Soils and Land Use Reference Material for Canon Envirothon

Importance of Soil

"Soil is the essence of life"; most life on earth depends on soils as a direct source of food, water and shelter. Soil quality determines the nature of plant ecosystems and the capacity of land to support animal life and society. Soil is home to billions of organisms; these organisms aid and assist in the breakdown of organic material which improves soil quality. The ability to preserve and manage the soil resource is detrimental to continue to support life.

Functions of Soil

The many functions of soil can be grouped into five crucial ecological roles:

1. Medium for plant growth – Soil is a source or macro (nitrogen, phosphorous, potassium, etc) and micronutrients (iron, manganese, zinc, copper, etc). Soil provides ventilation for plants root systems; allowing CO_2 to escape and fresh O_2 to enter the root zone. Soil pores absorb rainwater and hold it where it can be used by the plants roots. A deep soil may store enough water to allow plants to survive long periods without rain. Soil also moderates temperature fluctuations; the insulating properties of soil protect the deeper portion of the root system from extreme hot and cold temperatures.
2. Regulator of water supplies – Soil plays a vital role in the cycling of freshwater. Soil filters and regulates water supply by storing water after a precipitation event. Nearly every drop of water in our rivers, lakes, estuaries and aquifers has either travelled through soil or flowed over its surface.
3. Habitat for organisms – Soil is home to billions of organisms, belonging to thousands of species. Small quantities of soil are likely to contain predators, prey, producers, consumers and parasites. These organisms decompose organic matter and convert minerals and nutrients into forms that are available to plants and animals.
4. Recycler of raw materials – Soil has the capacity to assimilate great quantities of organic waste. Turning this waste into humus. Soil also converts the mineral nutrients in the wastes into forms that can be utilized by plants and animals. Soil also returns the carbon to the atmosphere as carbon dioxide, where it will again become a part of living organisms.
5. Engineering medium – 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 can be placed into six categories:

1. Parent material – Soil is highly dependent on the existing parent material. Parent material influences many soil properties; for example soil might inherit a sandy texture from a coarse-grained, quartz-rich parent material such as quartzite or sandstone. Soil texture, in turn, helps

control the percolation of water through the soil profile, thereby affecting the translocation of fine soil particles and plant nutrients. The chemical and mineral composition of parent material also influences both chemical weathering and the natural vegetation; for example the presence of limestone will delay the development of acidity in soil. Parent material also influences the quantity and type of clay minerals that are present in the soil profile; which affects soil quality such as nutrient holding capacity.

Parent material classes:

- Residual – formed in place by rock
- Colluvial – transported by gravity
- Alluvial – transported by rivers
- Marine – transported by oceans
- Lacustrine – transported by lakes
- Glacial – transported by ice
- Eolian – transported by wind
- Organic – accumulated plant debris

2. Climate - Climate is suggested to be the most influential of the soil forming factors acting on parent material because it determines the nature and intensity of the weathering that occurs over large geographic areas. The two variables of climate that influence soil formation are effective precipitation (effective precipitation must penetrate into the soil; the greater the penetration depth, the greater the depth of weathering and the more soil development will occur) and temperature (for every $10^{o}C$ rise in temperature, the rates of biochemical reactions more than doubles). If warm temperatures and abundant water are present in the profile at the same time, the process of weathering, leaching and plant growth will be maximized.
3. Vegetation – Vegetation affects soil profile development by enhancing the organic matter accumulation, biochemical weathering, profile mixing, nutrient cycling and aggregate stability. Under conifer forests more cations are lost by leaching compared to deciduous forests; which will result in a stronger development in soil acidity. Coniferous forests tend to have a thick forest floor because of the acidic, resinous needles; whereas deciduous forests have a thin forest floor with less distinct layers.
4. 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, which in turn, increases the stability of soil aggregates and ensures the infiltration of water into the soil.
5. Topography – Topography is described by the differences in elevation, slope, aspect and landscape position. Soils on steep terrain tend to have shallow, poorly developed soil profiles than those on nearly level ground. Topography also determines how much soil material is relocated by water, wind and gravity. South-facing slopes are generally warmer and drier that north-facing slopes; as a result south slopes tend to be lower in organic matter and are not so deeply weathered.
6. Time – Soils are dynamic and are 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. Some examples of soil development and time are as follows:

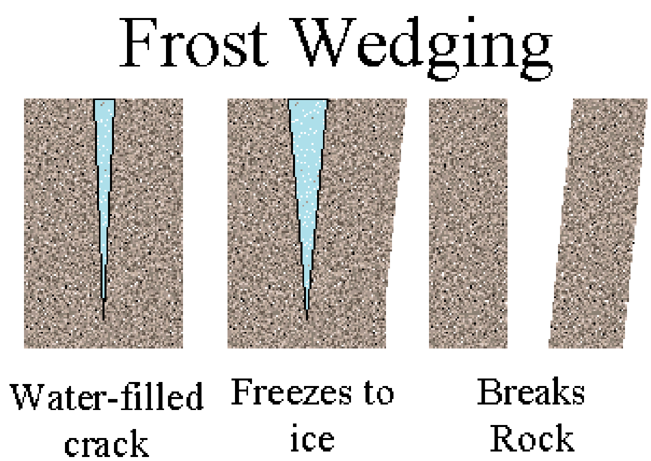
- The presence of a B horizon is likely to take centuries.
- The accumulation of silicate clays only becomes distinguishable after thousands of years.

Soil Forming Processes

The soil forming processes include:

1. Chemical weathering – Chemical weathering is also known as decomposition. It is 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 do not. One example of chemical weathering is oxidation.

2. Physical weathering – Physical weathering is also known as disintegration. It is caused when the size of the rock or soil particles is reduced without changing the chemical makeup of the soil or rock particles. One example of physical weathering would be frost wedging.

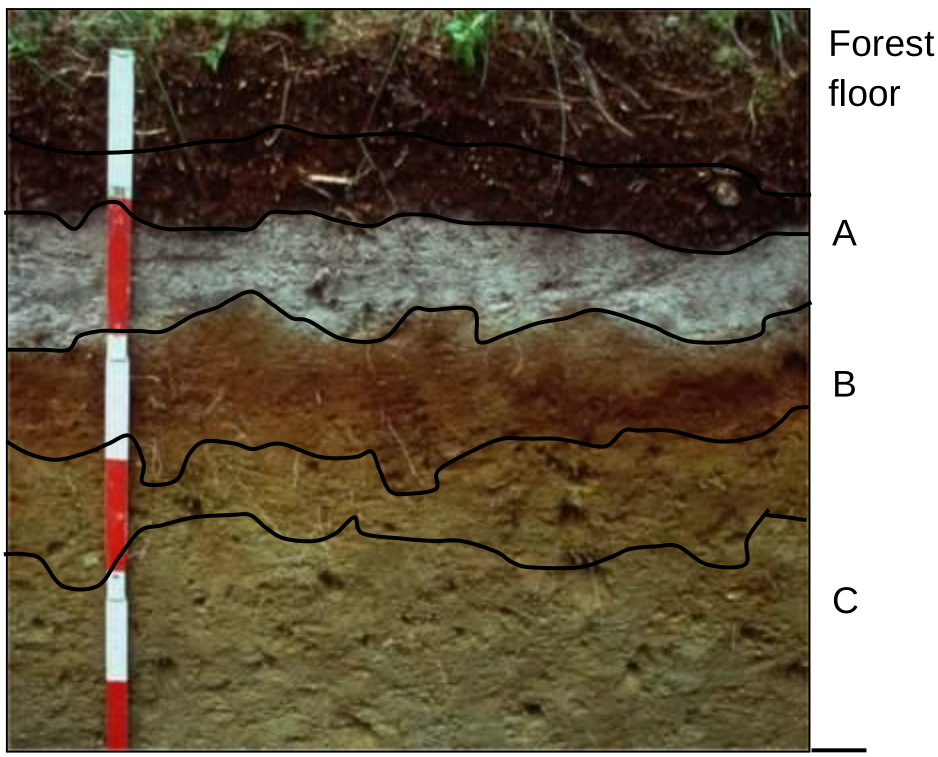


3. Biological weathering – Biological weathering occurs when organisms assist in the breakdown and formation of sediment and soil. This type of weathering can react with particles to change the physical size as well as the chemical composition.

Soil Horizons

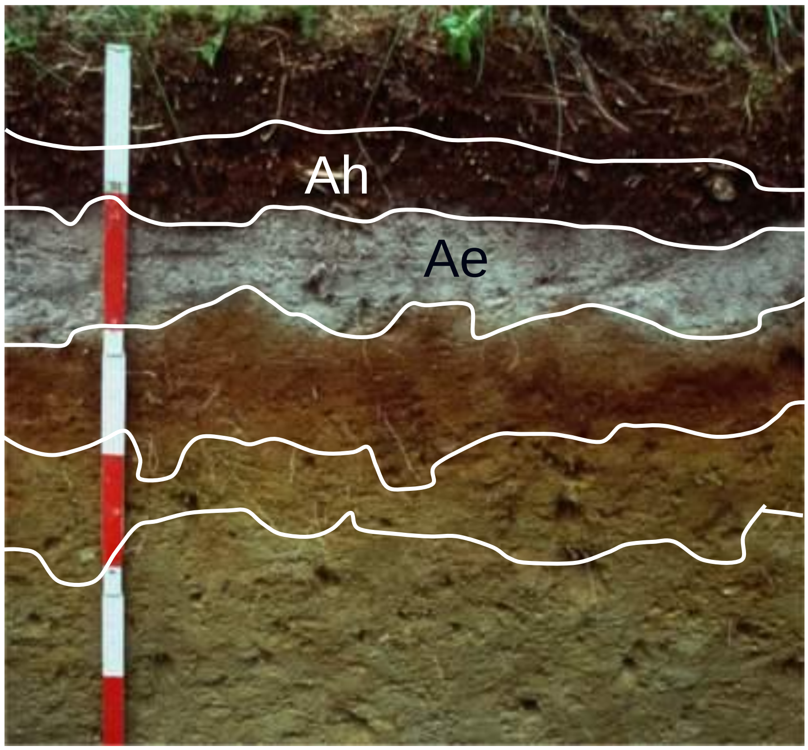
Based on the Canadian System of Soil Classification, soil may consist of five horizons. These horizons are as follows:

1. Forest Floor
2. A - Horizon
3. B - Horizon
4. C - Horizon
5. R – Bedrock

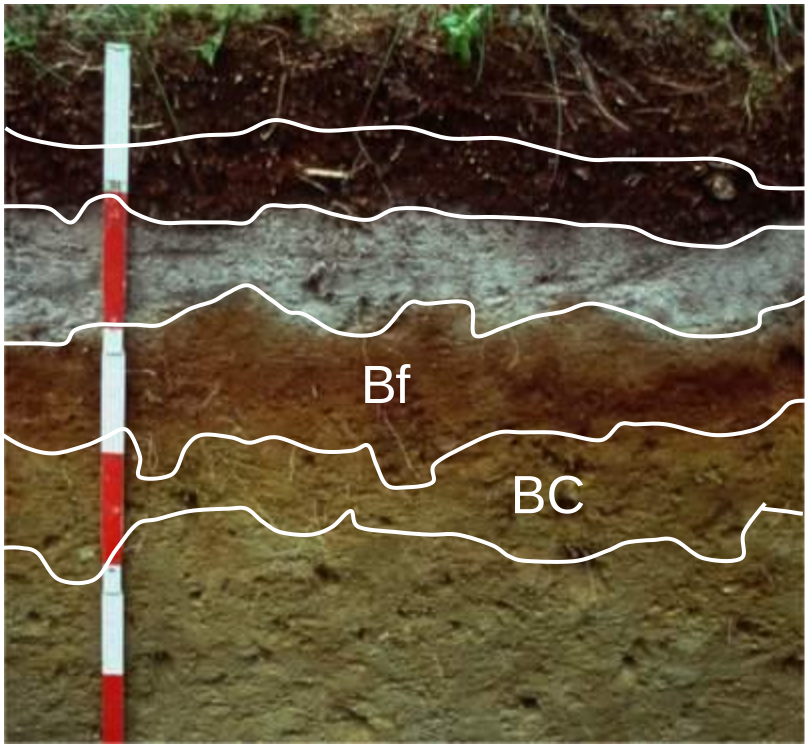


1. Forest floor - The forest floor consists of primarily organic material. The forest floor horizon can be separated into three layers:
    1. L (Litter layer) – Found on the ground's surface and is composed of needles, leaves, twigs and other organic materials.
    2. F (Fermented layer) – Partially decomposed organic materials such as needles, leaves and twigs.
    3. H (Humus layer) – Partially decomposed organic materials such as needles, leaves and twigs.

2. A Horizon – The A horizon is the first mineral horizon; it can be identified by three of the following examples. 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 color). Ap (plow) – Horizon that has been disturbed by cultivation, logging and habitation.



3. B Horizon – The B horizon is also known as the zone of accumulation. This horizon is characterized by enrichment in organic matter (Bh), iron and aluminum (Bf), or enrivhed with silicate clays (Bt). This horizon may also be characterized by grey colors and/or mottling (Bg).

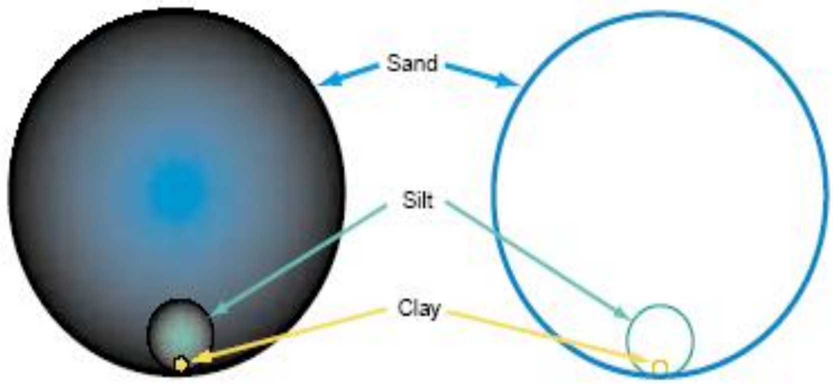


4. C Horizon – The C horizon is characterized as parent material that is relatively unaffected by the soil forming processes. An example of a C horizon that is located in poorly drained areas is characterized by grey colors and/or mottling is denoted as Cg.

Soil Properties

There are seven soil properties that are concentrated on and they are as follows: texture, organic matter, color, structure, pH, bulk density and porosity. A brief description of each of the soil properties as well as any possible soil field test Is described below.

1. Texture – The knowledge of the proportions of different sized particles in soil is critical for understanding soil behavior and management. Soil texture is a measure of the proportions of sand silt and clay in any given soil. A representation of each soil separate along with it's diameter ranges as found below:

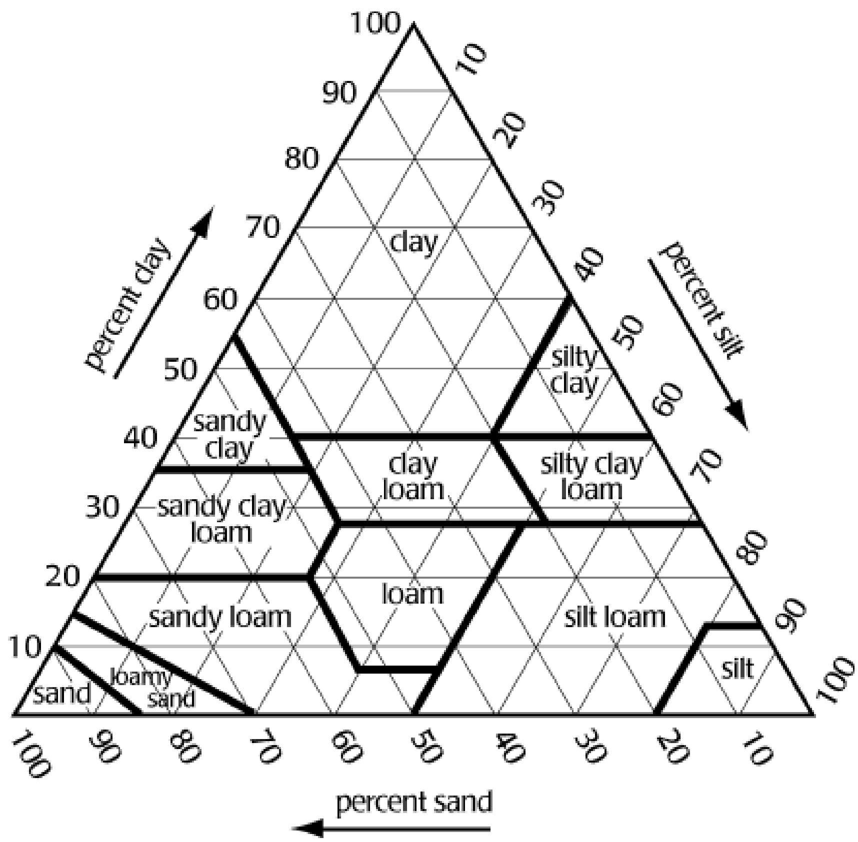


Soil Separate	Diameter (mm)
Sand	2.0 - 0.05
Silt	0.05 - 0.002
Clay	< 0.002

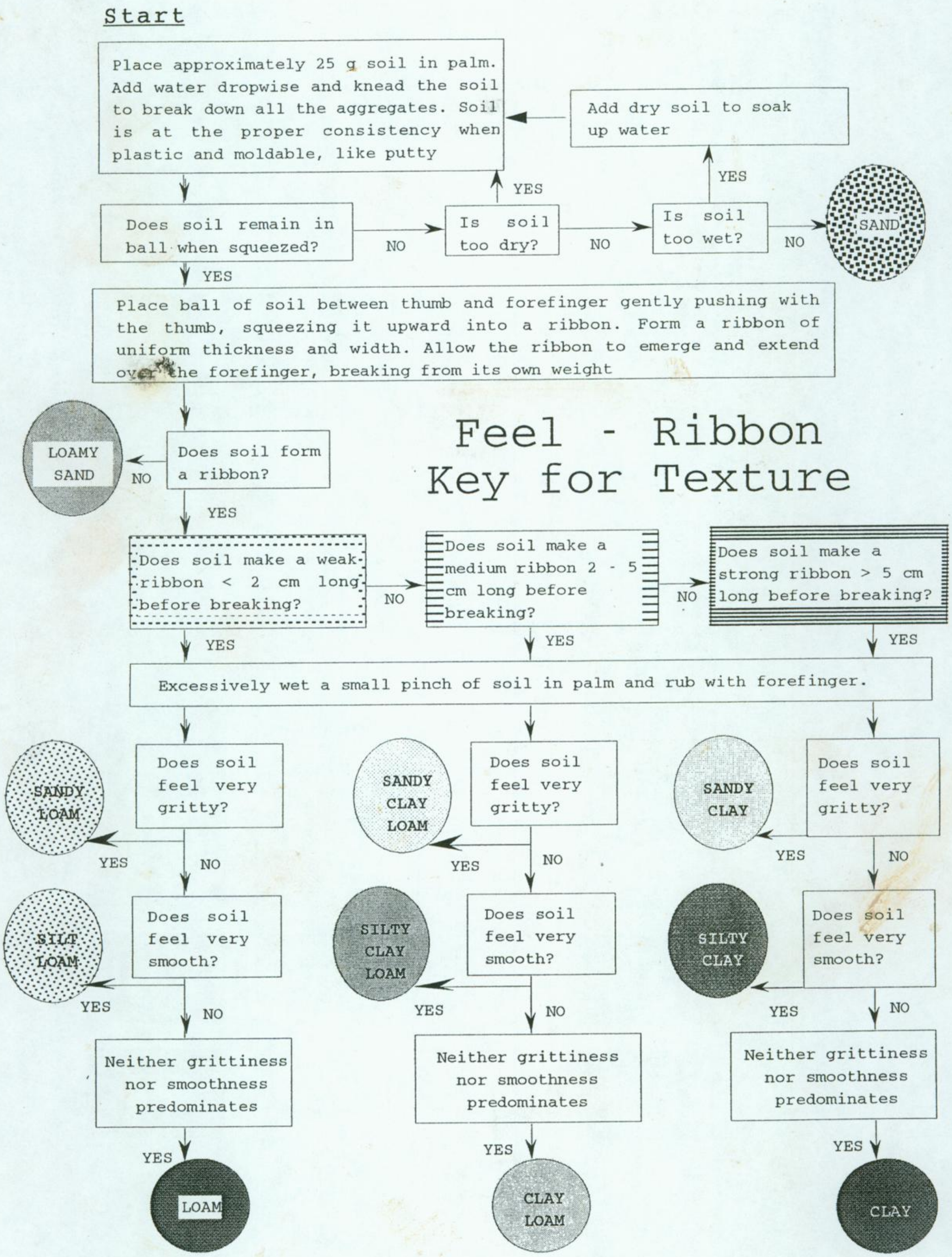
Different combinations of sand, silt and clay gives rise to soil texture classes. There are eight texture classes in the Canadian System of Soil Classification:

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

The soil texture triangle (as seen below) can be used to determine soil texture when the proportions of sand, sit and clay are determined.



If the proportions of sand, silt and clay are not determined; then a soil texture field test can be used to determine which texture class a given soil belongs.



From Thein, S. J. Kansas State University

2. Organic Matter - Soil organic matter has many beneficial effects to soil. It has the ability to increase the soil's infiltration rate as well as increases the water holding capacity and nutrient holding capacity. Organic matter has the ability to change 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.

3. Soil 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. Generally soils with rapid, well and moderately well drainage have bright colors. Soil that has dark brown or black colors suggests high levels of organic matter. Soil color is described by using the Munsell color charts. These charts describe soil by its Hue, Value and Chroma. An example of a soil color would be 10YR 5/6.

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

   Soil structure can be identified in the field by using the following soil structure identification sheet.

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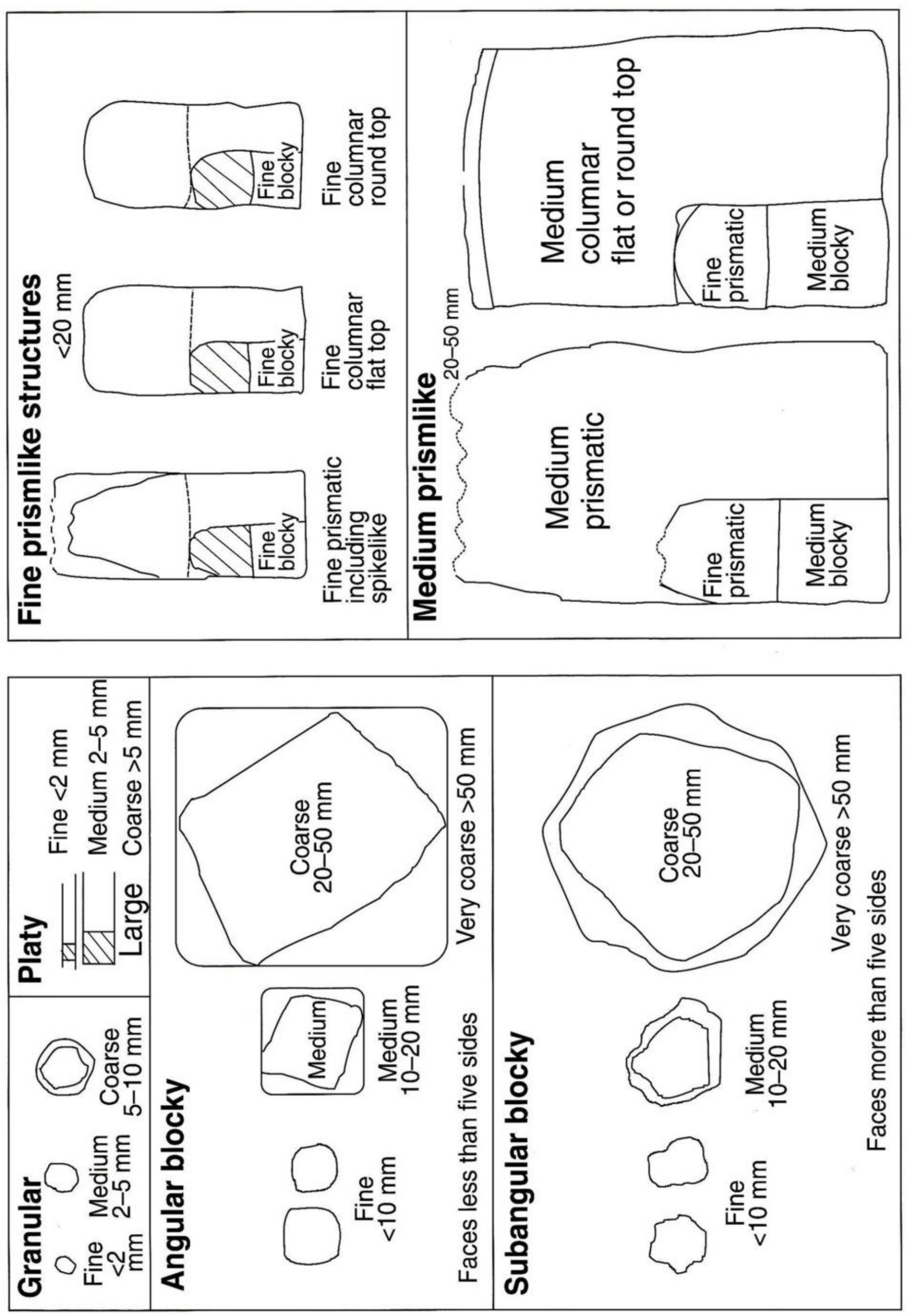
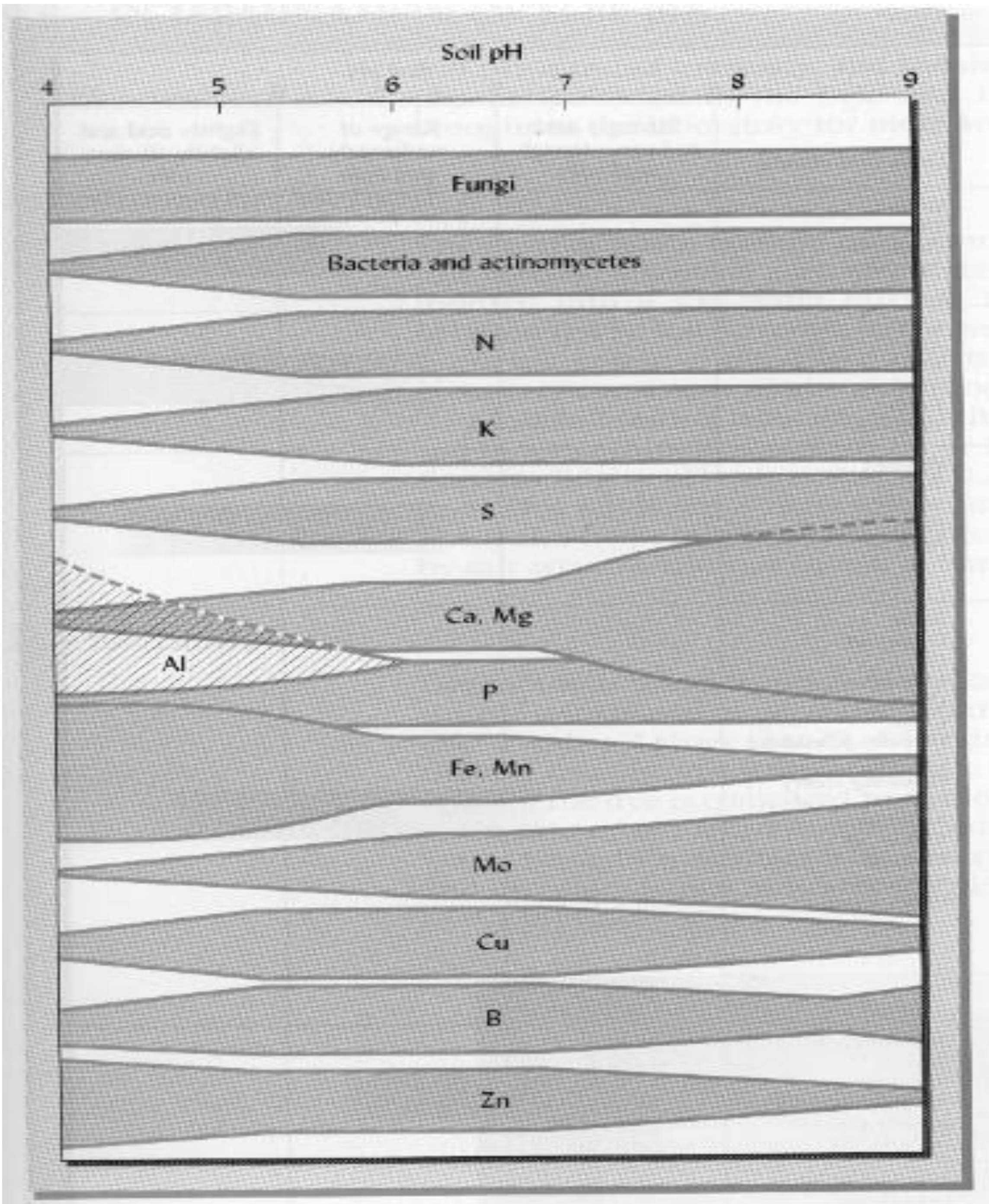


Figure 43 Types, kinds, and classes of soil structure.

5. Soil pH – pH is the degree of acidity or alkalinity of soil and is a key variable that affects all soil properties (chemical, physical and biological). The solubility of minerals and nutrients as well as

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. The following is a representation of soil pH and the zones of microbial activity and the availability of nutrients.



6. Bulk Density – Soil bulk density is a measure of the mass of a unit volume of dry soil. Bulk density is directly related to pore space; the more pore space presents in a soil the lower the bulk density. The presence of organic matter will decrease the bulk density. Soil that is deep in the profile will tend to have higher bulk density as a result of lower organic matter content, less aggregation, fewer roots and compaction. Soils with higher bulk density usually indicate a poorer environment for root growth, reduced aeration and reduced water infiltration.

7. Porosity – One of the main reasons for measuring bulk density is to calculate pore space. Soil pore space or porosity serves a number of functions in soil such as: allowing the movement of air within the soil; allowing drainage of water in soil; accommodating plant roots and root hairs; accommodating the soil organisms that are present. The lower the bulk density a soil the higher the percent pore space.

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. Soil drainage is affected by two groups of factors:

1. Soil External Factors

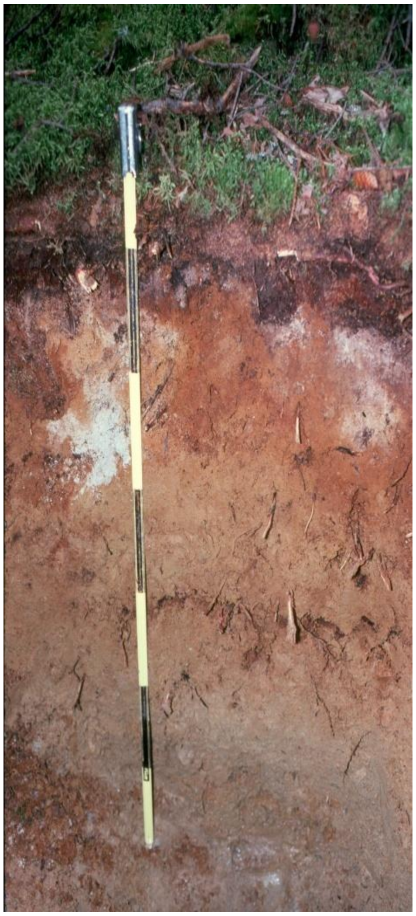
    - Positions on the slope – Soils in upper positions tend to be better drained than those in the lower slopes.
    - Aspect – Southern aspects are warmer than northern aspects; therefore southern aspects will have less soil water and better drainage.
    - Climate – Areas that receive high amounts of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

2. Soil 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.

The Canadian System of Soil Classification identifies six drainage classes:

1. Rapidly
2. Well
3. Moderately Well
4. Imperfectly
5. Poorly
6. Very Poorly

Soils with Rapidly, Well and Moderately Well drainage tend to have bright colors; soils with Imperfectly, Poorly and Very Poor drainage tend to have a grayish color.



Imperfectly drained

Poorly drained

Imperfect to Poorly drained

Imperfect to Poorly drained

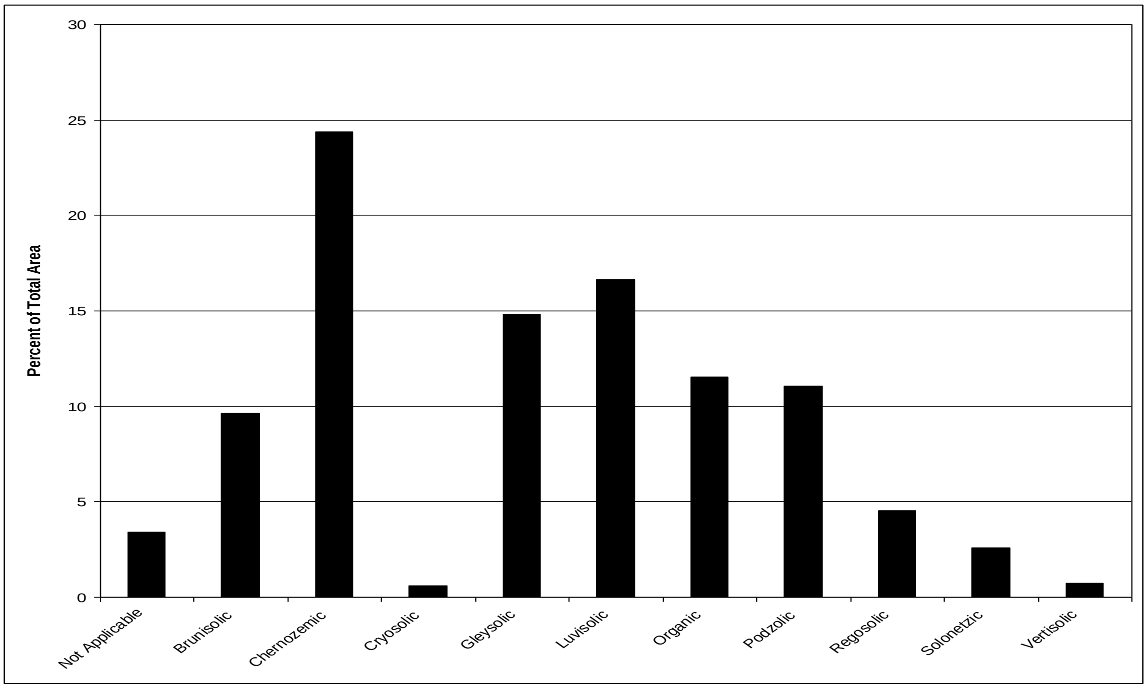
Soil Classification

Canadian System of Soil Classification – There are 10 classes of soil orders in the Canadian system:

1. Brunisolic Order – Soils formed under forests and have brownish-colored B horizons; they lack the degree or kind of horizon development specified for soils of other orders.
2. Chernozemic Order – Soils formed under grassland communities and have surface horizons darkened by organic matter.
3. Cryosolic Order – Soils formed where permafrost exists.
4. Gleysolic Order – Soils that have properties that indicate prolonged periods of saturation with water. The soils found in this order will have grey coloring.
5. Luvisolic Order – Soils that have an increased accumulation of silicate clay in the B horizons.
6. Organic Order – Soils composed largely of organic materials (bogs, peat and swamp soils).
7. Podzolic Order – Soils that have B horizons that are enriched with an accumulation of organic matter combined with Al and Fe.
8. Regosolic Order – Soils that do not contain a B horizon and are referred to as weakly developed.

9. Solonetzic Order – Soils that are identified by the presence of columnar or prismatic structure within the B horizons.
10. Verisolic Order – Soils that occur in heavy textured materials and have shrink-swell characteristics.

Based on the Soil Landscapes of Canada (2007) the Soil Order Inventory for Canada is as follows:



Soil Erosion

Definition – The processes by which soil is removed from one place by forces such as wind, water, ice or gravity and eventually deposited at some new place.

There are two basic types of erosion:

1. Natural Erosion – Erosion that occurs under natural conditions (without the aid of human interaction).
2. Accelerated Erosion – Erosion that occurs more rapid than normal, primarily as a result of human activities.

Accelerated erosion is often 10-1000 times more destructive than natural erosion.

Water Erosion

Wind Erosion

When soil erosion occurs, the soil that is eroded away is almost always more valuable than what is left behind. Erosion removes organic matter, fine particles (such as clay) and essential nutrients (such as nitrogen, phosphorous and potassium). The soil that is left behind usually has lower water-holding capacity, less biological activity and a reduced supply of nutrients. These factors limit the plant growth for the remaining soil.

Sediment and nutrients get transported to streams, lakes and rivers where they can have a huge impact on the stream ecosystem. The nutrients impact water quality by increasing the concentration of nitrogen and phosphorous in streams. Erosion can also pollute streams by transporting toxic metals and organic compounds (such as pesticides).

The control of soil erosion is detrimental to ensuring that there is a lucrative soil resource for future generations. Some examples of ways to control soil erosion in an agricultural setting are as follows:

- Conservation Tillage – Conservation tillage is used to minimize the effects of soil erosion on agriculture areas. It produces equal or higher crop yields while saving time, fuel, money and soil.
- Vegetative Barriers – Rows of vegetation planted on the contours of the land can be used t slow down run-off, trap sediment, and eventually create natural terraces.

Some examples of ways to control soil erosion in a forestry setting are as follows:

- Intensity of Harvest - Selective cutting on steep slopes and soil with a high erosion potential minimize surface runoff.
- Method of Tree Removal - Skidding trails should be cushioned with bows and tops to minimize soil compaction and mineral soil exposure which will maintain soil porosity.
- Schedule of Harvest - Forests located on heavy soils should not be harvested during wet conditions because damage to the forest floor occurs more readily when the soil is wet.
- Forest Roads - Building roads with proper materials, drainage and minimizing mineral soil exposure helps control the rate of soil erosion.
- Buffer Strips - Leaving vegetation strips along streams protect them from soil sediment and nutrient inputs which can cause water pollution.

Resources:

The Nature and Properties of Soils by Nyle C. Brady and Ray R. Weil
The Canadian System of Soil Classification by Agriculture and Agri-Food Canada
http://sis.agr.gc.ca/cansis/references/1998sc_a.html