Forest Soil - How does it function?

Forest soils are comprised of the original geologic **mineral substrate** that has been deposited across the **topography** of the landscape, acted upon by various **biotic organisms**, and over **time** weathered by the **climate** conditions of the region. The most biologically active portion of any soil is near the surface, where the levels of oxygen and water are most conducive for plant root growth and microorganism activity. For this reason approximately 90% of all forest tree roots occur within the upper 6 inches of soil. The uppermost soil layer is most heavily influenced by the incorporation of organic matter – mostly from grass, forb and shrub fine root turnover and decomposition, but also the deposition of woody debris on the soil surface.

The soil profile

The **organic (O) horizon** consists of detritus, leaf litter and other organic material on the surface of the soil. This layer is dark because of decomposition. This horizon does not exist in all soils.

The **A horizon, or topsoil,** is usually darker than lower soil layers, and is loose and crumbly with varying amounts of organic matter. This horizon is usually the most productive layer of the soil.

The **E horizon**, not shown here, is the zone of maximum eluviation (maximum transport of minerals downward to the B horizon). It is light in color with decreased pH. There are few roots in this zone.

The **B horizon, or subsoil,** is usually lighter in color, dense, and low in organic matter content. Most of the materials leached from the A horizon stop in this zone. Because of this leaching, the B horizon has a higher clay content than the A horizon.

The **C horizon** is a transition area between the soil and the parent material. This is the area in which parent material has only just begun to develop into soil.

At some point, the C horizon will lead to the **final horizon: bedrock or parent material.**

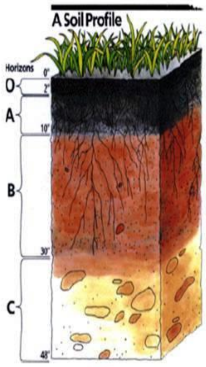
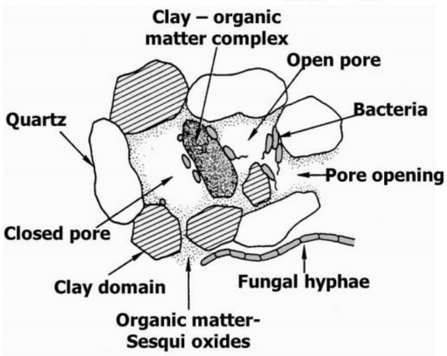


Image from:
http://www.mo15.nrcs.usda.gov/features/gallery/gallery.html

Model of a Soil Aggregate



Well developed and productive soils develop within soil aggregates called "colloids" that combine to form a blocky matrix within the soil. These blocky structures are comprised of mineral particles that are glued together by organic mater as well as decomposed and chemically altered minerals naturally found within the geologic parent material. Soil structure is important for multiple reasons, first because the larger cracks between colloids allow for rapid water infiltration, oxygen exchange and fine root penetration. The colloids hold onto water as well as important macronutrients such as Nitrogen, Phosphorus, Potassium, Sufur and Calcium, and micronutrients including Boron, Zinc, Manganese, Iron, Copper, Chloride and Manganese. Finally, a well developed soil structure also helps give a soil strength and resistance to disturbances such as erosion and compaction from surface traffic.

Forest Harvesting Impacts

Wet soils are more prone to soil compaction from the pressure and vibration of heavy machinery than dry soils. However, by using only well spaced designated trails, long term impacts on overall forest growth can be reduced to 2% or less.

Harvesting requires moving heavy logs, and this action has significant potential to cause soil compaction, whether it is through traditional means such draft horses, small tractors or custom equipment. Most modern logging equipment has been specifically designed to have low compaction potential through the use of multiple high floatation tires as well as specially designed tracked machines – actually less than those of a farm tractor. Timing activities with periods of either frozen ground, deeper snow (> 1 ft) or dry soil is optimal for reducing compaction potential. Also using efficiently spaced designated skid trails (that cover less than 15% of the total soil surface area) can limit the impacts of these trails on tree growth to less than 2%.   Alternatively using dispersed equipment travel – where the same site is not driven over more than once can also work – though this requires a greater sensitivity to soil conditions where only dry of frozen soils are driven on. Every soil has different potential for compaction and erosion, which is why soils have been mapped and analyzed for their potential uses. These maps, created by the Natural Resources Conservation Service (NRCS) can be easily accessed at: http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

Machinery such as this forwarder operates on low pressure tires to move logs from stumps to truck loading sites. Well placed trails minimize impacts to soils and forests.

Soil compaction occurs when pressure and vibration is applied to a soil surface that results in compression of soil air-spaces called "macropores". Without these pores soils are limited in their ability to allow water and air absorption, as well as stunt root growth. Ultimately compacted soils limit water infiltration, which in turn promotes surface water runoff and erosion, and a loss of long term soil productivity. Compacted soil can be identified by its resistance to penetration by a steel rod, platy horizontal soil cracking (that leaves a structure resembling the pages of a book), and severe resistance to water infiltration (water runs off the surface rather than soaking in).

Soil moisture is a key to tree and forb growth, but can also enhance equipment impacts on soils. One pass of heavy equipment over wet soil can cause significant compaction, whereas dry soils can be extremely resistant to the same effect. Soil texture is also a key component. Sandy soils have poor strength and are easily displaced, but are difficult to compact. Clay content soils can have great strength and resistance to compaction when dry, but are severely compactable and structurally weak when wet.

Soil Texture

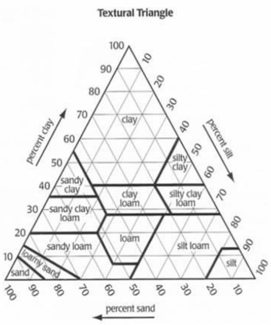
Soil comes in a variety of textures, but result from two principal mineral types. **Primary minerals**, such as those found in sand and silt, are those soil materials that are very similar to the parent material from which they formed. They are often round or irregular in shape. **Secondary minerals**, on the other hand, result from the weathering of the primary minerals, leading to the formation of plate-like micelles (clay). Clays have a large surface area, which is important for soil chemistry. The texture of a soil is based on the %sand, %silt, and %clay found in that soil. The identification of sand, silt and clay are made based on size.

In the U.S., we use the following definition:

- Sand 0.02 – 2.00 mm in diameter
- Silt 0.002 to 0.02 mm in diameter
- Clay <0.002 mm in diameter.

The texture of a soil can be determined from its sand, silt, and clay content using a textural triangle. The triangle on the right is the one created by the USDA NRCS (Natural Resources Conservation Service) and is primarily used in the United States. There are various different textural triangles used throughout the world, but most of them are similar.

Percent clay in this triangle is read on the left-hand side of the triangle, and the lines are horizontal. The percent silt is read on the right-hand side of the triangle, and the lines are read from upper-right to lower-left. The percent sand is on the bottom of the triangle, and the lines travel from lower-right to upper-left.



The Role of Woody Debris

Any forest management activity that generates woody residuals in the forests of Montana is subject to the Fire Hazard Reduction Agreement (HRA) that requires woody debris is reduced to acceptable state standards. These generally require that fuels do not allow for a fires flame lengths to exceed 4-ft in height during a "standard bad day". More information on this can be found at*: http://dnrc.mt.gov/forestry/ Assistance/Stewardship/slashred.asp*

Certain amounts of woody debris left on site can have beneficial effects to forest ecosystems for nutrient cycling, microhabitat and water quality purposes.

For best impacts from residual woody debris, also known as logging slash, materials should be in close contact with the soil, but not completely covering the soil surface. Needles and fine twigs contain the majority of the nutrients that cycle within the forest, and lose about 90% of these the first year to leaching and microbial activity. Good soil contact ensures that woody debris slows soil surface water flow, reducing erosion and increasing soil infiltration. Decomposition of these materials is also enhanced by close soil contact. Mixing with soil is not preferred as this can lead to erosion and poor water infiltration.

Wood itself does not contain much nutrient value, but does provide microsite habitat for a variety of smaller plants, seeds, wildlife as well as important soil fungi. A combination of fine and larger debris offers more microhabitat diversity than only fine or coarse materials. Bare soil is an important component of a recently disturbed forest as bare mineral soil offers the best germination site for tree seeds and a variety of other plant species that are important site colonizers that add to biodiversity. Depending on land manager objectives a range of 30 to 60% bare soil is appropriate – preferably in a dispersed pattern seen in picture at right.

Post-wildfire Effects

Wildfires are a phenomenon that have been part Montana forests for the past several thousand years. They can also have significant effects on a forests ability to absorb and provide water. Typically severe wildfires result in a large movement of surface ash and soils into streams, which depending on the time of year and watershed can have major short-term impacts on water quality and quantity. Such erosion events may also have long term impacts on soil and landscape productivity.

Restoration practices seek to slow surface water, preventing soil erosion and promoting water infiltration into the soil which in turn can moderate downslope flooding events. One of the most effective practices is to add soil surface roughness and organic matter, that holds and slows water. Contour felling and straw mulch are two proven practices, but what about salvage logging? Much controversy remains about this process as any event that loosens soil, such as equipment travel over burned soils, has the potential to increase erosion. Alternatively, anything that increases soil surface stability, such as the matrix of fine and larger woody debris left by conventional logging practices can help stabilize heat impacted soils and fine erodible ash. Extreme care must be taken to prevent or amend ruts created by logging and skidding practices and orient logging debris across slope contours versus up and down them.

Ash and organic soils erode off site (top picture) with first rain and soils can lose their most productive layers (bottom picture)

Salvage logging immediately after a wildfire that leaves a reasonable amount of logging debris in close contact with fire affected soils can help stabilize soils, minimizing erosion and retaining moisture on site. All post-fire activities should be care to avoid bringing exotic weedy species onto fire affected soils.

Fridley fire site salvage logged immediately after wildfire with good woody debris deposit on afflicted soils (left) showing no detectable soil loss, good water retention and good vegetation recovery the first year following the fire (right picture).