic Soils

- Current State of Practice uses elemental sulfur
- Elemental sulfur or iron sulfate can be applied to lower pH
- Sulfur is added & converted to sulfuric acid by biological activity in soil
- Sulfur must be added separately from seed & allowed to react 2-4 weeks prior to planting
  - Fast acting proprietary amendments available

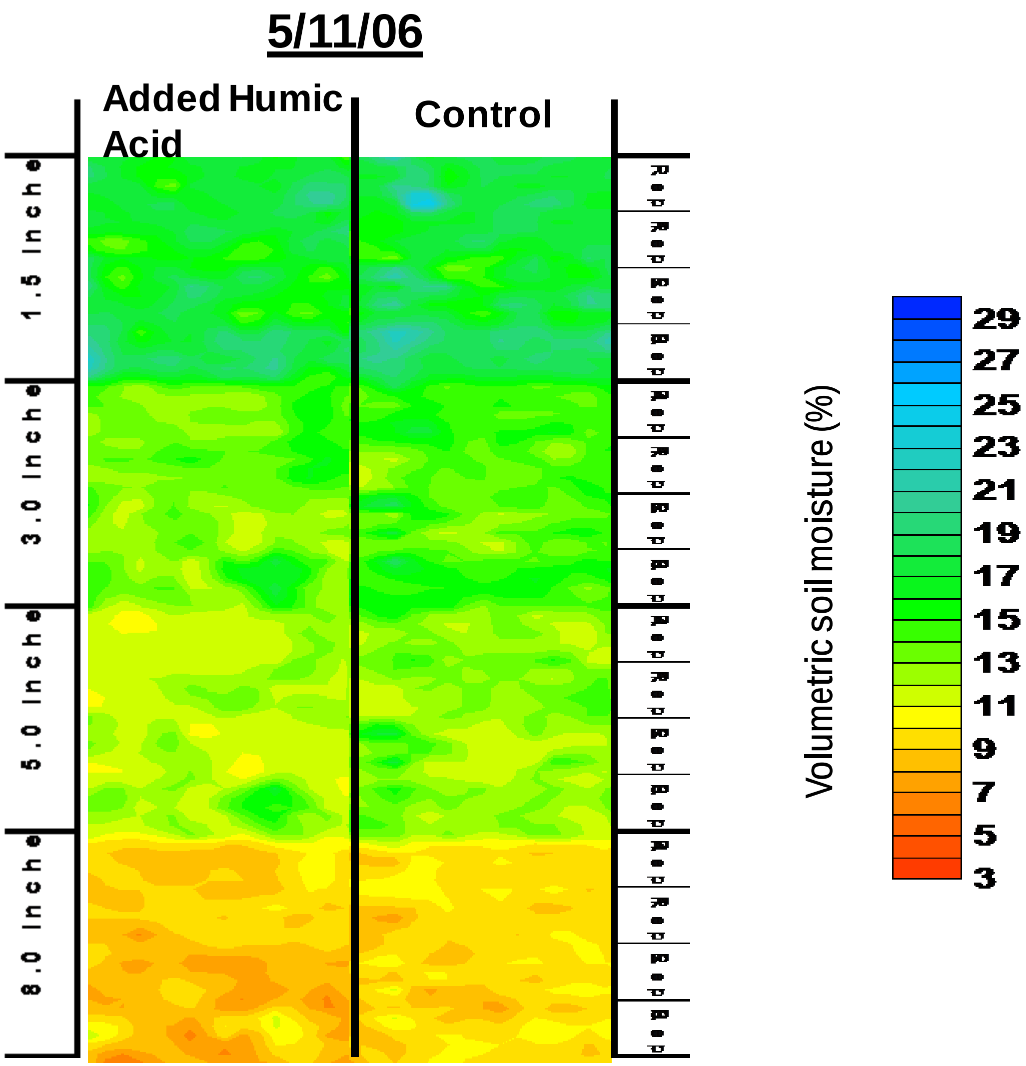
Organic Matter

- Soil organic matter is a complex and varied mixture of organic substances
- Soil organic matter, can be divided into two fractions:
  - The recognizable organic material
  - Humus
- For our purposes soil organic matter defined as the percent humus in the soil

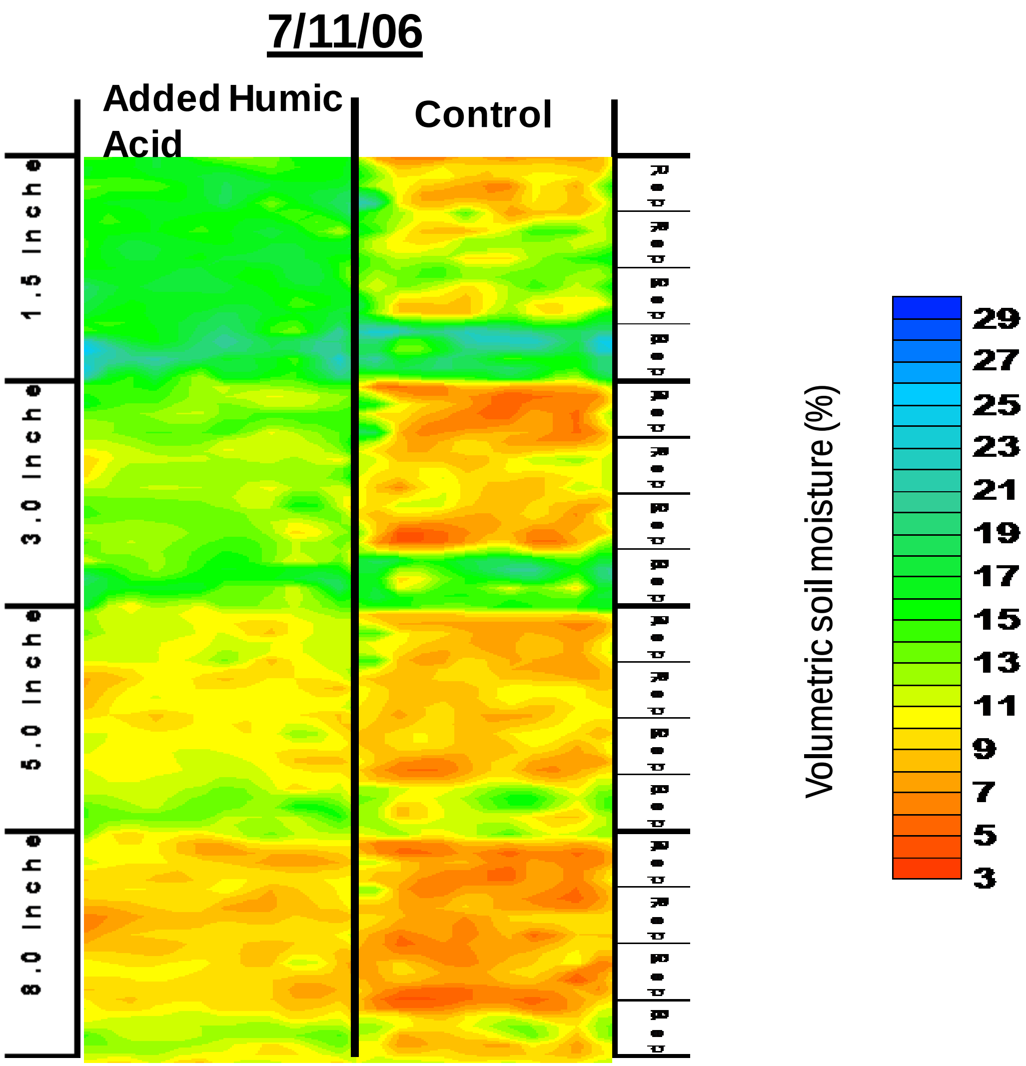
Humic Acid

- Helps break up clay and compacted soils
- Enhances water retention, reducing soil solution evaporation
- Improves root development and penetration through soil
- Improves transfer of macro & micro nutrients
- Stimulates the development of micro-flora populations

Average Soil Moisture at Increasing Depths

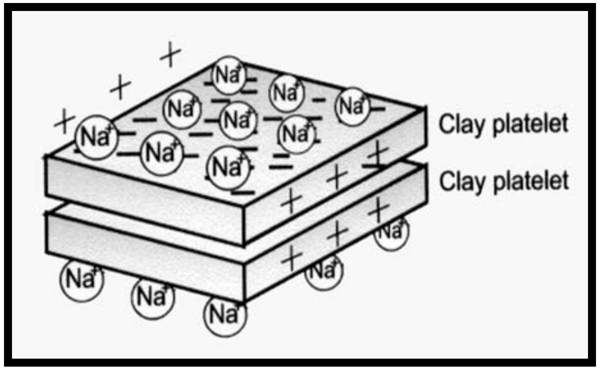


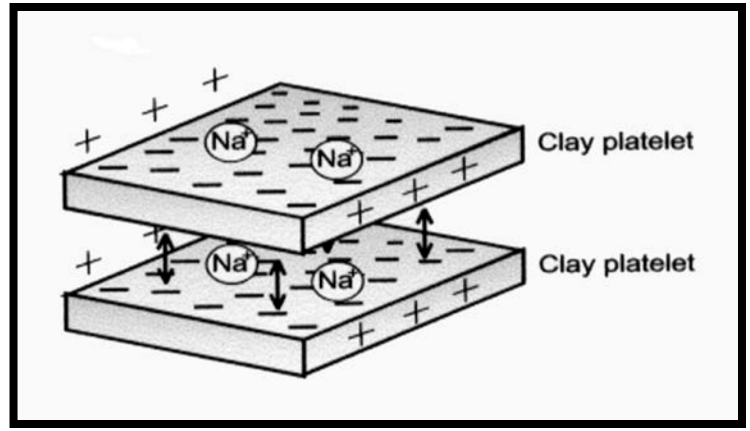
Average Soil Moisture at Increasing Depths - Early July, Drought Conditions

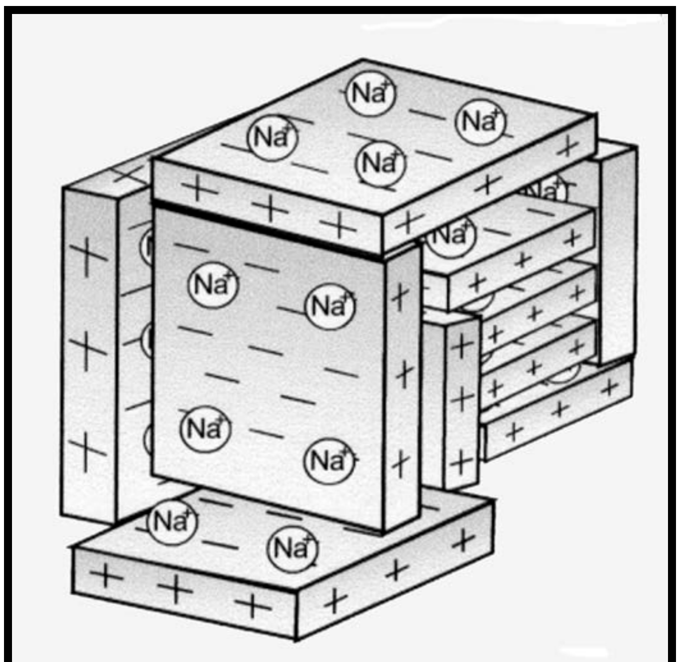


Cation Exchange Capacity

- Maximum quantity of total cations that a soil is capable of holding, at a given pH value, available for exchange with the soil solution
- Used as a measure of fertility, nutrient retention capacity, and the capacity to protect groundwater from cation contamination
- In general, the higher the CEC, the higher the soil fertility

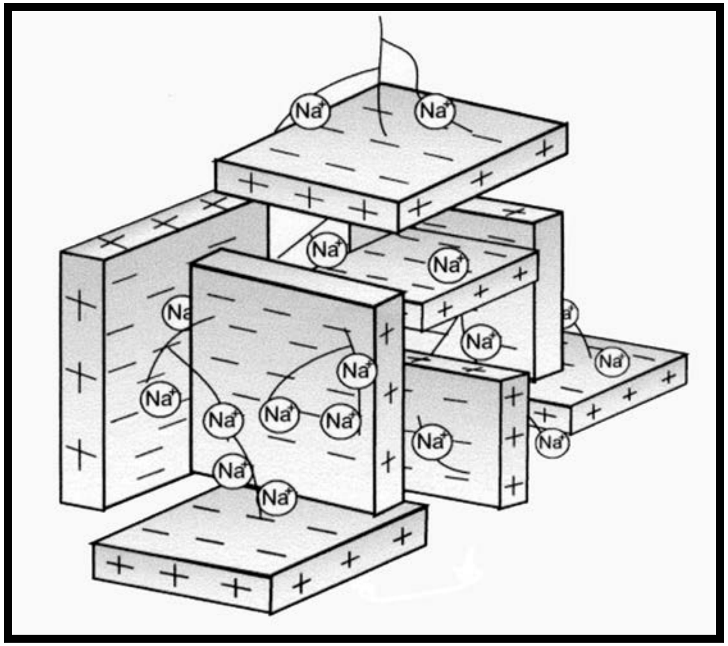






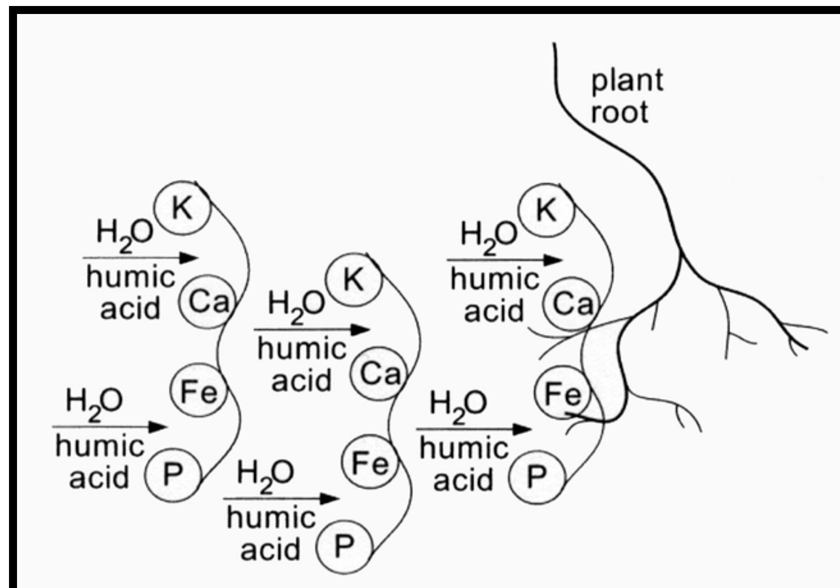
Clay Compaction

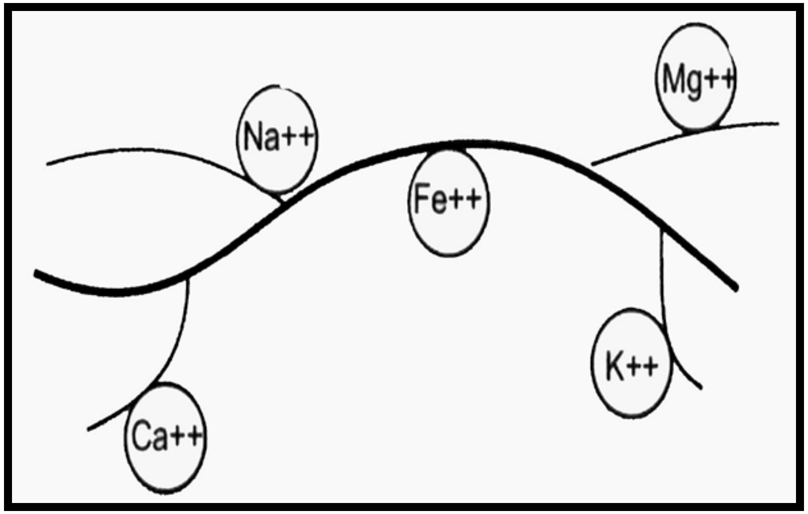
Soils with high clay content and salt overload cause the clay platelets to move even closer to each other.



Humic Acid encourages water penetration, as it penetrates the clay particle it segregates salts and removes them from the surface of the platelet. This action restores the negative charge to the clay platelet.

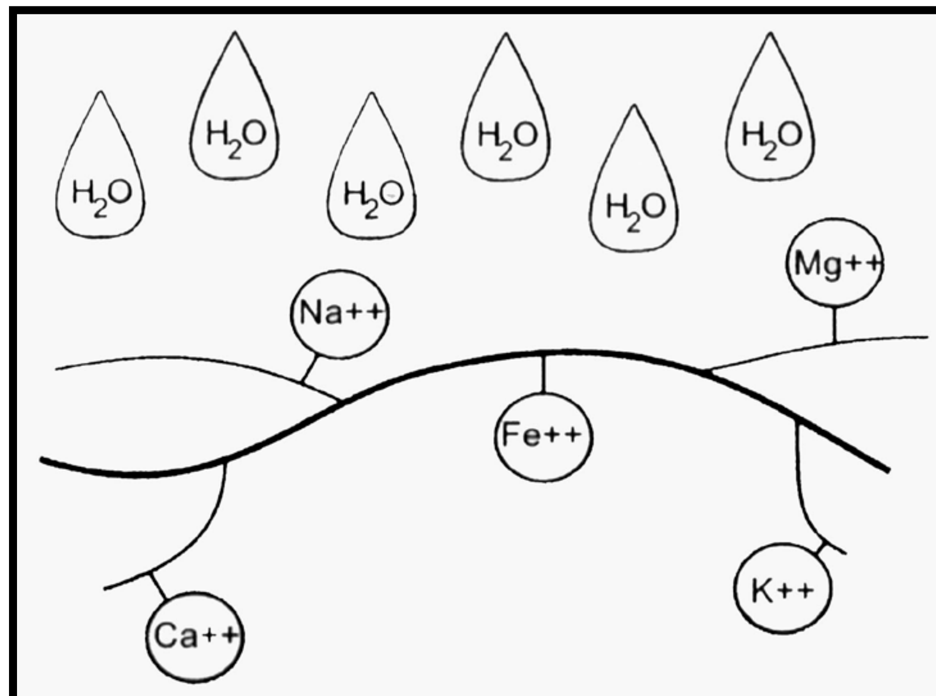
Soil solution containing macro & micro nutrients are bonded to the negatively charged humic acid molecule. Root hair has a stronger negative charge than that of humic acid, upon contact ion is absorbed by the root.





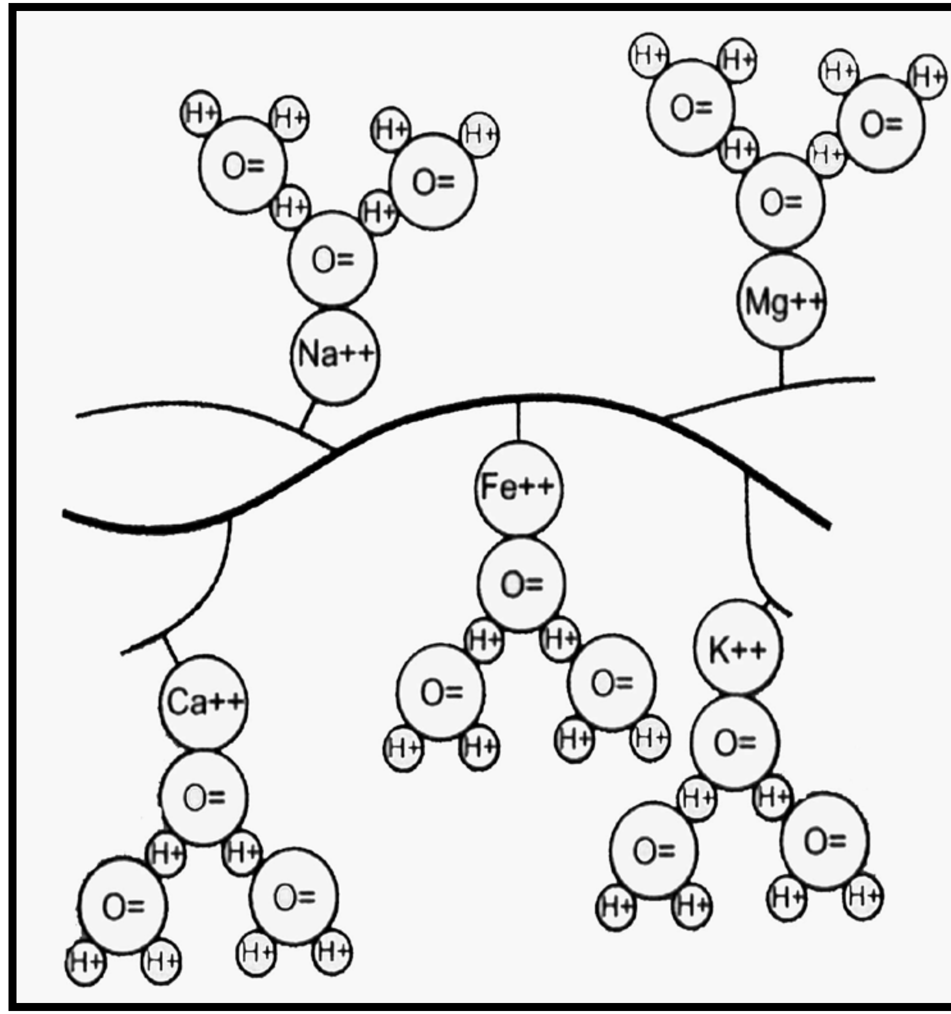
Cations and humic acid in contact with the root hair.

In water, the cations absorbed by humic acid partially ionize, moving slightly off the humic acid oxidation sites on the root restoring the ion's positive charge, attracting the oxygen end of water molecules.

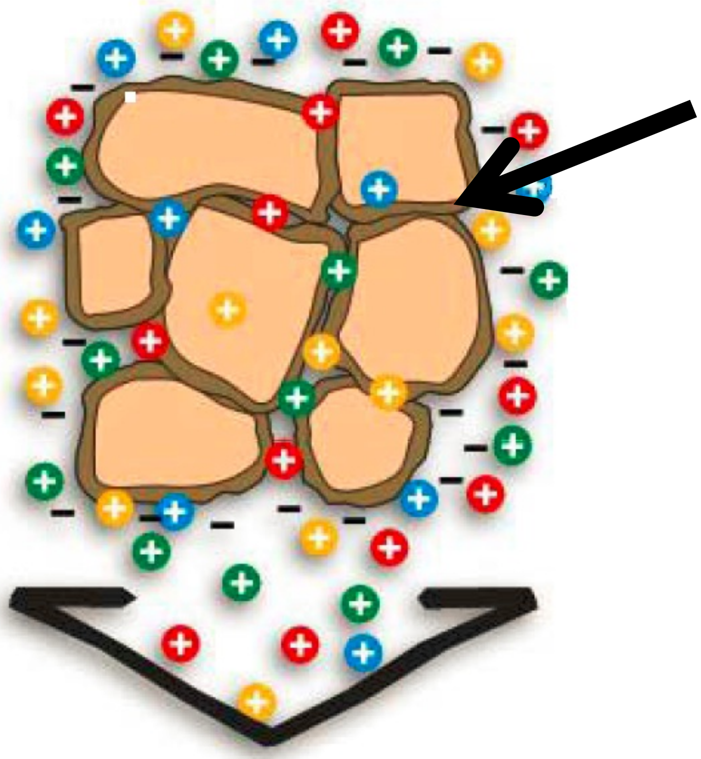


Water Sequestration

Water is dipolar, the end of the molecule containing the oxygen (neg) atom bonds to the ion. Hydrogen end of the molecule is now charged greater than the offsetting oxygen end. It attracts the negative end of the next water molecule, continues until attractive force dissipates, **reduces soil profile evaporation by up to 30%.**



Humic substances provide the Cation Exchange Capacity (CEC) that a Sand, Sandy Loam or Loamy Sand may lack.



Poor CEC
Low Humus

Good CEC
High Humus

Managing Organic Matter

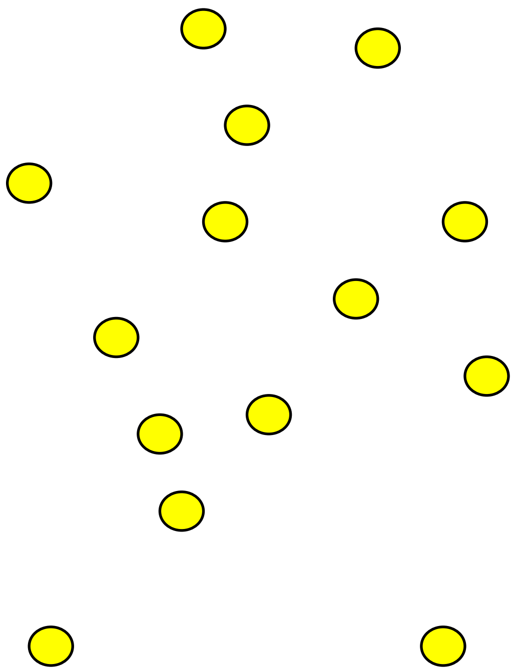
- The recognizable organic material
  - Long-term
- Humic acid and the bugs needed to generate more
  - Short-term

Salt Impacts

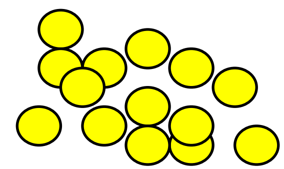
- Excessive salts and high levels of exchangeable sodium in the soil can be detrimental to plants
- Soils with too much exchangeable sodium are often highly compacted and have low permeability
- Hard, compressed soils are resistant to root penetration and water infiltration

Soil clay particles can be unattached to one another (*dispersed*) or clumped together (*flocculated*) in aggregates. Soil aggregates are cemented clusters of sand, silt, and clay particles.

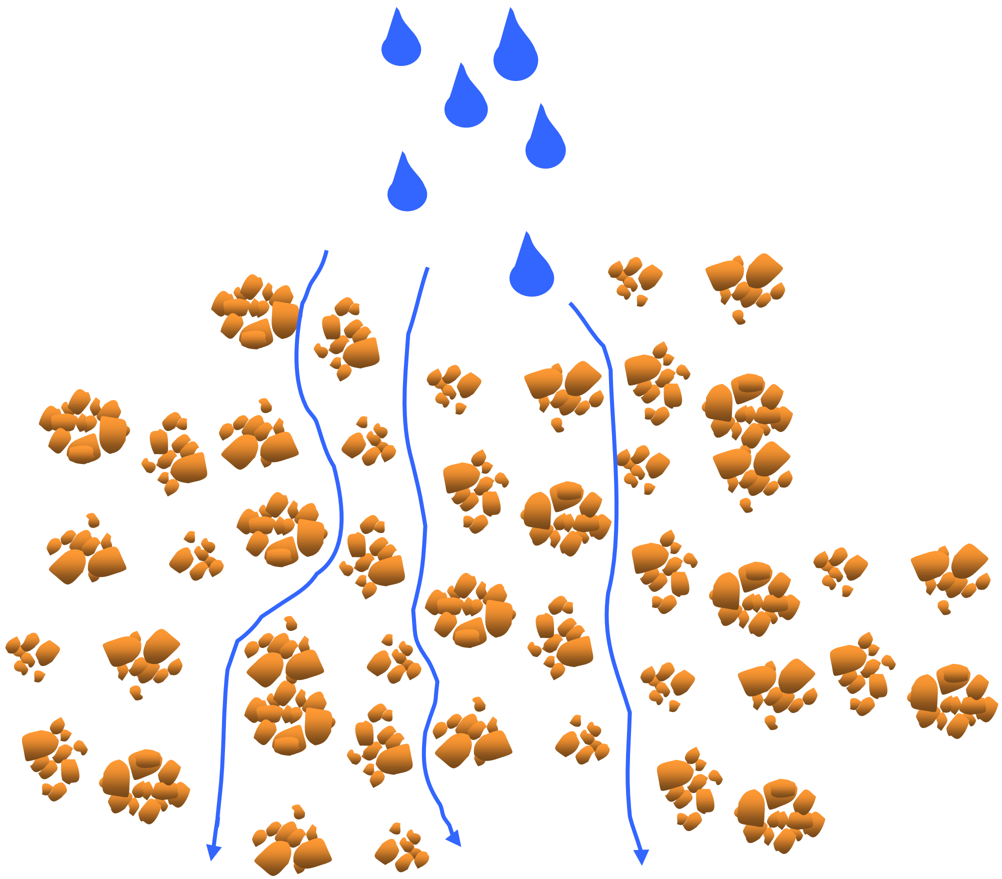
Dispersed Particles



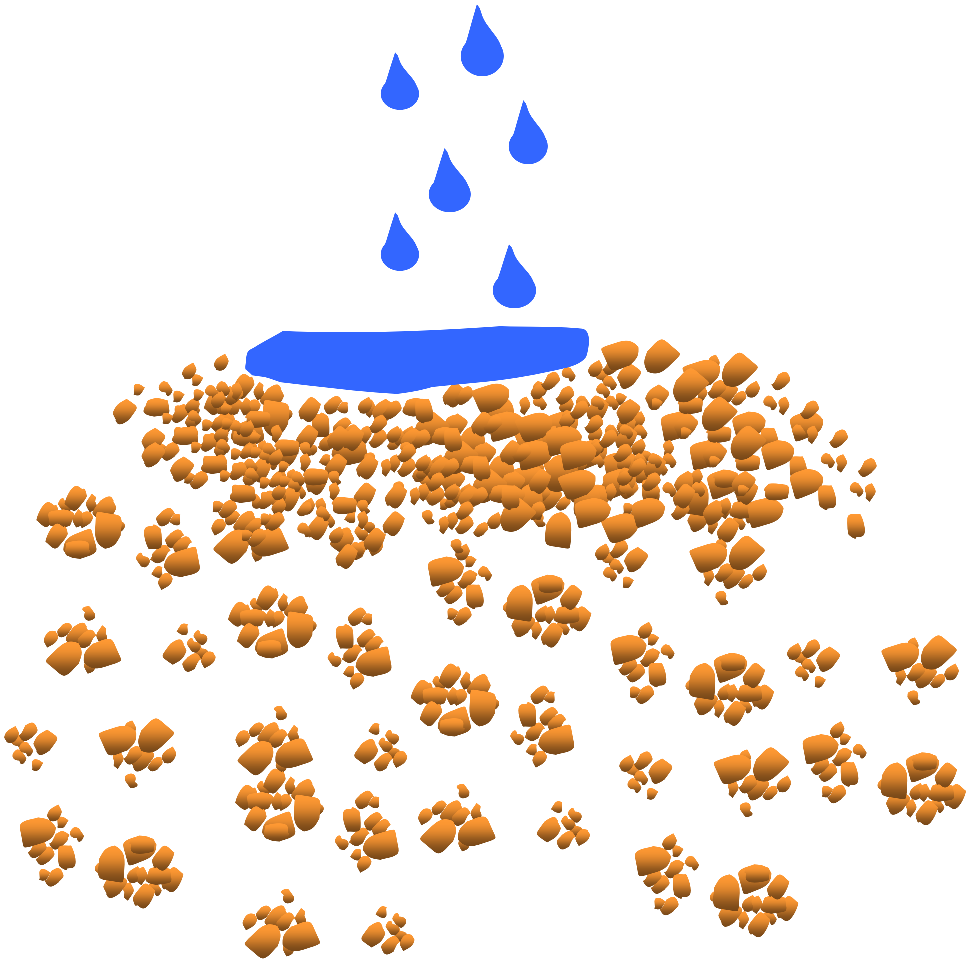
Flocculated Particles



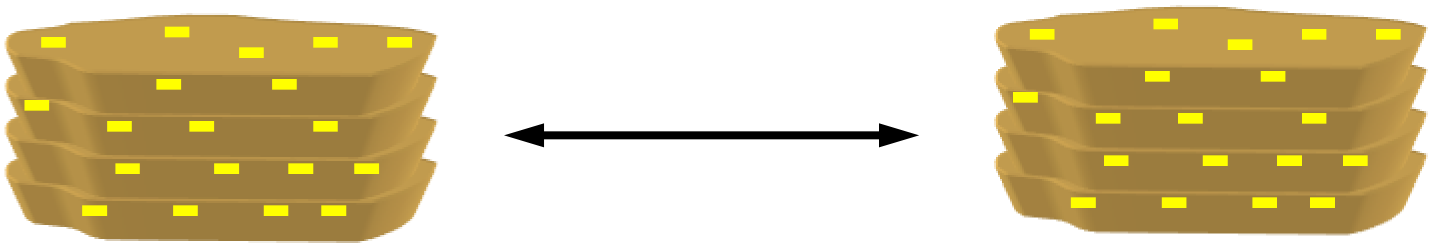
Flocculation is important because water moves mostly in large pores between aggregates. Also, plant roots grow mainly between aggregates.



In all but the sandiest soils, dispersed clays plug soil pores and impede water infiltration and soil drainage.



Most clay particles have a negative electrical charge. Like charges repel, so clay particles repel one another.

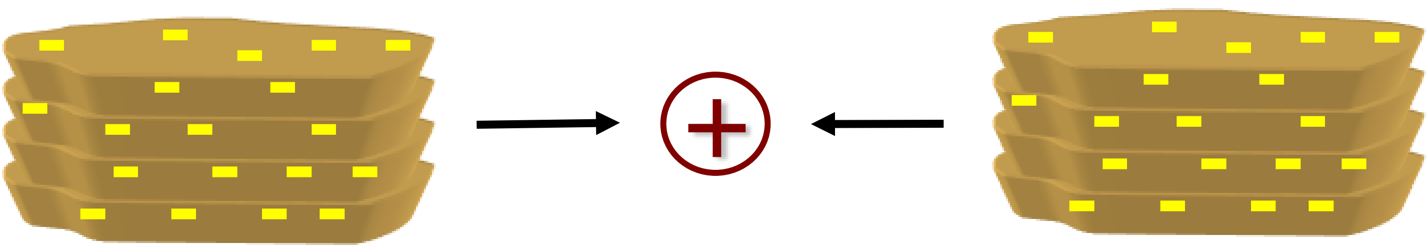


Negatively charged clay particle

Negatively charged clay particle

A cation is a positively charged molecule. Common soil cations include sodium (Na^+), potassium (K^+), magnesium (Mg^{2+}), and calcium (Ca^{2+})

Cations can make clay particles stick together (flocculate)



Negatively charged clay particle

Negatively charged clay particle

Flocculating Cations

- We can divide cations into two categories
  - Poor flocculators
    - Sodium
    - (Potassium)
  - Good flocculators
    - Calcium
    - Magnesium

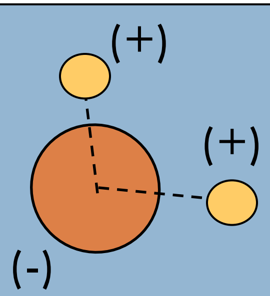
Ion		Relative Flocculating Power
Sodium	Na^{+}	1.0
Potassium	K^{+}	1.7
Magnesium	Mg^{2+}	27.0
Calcium	Ca^{2+}	43.0

Sumner and Naidu, 1998

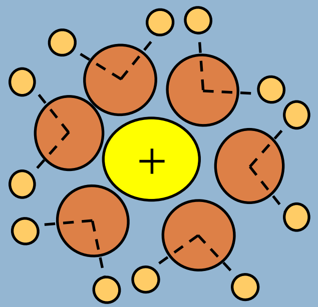
Flocculating Power of Cations

Cations in water attract water molecules because of their charge, and become hydrated.

Water molecule is polar: (+) on one end, (-) on the other end



Hydrated cation

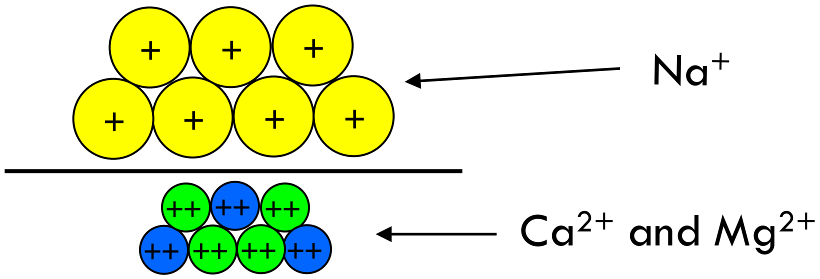


Cations with a single charge and large hydrated radii are the poorest flocculators.

Cation	Charges per molecule	Hydrated radius (nm)	Relative flocculating power
Sodium	1	0.79	1.0
Potassium	1	0.53	1.7
Magnesium	2	1.08	27.0
Calcium	2	0.96	43.0

Sodium Adsorption Ratio

The ratio of ‘bad’ to ‘good’ flocculators gives an indication of the relative status of these cations:



Mathematically, this is expressed as the ‘sodium adsorption ratio’ or SAR:

$$SAR = \frac{[Na^+]}{\sqrt{0.5\,[Ca^{2+}] + [Mg^{2+}]}}$$

where concentrations are expressed in mmoles/L

Electrical Conductivity

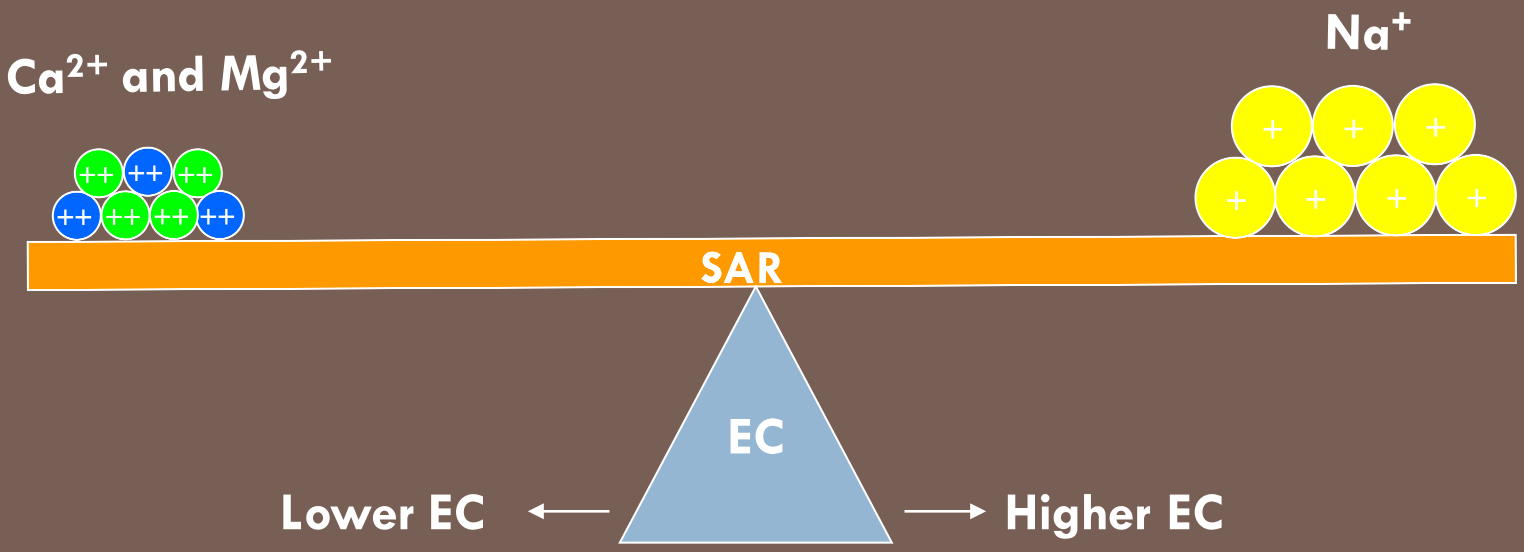
Ions in solution conduct electricity, so the total amount of soluble soil ions can be estimated by measuring the electrical conductivity (EC) of a soil water extract.

EC is measured in units of conductance over a known distance:

deci-Siemens per meter or dS/m

Soil with a high EC is salty; soil with a low EC is not.

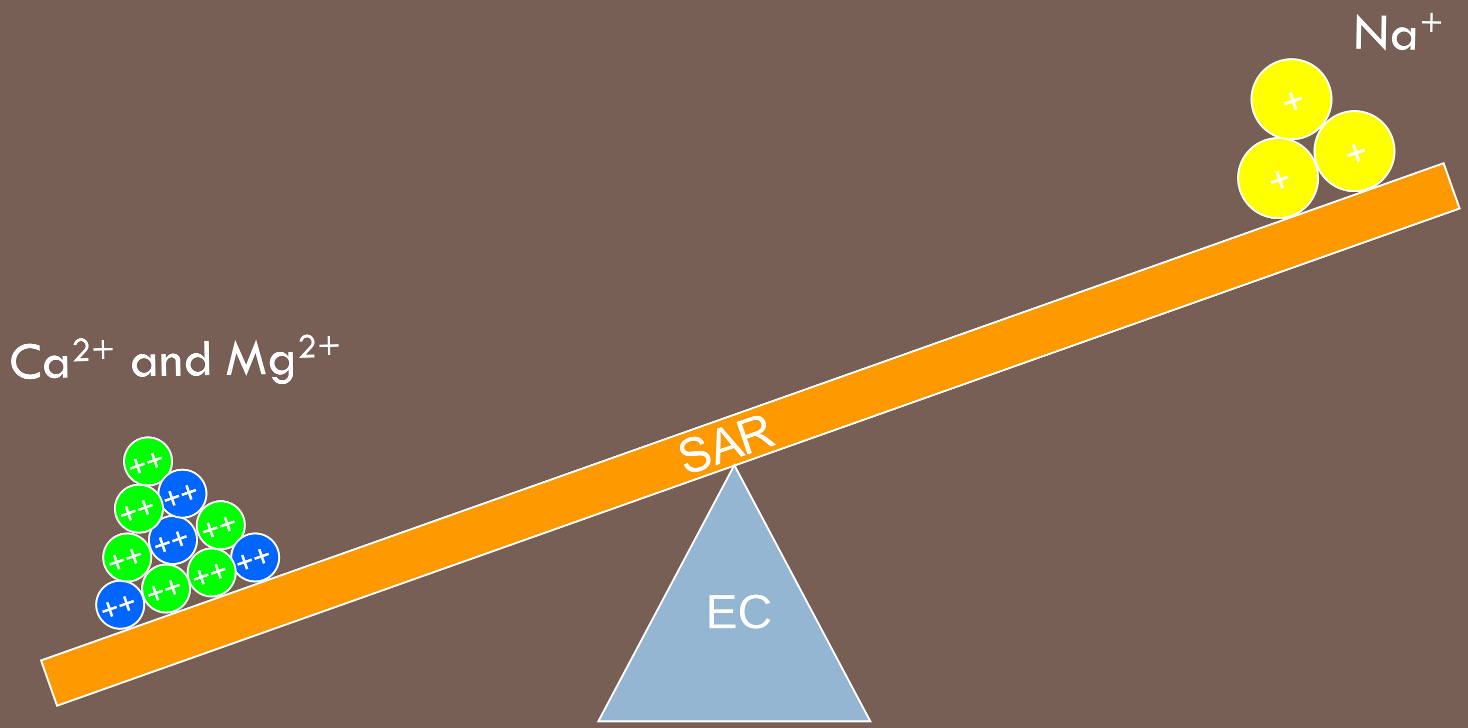
Aggregate stability (dispersion and flocculation) depends on the balance (SAR) between (Ca^{2+} and Mg^{2+}) and Na^{+} as well as the amount of soluble salts (EC)



Flocculated soil

Dispersed soil

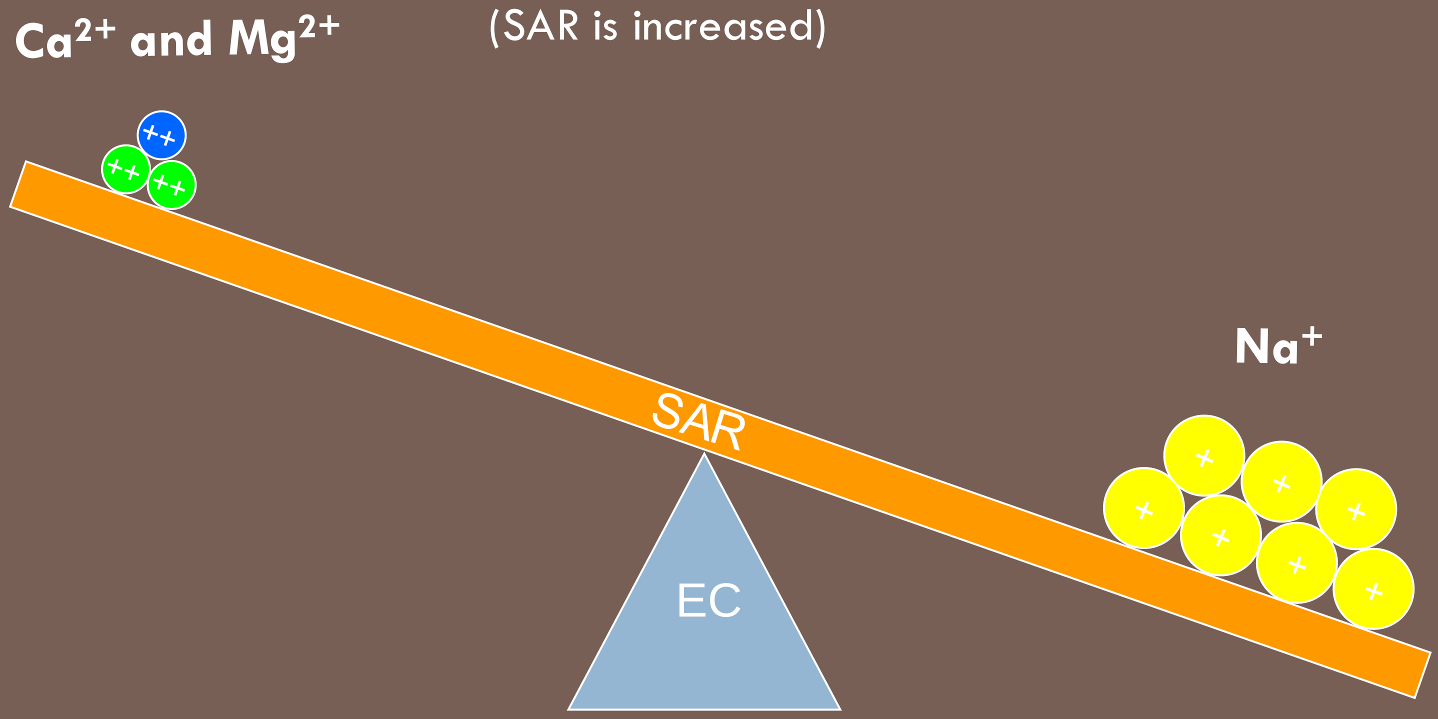
Soil particles will flocculate if concentrations of (Ca^{2+} + Mg^{2+}) are increased relative to the concentration of Na^+ (SAR is decreased)



Flocculated soil

Dispersed soil

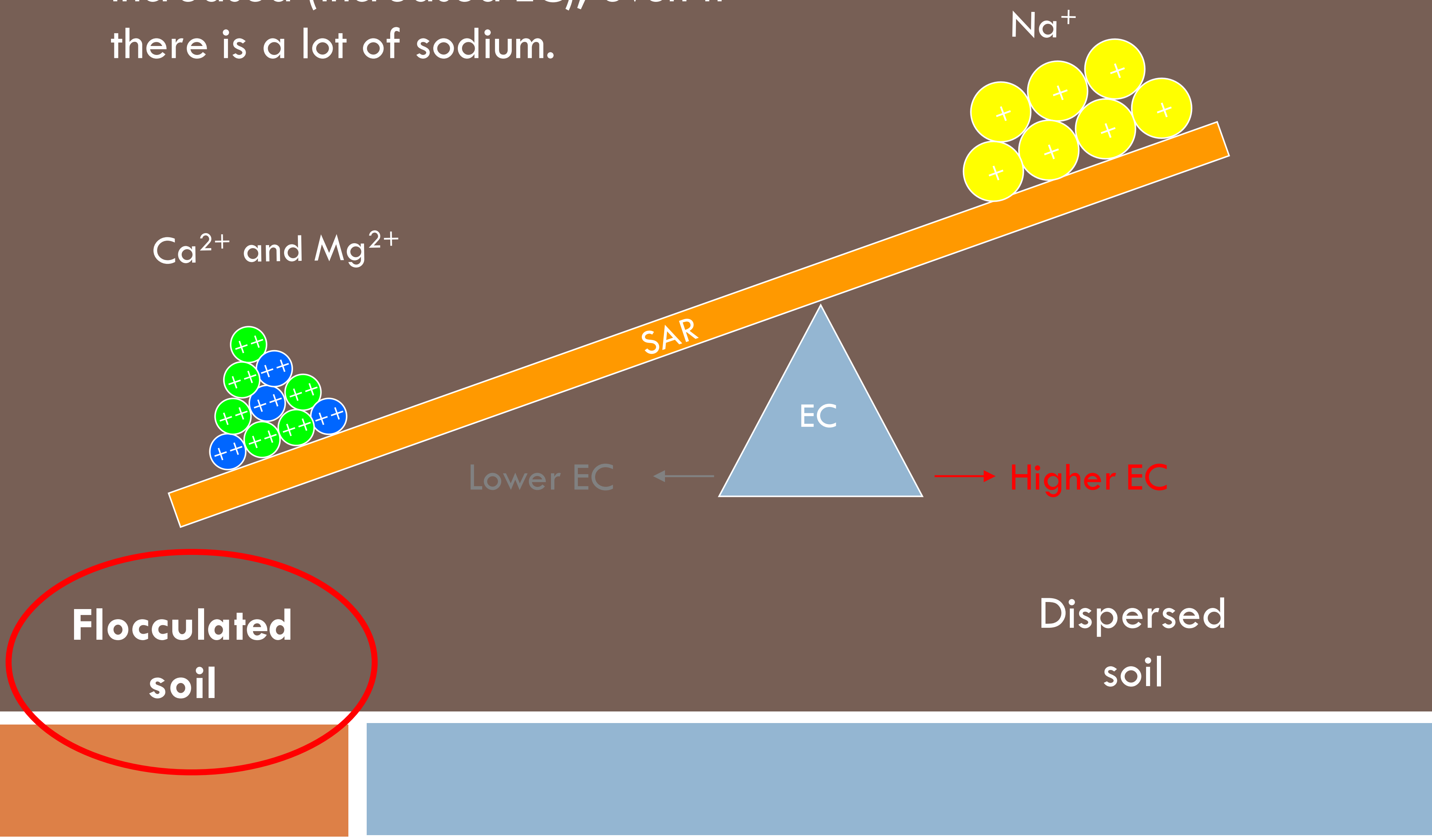
Soil particles will disperse if concentrations of (Ca^{2+} + Mg^{2+}) are decreased relative to the concentration of Na^+ (SAR is increased)



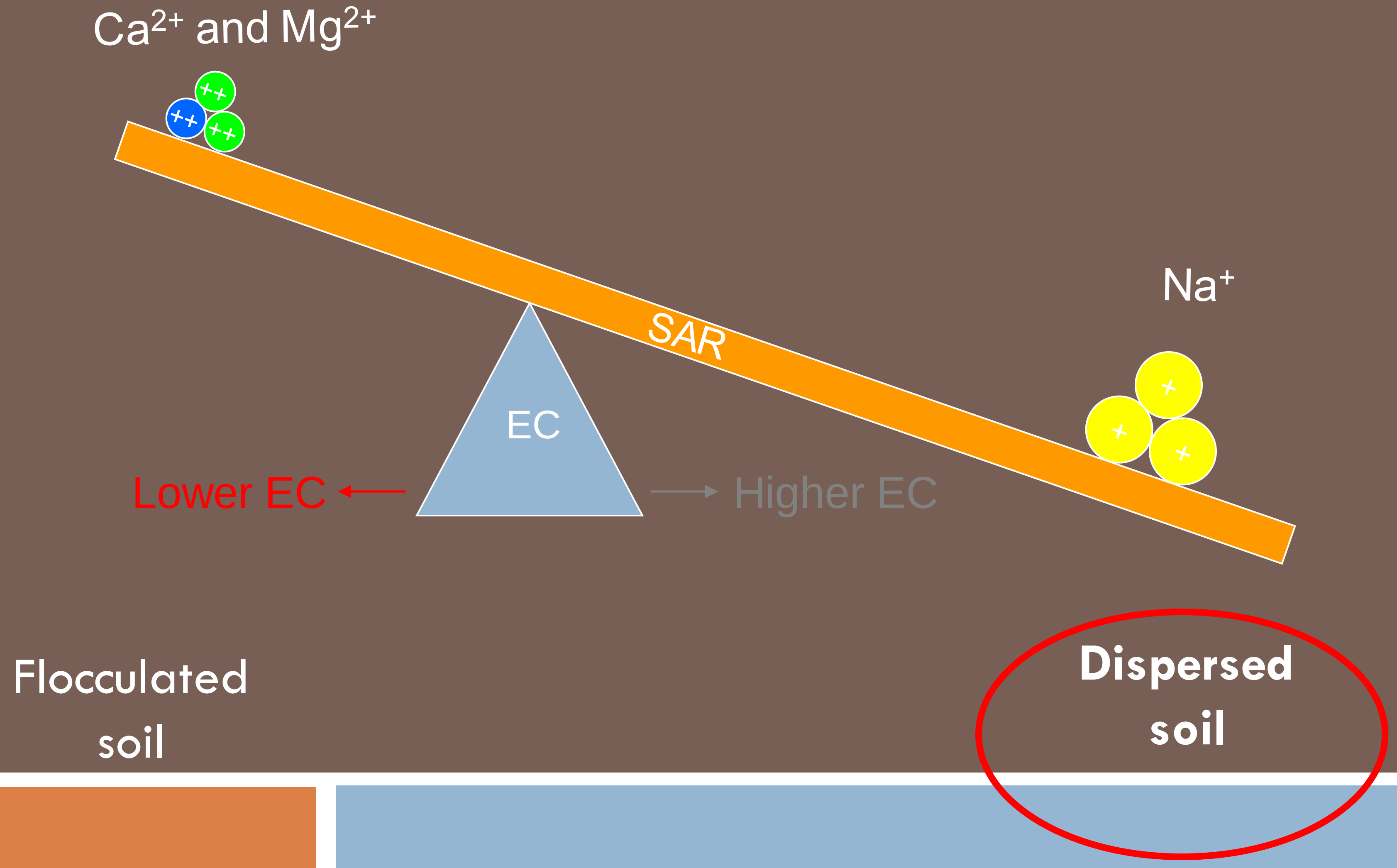
Flocculated soil

Dispersed soil

Soil particles will flocculate if the amount of soluble salts in the soil are increased (increased EC), even if there is a lot of sodium.



Soil particles may disperse if the amount of soluble salts in the soil is decreased (i.e. if EC is decreased)



Soils can be classified by the amount of soluble salts (EC) and sodium status (SAR). This classification can tell us something about soil structure.

Soil Classification	EC	SAR	Condition
Normal	<4	<13	Flocculated
Saline	>4	<13	Flocculated
Sodic	<4	>13	Dispersed
Saline-Sodic	>4	>13	Flocculated

Dispersed Soil

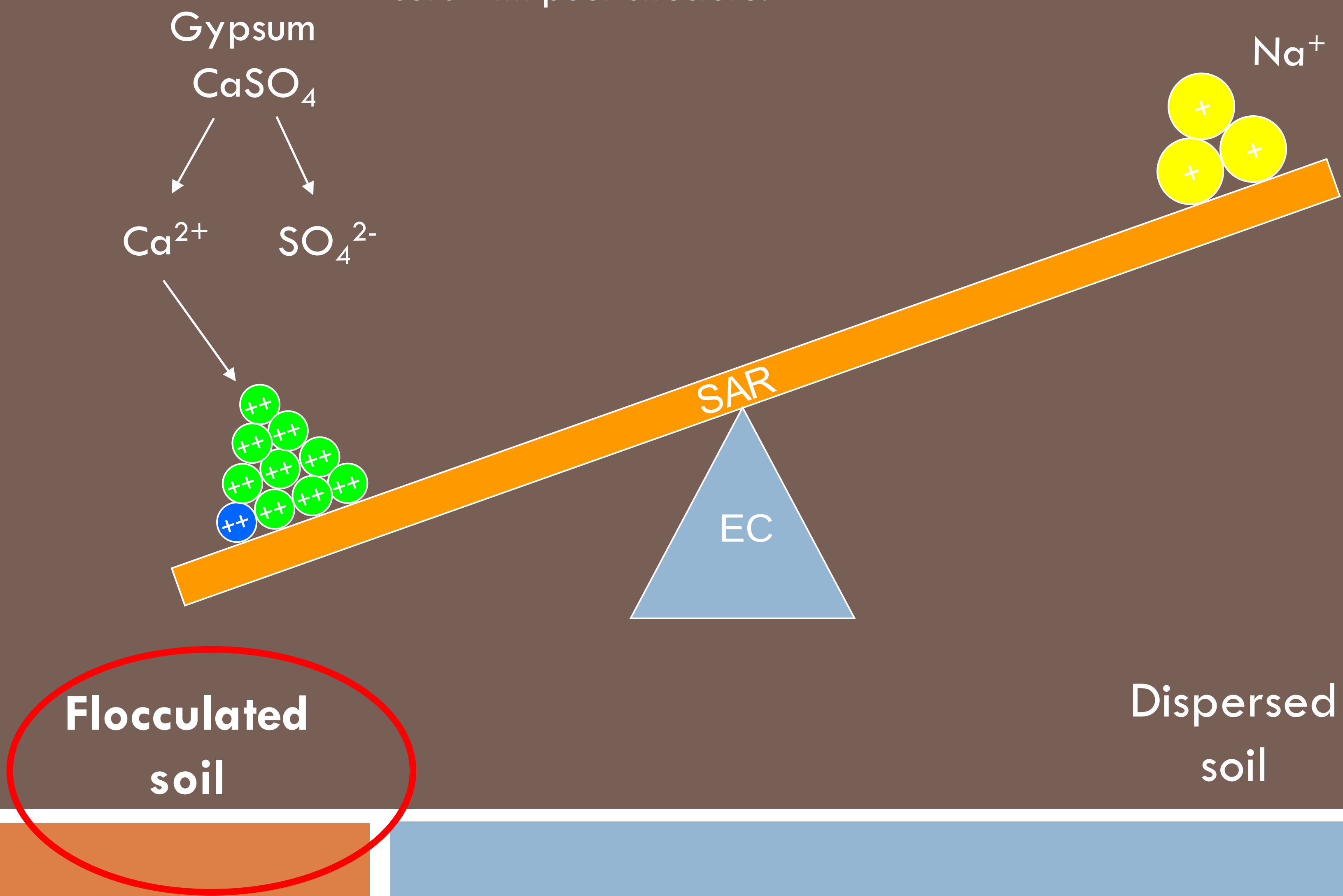
- Crack when dry
- Seal when wet, suffocate and rot roots
- Inhibit water from percolating
- Hard to dig in
- Hard when dry, sticky when wet

Observe your soil - sodic soils often crack when dry

Manage Soil Structure

- Observe your soil.
  - If water infiltrates very slowly, or if rain water infiltrates more slowly than irrigation water, the soil may have a sodium problem.
  - Sodium impacted soils may noticeably crack when dry.
- Analyze your soil.
  - Laboratory analysis can tell you the soil EC and SAR.
  - Amendments may be required to replace sodium or dissolve calcium carbonate on calcareous soils

Increasing *soluble* calcium improves aggregate stability in soils with poor structure.

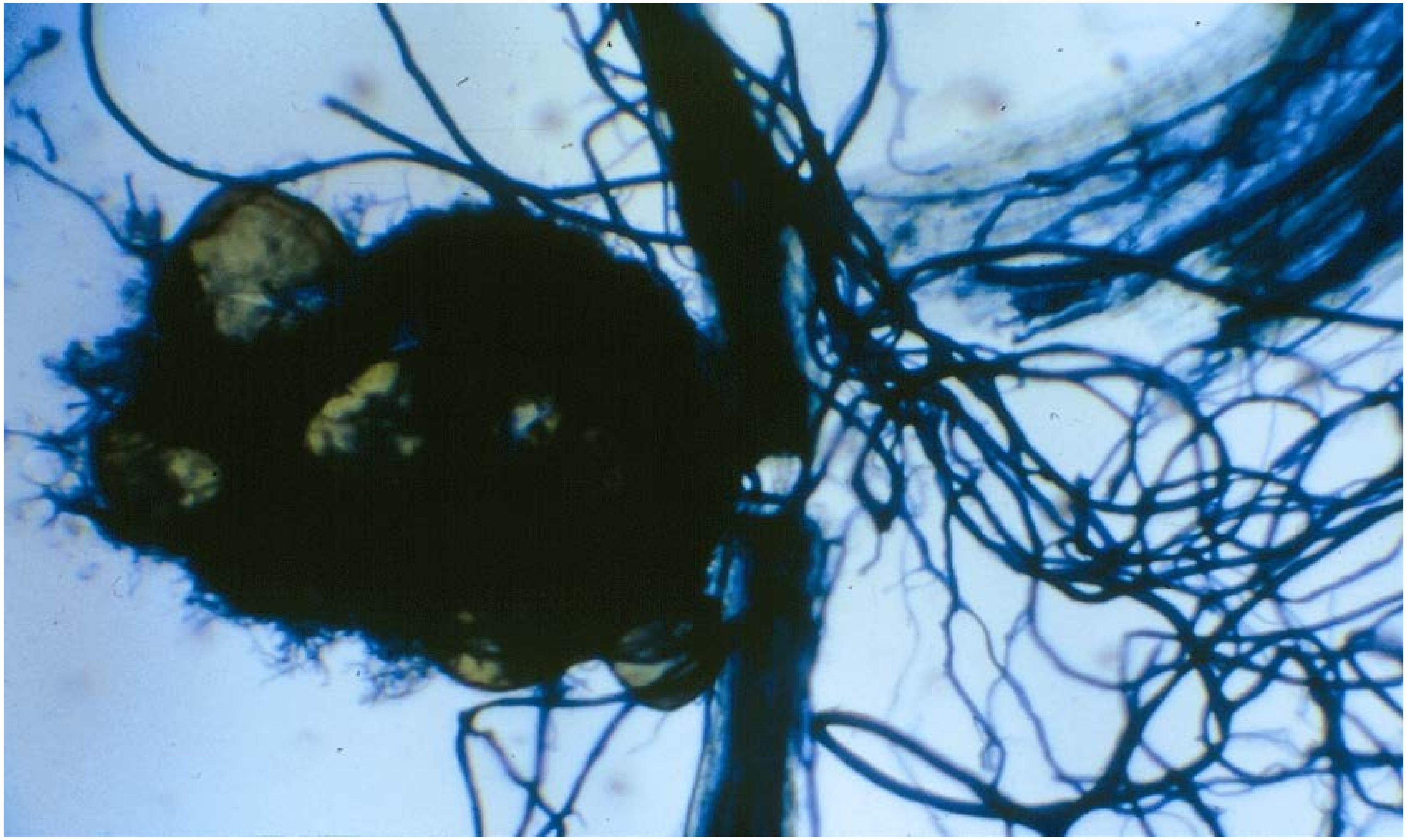


Biological Activity

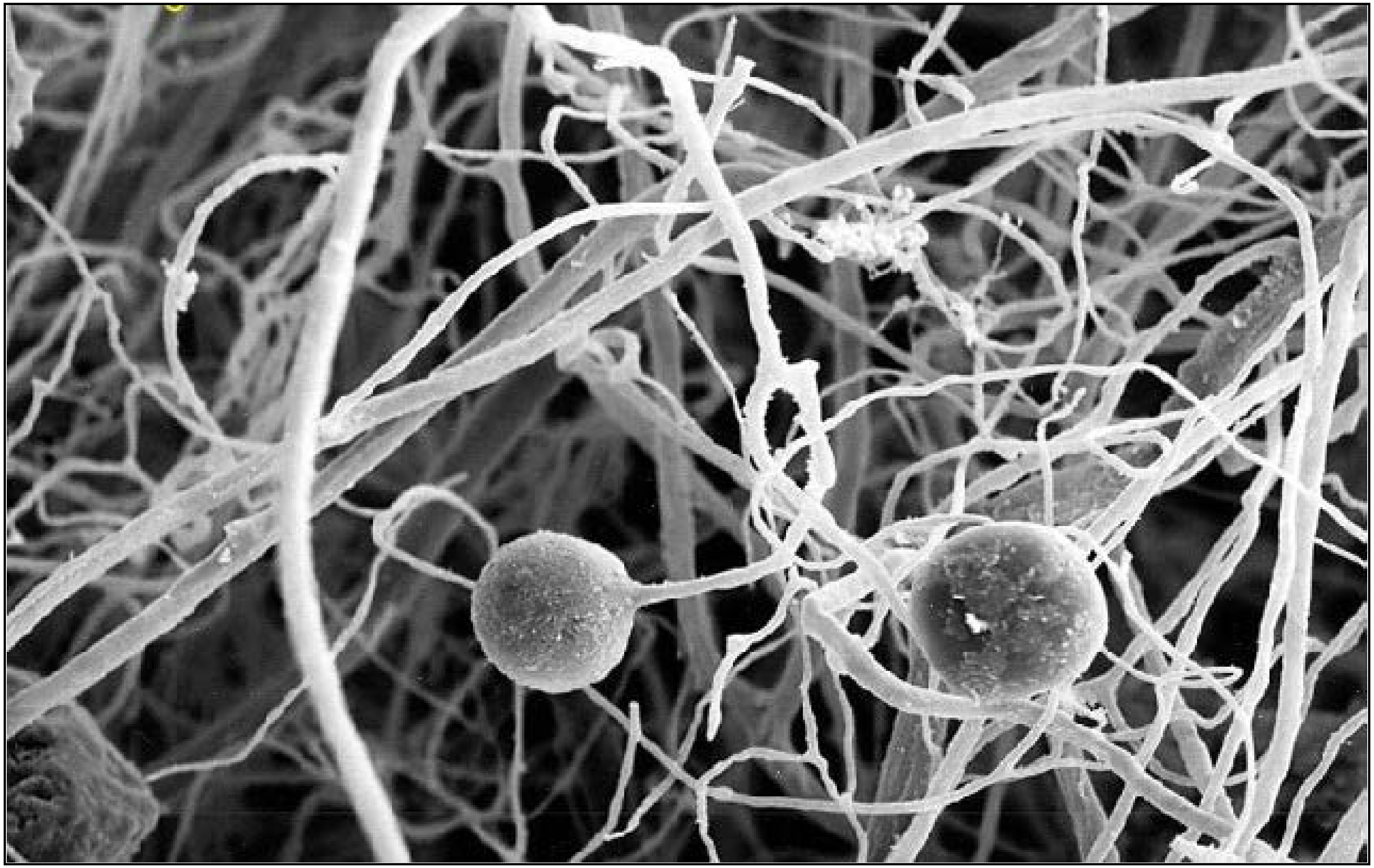
- Without proper biotic life and activity, the soil will not support the growth and root mass needed for natural erosion control.
- Benefits of healthy biotic life include:
  - Release of nutrient elements from organic matter reserves
  - Increased availability of mineral elements
  - Reduction in disease and pest problems

Biological Activity- Endo Mycorrhizae

- Enhances the absorptive rate of the root hair by 10 fold
- Form a symbiotic relationship with the plant. Fungi get food, carbohydrates, vitamins and amino acids. In exchange, fungi supplies water, macro & micro nutrients.
- Produces an antibiotic, reducing disease pressure for the plant
- Hyphae can enter micropores in the soil that the root hair is too thick to extract water or nutrients
- Erosion benefit- life cycle is 17 to 30 days, secrete glue like substance, and at death they decay and feed the soil bacteria population, further aggregate the soil.



Glomus mosseae spores, colonized root and hyphae extending from the root.



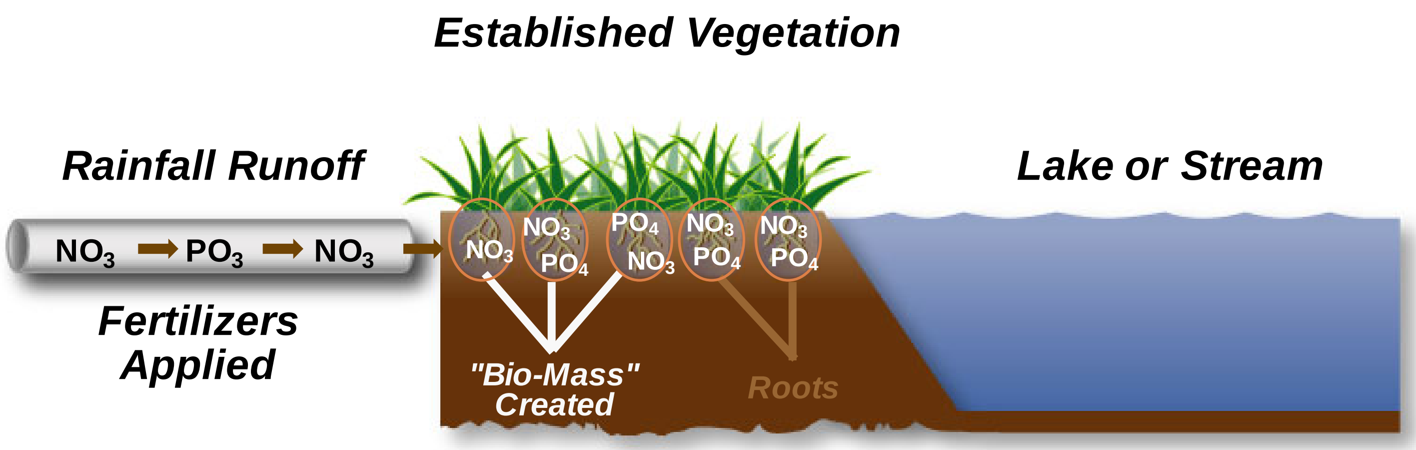
Hyphae, attached to turf grass roots, dramatically increases the level of nutrients and water accessible within the soil resource

Tall fescue 4 weeks after seeding

Fertilizer Alone

Fertilizer plus Humic Acid and Beneficial Bacteria

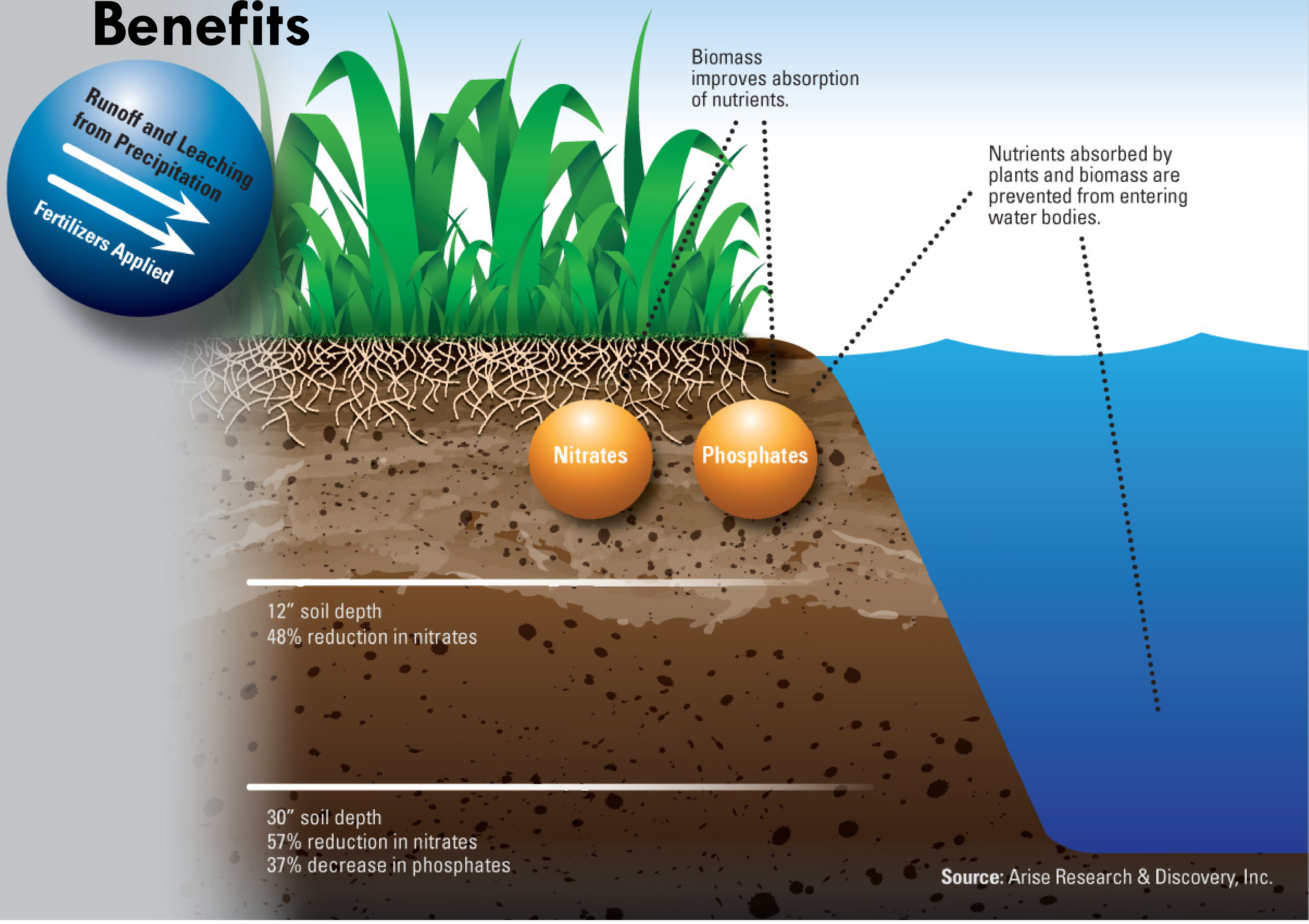
Balanced and Fertile Soils Retain Nutrients



- Nutrients retained and available to plants
- More efficient utilization of nutrients
- Reduced runoff into water bodies
- Assist with response to NPDES Regulations

Source: Arise Research & Discovery, Inc.

Nutrient Management Environmental Benefits



Case History

Project: WV DOT - Hwy 47 Cut near Parkersburg, WV

Challenge:

10 acre West facing slope, 0.75H:1V, 150 -250' tall, composed of very poor, high pH soils (pH = 10), derived from shale, red shale and sandstone. Sparse existing vegetation. Multiple attempts to establish vegetative growth all failed.

WV DOT had been liming slopes thinking they were acidic. Uncontrollable soil loss for several years. WV DOT faced with EPA fines and close to giving up on vegetated solution. Alternative is $21M retaining wall.

Solution: Soil test initiated. Proposal made to correct poor soil conditions with fertilizers, minerals, microbes, humic acid and mycorrhizae. Site specific seed specification developed and Flexible Growth Medium applied for extended erosion protection.

Install date: May 2007

Photo dates: April 2005 – October 2007

- Elemental Sulfur (90% pure flakes)
- Powdered Iron Sulfate
- Powdered Gypsum
- Superbio Microbes
- Jump Start 5
- 15-30-5 Fertilizer


04/27/2005
CHEROKEE

Athens OH
Clarksburg


FINN

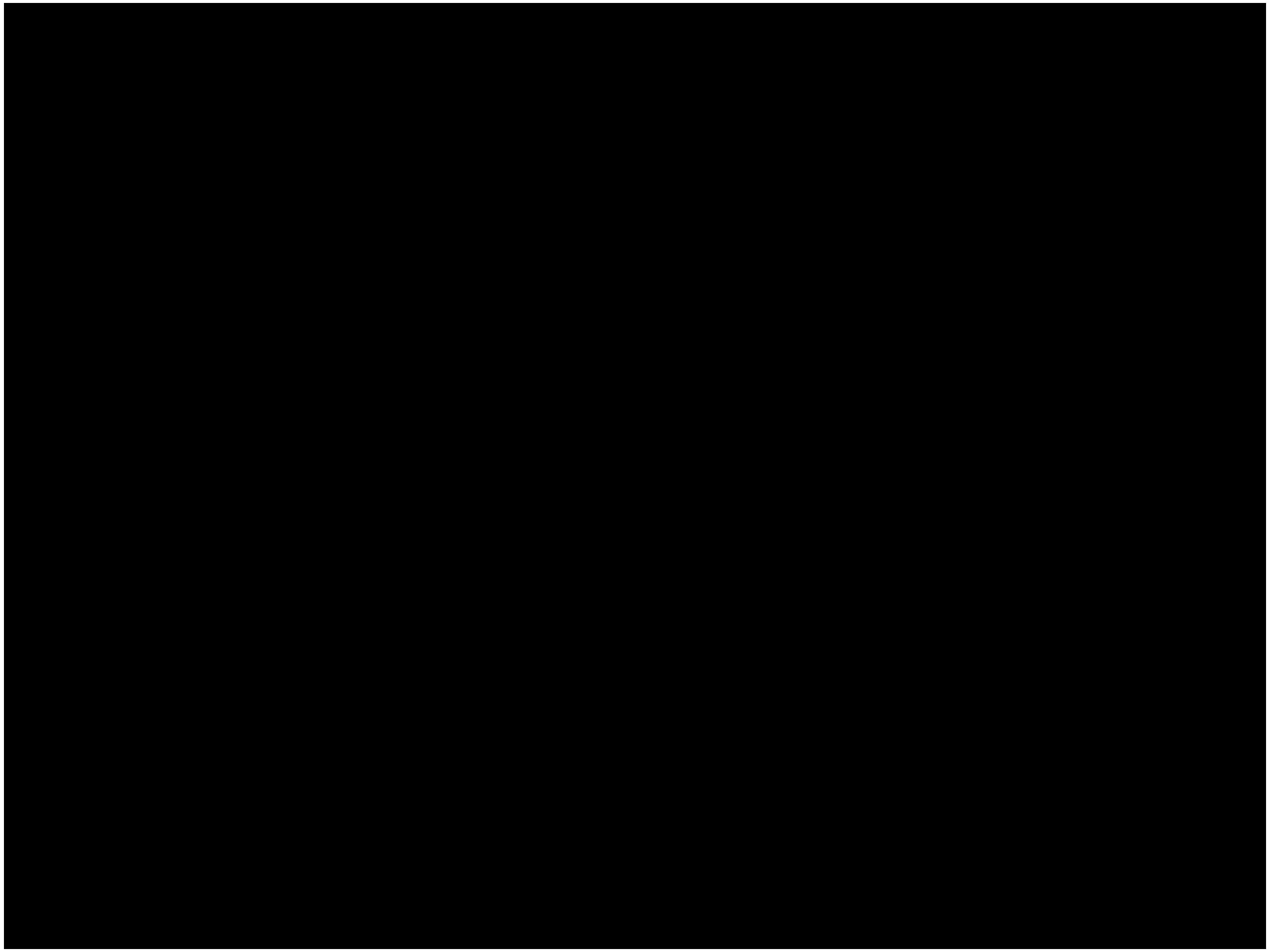

50
50
47


Good establishment even during drought year

Soil Test Sampling

- Review the site, note significant changes in the soil, such as color or texture.
- If multiple samples must be evaluated; be sure to identify where the soil sample came from on the sample bag and form.
- Remove core samples to a depth of 3" from common soil (if organic matter is on the surface, scrape away prior to sampling usually no more than ¼ to ½"), place in a container and mix together thoroughly.
- Remove approximately an 8 ounce cup of soil and place in the sample bag.
- Allow sample to dry prior to shipping.

Taking a Soil Sample Video



Questions?

- Thank you for your time.
- For an electronic copy of the slides:
  - LGirard@ProfileProducts.com
- For a Free Soil Test:
  - www.profileps3.com