GEOG203 – Environmental Systems

Soils & Biogeochemistry

Introduction to soils

Lecture #3 – October 13th 2006

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Definitions…

The **Soil** is the *natural*, *unconsolidated* mineral or organic material on the immediate *surface* of the earth that serves as a natural medium for the growth of land plants.

Composed of **Solid**, **Liquid** and **Gas**.

Other conditions (systems of classification)
- Presence of horizons
- Physical, chemical, morphological, mineralogical and/or biological properties that differ from the parent material

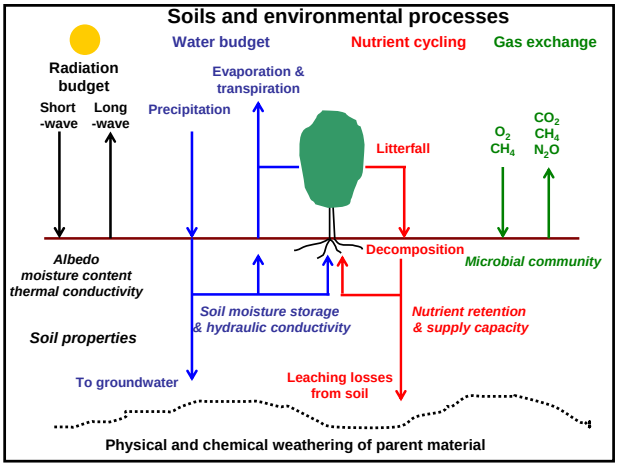
The study of soils

Soil Science is the science that deals with soils as a natural resource. It studies soil formation, classification and mapping, and the physical, chemical and biological properties and fertility of soils as such and in relation to their management for crop production.

Divided in 2 branches: **pedology** and **edaphology**

Pedology (from the Greek *pedon*, soil, earth), is the study of soils in its natural environment and deals with pedogenesis, soil morphology and soil classification

Edaphology is concerned with the influence of soils on living things, particularly plants, also applied to the study of how soil influences man's overall use of the land. General subfields within edaphology are agriculture soil science (agrology) and environmental soil science



Soil Properties

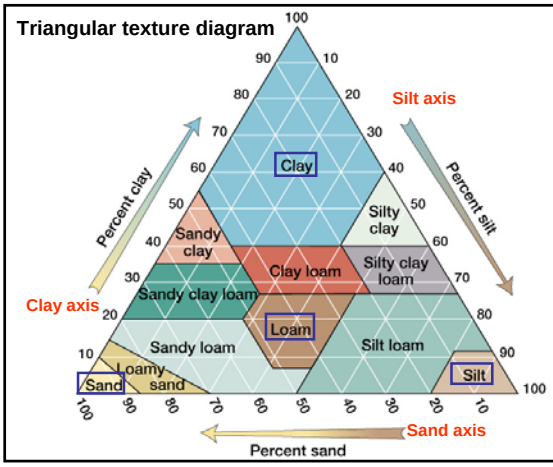
- **Texture**
- Moisture
- Cation Exchange Capacity (CEC)
- Soil Organic Matter (SOM)
- pH

The **soil texture** is the relative proportions of mineral material of different particle size in a soil.

Particle size classes:

- **Gravel** > 2 mm diameter
- **Sand** 0.05 to 2 mm diameter
- **Silt** 0.002 to 0.05 mm diameter
- **Clay** < 0.002 mm diameter (2 μm)
- Combined into **texture classes** through triangular texture diagram.

Triangular texture diagram



Importance of soil texture

Influences **soil infiltration rate**, and thus generation of overland flow and soil erosion.

Influences **soil permeability** and therefore drainage.

Controls **available water capacity** of soil – ability to supply water to plants for transpiration – and soil water budget.

Influences **soil structure**, allowing root growth and aeration.

Provides **cation exchange capacity** for retention of Ca, Mg, K, supply to plants and buffering against acid rain.

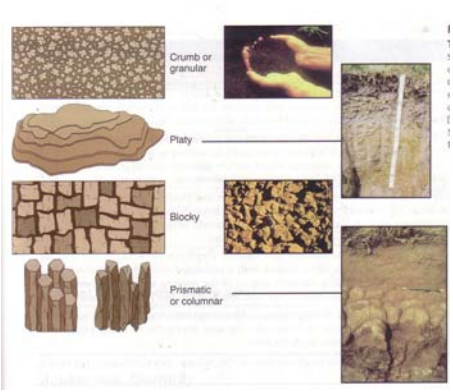
Soil infiltration

Govern by 3 forces: gravity and capilarty

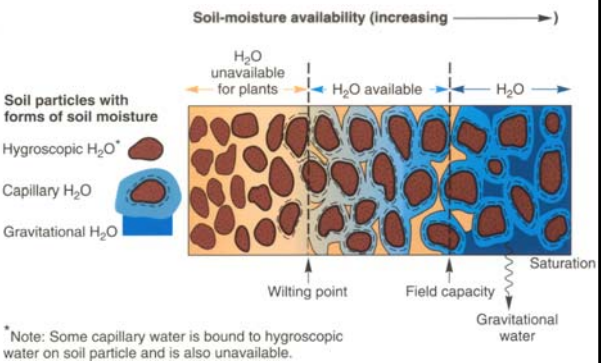
Gravity: weight

Capilarity: results from the soil texture

Soil Structure

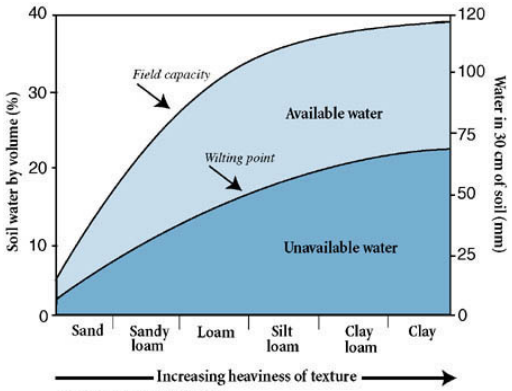


Soil moisture content

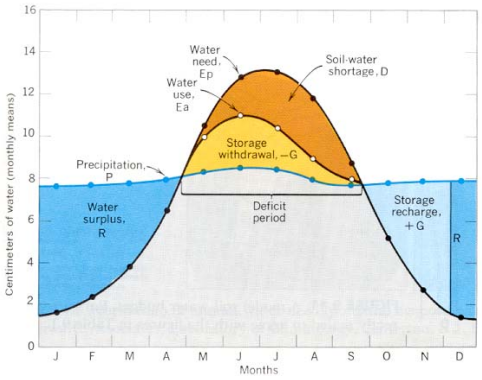


*Note: Some capillary water is bound to hygroscopic water on soil particle and is also unavailable.

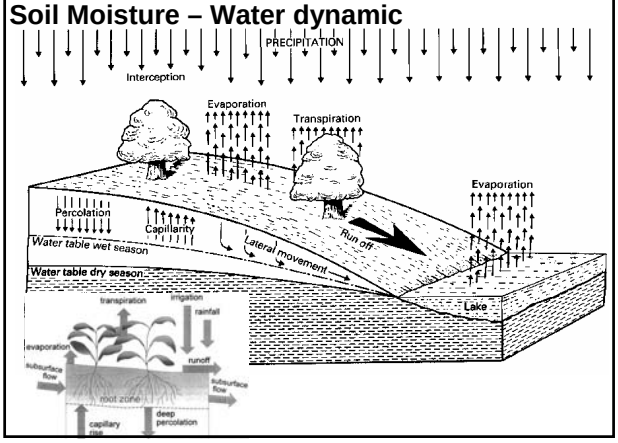
Water content as function of soil texture



Simplified - Seasonal soil water budget



Soil Moisture – Water dynamic

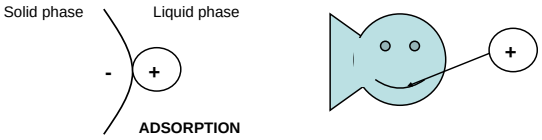


Cation exchange capacity

Cation Exchange Capacity is the sum of total exchangeable cations a soil can adsorb.

Originates from **clay minerals** and **soil organic matter**.

Exchange between the solution (water in the soil) and the particles (either mineral and organic)



Clay minerals

Different clay minerals formed by varying combinations of Si and Al sheets and isomorphous substitution:

Si^{4+} replaced by Al^{3+}

Al^{3+} replaced by Fe^{2+} or Mg^{2+}

Each substitution results in loss of one +ve charge

attracts cations (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, H^{+} and Al^{3+}) to clay surface.

Groups of clay minerals

Kaolinite: structure 1:1, low CEC

$Al_2Si_2O_5(OH)_4$

Smectite: structure 2:1, high CEC (expansion)

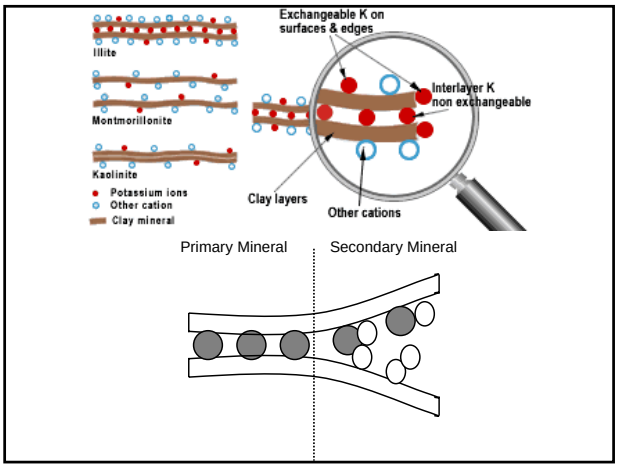
$(MgFe,Al)_3(Al,Si)_4O_{10}(OH)_2.4H_2O$

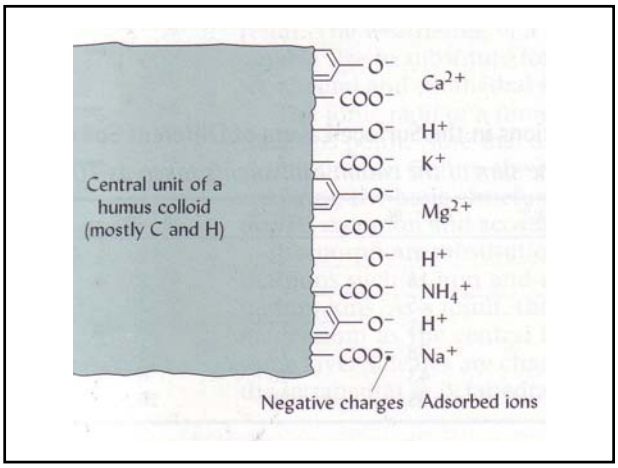
Illite: structure 2:1, intermediate CEC

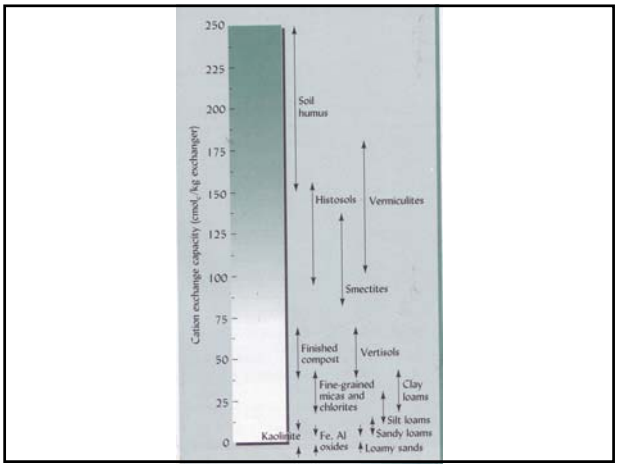
$(K,H_3O)(Al,Mg,Fe)_2(Si,Al)_4O_{10}[(OH)_2,(H_2O)]$

Chlorite: structure 2:2, low CEC

$(Mg,Fe)_3(Si,Al)_4O_{10}(OH)_2 \cdot (Mg,Fe)_3(OH)_6$







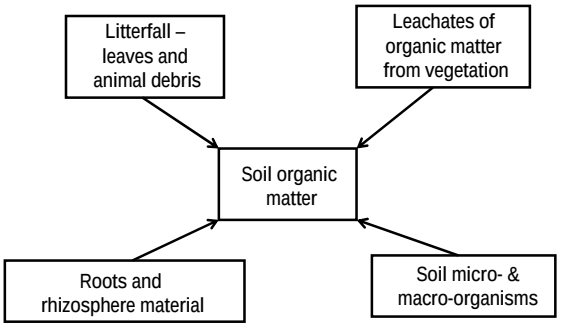
Soil organic matter

Input of organic matter from dead plant and animal tissues.

Output - as carbon dioxide (from decomposition of organic matter by organisms (bacteria, fungi, earthworms etc.)) and Leaching

The balance between input and output establishes the amount of organic matter in soils.

Inputs of organic matter to soils



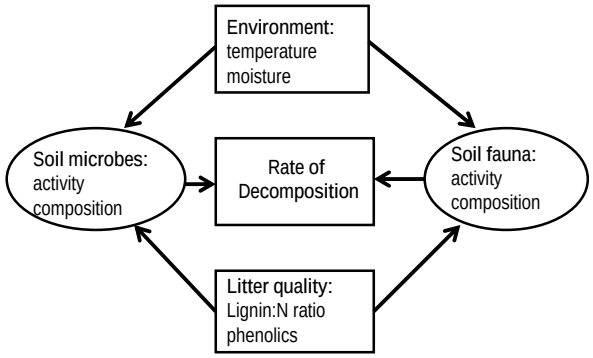
Gas exchange between soils and the atmosphere

The dominant exchange is the uptake of oxygen (O_2) by the soil and the release of carbon dioxide (CO_2) from plant root respiration and decomposition of organic matter.

Soils also exchange other "greenhouse gases":

- **Methane** (CH_4) – consumed from the atmosphere by forest and grassland soils, but produced by wetland soils (bogs, marshes).
- **Nitrous oxide** (N_2O) emitted from soils where strong cycling of N, disturbance (e.g. forest removal in Tropics) or application of large amounts of N fertilizer.

Factors controlling litter and organic matter decomposition rates



Importance of organic matter in soils

Improves soil structure and porosity, increases infiltration rate, increases available water capacity.

Supplies nutrients (Ca, Mg, K, N and P) to plants through slow decomposition.

Humus possesses a cation exchange capacity leading to retention of cations (Ca, Mg, K) and buffering against acid rain.

Nutrient cycling

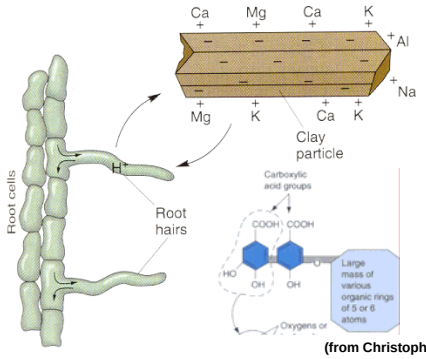
Inputs of nutrients to soil:

- Weathering of minerals (ease of weathering and content of Ca, Mg, K and P).
- Death and decay of vegetation (litter, soil organic matter).
- Atmosphere (N and particulates containing Ca, Mg and K).

Outputs of nutrients to:

- Vegetation (plant uptake).
- Atmosphere (loss of gaseous forms of N).
- Ground water table and streams through leaching.

Exchange of nutrient cations between clay and organic matter and roots

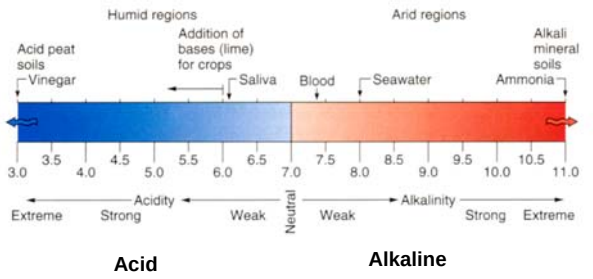


also humus

(from Christopherson)

$pH = - \log_{10} [H^+]$

pH in soils



Acid **Alkaline**

Importance of pH
Link with CEC