normally excluded when burn frequency and intensity increases.

Temperate Deciduous Forests

These forests reach maximum abundance between the tropics and 45° N latitude. The climate is characterized by relatively cold winters and warm summers with reasonably evenly distributed rainfall (averaging 750 to 2500 mm year^{-1}) throughout the year. Leaf fall corresponds to a period of cold and unavailability of water. Conifers become more prevalent at the drier and colder, and mountainous margins of this biome. Entisols, Inceptisols, Alfisols, Spodosols, and Ultisols are the most common soil orders.

Boreal Forest

The boreal regions of the world are characterized by long, cold, snowy winters. These biomes are the result of a climate found only in the interior of large continental landmasses in the northern hemisphere. Conifers are the most abundant tree species with some cold-tolerant, deciduous broadleaved vegetation occurring at the southern and milder margins. Entisols, Inceptisols, Spodosols, and Histosols are the most common soil orders.

Further detail on the extent and development of the world's forest biomes can be found in the section on Further Reading.

Summary

Forests provide a unique set of environmental factors influencing soil formation. The most important of these is the microclimate at the earth's surface engendered by the canopy of trees and understory vegetation, the role of tree roots in cycling nutrients from great depths, and the large additions to soil organic matter made by tree roots and foliage. Fully one-third of the earth's soils developed under a original cover of forest. Although forests can occupy very fertile soils, much of the world's remaining forest exists on landscapes marginally suited for other human uses.

The two dominant soil-forming processes in forests are podzolization and desilication. These two processes occur in the two forest biomes least influenced by humans, the boreal and tropical forests, respectively.

Some tree genera and species assemblages will thrive on most of the soil orders making it difficult to predict forest composition based solely on soil. Forest composition and productivity depend more on local-scale factors such as topography, soil physical properties, and inherent differences in local climate, than to soil categories.

See also: **Soil Biology and Tree Growth**: Soil and its Relationship to Forest Productivity and Health; Soil Biology; Soil Organic Matter Forms and Functions; Tree Roots and their Interaction with Soil. **Soil Development and Properties**: Landscape and Soil Classification for Forest Management; Nutrient Cycling; Nutrient Limitations and Fertilization; The Forest Floor. **Tree Physiology**: Nutritional Physiology of Trees; Root System Physiology.

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Landscape and Soil Classification for Forest Management

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Soil Classification

Soils vary across the earth's surface, and understanding and managing this variation is key to understanding, managing, and sustaining both natural and anthropogenic ecosystems. Properties of the soil at any point in the landscape are the product of an array of complex processes, tempered by the environmental factors climate, biota, and topography, acting on a parent material over time. Because of the vast numbers of combinations and intensities of these five state factors, the number of different soils is seemingly endless. It is generally agreed, however, that it is possible to group soils into classes having many properties that are similar which is the basis for soil classification.

Properties chosen to form classes vary among soil classification systems, and the choice of properties used as the basis for developing classes and the property limits used to separate classes are often debated. The goal of all systems, however, is to provide classes that have similar properties and/or similar responses to external inputs. In addition, soil classification provides a means for organizing knowledge about soils and for enhanced communication among soil scientists since a few terms can be used to convey a great deal of information. Grouping soils into classes with similar properties also provides a mechanism for identifying appropriate uses of the soil, for estimating production, for extrapolating knowledge gained at one location to other locations, and for determining research needs.

Most national and international soil classification systems, such as *Soil Taxonomy*, are general-purpose natural classification systems. The systems were developed to group soils based on their properties without consideration of any particular use. Thus, these systems use many properties to form classes, and interpretations of soil behavior under any of a broad range of uses can be made from an understanding of how properties that define the class affect the intended use.

This is in contrast to soil classification systems developed and used for more narrow purposes such as forest management. Forest managers are mostly interested in soil properties that influence the occurrence and productive potential of a forest stand such as texture, rooting depth, native fertility, and water supplying capacity. Because only a subset of all possible soil properties are of interest, classes are defined based on combinations of properties thought to affect the narrow purpose of the classification system. Thus, the system will be more precise than natural classification systems in predicting expected behavior for the intended use. If land use or management system changes, however, the use-specific classification system may not include the properties needed to effectively implement the change without major changes to the system.

Soil Taxonomy

This section presents a general overview of the structure, basis for class differentiation, and nomenclature of *Soil Taxonomy* which was developed in the USA. Presentation of *Soil Taxonomy* is not meant to imply that it is the only or the best system of soil classification. The structure and nomenclature used in *Soil Taxonomy* are similar to those used in other classification systems. *Soil Taxonomy* is presented as an example that is intended to provide a basis for understanding the basis behind and structure of natural soil classification systems. Its use as an example reflects the author's base of knowledge and experience as do other examples presented in this article.

Soil Taxonomy comprises six categorical levels. These are: order, suborder, great group, subgroup, family, and series. The structure of the system is somewhat analogous to the plant and animal taxonomies in that the highest category (order) is the most general and has the fewest classes (12), and the lowest category (series) is the most specific and has the most classes (16 000 +).

Details of criteria used to separate taxa in *Soil Taxonomy* at all categorical levels are beyond the scope of this text. The general criteria used for each category, however, are given below:

- Order: properties resulting from major soil-forming processes that aid in understanding and interpreting soils at a grand scale.
- Suborder: properties that have a major influence or that reflect these influences on current soil formation processes. Many are also important for plant growth and interpreting soil behavior.
- Great group: properties that impose or reflect subordinate or additional controls on current soil-forming processes and soil behavior such as horizons that retard water movement and root extension.
- Subgroup: properties that reflect either (1) a transition from one taxon to another at a higher category, (2) a transition to properties not recognized at higher categories but are common among many classes (shallow rock, water, etc.), or (3) the central concept of the great group (Typic).
- Family: properties that reflect important conditions affecting soil behavior or potential for further change.
- Series: lowest level of *Soil Taxonomy*. Differentiating criteria are the same as those for higher categories, but ranges in properties are defined more narrowly to aid interpretations of soil behavior and response to management at a local level.

A robust classification system must be based on properties of the population of individuals being classified and not abstract concepts of the processes that have led to the different individuals. Thus, differentia used to separate classes in *Soil Taxonomy* are based on soil properties. However, because understanding a soil's genesis is important for understanding its properties and expected behavior, properties that reflect or influence processes of soil formation have great importance in this system. For this reason, *Soil Taxonomy* is considered a morphogenetic system, i.e., the system is based on observable and measurable soil properties, but many of these properties represent pathways and processes important to soil genesis.

A soil's placement in a particular taxon in *Soil Taxonomy* depends on the presence or absence of diagnostic horizons and features that are considered to be marks of the soil's genesis but that are rigidly defined by morphological, physical, chemical, and mineralogical properties of the soil. Thus, a soil's classification offers information on processes that have been important in its development, but more importantly, because taxa are defined by soil properties, they can be interpreted in terms of expected behavior and response to management. The interpretive detail that can be ascertained from a soil's classification depends on the categorical level at which the interpretations are made. At the order level, few specifics can be said about interpretation for a particular use. The number of specific interpretative statements increases at lower levels of classification to a maximum at the series level.

Most users of soil information that includes a classification are unlikely to have the depth of understanding of diagnostic horizons and features needed to properly classify a soil. However, with an understanding of the nomenclature is used to indicate specific horizons and features, a great deal of information about the properties of a soil can be determined from its classification. In *Soil Taxonomy*, most of the formative elements used to name classes are terms derived from Latin or Greek, and many have similar meaning to terms used in everyday speech. Thus, the nomenclature of a class can reveal many general properties of soil even if the exact definition of the diagnostic horizon or other differentiating characteristic is unknown. The formative elements and concept of the 12 orders is given in **Table 1**. A list and brief definition of formative elements for properties most important to forest management are given in **Table 2**.

Orders

Names of orders end in 'sol.' The formative element for orders begins with the vowel preceding the 'o' or 'i' before 'sol' and ends with the last consonant before the 'o' or 'i.'

Suborders

Names of suborders have two syllables. The first connotes something about the diagnostic properties of the soil, and the second is the formative element from the order. For example: Udalfs – Alfisols with udic moisture regimes, Psamments – sandy Entisols, Aquults – Ultisols with an aquic moisture regime.

Great groups

Names of great groups consist of the suborder and a prefix that is formed by one or two formative elements suggesting something of the diagnostic properties of the soil. For example: Paleudalfs – old (deeply weathered) Udalfs, Udipsamments – Psamments with a udic moisture regime, Epiaquults – Aquults with seasonal saturation from water perched above a water restrictive horizon.

Table 1 Formative elements and the central concept of the 12 orders in *Soil Taxonomy*

Order	*Formative element*	*Central concept*
Alfisols	alf	Soils with an argillic or kandic horizon and greater than 35% base saturation in the lower subsoil. Generally considered to have developed under forest vegetation.
Andisols	and	Soils developed from volcanic ejecta.
Aridisols	id	Soils occurring in a dry climate that have undergone sufficient soil development to have a diagnostic horizon.
Entisols	ent	Soils with no diagnostic horizon because of young age, resistant parent materials, or other factors that prevented soil development.
Gelisols	el	Soils in cold climates that have permafrost within 100 cm.
Histosols	ist	Soils composed of organic soil materials.
Inceptisols	ept	Weakly to moderately developed soils that do not have horizons or features that are diagnostic for other orders.
Mollisols	oll	Soils with mollic epipedons generally considered to have developed under grassland vegetation.
Oxisols	ox	Soils that have an oxic horizon or clayey surface horizon with a kandic horizon; commonly found on old stable tropical landscapes.
Spodosols	od	Soils with a spodic horizon; commonly sandy and developed under coniferous or other vegetation that produces acid leachates.
Ultisols	ult	Soils with an argillic or kandic horizon and less than 35% base saturation in the lower subsoil. Generally considered to have developed under forest vegetation.
Vertisols	ert	Soils with the amount and type of clay to generate high shrink – swell.

Table 2 Formative elements used in names of suborders, great groups, and subgroups that relate to forest composition and productivity

Formative element	*Derivation*[a]	*Connotation*
Abruptic	L. *abruptum,* torn off	Abrupt textural change
Aeric	Gr. *aerios*, air	Aeration (not as wet)
Al	Modified from Aluminum	High aluminum, low iron
Alb, Albic	L. *albus*, white	An albic horizon
Aqu	L. *aqua*, water	Aquic moisture regime
Ar	L. *arare*, to plow	Mixed horizons
Arenic	L. *arena*, sand	Sandy epipedon between 50 and 100 cm thick
Arg	L. *argilla*, white clay	Presence of argillic horizon
Cry	Gr. *kryos*, icy cold	Cold
Cumulic	L. *cumulus*, heap	Thickened epipedon
Dystr, Dys, Dystic	Gr. *dys*, ill	Low base saturation
Endo	Gr. *endo*, within	Saturated by a groundwater table
Epi	Gr. *epi*, on, above	Saturated by a perched water table
Eutro, Eu Eutric	Gr. *eu*, good	High base saturation
Fluv	L. *fluvius*, river	Floodplain
Frag	L. *fragilis*, brittle	Presence of a fragipan
Fragloss		Combination of frag and gloss
Grossarenic	L. *grossus*, thick + L. *arena*, sand	Sandy epipedon > 1 m thick
Hist	Gr. *histos*, tissue	Presence of organic materials
Hydr, Hydric	Gr. *hydor*, water	Presence of water
Lithic	Gr. *lithos*, stone	Presence of shallow lithic contact
Molli	L. *mollis*, soft	Presence of a mollic epipedon
Natr, Natric	L. *natrium*, sodium	Presence of natric horizon
Oxyaquic	Combination of oxy (oxygen) and aquic	Aerated
Pachic	Gr. *pachys*, thick	A thick epipedon
Pale	Gr. *palaeos*, old	Excessive development
Petroferric	Gr. *petra*, rock + L. *ferrum*, iron	Presence of a petroferric contact (continuous ironstone)
Psamm	Gr. *psammos*, sand	Sand texture
Quartz	Ger. *quarz*, quartz	High quartz content
Terric	L. *terra*, earth	A mineral layer under organic soil
Torr	L. *torridus*, hot and dry	Torric moisture regime
Ud	L. *udus*, humid	Udic moisture regime
Ultic	L. *ultimus*, last	Low base saturation
Umbr, Umbric	L. *umbra*, shade	Presence of umbric epipedon
Ust	L. *ustus*, burnt	Ustic moisture regime
Xer	Gr. *xeros*, dry	Xeric moisture regime

[a] Gr., Greek; L., Latin.

Subgroups

Names of subgroups consist of the great group modified by one or more adjectives. The adjective 'Typic' is used for the subgroup thought to typify the central concept of the great group. Other types of subgroups are (1) intergrades toward other great groups, e.g., Aquic Paleudalfs are intergrades to the Paleaqualfs, and (2) extragrades – subgroups not intergrading toward any known kind of soil, e.g., Lithic Udipsamments are intergrading to rock.

Families

Names of families are polynomial and consist of the subgroup and three or more descriptive terms that indicate the particle-size class, mineralogy, cation exchange activity, soil temperature, and other properties of the soils. For example, fine, smectitic, active, thermic Aquic Paludalfs are the Aquic Paleudalfs that have a fine particle size class (35–60% clay), dominantly smectitic clays, an active cation exchange capacity class (0.4–0.6 $\mathrm{cmol\,kg^{-1}}$ clay), and a thermic temperature regime (18–22°C mean annual temperature at 50 cm). The particle-size, mineralogy, and cation exchange activity classes are based on the weighted average of upper part of the subsoil. More or fewer terms may be part of the family depending on the subgroup.

Series

Names of series are abstract place names. The name of a series has no meaning to people who have no other source of information about properties that define the series. Common use of classification systems specific to forest management raises the question of the utility of Soil Taxonomy or other natural classification systems to management of the forest resource. By definition, forest management classification systems only consider a subset of soil properties and are often developed for use in a specific region. Thus, properties considered and terminology used to describe these properties may vary among systems. Because of these variations, communication, soil-based technology transfer, and understanding of the soil system across wide regions can be enhanced through use of classification based on Soil Taxonomy or other natural classification systems.

Soils and Landscapes

Because topography is one of the five state factors (climate, topography, biotic influences, parent material, and time) that control soil formation, soils and landscapes are intimately linked. Likewise, the slope, aspect, and shape of the landscape have a strong influence on forest ecology and productivity. Major landscape influences on both soil and ecosystem properties are related to redistribution of water from precipitation, landscape redistribution of solutes, parent material, and, in steep landscapes, slope and slope aspect.

Slope shape is the three-dimensional geometry of a slope which is derived by combining the shape of the vertical slope profile with the shape of the profile along the slope contour. In each direction, the slope can be linear, concave, or convex, and any point in the landscape can be designated as concave – concave, concave – linear, etc. to better communicate the conformation of the landscape. The shape of hillslopes strongly influences lateral movement of water across the landscape as both overland flow and in the shallow subsurface as throughflow. Flow tends to be parallel on linear slopes, convergent in landscape segments with concave slope, and divergent in landscape segments with convex slope. The influence of slope shape on redistribution of water from precipitation creates microenvironments on the landscape in which areas of divergent flow are drier than the landscape as a whole and areas of convergent flow are wetter than the general landscape. These microclimates influence both soil development and vegetation composition and productivity.

Hillslopes can be divided into segments along a two-dimensional profile that is based on slope shape and inflections in the slope gradient. In humid climates, the most commonly used terms for these segments are summit, shoulder, backslope, footslope, and toeslope (**Figure 1**). The summit is the level or slightly convex uppermost part of a hillslope profile. Water movement on summits is mostly vertical although there may by an appreciable lateral

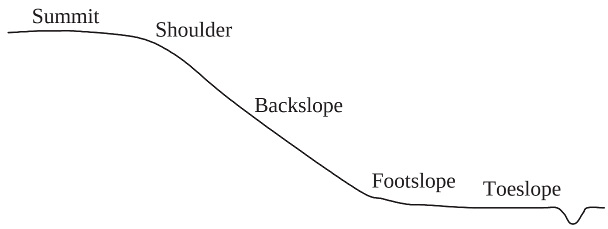

Figure 1 Terms used to describe various hillslope positions.

component on narrow convex summit positions. Soils on summits are often well drained, but the interior of broad level summits may have poorly drained soils if soil horizons or geologic strata slow the rate of vertical water movement. The shoulder is the convex portion of the hillslope below the summit. The shoulder position commonly has greater lateral flow of water and soils may be drier than the summit. Below the shoulder is the more linear backslope where surface runoff is greatest. Relative proportion of lateral and vertical water movement on backslopes depends on slope gradient and the stratigraphy of soil horizons and geologic strata. The backslope descends to the concave footslope which is an area of convergent flow and accumulation of sediments and solutes transported from upslope by overland flow and throughflow. Downslope from the footslope is the toeslope which has linear or slightly concave slope shapes and low slope gradient. Toeslopes tend to have alluvial parent materials from adjacent or upslope streams.

General types of soil parent material are commonly related to certain landscape positions and/or geomorphic surfaces. Although exceptions are common, especially in areas with extensive windblown materials, soils on summit, shoulder, and upper backslope positions tend to be developed from residual parent materials, and soil properties will be related to properties of the underlying rock or sediment. Gravity and water transported colluvial parent materials are usually found on lower backslope and footslope positions, and soil properties will be influenced by the properties of the colluvium which may or may not be similar to that of the subjacent residuum. Alluvial parent materials are found on floodplains and terraces, and properties of the soils in these settings will be influenced by the textural, chemical, and mineralogical characteristics of the sediment and by the position of the soil within the floodplain or terrace as it relates to stream transport capacity during deposition, i.e., coarse-textured sediments on levees and fine-textured sediments in backswamp positions.

Slope gradient and aspect can have implications for forest productivity and ecology. Slope gradient impacts are mostly related to its effects on rate and amount of overland flow, especially in managed forests. Both tree harvest and forest roads can lead to high amounts of soil erosion in strongly sloping areas if management and construction practices are not carefully planned and implemented. Slope aspect, especially on steep mountainous slopes, has impact on species composition, forest productivity, and soil development. These impacts arise from differences in the amount of solar radiation and corresponding temperature differences that are related to direction to which the slope faces. Because of the sun angle, aspects that face the equator and the afternoon sun (south and west in the northern hemisphere) receive more solar radiation and are warmer than those that face away from the equator. Higher temperature results in greater amounts of evapotranspiration and thus, these slopes have drier soils and less water available for plant growth than those facing away from the equator. This difference in water availability affects species composition and productivity and soil properties, especially thickness and organic carbon content of the surface horizon. In addition, reduced evapotranspiration on slopes facing away from the equator results in more water leaching through the soil, and soils on these slopes often are more developed than soils on similar warmer and drier slopes facing the equator.

In most cases, landscape differences will be reflected in soil map units and/or the classification of the named soil. There may be landscapes, however, in which differences are not reflected in the soil map units because of scale of mapping or intensity of the soil survey. In these cases, it may be useful to employ differences in landscape properties in conjunction with the classification and properties of the soil in evaluating forest ecology and productivity of a site.

Soil Survey

Although classification and mapping are closely related, they are not the same thing. Classification is best applied to individual pedons, and the classification of the pedon is a product of the classification system, which have arbitrary definitions. As a means to inventory the soil resource and/or provide a basis for land management, soil classification has limited applicability. Only when the classification is applied to land areas through a soil survey is the full utility of the classification systems realized for management.

A soil map unit is a natural segment of the landscape that is composed of one or more dominant soils. Environmental factors that influence soil formation (parent material, topography, and vegetation) are generally observable on the landscape, and when one or more of these factors changes, it reflects a change in the soil. Thus, landscape properties are used to infer occurrence of a particular soil on that landscape segment. This is the science that is the basis for soil survey. After relationships between type of soil and landscape properties have been identified through careful study, the landscape characteristics can be used to identify and map soils with only limited observations of the soil with depth.

Because soil map units are geographical bodies that are delineated on the ground, they almost always contain soils different from the named taxonomic unit. The soils other than the named taxa are referred to as inclusions. Inclusions are commonly categorized as similar to the named soil, i.e., different taxonomically but having similar interpretations of behavior, or dissimilar from the named soil, i.e., different both taxonomically and interpretively. Similar inclusions may be present by design in order to reduce map clutter and the number of potential management units. However, soil properties that result in similar interpretations for one land use may result in different interpretations for a different use. Thus, expected land use over the foreseeable future must be a consideration in map unit design.

Dissimilar inclusions occur because of (1) an incomplete understanding of the relationship between observable landscape characteristics and the type of soil or, more commonly, (2) because of map scale. If the smallest feature that can be drawn on the map is 2 ha in size, soils that occur as smaller bodies cannot be shown on the map even if the soil surveyor is aware they are present. Thus, the goal of soil mapping is to design and delineate map units that have a minimum amount of dissimilar inclusions.

Soil–Site Productivity Relationships

Soils and vegetation are intimately linked. A forest soil has been defined as one developed under and currently supporting forest vegetation. This implies that given sufficient time, properties of soils developed under a forest will have different properties from those developed under types of vegetation. These differences in genesis are reflected in soil classification systems. Differences in root distribution and relative amounts of above and below ground biomass between trees and grasses result in different surface soil properties which are reflected in differentia for Mollisols from other orders. Acid leachate from coniferous forest litter combined with sandy parent material results in podzolization being a dominate soil forming process leading to

Table 3 Recognition of soil properties that affect forest composition and productivity by taxa in *Soil Taxonomy*

Soil property	*Relation to site quality*	*Indicative classes in* Soil Taxonomy
pH (base saturation as covariable)	Affects nutrient availability	Soil orders (Mollisols, Alfisols, Ultisols), dystric and eutric great groups and subgroups, acid and nonacid families
Base saturation	Affects K, Mg, and Ca supply	Soil orders (Mollisols, Alfisols, Ultisols), dystric and eutric great groups and subgroups
Organic matter content	Source of N and P, promotes structure	Mollisols, umbric great groups and subgroups
Particle size distribution	Affects water and nutrient storage	Family particle-size class
Cation exchange capacity	Affects nutrient storage	Family cation exchange capacity classes, family particle-size and mineralogy classes, kandi and kanhapl great groups
A horizon structure	Promotes aeration and root proliferation	Mollisols and umbric great groups and subgroups
Depth of A horizon	Affects biological activity	Mollisols and umbric great groups and subgroups
Root restrictive horizons and strata	Limits rooting depth	Fragi great groups and subgroups, lithic subgroups, shallow families
Soil moisture regime	Soil moisture availability and aeration	Aquic, udic, ustic, xeric, and aridic suborders, great groups, and subgroups
Soil temperature regime	Affects root growth and microbial activity	Soil temperature regimes as family classes
Depth to redoximorphic features	Depth to seasonal saturation and related aeration	Aquic suborders, aquic and oxyaquic subgroups

development of spodic horizons and Spodosols (Podzols). Ancient conversion of forests to cropland has been shown to appreciably alter subsoil properties and resulting classification (Spodosols converted to Inceptisols). Numerous other examples of vegetation affects on soil development are available in the literature. Because vegetation affects soil genesis and properties, it is reasonable to expect the converse to be true. Soil conditions will have a major effect on forest composition and productivity.

The composition and productivity of a site depends on the inherit quality of the site and management inputs. Site quality is strongly influenced by soil, topography, and climate. Soil properties that affect site quality include soil temperature, nutrient supply and availability, soil organic matter content, texture, structure, consistence, depth to redoximorphic features (drainage), thickness of the A horizon, stone content, depth to horizons that restrict water movement and root elongation, and the thickness of the B horizon. Many of these properties are used to differentiate among taxa in *Soil Taxonomy* and other natural classification systems (**Table 3**).

Thus, classification and soil map units have often been interpreted as to their potential forest composition and productivity. These interpretations are based on observations, often unsystematic, of forest conditions over the area in which the soil occurs. Attempts to develop firm relationships between soil map units and forest productivity, however, have met with mixed success. Many studies have used soil map units to predict site productivity with considerable success while others have reported little or no relationship between map units and productivity. A part of this discrepancy is related to the landforms and species being considered, but the major factor may lie in the fact that map units in most soil surveys, at least in the USA, were designed for agricultural purposes with forest management as a secondary consideration if considered at all. Better communication and cooperation between forest managers and soil scientists during the initial stages of a soil survey so that soil and landscape differences that are important for forest management can be considered in map unit design may well improve the utility of soil surveys for forest management.

See also: **Soil Biology and Tree Growth**: Soil and its Relationship to Forest Productivity and Health. **Soil Development and Properties**: Forests and Soil Development; Nutrient Cycling.

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The Forest Floor

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Introduction

One of the most striking features of forests is the canopy, which consists of leaves and branches forming a noticeable layer that shades the ground and provides habitat for numerous birds, mammals, and insects. In addition to providing habitat, the canopy provides a substantial input of organic litter to the soil surface as the trees cyclically shed foliage, flowers, fruit, twigs, and bark. Over time as forests grow and develop, organic remains of plants and animals accumulate on the soil surface. The accumulation of foliage and branches is collectively referred to as the forest floor. The forest floor, along with tree roots, is an integral component of the forest soil system that distinguishes forest soils from agricultural soils.

The forest floor has a tremendous impact on the soil environment. One of the most important factors affecting tree growth is the capacity of the soil to transfer energy, water, and gases from the soil surface to organisms and roots living deeper in the soil. One of the fundamental soil physical properties influencing this transfer is soil structure, which refers to the aggregation of primary soil particles (sand, silt, clay) into secondary units. Well-developed granular structure occurs in the surface mineral soil horizons creating pores that are large enough for water to flow freely through. Soil structure is described by shape (i.e., granular refers to small spheres, and blocky refers to larger aggregates). There is no quantitative expression currently available to describe soil structure.

Bulk density is a commonly used soil physical property that is influenced by soil structure. Bulk density is a measure of dry mass per unit volume of undisturbed soil. The undisturbed volume includes both the solid particles as well as pore space. For a given type of soil particle (organic vs. mineral), increased pore space results in lower values of bulk density. The particle density of organic matter is approximately half that of mineral soil, which averages $2.65\,\mathrm{Mg\,m^{-3}}$. The combination of low particle density and a relatively high volume of pores impart a low bulk density to the forest floor, which ranges from less than 0.1 to $0.30\,\mathrm{Mg\,m^{-3}}$. Contrast that figure with the range for typical surface mineral soil horizons of 1.0–$1.3\,\mathrm{Mg\,m^{-3}}$. For purposes of comparison, the density of water is $1.0\,\mathrm{Mg\,m^{-3}}$.

The large pore space volume associated with the forest floor has several important consequences. Air filled pores of forest floors act as an insulator, buffering soil temperature by reducing daily high and increasing daily low temperatures. Water infiltration, the movement of water into the soil, and water storage capacity are high because of the large volume of pore space. Consequently, overland water flow in forest soils is rare. The forest floor provides a physically favorable environment for plant roots and soil fauna. Low bulk density does not restrict root growth or organism movement, while high pore space and water holding capacity ensure adequate moisture and aeration required by aerobic organisms. These favorable physical properties promote a high level of biological activity which decreases with depth below the soil surface.

Characterization of Organic Horizons

The forest floor is differentiated from mineral soil on the basis of organic matter expressed as carbon (C) concentration. The organic material comprising the forest floor exists in a decay continuum, ranging from relatively undecayed plant material on the surface to black, highly decomposed organic material referred to as humus. The US soil classification system divides the decay continuum into three discrete layers or horizons (**Figure 1**): (1) Oi, fibric material, relatively undecomposed; (2) Oe, hemic material, moderately decomposed; and (3) Oa, sapric