Soil Science for Master Gardeners

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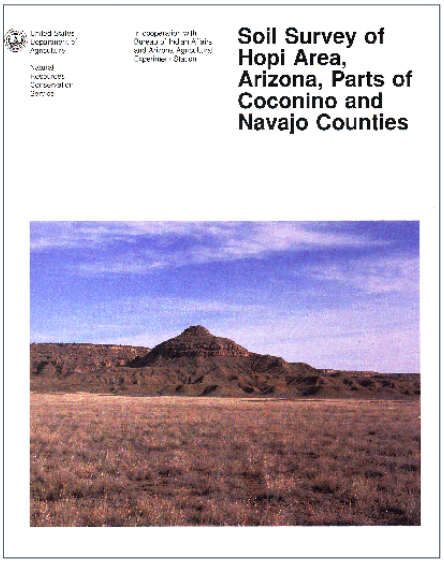
Soil Information Sources



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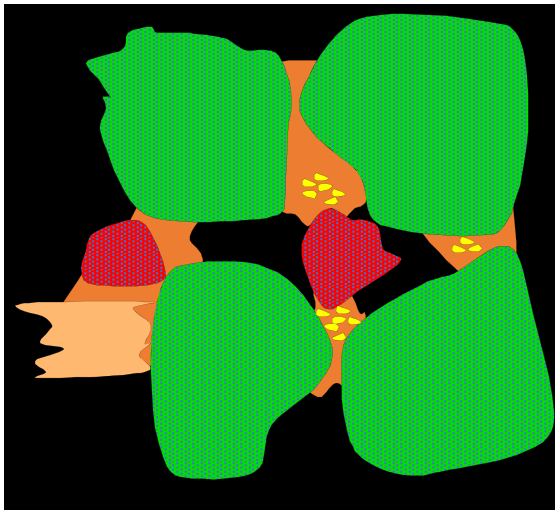
Soil Components

- Mineral Particles
  - sand
  - silt
  - clay
- Open Spaces (pores)
  - air
  - water
- Organic Materials
  - carbon-based



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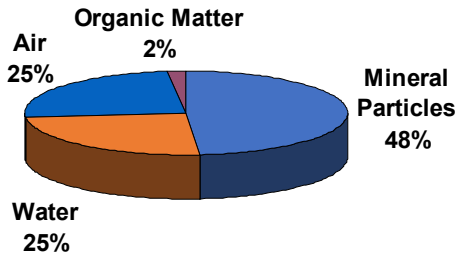
Composition of Soil by Volume

Pores can be filled with either air or water



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Parent Materials

- Residual
  - rock weathered in place
  - organic deposits at soil surface
- Transported
  - gravity: colluvial
  - water: alluvial, marine, lacustrine
  - wind: eolian (loess)
  - ice: glacial

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Factors of Soil Formation

- Parent materials (geological or organic soil precursors)
- Climate (especially rainfall and temperature)
- Biota (living organisms - vegetation, microbes, soil animals, human beings)
- Topography (configuration of soil surface)
- Time parent materials are subjected to soil formation processes

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Weathering

- Physical weathering (disintegration)
  - heating/cooling
  - water, ice, wind abrasion
  - plants and animals
- Chemical weathering (chemical alteration)
  - hydrolysis (splitting by water)
  - hydration (combining with water)
  - acid weathering
  - oxidation

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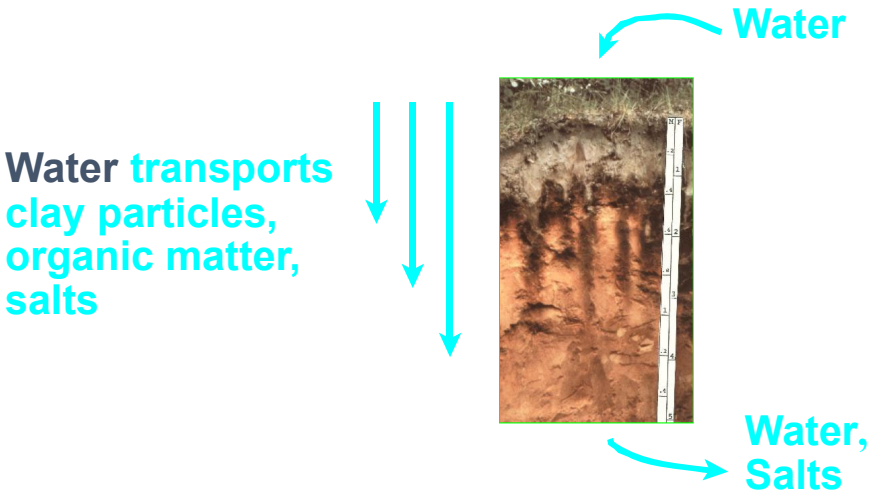
Soil Formation in Moist Environments



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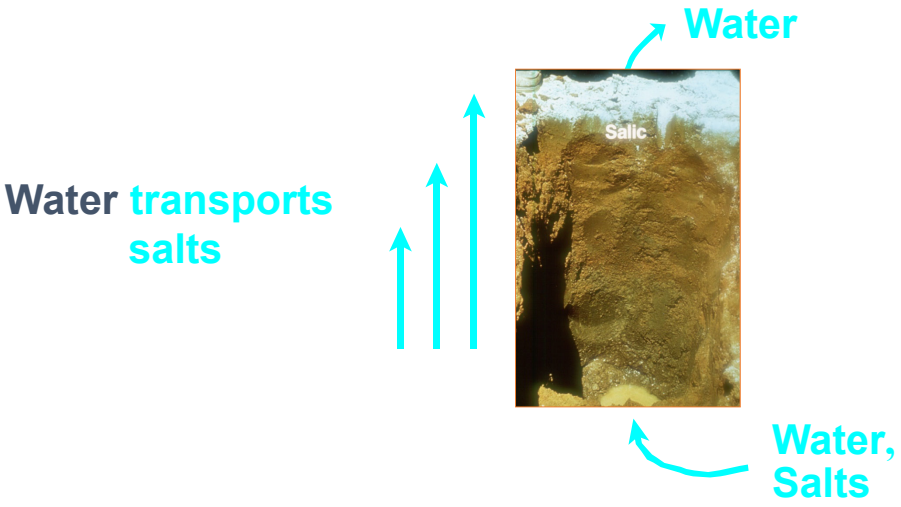
Soil Formation in Arid Environments



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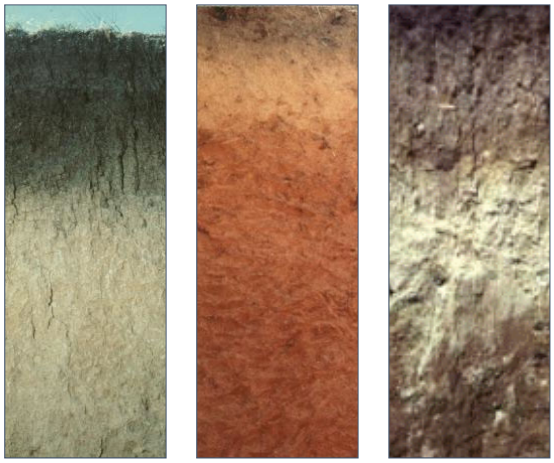
Soil Horizons

Soils develop horizontal layers, or horizons, as materials move through the soil profile



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Soil Horizons

- A horizon
  - dark layer, high in organic matter
- E horizon
  - layer of leaching
  - depletion of organic matter, clays, iron & aluminum oxides
- B horizon
  - zone of accumulation
  - enrichment of organic matter, clays, iron & aluminum oxides
- C horizon
  - parent material

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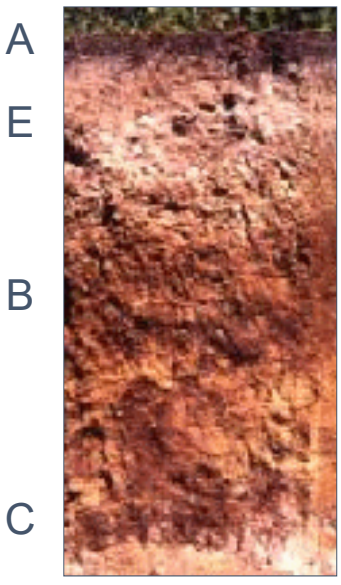
Soil Horizons



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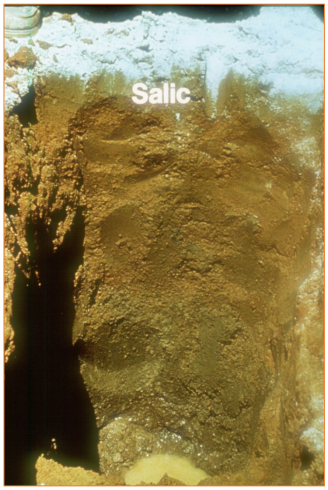
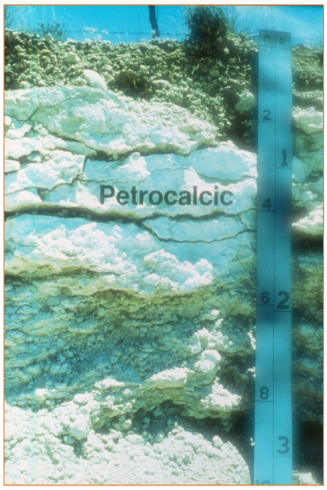
Arid Soil Horizons



Sodium chloride

Calcium carbonate (Caliche)



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Soil Physical Properties

- Color
- Texture
- Structure
- Drainage
- Depth
- Surface features

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Soil Color

- Organic matter:
  - dark brown — High organic matter content
- Drainage conditions and degree of oxidation (weathering):
  - red-brown — Good drainage
  - yellow — Moderate drainage
  - gray — Poor drainage

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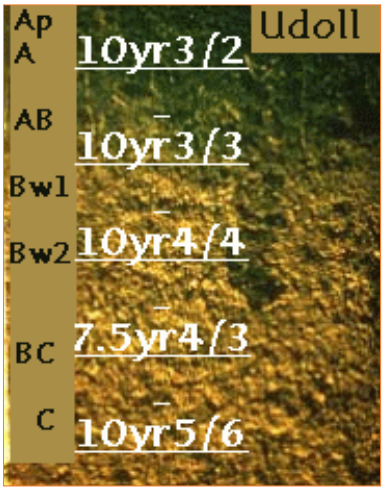
Soil Color



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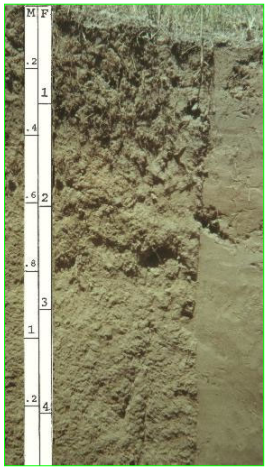
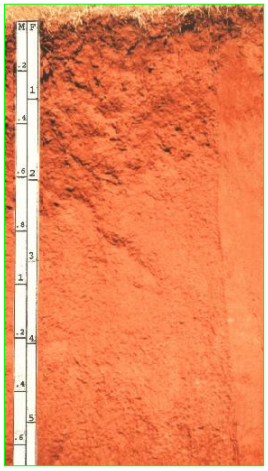
Soil Color

Organic soil



Young soil



Highly weathered soil

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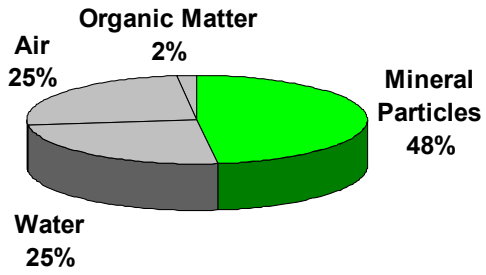
Mineral Particles

- Mineral Particles
  - sand
  - silt
  - clay
- Pore Spaces
- Organic Matter



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Soil Texture

- Soil texture is determined by the amount of sand, silt, and clay
  - excludes
    - organic matter
    - large particles (larger than 2 mm)
- Size of mineral particles
  - sand 2 to 0.05 mm
  - silt 0.05 to 0.002 mm
  - clay less than 0.002 mm

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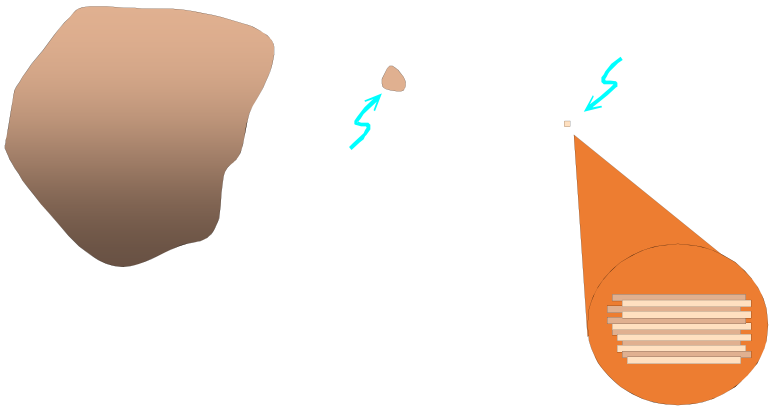
Relative Size of Soil Particles



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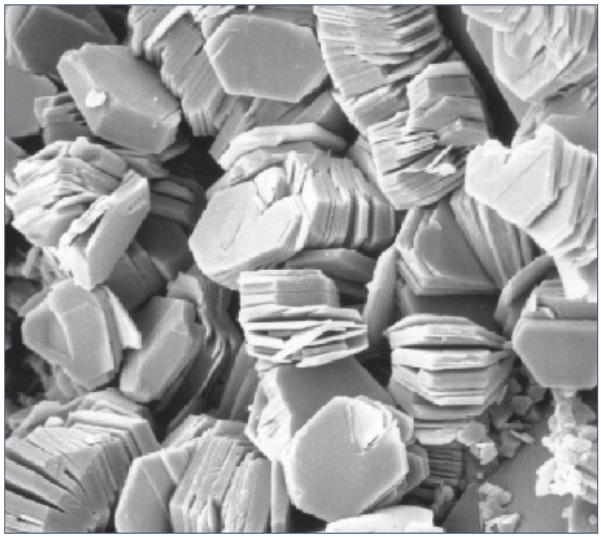
Structure of Clay Particles



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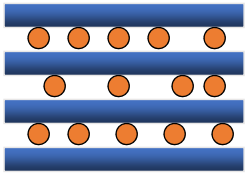
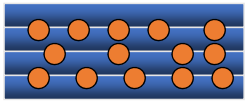
Structure of Clay Particles



Montmorillonite

Kaolinite



Mica

water and charged molecules

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Specific Surface Area

Area per weight (square meters per gram)

- 1 gram sand ~ 0.1 square meter
- 1 gram silt ~ 1 square meter
- 1 gram clay ~ 10 to 1,000 square meters

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Particle Surfaces are Important

- Coated with water
- Electrically charged
- Sites for microbial growth
- Sites of chemical reactions
  - weathering
  - adsorption of chemicals
  - retention of nutrients
  - soil aggregate formation

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Clay Particles have Electrical Charge

- Most clay particles are negatively charged
- Ions (charged molecules)
  - cations are positively charged ions
  - anions are negatively charged ions
- Cations are attracted to negatively charged clays
  - these cations are loosely held or exchangeable
  - this process is called cation exchange

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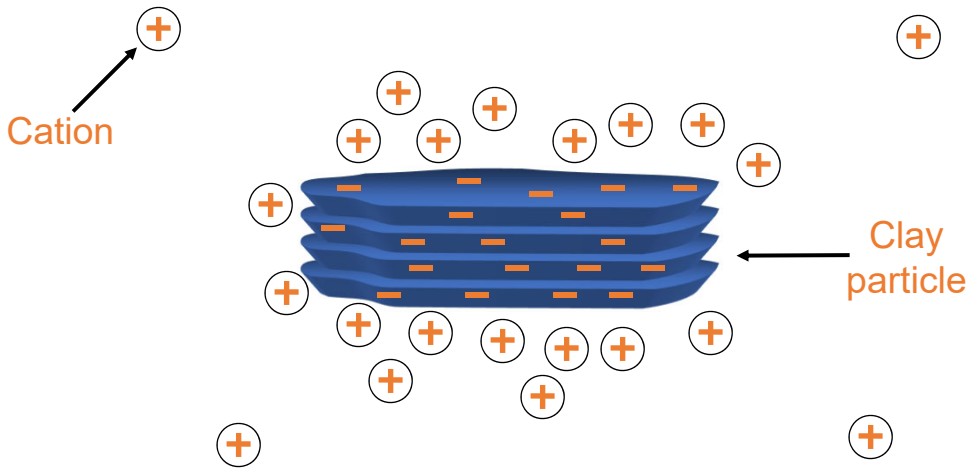
Cation Exchange



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Cation Exchange

- Exchangeable soil cations include
  - calcium, magnesium, potassium, ammonium, sodium
  - hydrogen, aluminum in acid soils
- Exchangeable cations can replace one another
- Exchangeable cations are available to plants, microbes, etc.
- The amount of exchange in a soil is called the Cation Exchange Capacity (CEC)

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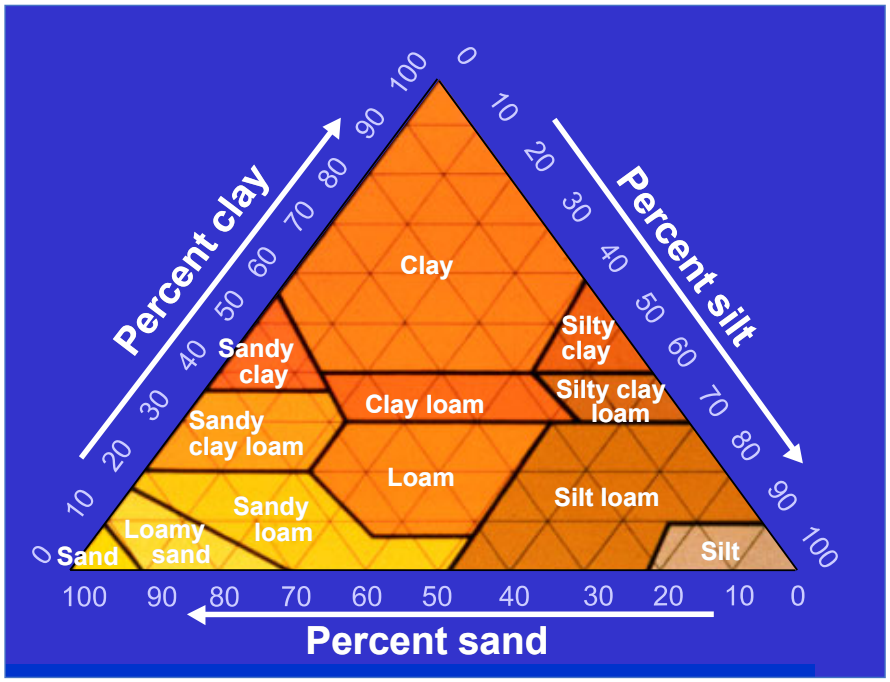

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Soil Structure

- Soil particles are grouped in aggregates
- Aggregates
  - vary in size, shape, and strength
  - are promoted by
    - organic matter
    - calcium and other 'flocculating' cations
  - can be destroyed by tillage and traffic
  - allow movement of air, water, roots

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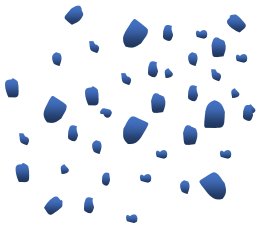
Soil Aggregates

Single Grain



Individual grains not held together
- common in sands

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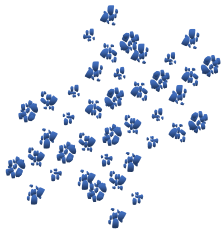
Soil Aggregates

Granular



Porous granules held together by organic matter and clay
- common in A horizons

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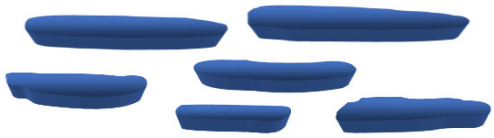
Soil Aggregates

Platy



Flat aggregates
- found in compacted layers and E horizons

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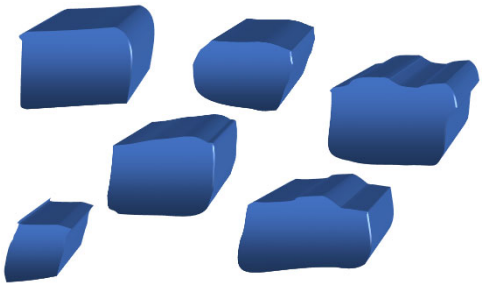
Soil Aggregates

Blocky



Roughly equidimensional aggregates
- found in clayey B horizons

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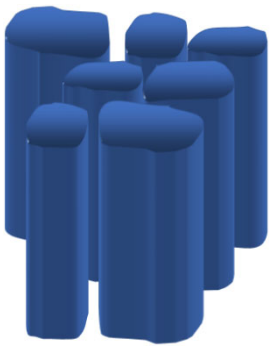
Soil Aggregates

Columnar
and
Prismatic



Vertical aggregates
- found in some B horizons

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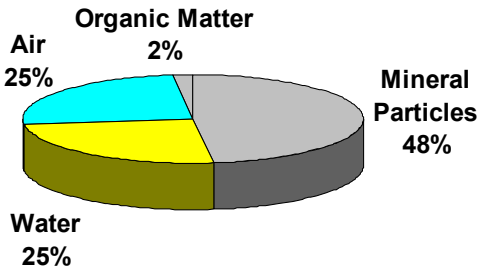
Soil Pores

- Mineral Particles
- Pore Spaces
  - water
  - air
- Organic Matter



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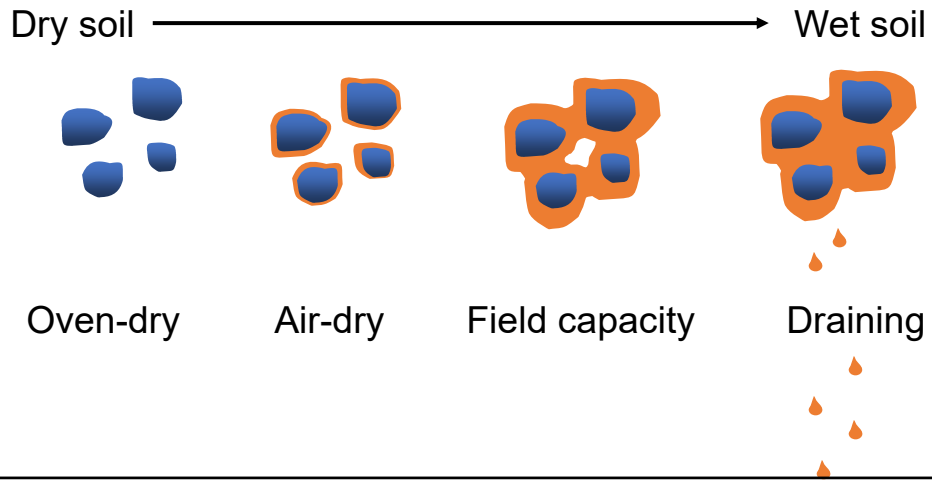
Soil Water

Water is attracted to particle surfaces



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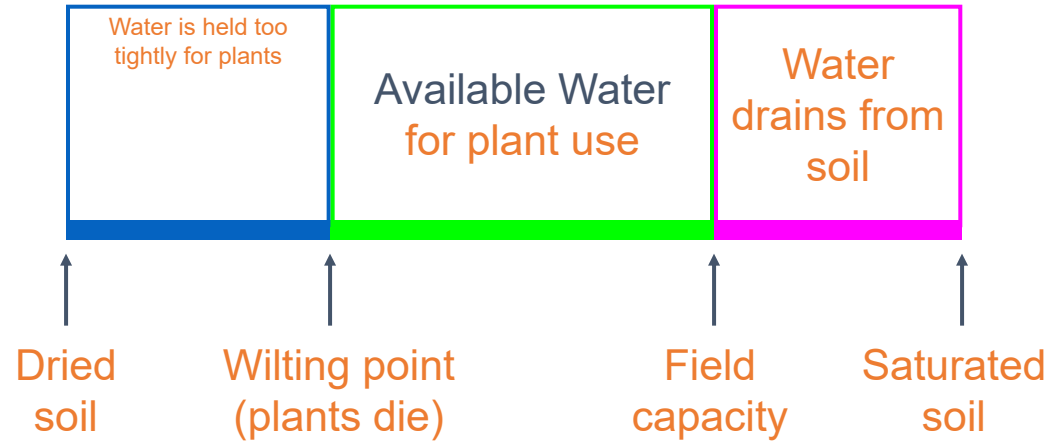
Available Soil Water



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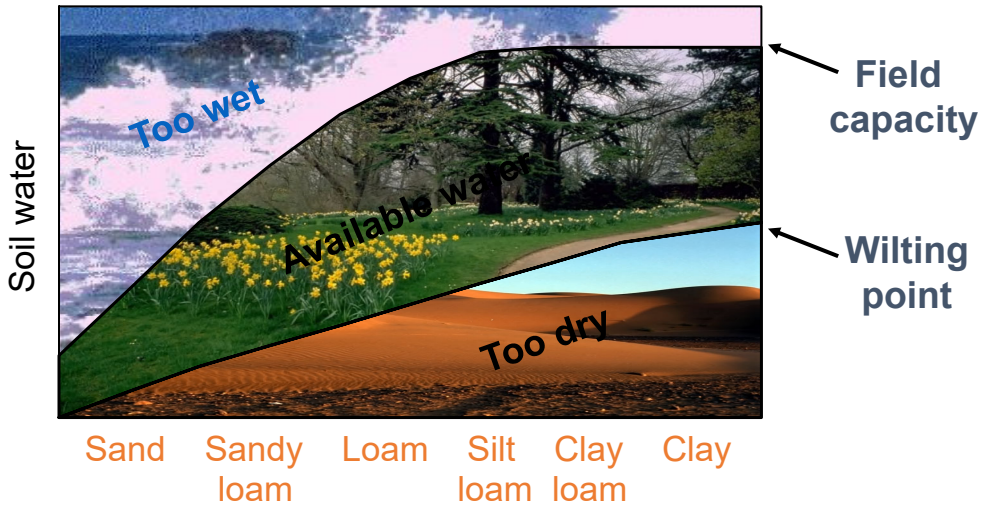
Soil Water



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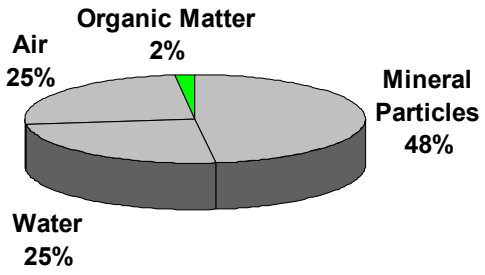
Organic Matter

- Mineral Particles
- Pore Spaces
- Organic Matter
  - biological remains
  - less than1% to over 20%
    - most AZ soils have < 2%
  - energy-rich material
  - broken down by organisms to form
    - humus (improves structure and water-holding capacity)
    - soluble nutrients



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Organic Matter (OM)

- Soil structure
  - aggregate formation promoted by OM
  - OM increases water infiltration & water holding capacity
- OM increases cation exchange capacity
- OM can increase microbial activity
- Nutrients
  - OM provides a nutrient source
  - OM helps keep some nutrients available
- OM can retain pesticides

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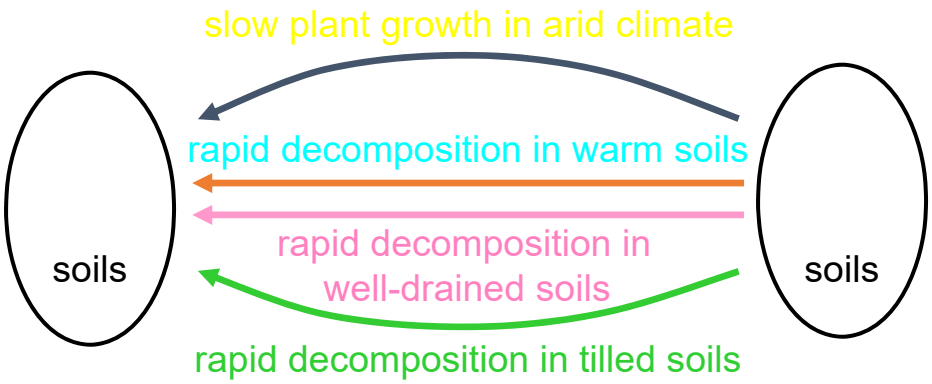
Organic Matter Content



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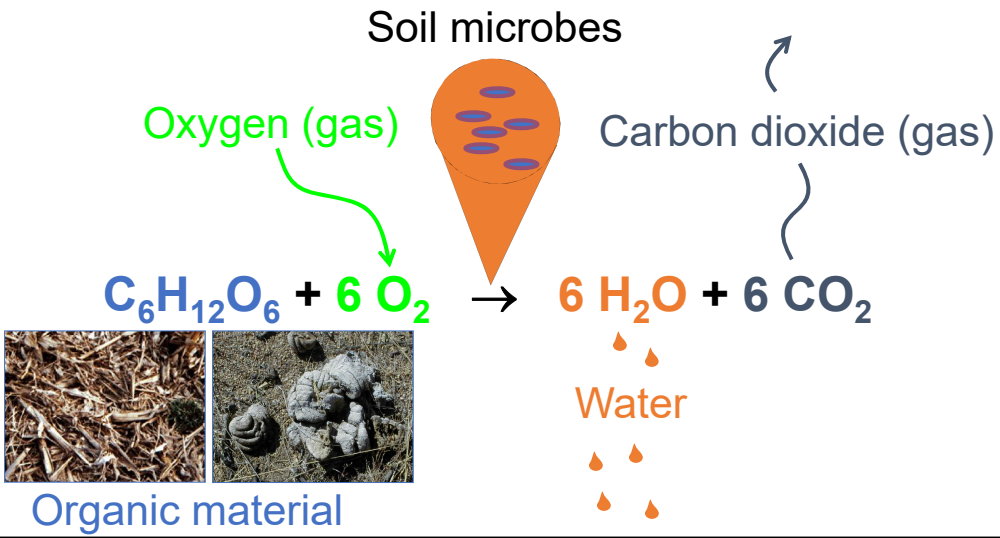
Aerobic Respiration



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Organic Materials in Soil

- Organic materials are decomposed by soil microbes
  - carbon (C) in organics used for substrate and energy
  - nitrogen is also required
    - about $^{1}/_{10}$ as much N as C is needed
    - C:N ratio of 10:1
- Organics with C:N ratios greater than about 10:1 require additional N

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C:N of Some Organic Materials

Material	C:N ratio

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Managing Organic Amendments

- High C:N ratio organics
  - add adequate N during soil application
  - compost
    - to reduce C:N ratio
    - to eliminate weed seeds
- Low C:N ratio organics
  - add directly to soil
  - watch for "burning" by high N organics
- High O_2 consumption
  - anaerobic conditions in poorly aerated soils

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Plant Nutrients

What's in a plant?

- Carbon (C) 45%
- Hydrogen (H) 6%
- Oxygen (O) 43%
- Nitrogen (N) 1 to 6%
- Phosphorus (P) 0.1 to 1%
- Potassium (K) 1 to 6%
- Calcium (Ca) 0.1 to 4%
- Magnesium (Mg) 0.1 to 2%
- Sulfur (S) 0.1 to 1.5%

These are called *Macronutrients* because plants need relatively large amounts of them

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Plant Nutrients

Micronutrients (measured in parts per million or ppm)

• Iron (Fe)	10 to 1000
• Manganese (Mn)	10 to 1000
• Molybdenum (Mo)	0.1 to 10
• Chlorine (Cl)	100 to 30,000
• Copper (Cu)	2 to 50
• Boron (B)	2 to 75
• Zinc (Zn)	10 to 100
• Nickel (Ni)	0.1 to 1

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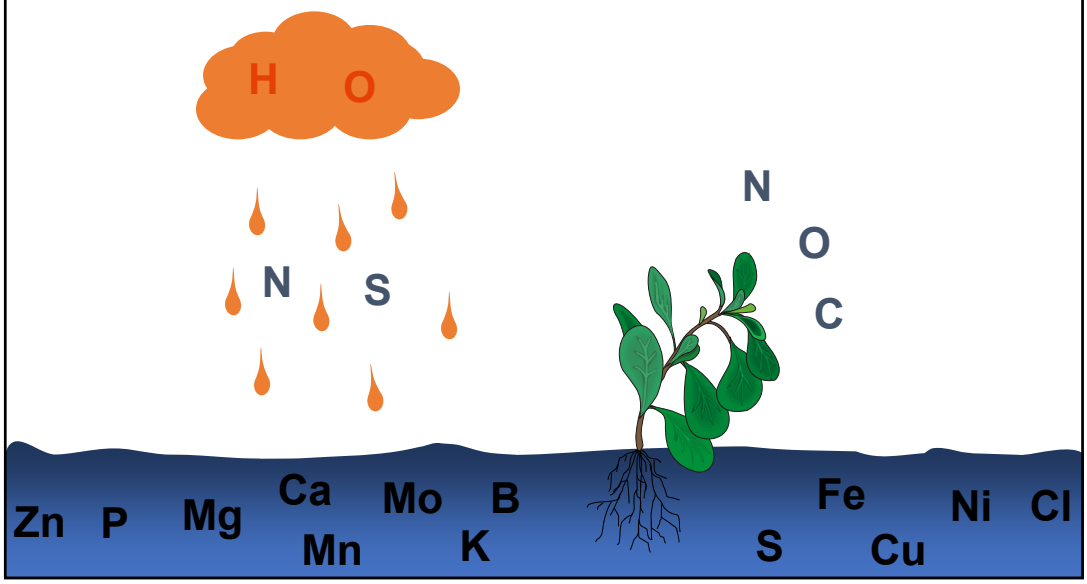
Sources of Plant Nutrients



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Primary Nutrients

- The three nutrients that most often limit plant growth
  - nitrogen (N)
  - phosphorus (P)
  - potassium (K)

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Nitrogen

- Nitrogen deficiency symptoms

- yellow or reddish leaves
- leaf tips & margins yellow and die starting with oldest leaves
- stunted plants

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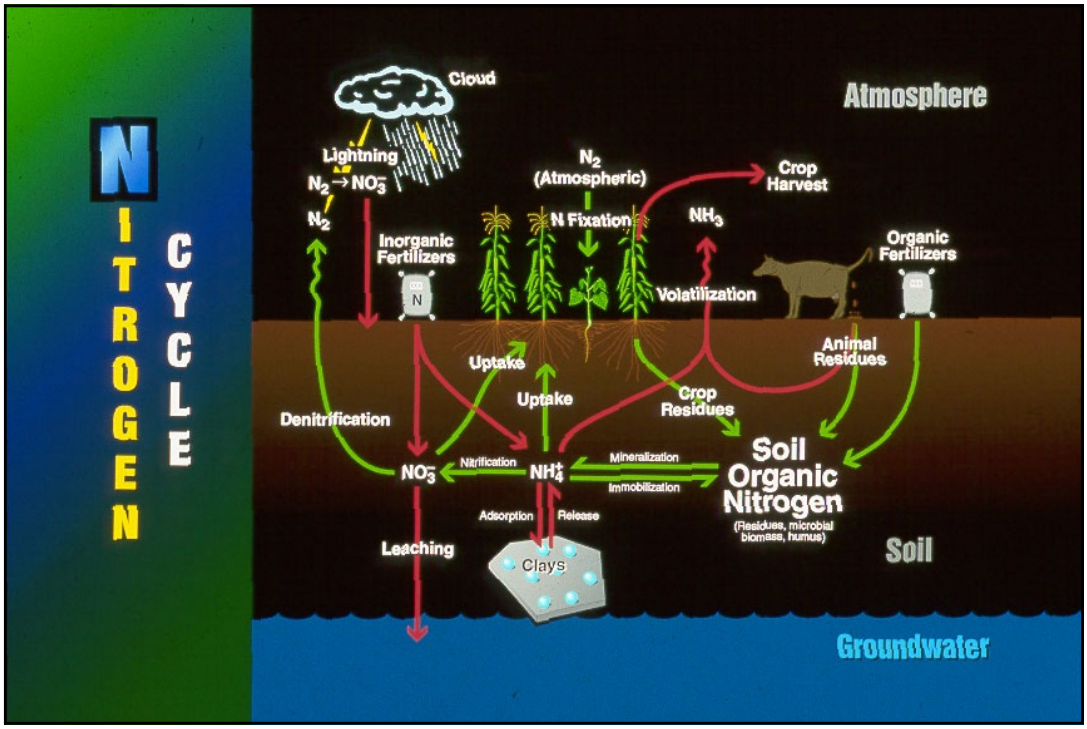

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Phosphorus

- Phosphorus deficiency symptoms
  - purplish foliage - oldest leaves first
  - slow growth, stunted plants
  - dark green coloration
  - delayed maturity

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Potassium

- Potassium deficiency symptoms

– leaf tips and margins ‘burn’ - oldest leaves first
– plants have weak stalks
– small fruit or shriveled seeds
– slow growth

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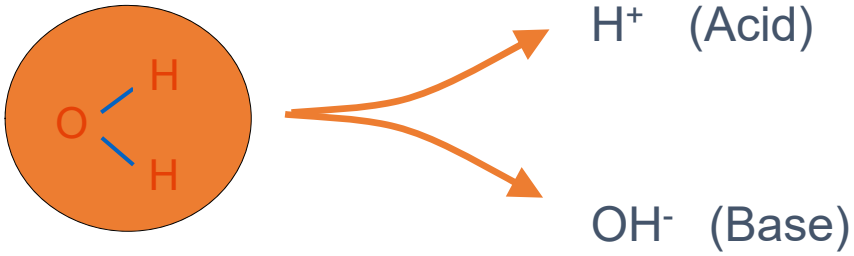
Acidity



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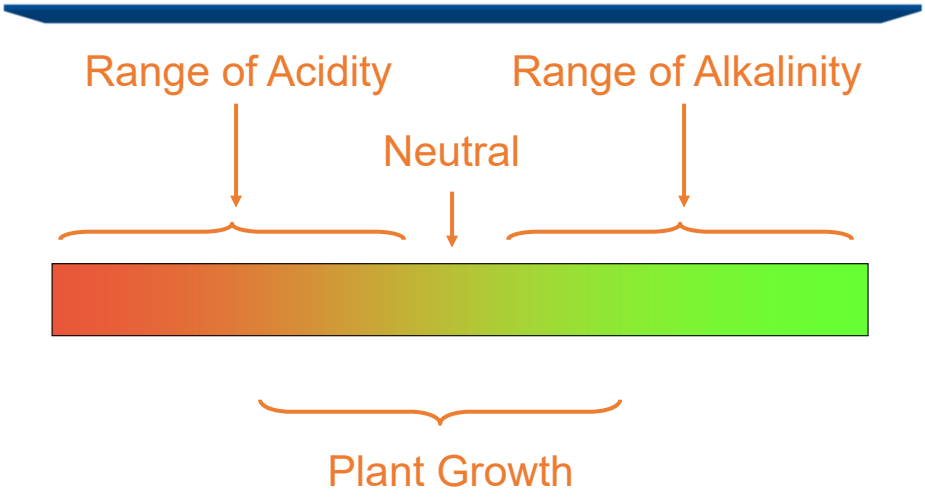
The pH scale

Each pH unit is 10 times more acid or alkaline than the next unit



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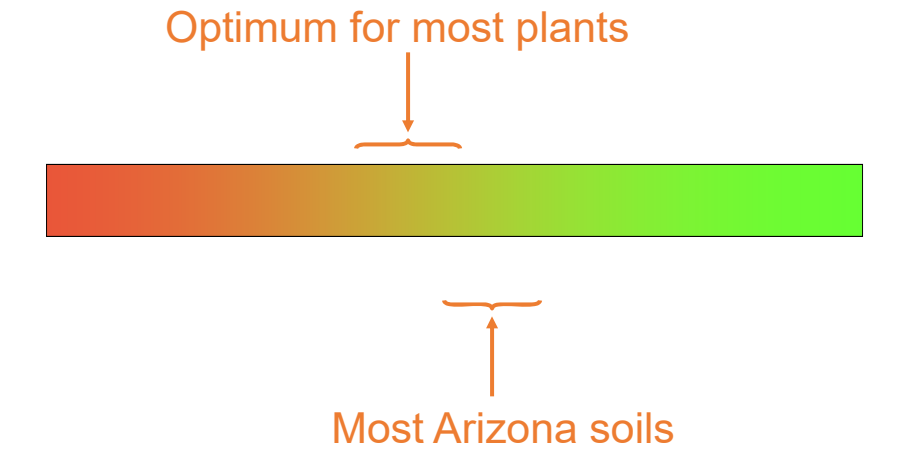
Soil pH



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Soil pH

- Alters nutrient availability
- Affects microbial activity
  - Can affect disease susceptibility

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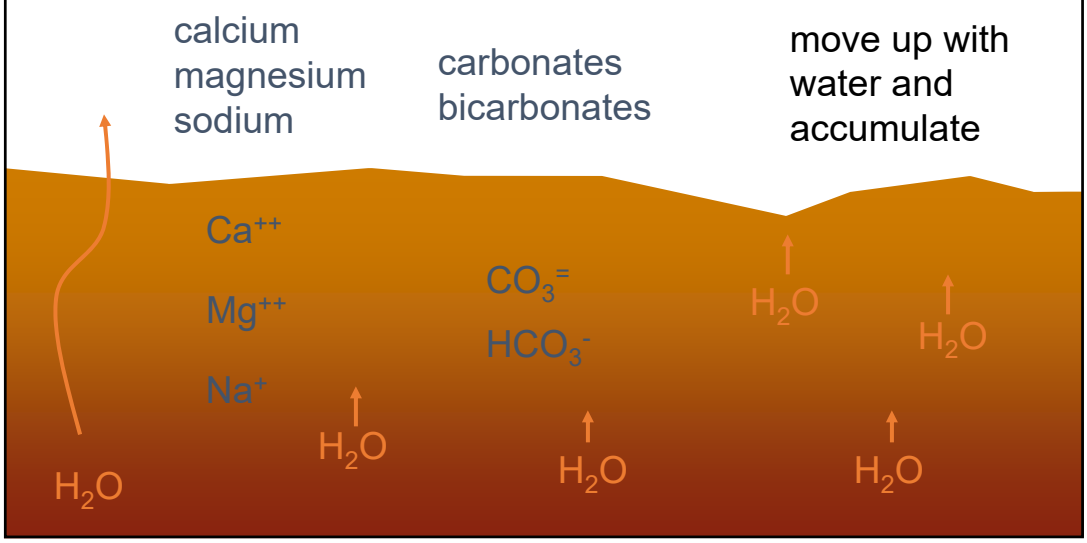
Alkalinity in Arid Soils



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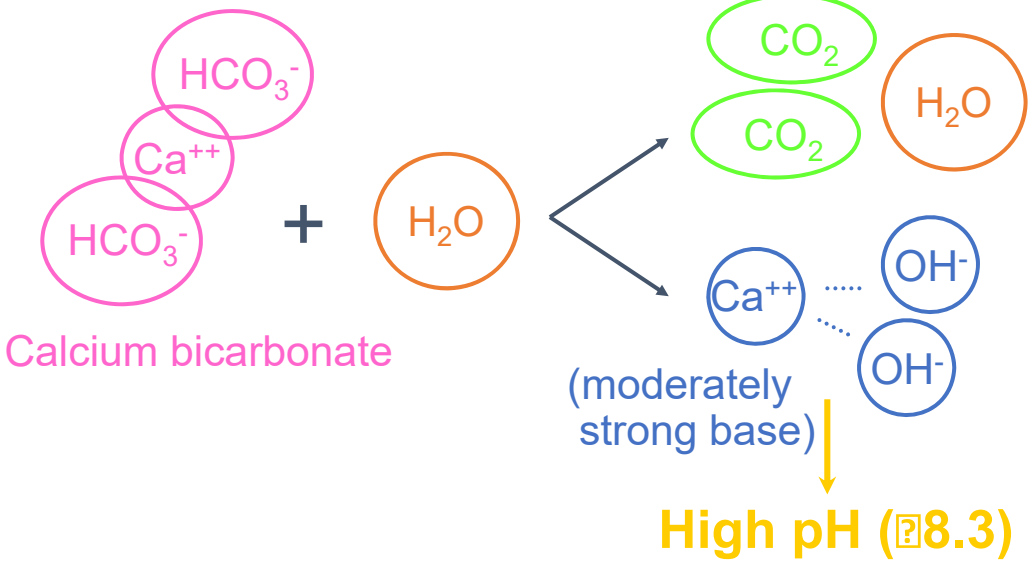
Alkalinity in Arid Soils



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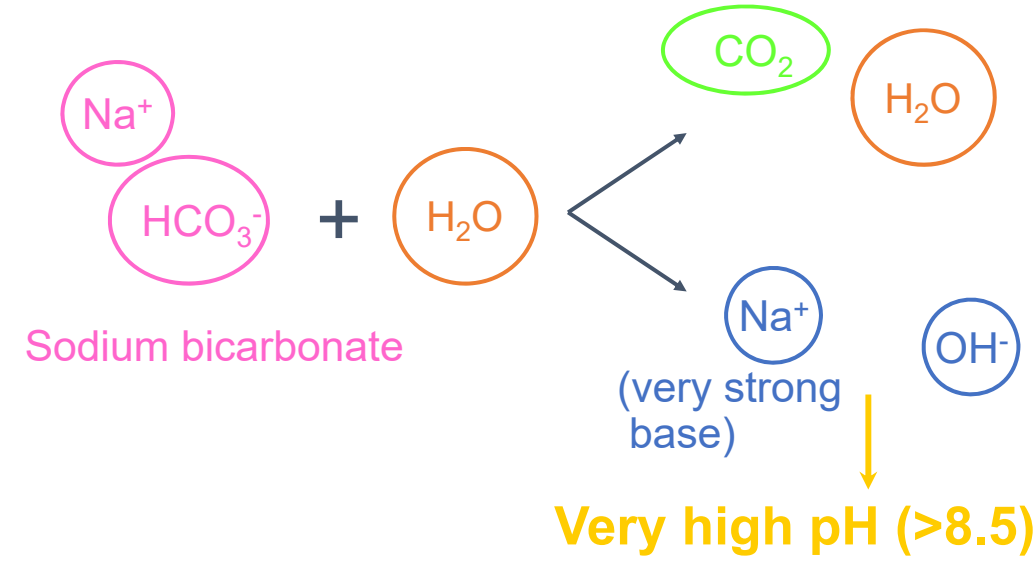
Alkalinity in Sodic Soils



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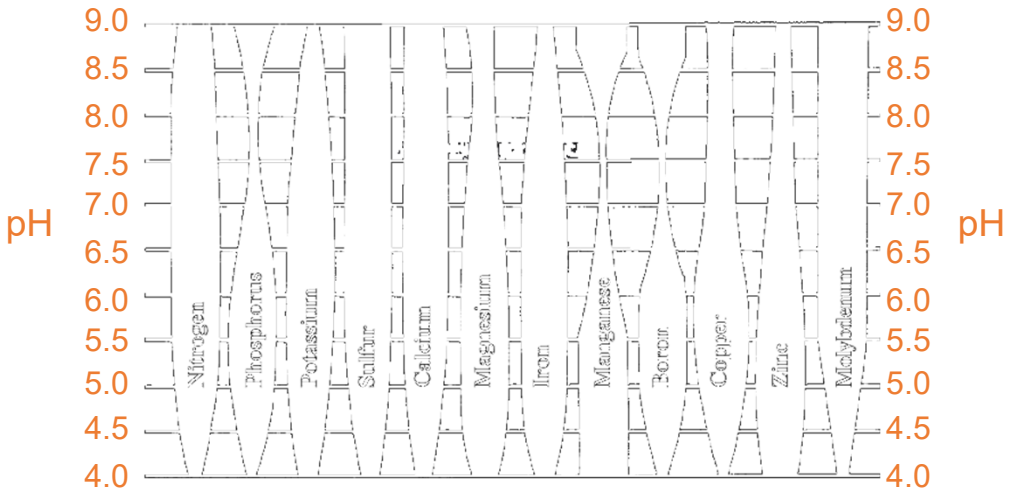
Effects of pH on Nutrient Availability

The thicker the bar, the more available the nutrient



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Iron Chlorosis

Iron deficiency appears on youngest leaves of plants growing in alkaline soils

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Treating Soil Alkalinity

- Acidify the soil
  1) sulfuric acid
     H_2SO_4
  2) sulfur (biological reaction)
     $2S + 3O_2 + 2H_2O \rightarrow 2H_2SO_4$
  3) aluminum sulfate:
     $Al_2(SO_4)_3 + 6H_2O \rightarrow 2Al(OH)_3 + 3H_2SO_4$
- NOTE: gypsum ($CaSO_4$) is NOT an acidifying compound and will not lower pH of most soils!

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Fertilizing Alkaline Soils

- Apply nutrients to high pH soils
- Metal nutrients are insoluble in alkaline soils
  - iron, manganese, zinc
- Use chelated forms
  - more soluble than unchelated forms
  - stay in solution longer
  - more available to plants

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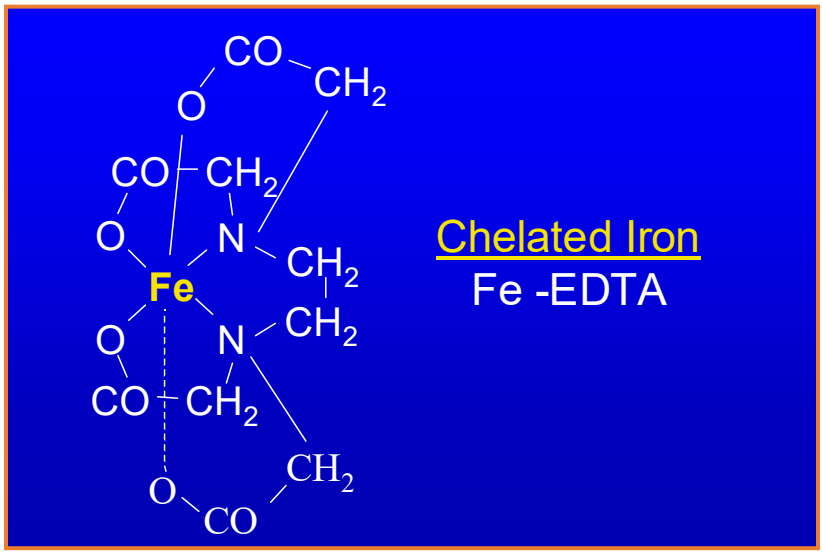
Chelates



Chelated Iron
Fe -EDTA

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Treating Plants in Alkaline Soils

- Apply nutrients directly to plant foliage
  - Iron, Copper, Zinc
    - use sulfate salts
      - iron sulfate
      - copper sulfate
      - zinc sulfate
    - use chelated forms
      - EDTA
      - DTPA
      - others

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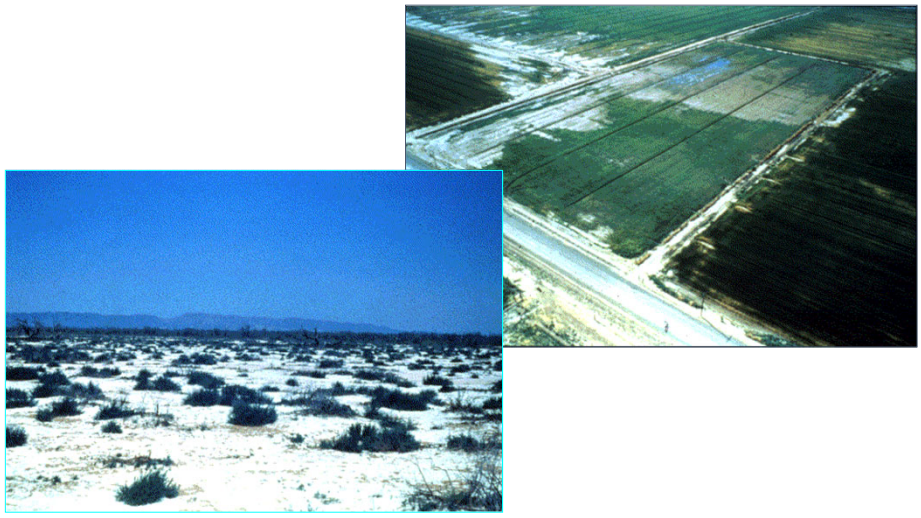
Salts and Soil



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Salt-Affected Soils

- Salt-affected soils
  - Occur naturally in arid climates
  - Can be formed by addition of salts in irrigation water

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Water Transports Salts

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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)

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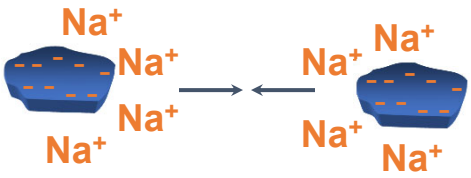
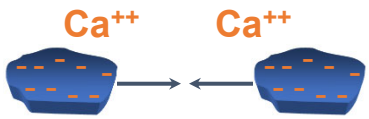
Salts Affect Soil Structure

A little sodium makes particles repel one another.

A lot of sodium



or a little calcium



make particles attract one another.

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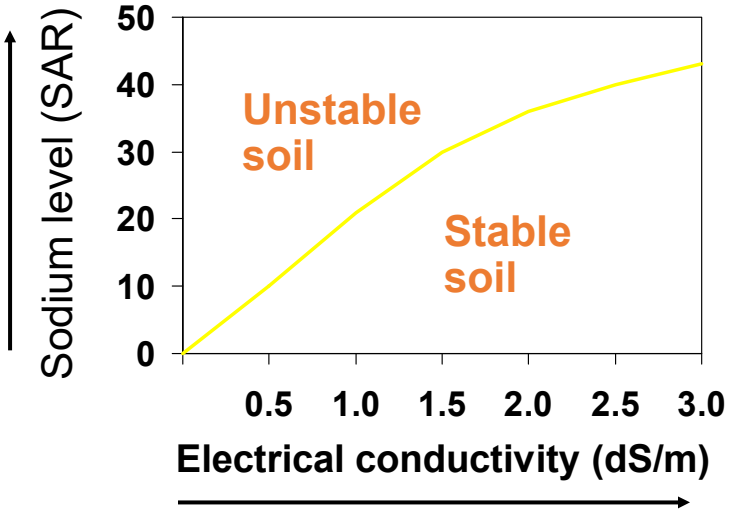
Salts Affect Soil Structure



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Tests for Soil Salts

- Measuring total soil salts
  - EC - electrical conductivity
- Measures of the amount of sodium
  - SAR - sodium adsorption ratio
  - ESP - exchangeable sodium percentage

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Classifying Salt-Affected Soils

Measurement	Normal	Saline	Sodic	Saline-Sodic
EC (dS/m)	<4	>4	<4	>4
ESP	<15	<15	>15	>15
SAR	<13	<13	>13	>13

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Electrical Conductivity (EC)

EC (dS/m)	Plant response

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Salt-Affected Soils

- Plant age affects tolerance to salts
  - Seedlings are most sensitive
  - Mature plants are least sensitive
- Different plant parts may be variably affected
  - Seeds
  - Vegetation
- Plant species vary in salt tolerance

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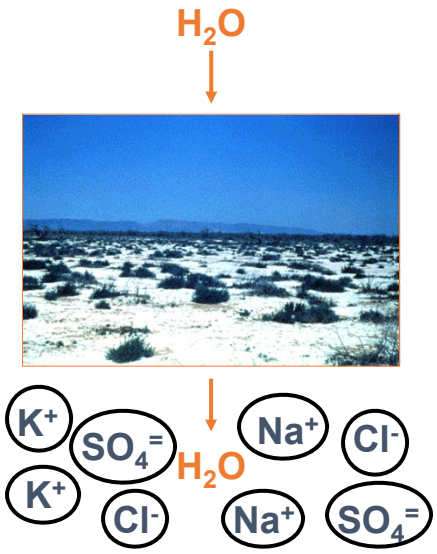
Managing Non-Sodic Saline Soils



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Avoiding Salts

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Sodium-Affected Soils

- Poor structure
- Poor drainage
- May have surface cracking when dry
- Very high pH (>8.5)

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Managing Sodic Soils

1. Stabilize structure by adding gypsum ($CaSO_4$) to replace Na^+ with Ca^{2+}
2. Reduce salt level by flushing with water to wash out Na^+ and excess gypsum*

*may be very difficult in soils with poor structure!

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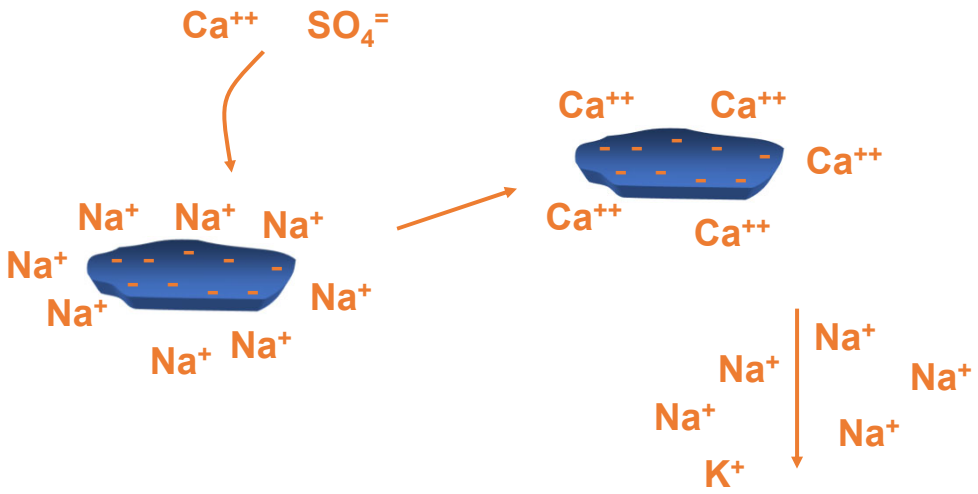
Managing Sodic Soils



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Fertilizers

- Label must contain percent (by weight) of
  - total nitrogen (N)
  - available phosphate (as P_2O_5)
    - P_2O_5 times 0.43 = P
  - soluble potash (as K_2O)
    - K_2O times 0.83 = K
- Other nutrients may be specified

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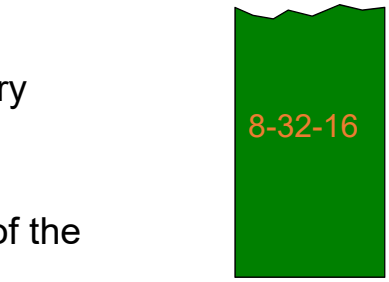
Types of Fertilizer

- Complete
  - contains all three primary nutrients (N, P and K)
- Incomplete
  - is missing at least one of the primary nutrients



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Common incomplete fertilizers

Fertilizer	N	P_2O_5	K_2O

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Slow-release fertilizers

- Release nutrients (usually nitrogen) over a long period of time
  - slowly soluble materials
    - urea formaldehyde
  - granules coated with resins or sulfur
    - sulfur-coated urea
    - Osmocote®
  - materials that must decompose to release nutrients
    - organic fertilizers

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Organic fertilizers

- Remains or by-products of plants or animals
  - cottonseed meal
  - blood meal
  - fish meal
  - manures
- Relatively low nutrient contents
- Contain micronutrients
- Slow release
- Low burn potential
- Condition soil by adding organic matter

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Typical composition of organic fertilizers

	% Moisture	N	P	K
		(% of dry weight)		
Chicken				
Cattle				
Hog				
Horse				
Sheep				
Municipal solid waste compost				
Sewage sludge				

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Fertilizer formulations

- Fertilizers can be combined with herbicides
  - common in turf formulations
- Fertilizers
  - granular solids
  - slow-release granules
  - liquids/water soluble powders
  - slow-release spikes/tablets

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Fertilizers are salts

Material	Nutrient level	Relative saltiness
Ammonium nitrate		
Ammonium sulfate		
Potassium nitrate		
Urea formaldehyde		
Urea		
Single superphosphate		
Potassium chloride		
Potassium sulfate		
Epsom salts		

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Avoiding fertilizer burn

- Do not over-apply fertilizers
  - particularly nitrogen fertilizers
- Make sure adequate moisture is present after applying fertilizer
- Periodically flush soluble salts from soil
  - make sure adequate drainage is available
  - irrigate 2 to 3 times as long as normal every 6 to 8 weeks to flush salts from soil

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Soil Testing

Available nutrients
- Phosphorus
- Potassium
- Calcium
- Magnesium
- Nitrogen
- Sulfur
- Micronutrients

Soil properties
- Texture
- pH
- Cation Exchange Capacity (CEC)
- Electrical Conductivity (EC)
- Sodium Adsorption Ratio (SAR) or Exchangeable Sodium Percentage (ESP)

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Soil Sampling

- Obtaining a representative sample is the critical step in soil analysis
  - A 1 cup sample from a 1,000 square foot field is 1/100,000 of the field!
- A good soil sample
  - made up of 15 to 25 cores or subsamples
  - never take less than 5 subsamples

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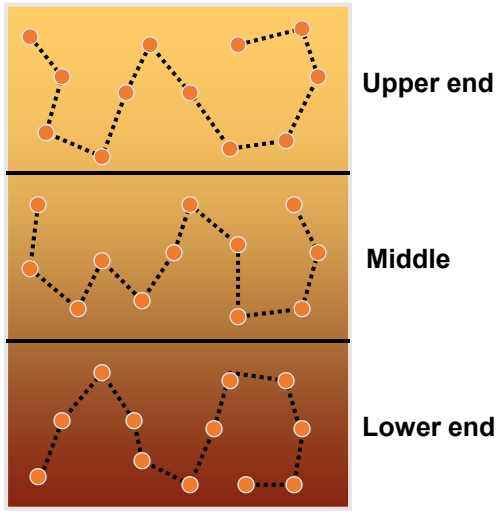
Soil Sampling

- Divide fields into uniform areas for sampling
  - soil type
  - slope
  - degree of erosion
  - cropping/use history
  - growth differences



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Soil Sampling

- Sample to the proper depth
  - usually eight inches
- Make sure soil cores represent sampled area
  - mix individual cores thoroughly to make sample
- Time of sampling
  - depends on analyses, field operations, etc.
- Sampling tools
  - soil probe or sampling tube is best

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