Introduction to Soil Science

By:
Sheldon Hann
Agriculture and Agri-Food Canada
Email: hanns@agr.gc.ca

Outline

- Importance of Soil
- Function of Soil
- Soil Forming Factors
- Soil Forming Processes
- Soil Horizons
- Soil Properties
- Soil Drainage

Importance

"Soil is the essence of life."

- Most life on earth depends upon the soil as a direct or indirect source of food, water and shelter.
- Soil is home to billions of organisms.

  (1ha of land ~ 25 million insects and 1 million earthworms)
- Soil takes 1000's of years to develop and is destroyed easily, so it must be conserved in order to continue to support life.
- 10mm of soil takes between 100 to 1000 years to develop.

Function

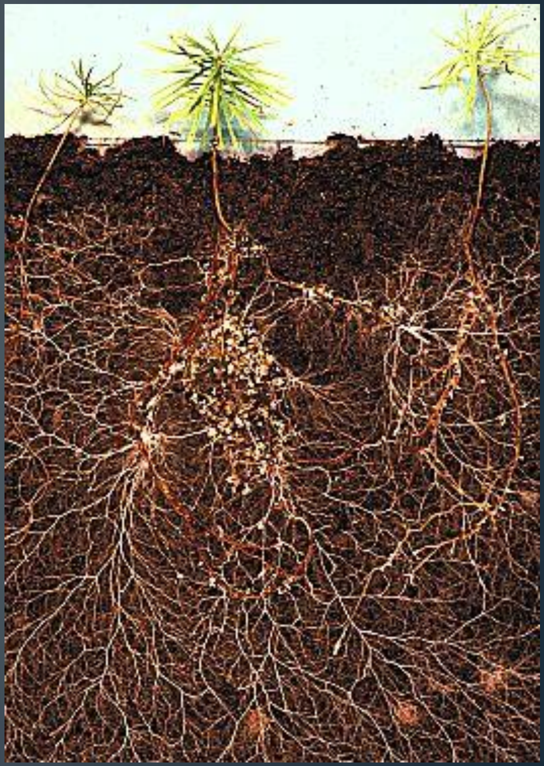
The function of soil includes:

1. A medium for plant growth.
2. A regulator of water supply.
3. Habitat for organisms.
4. A recycler of wastes.
5. Support of structures

Function

Medium for plant growth:

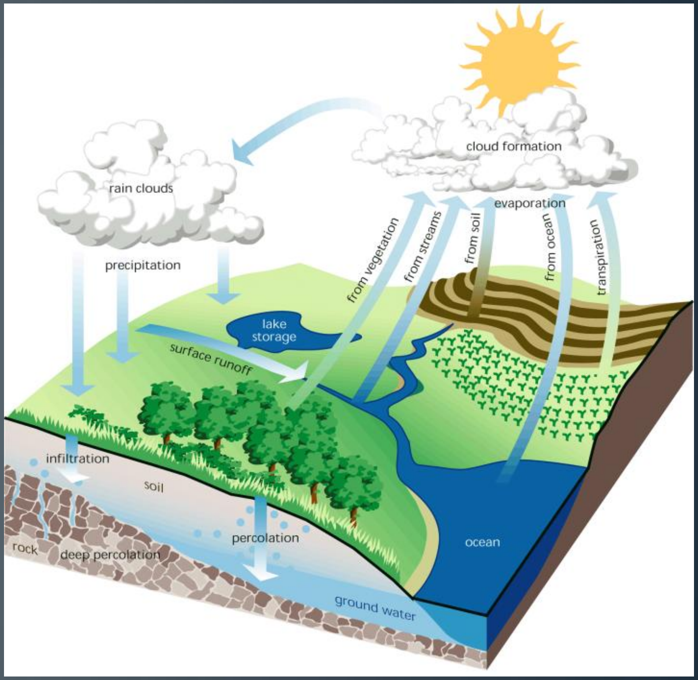
- Soil is a source of macro and micronutrients.
  - Macronutrients include nitrogen, phosphorous, potassium, etc.
  - Micronutrients include iron, manganese, zinc, copper, etc.
- Soil is a source of water and nutrients for plants during the growing season.
- Soil anchors plants, which increases the stability of the soil.



Function

Regulate water supply:

- Soil plays a vital role in cycling freshwater.
- Soil filters and regulates the water supply by storing water after a precipitation event.
- This stored water can then be released during the growing season, to minimize drought.



Function

Habitat for organisms:

- Soil is composed of billions of organisms.
- These organisms decompose organic matter and convert minerals and nutrients into forms that are available to plants and animals.

Function

Recycle wastes:

- Soil has the ability to recycle natural wastes, if these wastes are added in appropriate amounts.
- Plant residues and manure can be added to soil which will enrich nutrient concentrations and may improve soil properties.

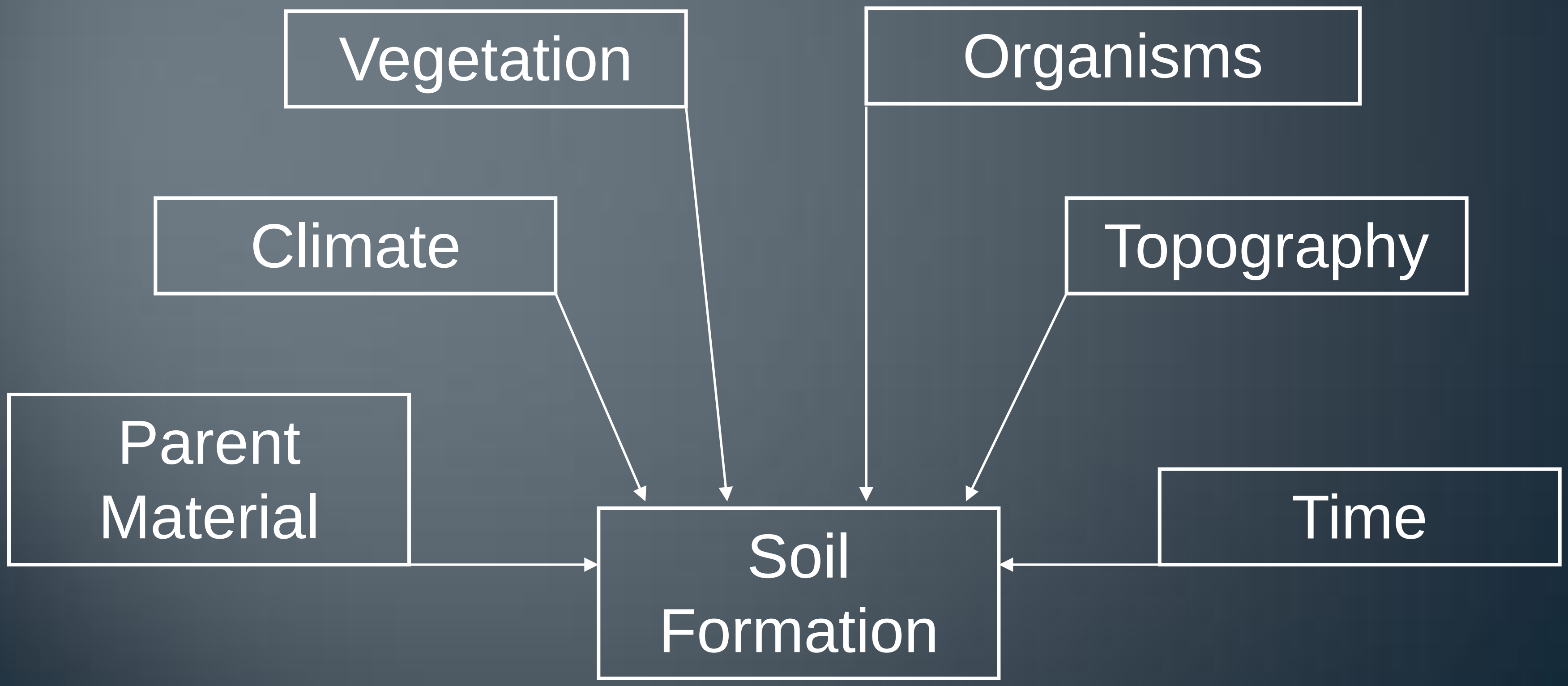
Function

Support for structures:

- Soil is used for structures such as roads, causeways and as the foundation for buildings and bridges.
- Soil is also used for the establishment of forestry and agriculture crops.

Soil Forming Factors

The soil forming factors include:



Soil Forming Factors

Parent Material:

- Soil is highly dependent on the existing parent material.
- Soil texture is influenced by parent material
  - Granite or Sandstone - Coarse Textured Soils
  - Shale - Fine Textured Soils
- The chemical and mineral composition of the parent material influences the weathering of the material as well as effects what natural vegetation will be present.
  - Limestone-based soils will delay the development of acidity in the soil.

Soil Forming Factors

Climate:

- Temperature and effective precipitation affect the rates of chemical, physical and biological weathering.

- If warm temperatures and abundant water are present the processes of weathering, leaching and plant growth will be maximized.

- For every 10°C rise in temperature, the rates of biochemical reactions more than double.

Soil Forming Factors

Vegetation:

- Vegetation affects soil profile development by enhancing the organic matter accumulation, biochemical weathering, profile mixing, nutrient cycling and aggregate stability.
- Soils under conifer forests tend to have a stronger development in soil acidity.
- Coniferous forests tend to have a thick forest floor layer because of the acidic, resinous needles; whereas deciduous forests have a thin forest floor with less distinct layers.

Soil Forming Factors

Soil Organisms:

- Soil organisms decompose organic matter and have a key role in the nutrient cycling process; they help by converting minerals and nutrients into forms that are available to vegetation.
- Organisms like earthworms provide aeration and soil mixing.
- This aeration and mixing increases the stability of soil aggregates and ensures the infiltration of water into the soil.

Soil Forming Factors

Topography:

- Topography is described by the differences in elevation, slope, aspect and landscape position; these factors can delay soil development.
- Soils on steep terrain tend to have shallow, poorly developed soil profiles than those on nearby level ground.
- Topography also determines how much soil material is relocated by water, wind and gravity.
- South-facing slopes are generally warmer and drier than north-facing; as a result south slopes tend to be lower in organic matter and are not so deeply weathered.

Soil Forming Factors
Time:

- Soils are dynamic, continuously changing overtime.
- The development of soil can take hundreds of years, therefore the time that has elapsed is an important factor.

- The longer the time a soil has been forming, the more highly developed that soil will be.
  - The presence of a B horizon is likely to take centuries.
  - The accumulation of silicate clays only becomes distinguishable after thousands of years.

Soil Forming Processes

The soil forming processes include:

- Chemical weathering
- Physical weathering
- Biological weathering

Soil Forming Processes

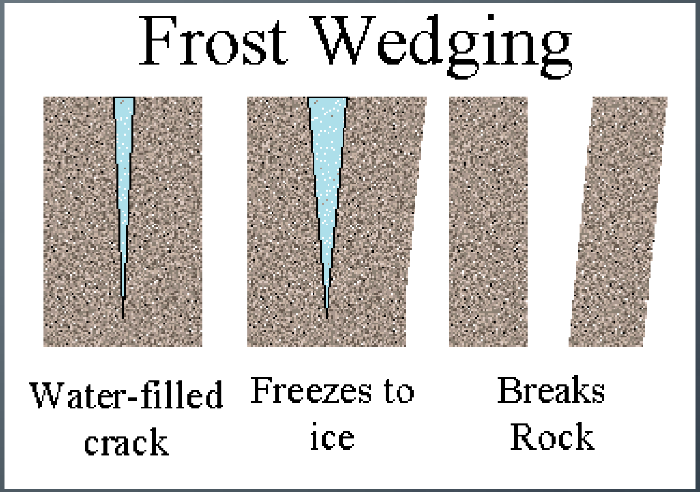
Chemical weathering:

- Also known as “decomposition”.
- Caused by the chemical action of water, oxygen and organic acids.
- Decomposition occurs when the chemical makeup of the soil or rock particles change; but the physical size of the particles does not.
- An example of chemical weathering is oxidation.

Soil Forming Processes

Physical weathering:

- Also known as “disintegration”.
- Here the size of rock and soil particles are reduced without changing the chemical makeup of the particles.
- An example of physical weathering would be frost wedging.



Soil Forming Processes

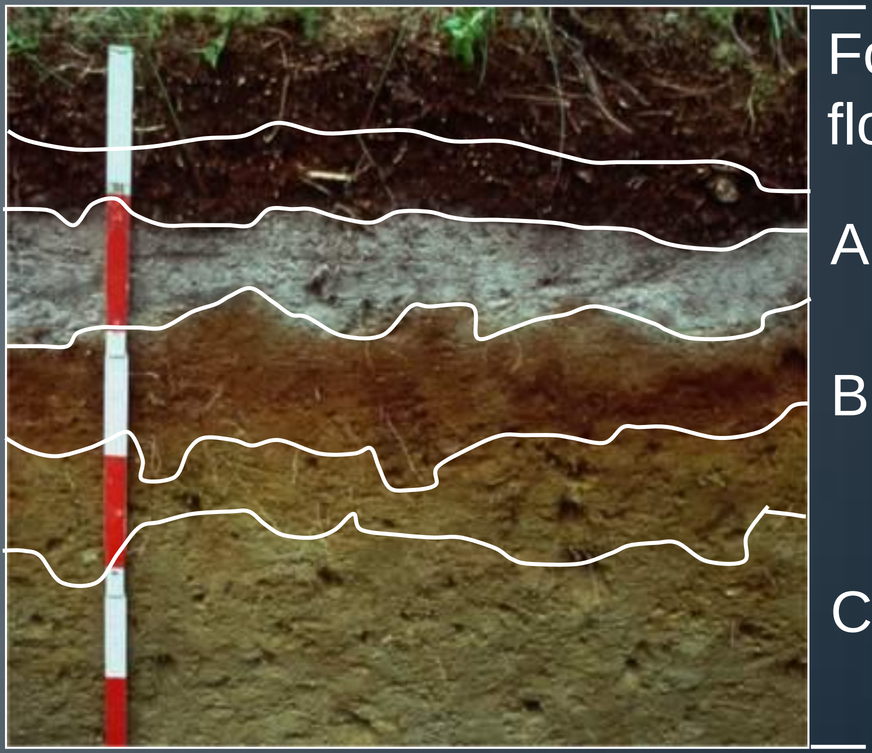
Biological weathering:

- Organisms can assist in the breakdown and formation of sediment and soil.
- Biological weathering can react with particles to change the physical size as well as chemical composition .
- An example of biological weathering would be root weathering.

Soil Horizons

Soil Horizons:

- Soil may consist of five horizons:
  1. Forest floor
  2. A horizon – zone of loss.
  3. B horizon – zone of accumulation
  4. C horizon – relatively unaltered parent material
  5. R - bedrock



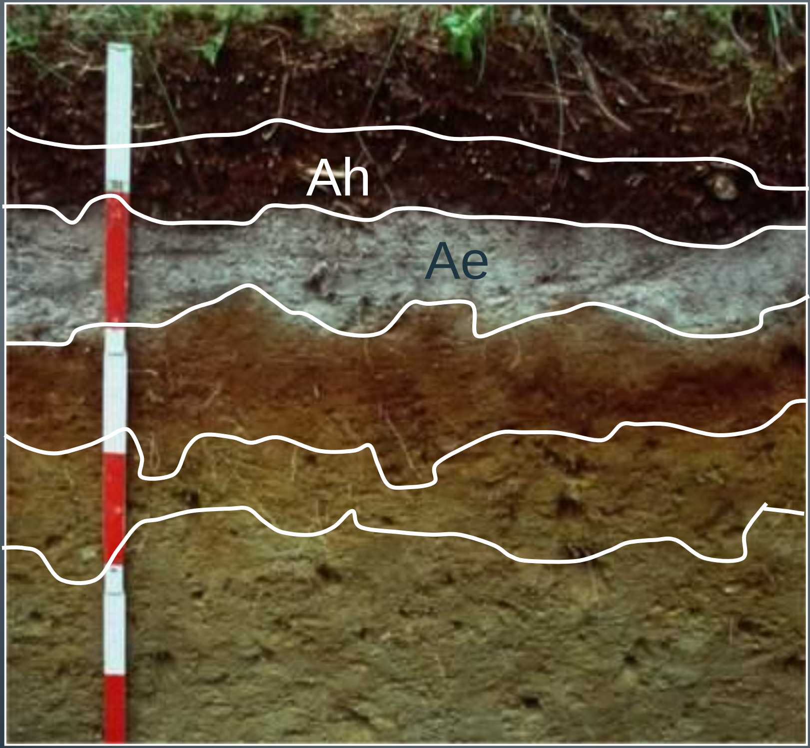
Soil Horizons

Soil Horizons – Forest floor:

- The forest floor consists of:
  - L (Litter layer) – Found on the ground surface and is composed of needles, leaves, twigs and other organic materials.
  - F (Fermented layer) – Partially decomposed organic materials such as needles, leaves and twigs.
  - H (Humus layer) – Fully decomposed organic material, often black-brown to nearly black in color.

Soil Horizons

Soil Horizons – A horizon:

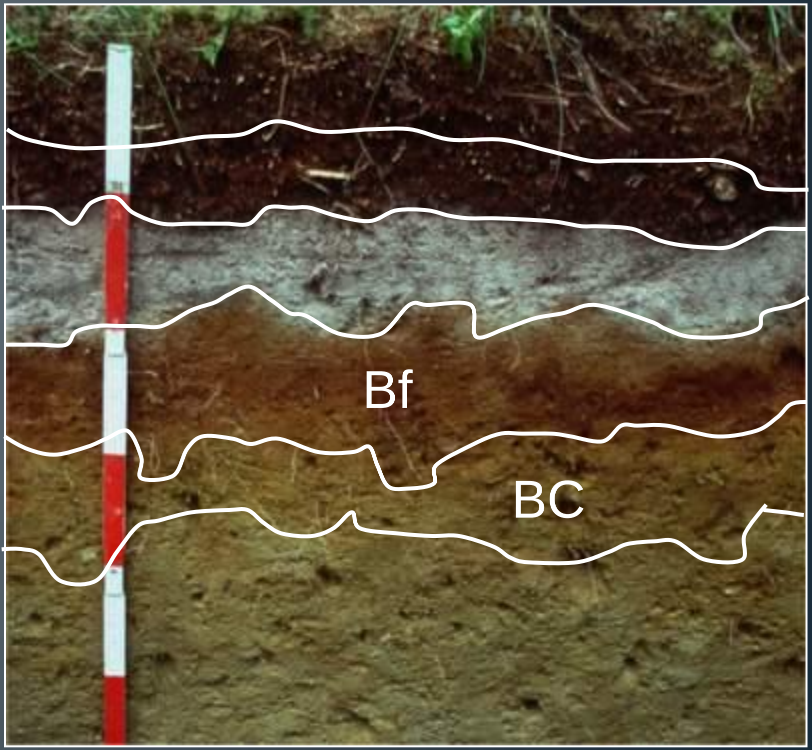


- First mineral horizon
- Ah (humus)-Due to biological activity, organic matter has accumulated in this horizon.
- Ae (eluviation)-Identified by the absence of clay, iron, aluminum and organic matter (grey to white in color).
- Ap (plow)-Horizon that has been disturbed by cultivation, logging and habitation.

Soil Horizons

Soil Horizons – B horizon:

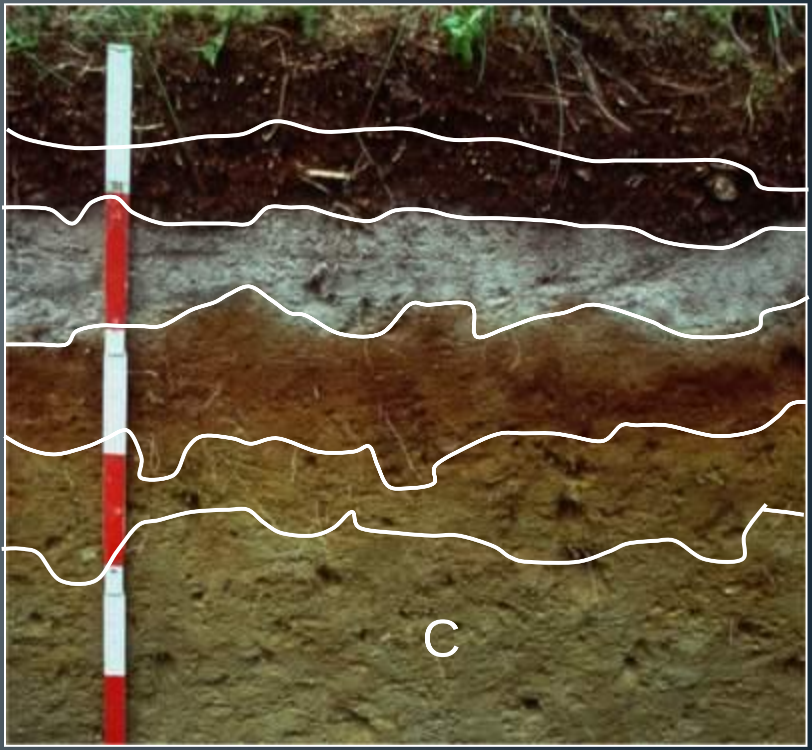
- Zone of accumulation.
- Bf (iron)-Horizon enriched with iron (Fe) and aluminum (Al).
- Bh (humus)-Horizon enriched with organic matter.
- Bg (gleying)-Horizon characterized by gray colors and/or mottling.
- Bt-Horizon enriched with silicate clays.



Soil Horizons

Soil Horizons – C horizon:

- Horizon characterized as parent material that is relatively unaffected by the soil forming processes.
- Cg (gleying)-Horizon characterized by gray colors and/or mottling.



Soil Properties

Soil properties include:

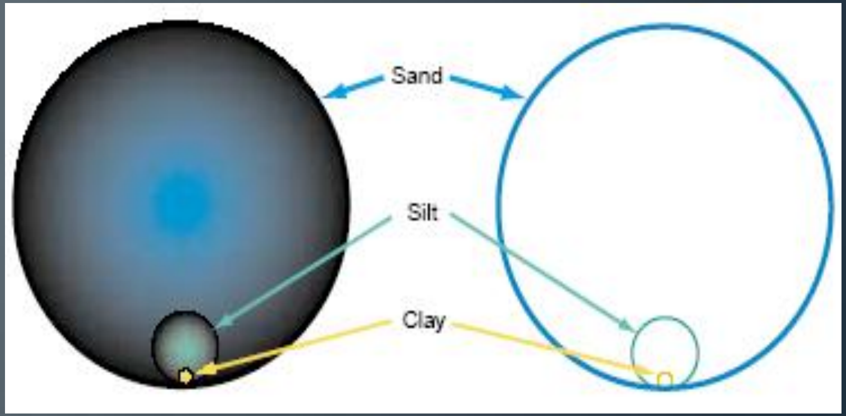
- Texture
- Organic matter
- Color
- Structure
- pH

Soil Properties

Texture:

- Refers to the proportions of sand, silt and clay found in a given soil.

Soil Separate	Diameter (mm)
Sand	2.0 - 0.05
Silt	0.05 - 0.002
Clay	< 0.002



- Different combinations of sand, silt and clay give rise to soil texture classes.

Soil Properties

Texture Classes:

	Texture Class	Description
Coarse	S	Sand
↑	LS	Loamy Sand
	SL	Sandy Loam
	L	Loam
	SiL	Silty Loam
	SCL	Sandy Clay Loam
↓	CL	Clay Loam
Fine	C	Clay

* Loam is a soil that has an even mixture of sand, silt and clay.

Soil Properties

Organic Matter:

- Increases the soil's infiltration rate as well as increases the water holding capacity and nutrient holding capacity.
- Changes the structure of the soil by affecting the pore size.

- Organic matter helps reduce the plasticity, cohesion and stickiness of heavy soils.
- Generally organic matter content in soil decreases with soil depth.
- Generally productivity increases as organic matter within the soil increases.

Soil Properties

Color:

- Soil color provides valuable clues to the nature of other soil properties and conditions. Such as parent material of the soil, soil drainage, amount of iron and organic matter in soil.
    - Soils that come from siltstones have a olive-gray color and those that come from sandstones have a yellowish-brown color.
    - Generally soils with good drainage have bright colors.
    - Dark brown or black colors suggest high levels of organic matter.
- Soil color is described by using the Munsell color charts. These charts describe soil color by its Hue, Value and Chroma.
- An Example of soil color would be: 10YR 5/6

Soil Properties

Structure:

- Structure relates to the arrangement of primary soil particles called “Aggregates” or “Peds”.
- Structure greatly influences water movement, heat transfer, aeration and porosity of soil.
- Structure is characterized in terms of shape, size and distinctness.
- There are 4 principle shapes of soil structure
  - Spheroid – Granular
  - Plate-like - Platy
  - Block-like - Blocky
  - Prism-like – Columnar and Prismatic

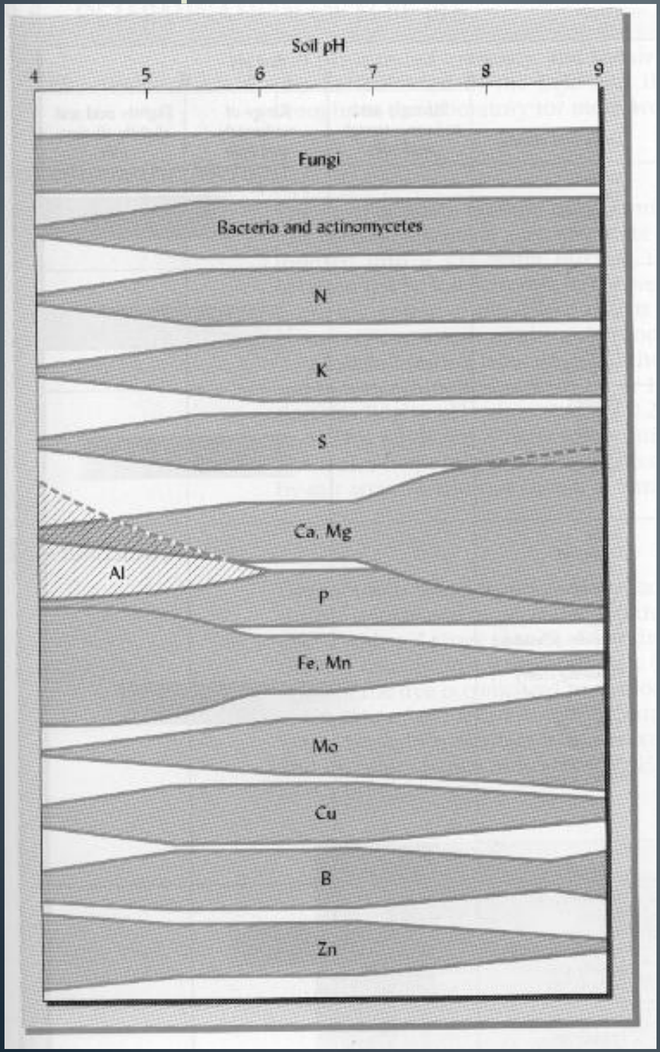
Soil Properties

Soil pH:

- The degree of the acidity or alkalinity of soil is a key variable that affects all soil properties (chemical, physical and biological).
- pH scale goes from 0 (acidic) to 14 (basic) with pH 7 as the neutral point.
- Soil pH can have a range of values between 4 and 8.

Soil Properties

Soil pH:



- The solubility of minerals and nutrients as well as the microbial activity in soil is highly dependent on pH.
- Microbial activity tends to decrease when pH reaches below 5.5.
- Nutrients such as Ca and Mg become more soluble and therefore available once pH reaches 7.

Soil Drainage

Soil Drainage is defined by the length of time it takes water to be removed from the soil in relation to the supply.

- Drainage is affected by two groups of factors:
  1. Soil-External Factors
  2. Soil-Internal Factors

Soil Drainage

External Factors

- Position on the slope – Soils in upper positions tend to be better drained than those in the lower slopes.
- Aspect – Southern aspects are warmer than northern aspects, therefore southern aspects will have less soil water and better drainage.
- Climate – Areas that receive high amounts of rainfall will have poorer drainage than those that receive low amounts.
- Bedrock – The presence and type of bedrock can affect the rate and the flow direction of soil water.

Soil Drainage

Internal Factors

- Soil texture – Coarse to medium textured soils will tend to have better drainage.
- Stoniness – Soils with gravels and cobbles have a improved drainage.
- Bulk density – Soils with high bulk density tend to be more poorly drained than those with low bulk density.

Soil Drainage

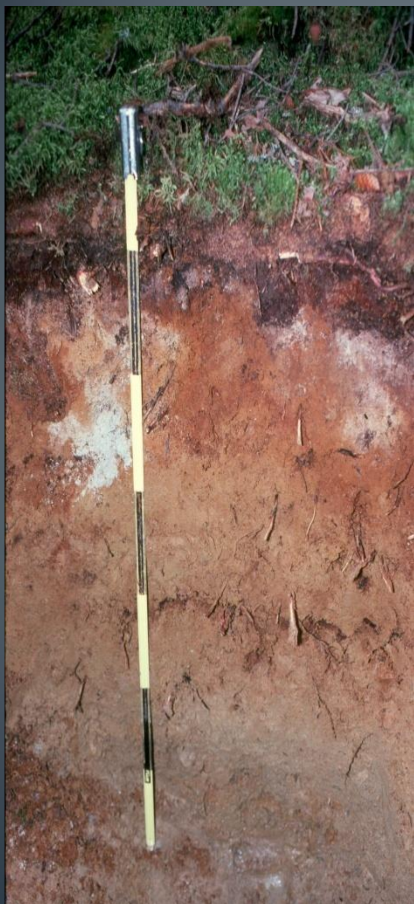
Drainage Classes

- Six classes:
  1. Rapidly
  2. Well
  3. Moderately Well
  4. Imperfect
  5. Poor
  6. Very Poor

- Soils with good drainage tend to have bright colors.

- Soils with poor drainage tend to have a grayish color.

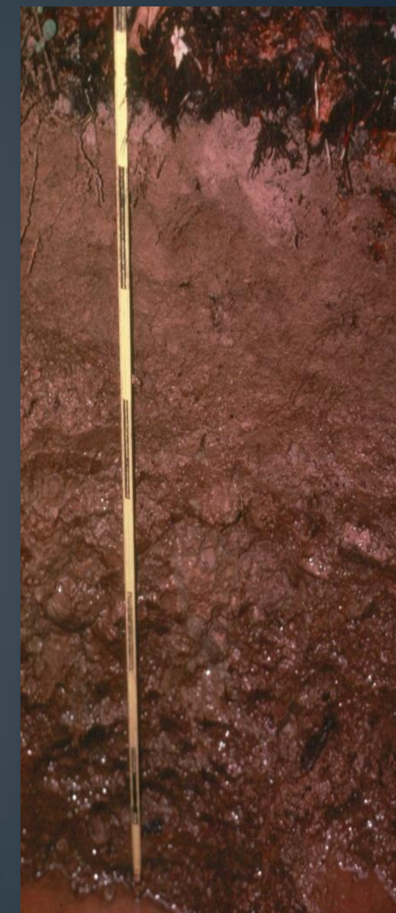
Soil Drainage



Imperfectly drained

Poorly drained

Imperfect to Poorly drained



Imperfect to Poorly drained

Exercise

1. Texture Triangle
2. Texture Feel Test
3. Soil Color

Exercise

Texture Triangle:

- You have six soils which require texture classification; the particle size distribution is as follows:

Soil #	Sand %	Silt %	Clay %	Texture Class
1	15	73	12	
2	7	35	58	
3	96	2	2	
4	45	31	24	

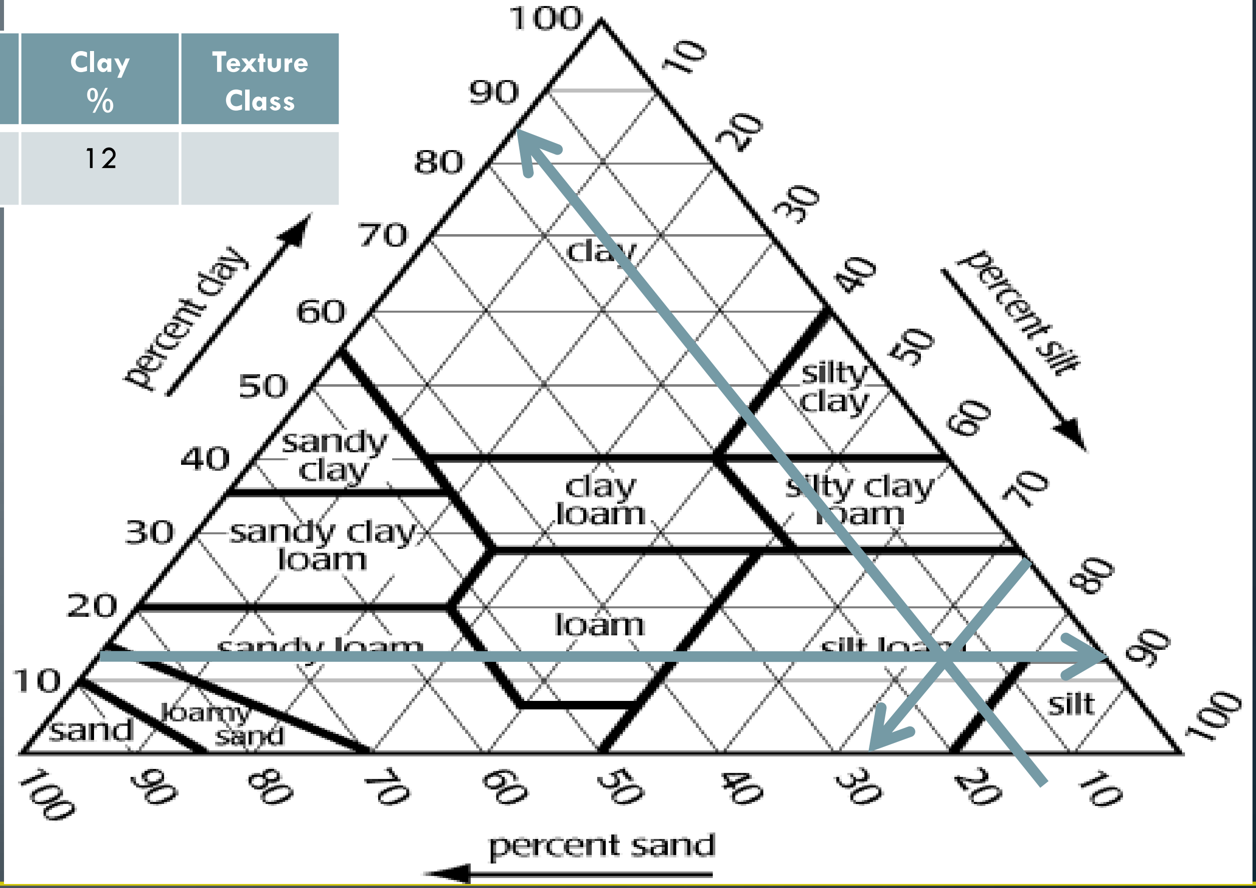
Exercise

Texture Triangle:

- So to determine the texture class for Soil #1:

Soil #	Sand %	Silt %	Clay %	Texture Class
1	15	73	12	

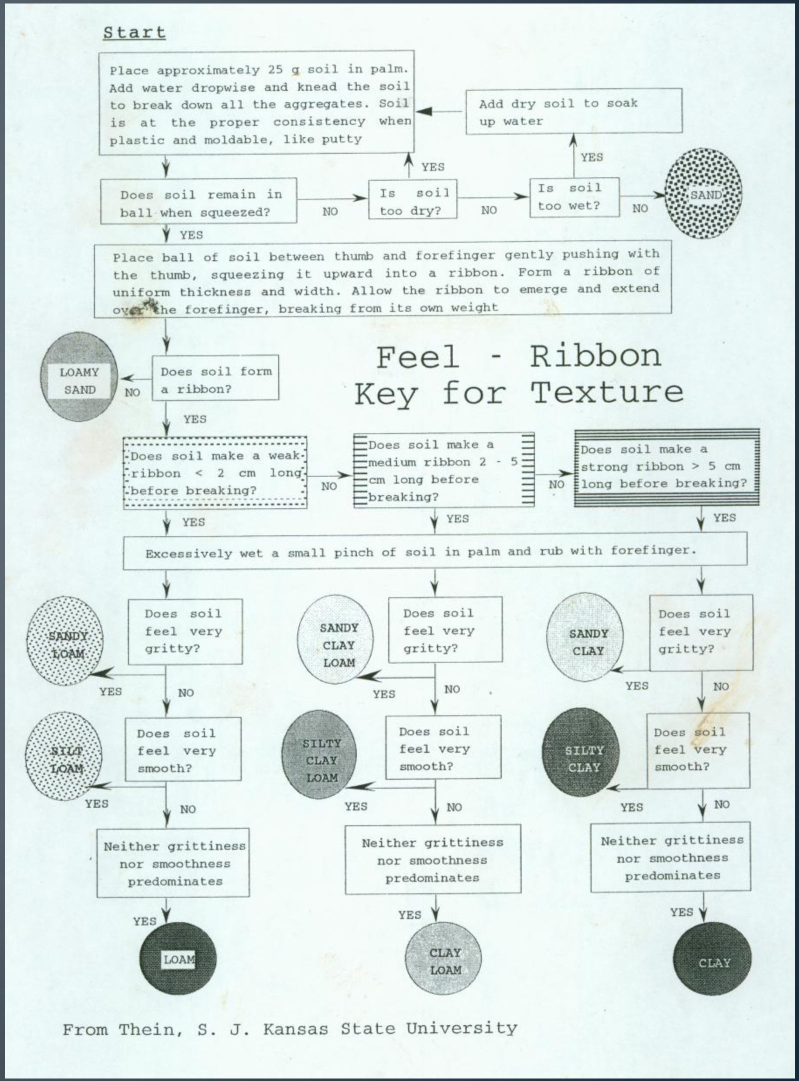
Silt Loam



Exercise

Texture Feel Test:

- Based on the “Feel-Ribbon Key for Texture” determine the texture class of the six soil samples.

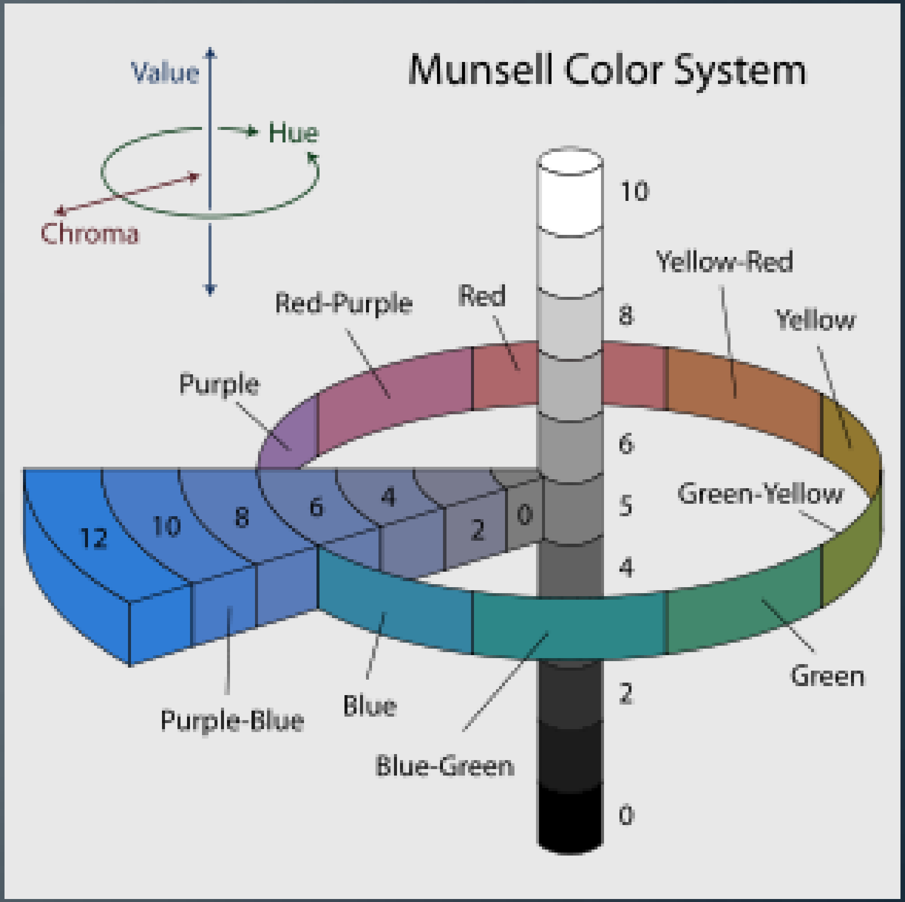


Exercise

Soil Color:

- Based on the Munsell color charts determine the color of the six soil samples.
- Remember the order for color:

  Hue Value/Chroma



Exercise Answers

Soil #	Texture Feel Class	Soil Color
1		
2		
3		

Current Issue Learning Objectives:

1. Soil and Water Conservation best management practices; their purpose and implementation.
2. How are soil and water conservation best management practices interrelated to the management of wildlife, forestry and aquatic systems?
3. How do agriculturists maintain a balance between their quality of life versus the quality of the environment?

Current Issue Learning Objectives:

Soil and Water Conservation best management practices:

Soil Management: Tillage conservation, contour planting, terracing, buffer strips, riparian management, crop rotations, cover and trap crops, residue management.

Soil Nutrient Management: Soil tests for N-P-K applications, fertilizer application management.

Livestock Management: Feed quality and methane production, rotational grazing.

Manure Management: Straw additions to manure to decrease N2O and CH4, timing of manure application.

Agroforestry Management: Shelterbelts and windbreaks.

Learning Objectives:

- 1, Identify and recommend soil and water conservation best management practices in agriculture.

  2. Describe the role of the federal government in conservation programs that benefit both agricultural producers and the environment.

  3. Identify the concept of soil quality/health to provide the needed functions for the conservation planning process.

  4. Identify various types of soil erosion and utilize different methods to estimate and predict soil erosion to assess land use impacts.
- a. RUSLE 2 Equation
  b. Aerial Photographs
  c. Topographic Maps
  d. Soil Maps
  e. USDA Classification System
  f. Soil Surveys

  5. Explain why land-use planning is important to our ecosystems and to our economy to achieve sustainable agriculture.

Questions?