# Forest Soil

The dynamic interaction between vegetation and soil is so strong that it's unclear which is dominant. Soil helps secure and renew the forest; forests help secure and renew the soil. The forest covers and protects the soil from extreme heat and cold while slowing the natural forces of erosion like water, wind, and gravity. Soil sustains the forest and provides raw materials for its life: fallen leaves, woody debris, and dead animals recycle through the soil. Time, weather and soil-borne organisms break these decaying plants and animals down into nutrients that rebuild the soil, and again become available for plant growth.

Healthy soil is a living body made up of inorganic material, decaying organic matter, water, air and billions of living organisms. Productive forests require healthy, living soil, clean air, and water. Healthy soils are alive with organisms of all shapes and sizes including bacteria, insects, worms, fungi, and animals. Some organisms form partnerships with tree roots helping them to extract nutrients from the soil. Others are important in breaking down organic matter and cycling nutrients, making them available to the next generation of plants and animals. Soil teams with life, and the smallest bacteria's role is as important as the largest carnivore's in cycling nutrients through the ecosystem. Every creature, great or small, plays an important role in the "Web of Life."

Ecosystems have groups of life forms that fill similar niches. Ecologists refer to these groups as trophic levels. Primary producers are autotrophs, plants that harness energy from the sun, carbon from the air, plus nutrients and water from the soil to grow lush and strong. Consumers are heterotrophs; they feed on others. Primary consumers are herbivores, or grazing animals, that receive all their nutrition from eating plants. Deer, rabbits and insects (i.e.: grasshoppers) are all primary consumers. The pocket gophers and squirrels that graze underground on plant roots are also primary consumers. Secondary consumers are carnivores that feed on the primary consumers; songbirds feeding on insects and wolves feeding on elk are examples. Tertiary consumers are next in the chain. A hawk, feeding on songbirds, that fed on insects, that fed on plants is an example.

Humans are grouped in a special class called omnivores, because we consume at all levels. We eat fruits and vegetables and grains like primary consumers, and we consume other consumers when eating meat. Bears are also omnivores eating berries and meat, but they take it a step further, feeding on decomposers like "grubs" from a rotting log.

Decomposers are the soil microorganisms that break down organic material and cycle nutrients back to plants, starting the cycle over again. Decomposers can be divided into three groups according to size: Microbiota- algae, autotropic and heterotropic bacteria, fungi and protozoa Mesobiota- nematodes, small worms, small insects and larvae, and mites.  Macrobiota- plant roots, large insects, large worms and burrowing vertebrates like squirrels and gophers. Decomposers exhibit the greatest species diversity of the healthy Temperate Forest due to their task specific nature in the nutrient cycling process. Bacteria fill a niche at the molecular level, converting one chemical structure into another in the decomposition assembly line. The division of labor is far more elaborate than Henry Ford ever dreamed.

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**Soil Formation and Erosion**

Soil formation begins with the degradation of parent material. Parent material is the solid rock of the earth's crust formed by geologic forces. These solid rock features maybe very near or quite far from the location we find them in the form of soil. There are many forces that break rocks into soil particles like volcanic eruptions, glaciers, and floods. Water is a major influence in breaking down parent material. One way is through freezing and thawing on the surface of exposed rock, which causes breaking and cracking. Moving water also erodes parent material grinding rocks together in streams. Atmospheric $CO_2$ dissolved in water creates a weak acid, like the "zing" in soda pop, which allows water to act as a solvent in breaking down parent material. Glacial ice erodes tons of material, grinding it into inorganic soil. Water moves the eroded sediment and deposits it in land forms like the Mississippi River Delta.

Through natural erosion soil is a renewable resource, but this occurs over very long time horizons. Depending on the site it takes 200-1,000 years to form 1 inch (2.54 cm) of topsoil. Soil develops when organisms decay, when solid rock weathers and crumbles, and when sediments are deposited by erosion.

Soil is arranged in layers or horizons. The surface horizon of forest soil is a layer of organic leaf litter. Beneath this is the uppermost layer of non-organic material called topsoil. Typically this layer is mixed with large amounts of decaying organic matter known as humus. Topsoil provides the best environment for growing plant roots, microorganisms and other life. The two horizons that underlay topsoil are mineral soil and bedrock.

Trees depend on soil to supply four needs: stability, nutrients, water, and oxygen. Anchorage of roots is particularly important in forests to support tall, healthy trees. Roots are the best water absorbing structures of plants, and soil meets nearly all their water and nutrient needs.

Some energy is lost, usually as heat, every time energy changes form. This is the Second Law of Thermodynamics. An example is the conversion of plant carbohydrates to glycogen in our bloodstream. We can't harness the energy of every calorie because in the process heat is given off. It's interesting to look at the population numbers of groups that fill the same niche and how energy passes between trophic levels. Primary producers must be efficient at their task and plentiful enough to support the consumers. For this reason, rapid growth of the world's human population increases strain on the trophic levels we rely on to meet our needs. This law is the basis for the predator-prey relationships that create checks and balances through out the food chain.

In the temperate forest the number of producers is small, but the trees that make up the majority of the producers are large and able to support many consumers. These graphs represent a snap shot of each ecosystem in a healthy natural condition.

Most nutrient cycling takes place in the top two feet of soil where supplies of air, water and food enable microorganisms to thrive. Soil microorganisms include bacteria, fungi and algae. These micro-organisms work in conjunction with insects and burrowing animals to break down dead or dying plant and animal life. In the process they release carbon dioxide into the air and nutrients into the soil.

The Earth's atmosphere is approximately 78% nitrogen, and 21 % oxygen gases. Carbon dioxide and other gases make up the remaining 1 %. To grow, plants take in CO2, water, and nutrients from the soil, and sunlight, while returning oxygen to the atmosphere. Plants require large quantities of nitrogen to grow, but they can't "breathe" it in directly. Some plants need the help of bacteria to change atmospheric nitrogen into a usable form. In some cases specialized bacteria "fix" or convert atmospheric nitrogen into organic forms, which are usable to plants and can later enrich the soil. This happens in the soil, where bacteria grow near to, or together with, plant roots. This mutually beneficial relationship between plants and bacteria is described as a "symbiotic relationship". Alder is an efficient nitrogen fixer that uses this process. Bacteria form these associations with alder as well as other tree species.

In an effort to stabilize the riparian zone of the Toutle River following the Mt. St Helens eruption, cottonwood clones were planted, but alder re-established itself as the dominant species, due to its ability to "fix" nitrogen in the nutrient poor deficient ash deposits.

Alfalfa is commonly used in crop rotations for its ability to "fix" nitrogen. It renews depleted soil by adding nitrogen and organic matter when used as a cover crop and tilled back into the soil. It may be feasible to rotate alder or other species to maintain productive forest soils. As noted in the Mt. St. Helens example, alder is an aggressive colonizer. It may be possible to allow alder to colonize and then harvest it for biomass fuel and pulp to meet some of our energy and paper needs, while taking advantage of the nitrogen added to the site and the stabilization of the soil offered by the alders remaining root structures.

**Soil Measurements**

Soil temperatures and moisture levels are important properties affecting production capacity. While the amount of precipitation in the form of rain and snow determines the moisture level of a site, an important factor affecting soil moisture is the amount of organic matter in the soil. Temperature and humidity directly affect moisture level through evaporation. Ground and plant canopy cover minimize evaporation by absorbing the sun's radiation, and in the process use the energy to power photosynthesis.

Soil temperatures trigger biological controls of seeds and influence rates of decomposition. For instance, Douglas fir requires a cold period to "scarify" or weaken its seed's protective coating before they can break dormancy and germinate. Many commercial tree nurseries simulate this through refrigeration.

Temperature affects the metabolic growth rate of plants, insects and decomposers. In cold soils decomposition of organic residues is slower than in warm soils. Such differences can often be observed on north versus south-facing slopes.

Soil texture or grain size is also an important quality that determines a soil's productivity or suitability for various uses. Texture is the physical feel of a soil. Clay, silt and sand refer to the different grain sizes present in the soil and give it a distinctive feel when rubbed between your fingers.

Soil with equal portions of clay, silt and sand is known as loam, the best soil *for* most plant growing applications. Clays are soils largely compiled of very small grains. Soil dominated by clay holds moisture for long periods of time, releasing it slowly. Silts are soils of medium grain size. Sandy soils have much larger mineral particles and drain very quickly creating drier sites where species like lodgepole, ponderosa and long-leaf pine are able to thrive.

Soil structure is the organization of soil particles and how they stick together. Loose sand is structure-less soil. Think about soil clods, and whether they are really hard, or so fragile, that you can't pick them up without their crumbling. A good way to think about structure is viewing the soil as a house. If demolished, all the parts remain, but it is no longer a house because it has no structure.

Soil animals and insects make important contributions to soil structure acting as natural rototillers as they burrow through the soil. Home gardeners know that earthworms are a sign of a healthy soil. These worms decompose organic matter and loosen soil, providing air for root and soil organism respiration. These living components of soil perform the task of aeration without disrupting the integrity of the soils organization.

Soil density is a measure of how tightly compressed soil particles and clods are. This determines the pore space between the particles and clods. Pore size and number of pores determines the permeability or the rate at which water, air and roots move through the soil.

Soil erosion caused by unsustainable practices is a global problem. Water courses carry sediment and deposit it in stream beds, deltas and oceans. The resulting siltation of stream beds causes increased flooding. The 1993 flooding of the Mississippi River was caused by an aberrant weather pattern, but siltation of the river bed decreased its ability to quickly drain the Midwestern U.S. Surface water run-off transports an estimated 3.3 billion tons (3 billion metric tons) of sediment into the waterways of the United States annually. In managed forests, roads and roadsides can be engineered to minimize erosion and sedimentation.

Soil is most susceptible to erosion after the removal of plants, surface litter and duff, which protect it from wind and water erosion. Roots hold the soil together and anchor it in place. If plants are removed temporarily, (i.e. trees being logged), and the surface duff and organic layers remain intact, there may be little or no erosion.

The infiltration rate is how quickly soils absorb water. In the forest, surface duff largely influences the infiltration rate, followed by the permeability and structure of the underlying soil. Soils with good structure absorb water quickly, and minimize surface run-off. Soil structure determines how easily the particles detach to start the erosion process. Steeper sites provide energy for the scouring action of surface water run-off. Maintaining good ground cover lessens the effect of all erosive forces. Plants absorb the impact of raindrops while their litter and roots enhance infiltration and hold soil in place.

Soils are susceptible to leaching. Leaching is the process by which water dissolves chemical components in the upper layers of the soil and carries them to lower layers of the soil or into ground water. This can put valuable nutrients out of reach of even the largest plants and trees.

## Soil Conservation

Wind is estimated to cause about 30% of annual soil erosion, on agricultural cropland. Wind erosion is primarily due to tilled fields lying exposed for long periods between growing seasons. Forest crops are rotated over decades rather than annually, so wind is not a major erosive factor for forests.

Agricultural practices have evolved to minimize soil erosion, including a greater use of trees. Farmers have adopted practices including minimum tillage, strip cropping, contour plowing, streamside filter strips and agroforestry. In agroforestry crops are planted between hedgerows of trees which provide products such as fruit and fuelwood. Alternating between row crops and soil-building cover crops

along a contour is known as strip cropping. This employs the same principle as using buffer strips in forest harvesting. The undisturbed strip has a root structure that remains holding the soil in place, and the vegetation on the surface dissipates the energy of the surface water run-off. Farmers and ranchers are establishing or protecting forest buffer strips next to streams and rivers to control sediment and nutrient losses from farmland.

It's possible to harvest wood products from the forest while maintaining a healthy vibrant ecosystem. This requires proper planning and regular maintenance of the transportation network used to access harvest sites. Proper planning takes into account the slope and stability of an area, ensuring that roads will stay intact while minimizing erosion. Planning also ensures the most efficient routes to access harvest areas, minimizing the total number of roads. Water-courses are fully considered in long range planning to minimize sedimentation of streams. Proper maintenance of drainage systems is critical to maintaining road and water quality.

The transportation network in the well-planned forest includes everything from interstate highways to skid trails. With proper planning and modem harvest systems the transportation network is as small and efficient as possible, to maximize the undisturbed soil that supports healthy forests for all uses. Soil under laying the transportation network of roads and skid trails becomes compacted and is generally not as conducive to growing trees.

Forest harvest operations can spread organic material (slash) across the site. This speeds the cycling of nutrients, most of which are contained in the foliage and bark, and reduces soil compaction. Heavy compaction of the soil can reduce infiltration of water along with the penetration of plant roots, burrowing insects, and animals. Harvesting techniques can be used to maintain soil organic matter and fertility, benefiting future tree and plant growth.

Proper timing of equipment use in the forest or the field can minimize soil disturbance. The type of equipment and ground pressure exerted also effects soil disturbances. Soil type and moisture level can create problems for harvesting if the soil doesn't allow sufficient floatation and traction. Pulling or lifting trees to a landing can be almost impossible without creating soil problems. Planning to minimize harvesting in the wet seasons can help maintain soil integrity and minimize costly road repairs.

Some harvesting systems nearly eliminate soil disturbance. Helicopters can be relatively costly and dangerous, but in unusually sensitive and extremely steep areas they're effective tools to maintain the productivity of the site and minimize soil erosion. In many cases, a well-designed cable system can achieve comparable environmental results, with much lower cost. There are many harvesting methods available; the appropriate system needs to be economically feasible and environmentally compatible with the harvest site.

Water caused soil erosion is one reason for buffer strip requirements on watercourses. Riparian buffer areas help maintain stream banks and reduce bank erosion, but up-slope practices are more important in preventing excess soil run-off in streams. Buffer strips facilitate deposition because they slow down surface water and enhance infiltration.

The woody debris and foliage left after logging can contribute important nutrients and organic matter to the topsoil. Although often unsightly, tree stumps and logging debris also help stabilize the soil long after the re-establishment of the next forest. The maintenance of soil productivity and stability during and after the harvesting process is now a primary management objective.

Forest Soil

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Large woody debris in streams creates pooling, improving fish habitat.

There are three steps that occur in the soil erosion process:

. - Detachment of soil particles either by impact or scouring
. - Transportation of the suspended particles down slope, or downstream . - Deposition of the suspended soil particles when the water slows down

**Fertilization**

Fertilizers partially restore plant nutrients lost by erosion, leaching and crop harvesting, and can make up for natural site deficiencies. The two types of fertilizers are organic and inorganic. Organic fertilizers include manure, "green manure" and compost. The organic waste material spread back across a forest harvest site is organic fertilizer. Compost is a rich combination of plant and animal wastes, and is quite common with home gardeners.

Inorganic commercial fertilizers generally contain nitrogen (in a usable form), and sometimes phosphorus and potassium. Their ease of transport, application and storage makes inorganic fertilizers economically attractive. However, inorganic fertilizers don't add humus and when used without accompanying organic amendments reduce the soil's ability to hold moisture and nutrients against drainage losses. These nutrients can also have downstream effects on aquatic systems.

The fertilizer grade lists the contents as a sequence of three numbers that tell, in order, the percentage of nitrogen (N), phosphate (P205), which is also called Phosphoric acid, and potash (K20), a potassium source. The grade is often referred to as the "N-P-K" which stands for Nitrogen, Phosphorus and Potassium, in that order. Since all three primary nutrients are available in this fertilizer, it is a complete fertilizer.

Fertilizing is a common practice on industrial forest land. Various application methods are used including aerial broadcasting. One interesting "organic" fertilizer used on forested lands is sludge, or human waste. This may provide an answer to some waste management dilemmas that accompany population growth near forested areas.

Sustainability **of Soil**

Soils are renewable resources, but our uses of soils are not sustainable if erosion or other disturbances exceed formation or recovery. It is possible to maintain or improve soil conditions of a site by maintaining or increasing organic matter, nutrients and soil organism diversity. A variety of practices can be used, some more intensive or economical than others, to accomplish these important objectives. We need to remember a simple slogan about soil as we consider stewardship options:

1. keep it in place
2. keep it porous
3. keep it organically rich

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Glossary **of** Terms

**Biosphere** - the part of the Earth and its atmosphere in which living things exist.

**Consumers** - organisms that feed on other organisms to sustain life.

**Crust** - outer most layer of the earth comprised of soil rock.

**Decomposers** - organisms that digest dead organisms to sustain life.

**Green manure** - the nutrient rich, green foliage that can be returned to the site as a natural fertilizer.

**Loam** - soil containing a mixture of clay, silt, sand and humus.

**Mantle** - the layer of the earth between the crust and core.

**Niche** - the place and function of a species in an ecosystem.

**Omnivore** - animal organisms that can use plants and other animals as food sources.

**Producers** - organisms that use solar (green plants) or chemical energy ( some bacteria) to sustain life.

**Scarify** - weakening of a seed shell, enabling it to germinate.

**Slash** - the limbs, bark and small stem wood that is not usable for commercial wood products.





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